# Malibu Lagoon Restoration and Enhancement Project

## Comprehensive Monitoring Report (Year 5)

July 2018

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## Comprehensive Monitoring Report (Year 5)

27 July 2018

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Photo: Malibu Lagoon Restoration Project at sunrise (12 July 2018; 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. The restoration project is meeting the success criteria outlined in the Monitoring Plan (SMBRF 2012). Another subsequent year of monitoring (sixth year) for many of the criteria will allow the final post-restoration data to be evaluated against the long-term 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 75 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 be conducted once more in the sixth monitoring year during open lagoon conditions.

***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 5 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 to assess trends over time. Variability may be due to any number of factors, including biofouling, temperature fluctuations, and variability in other physical or climatic factors. One additional year of monitoring (2018) for the water quality parameters will continue.

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, 10 mg/L in May 2016, and 6.8 in August 2017. 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 good circulation throughout the 5-year post-restoration assessment period, especially during closed berm conditions. This meets 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 5 surveys.

***Sediment Quality – Sediment Constituent Sampling:*** Sediment grain size distributions predictably fluctuated based on variable water energy conditions, with some fine-grained sediments deposited in closed berm conditions, and larger-grained sediments present during open tidal flushing. These seasonal patterns of water and sediment movement are 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 meeting success criteria, which includes reducing overall nutrient loading over time, based on lower TN and TP maximum values post-restoration. Additionally, nutrients may have been sequestered into SAV, rather than deposited into the sediments.

***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. Benthic invertebrates will be additionally surveyed in the sixth monitoring year to support 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 four 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 five 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. In the five years since restoration, 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 shallower and narrower, prior to the restoration. A comparison of 22 common waterbirds in the western channels (restoration area) shows continuing high species richness in 2017, but a dip in counts of individuals since 2014. Both post-restoration total number of individuals and total species richness by year still remain higher for the western channel analysis as compared to pre-restoration data. Special-status species in

Year 5 continue to make heavy use of the site, in particular the beach and lower lagoon area (e.g. Brown Pelican, Western Snowy Plover, CA Least Tern). In 2017, a handful of pairs of Western Snowy Plovers attempted to breed at Malibu Lagoon for the first time in modern history (no prior records), with at least one chick successfully fledging.

***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 five years, algae cover 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 and dominated the August 2017 survey. 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. In the fifth monitoring year, the average (± standard error) native cover across all transects was 66.8 ± 9.5% in June 2017, and 59.7 ± 9.1% in April 2018, respectively. The average non-native cover was less than 10% across both Year 5 survey dates. The relative native cover ranged between 83.4 – 90.7%. Reductions or variability in non-native cover may be the result of extensive weeding and non-native species removal efforts.

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

***Conclusions:*** Year 5 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 for an additional year of monitoring will confirm this trend over time, with a final, Year 6 monitoring report planned for released in 2019. 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 continue to be 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, including use of the back channels which were previously anoxic dead zones. 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 an additional year to provide supplementary data to the 5-year monitoring program. A final report is planned for release in 2019.

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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 May 2018. During the Year 5 monitoring period, the Lagoon berm breached on 3 December 2017, and the 'open condition monitoring' occurred between the date of the breach and 9 May 2018 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 in 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 5-Year Comprehensive Monitoring Report (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. The report summarizes efforts from 2013, post-restoration, through mid-2018.

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, 2016, and 2017. For detailed methods, refer to the referenced monitoring literature.

Additional surveys are planned for a sixth and final monitoring year through 2018 and the beginning of 2019 to collect supplemental data, including extended deployment of the water quality sondes so that more total deployment time is recorded.

# 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 assesses 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*

California Rapid Assessment Method (CRAM) surveys were not required as part of the Monitoring Plan, but the surveys were added at the request of the California Coastal Commission to inform long-term wetland condition trends over time. The following description of the summary and objectives of 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*

Eight 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, 27 December 2016, and 26 June 2017 (Figure 3). CRAM will be completed once again during the sixth monitoring year (during open berm conditions) to assess a final condition trend across all monitored years. The May 2014, 2015 and June 2017 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 and June data may be skewed towards slightly lower condition scores, especially for the physical structure attribute. The pre-restoration survey was conducted on 1 June 2012 and is compared to 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, 26 June 2017.


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 75 based on the latest survey, with an additional increase in the hydrology and biotic attributes since the December 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 on 3 December 2017. The vegetation community was similar to the previous monitoring year (2016), 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 | 6/26/17 * |
|---|---|---|---|---|---|---|---|---|---|
| Attribute 1: Buffer and Landscape Context | 38 | 38 | 38 | 38 | 53 | 53 | 53 | 53 | 53 |
| Attribute 2: Hydrology Attribute | 50 | 58 | 58 | 58 | 58 | 58 | 58 | 67 | 75 |
| Attribute 3: Physical Structure Attribute | 50 | 88 | 75 | 75 | 88 | 88 | 88 | 100 | 88 |
| Attribute 4: Biotic Structure Attribute | 61 | 39 | 56 | 53 | 64 | 64 | 72 | 75 | 83 |
| **Overall AA Score** | **50** | **56** | **57** | **56** | **66** | **66** | **68** | **74** | **75** |

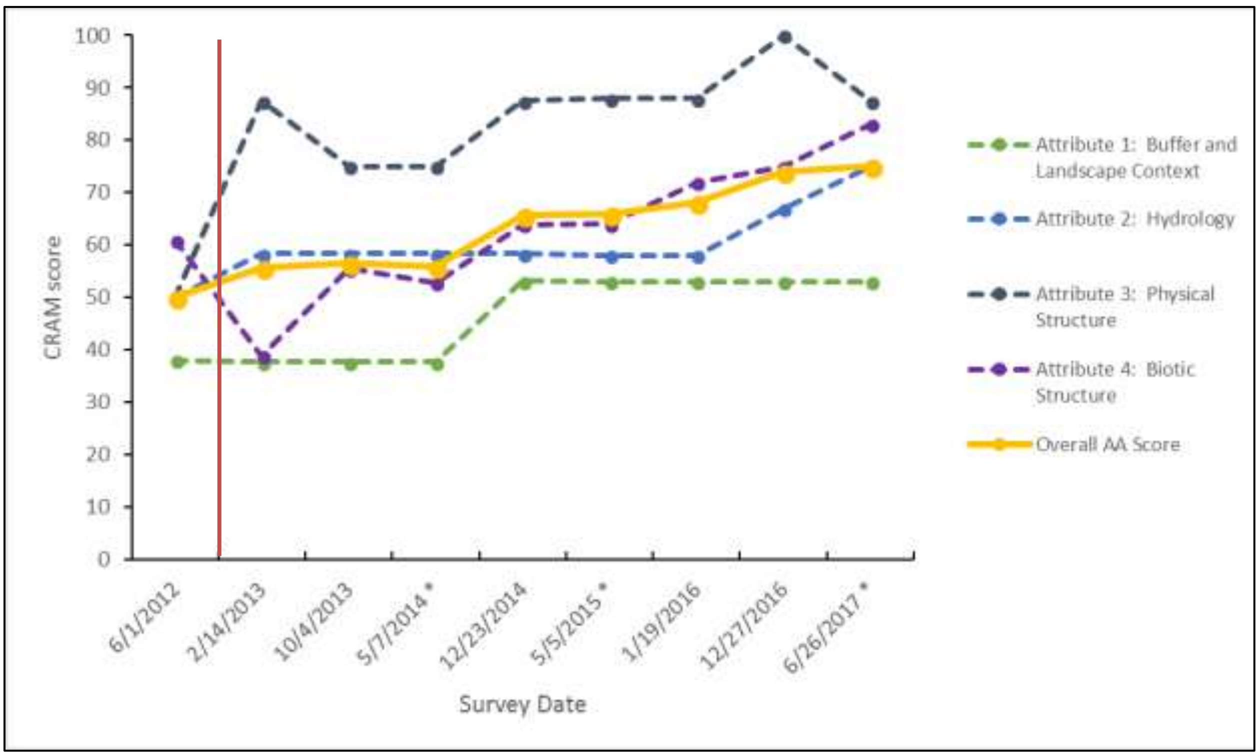



Figure 5. Graph of CRAM attribute and overall scores over time. Note: the 2012 survey date is pre-restoration and the asterisks indicate closed-berm condition surveys.

### *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 overall CRAM final score is also likely to remain consistently above the pre-restoration assessment final score. A final CRAM assessment will be conducted in the sixth year of monitoring during an open-berm condition and the trend over time will be assessed.

## 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 five consecutive post-restoration years. Surveys were conducted on 14 February 2013, 18 December 2014, 19 January 2016, 21 and 27 December 2016, 20 February 2018, and 9 May 2018 (Figures 6 and 7). Two survey days, 20 February 2018 and 9 May 2018 were needed in Year 5 to complete the monitoring. Horizontal and vertical locations of cross-section end-points were fixed by permanent monuments; however, in Year 5, field technicians were unable to locate a few monuments which were accidentally removed along with irrigation pipes. Missing monuments were referenced in the field using recorded GPS locations and the monuments were replaced; however, slight variances in Year 5 surveys may be due to small-scale variability in the transect location. Sediment scour or deposition depths were calculated from the data based on area approximated using a Riemann sums method and compared across survey dates.

Figure 6. Cross-channel elevation survey location at Malibu Lagoon, 6 January 2017.

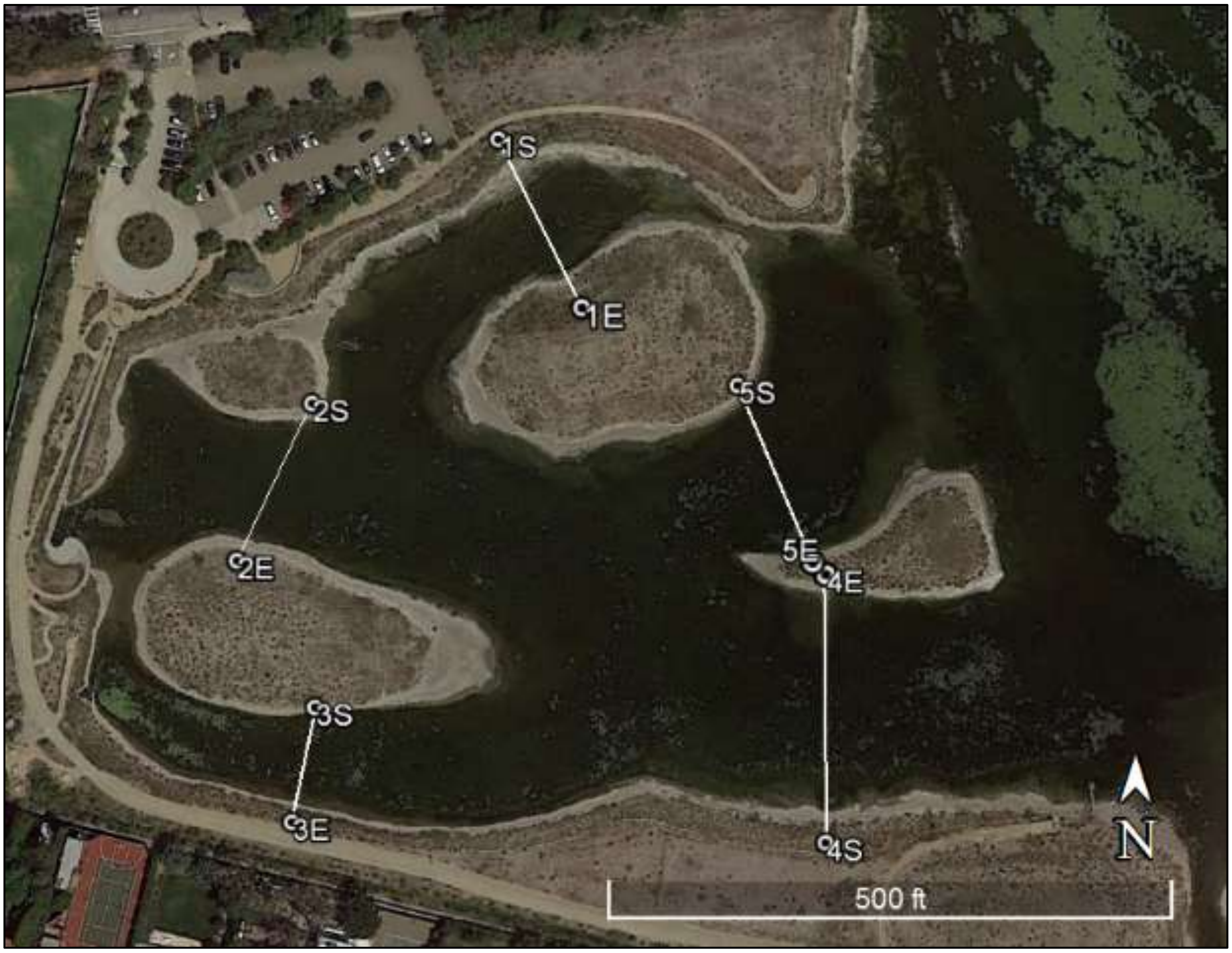



Figure 7. Map of cross-channel elevation transect locations.

### ***Results***

Results were calculated for all five post-restoration cross-section transects comparatively across all survey dates (Figures 8-12, dotted lines indicate Year 5 results). 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). The results of area for each cross-section transect compared across survey dates is shown in 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 showed a decrease in estimated area, indicating the possibility of erosion, but not significant enough to indicate a problem. It more likely should be attributed to natural morphological variability due to lagoon tidal flow and/or survey location variability due to the accidental removal of reference monuments for this transect.

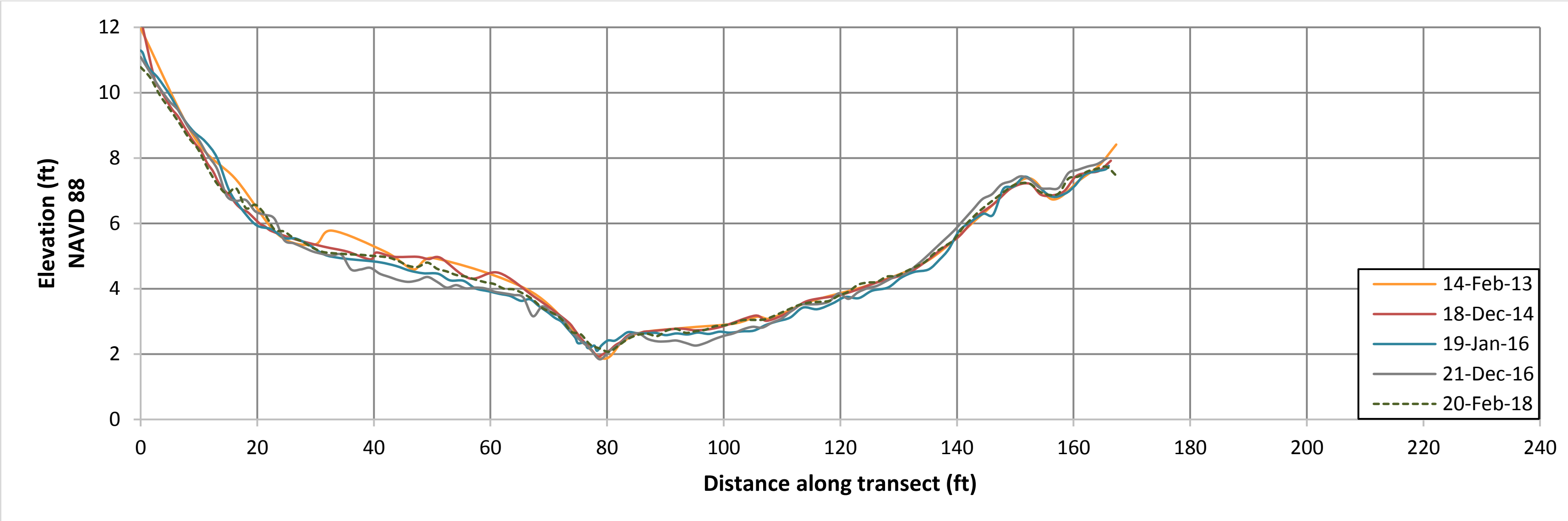



Figure 8. Channel Cross-section Transect 1. Dotted line indicates Year 5 survey.

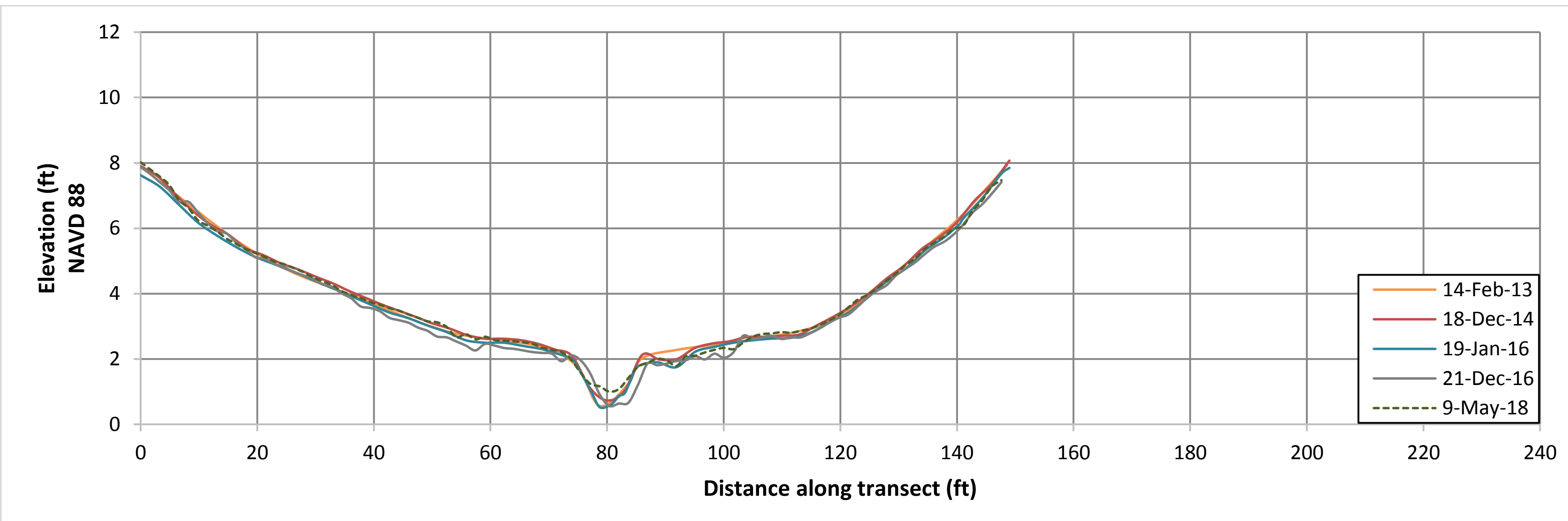



Figure 9. Channel Cross-section Transect 2. Dotted line indicates Year 5 survey.

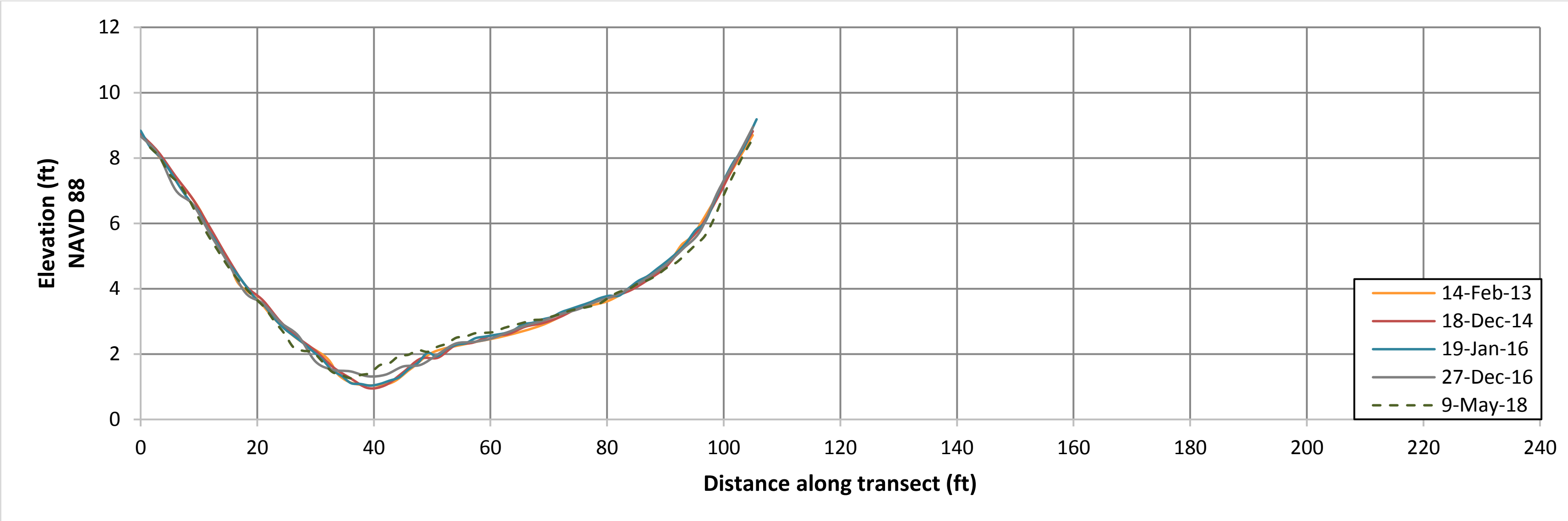



Figure 10. Channel Cross-section Transect 3. Dotted line indicates Year 5 survey.

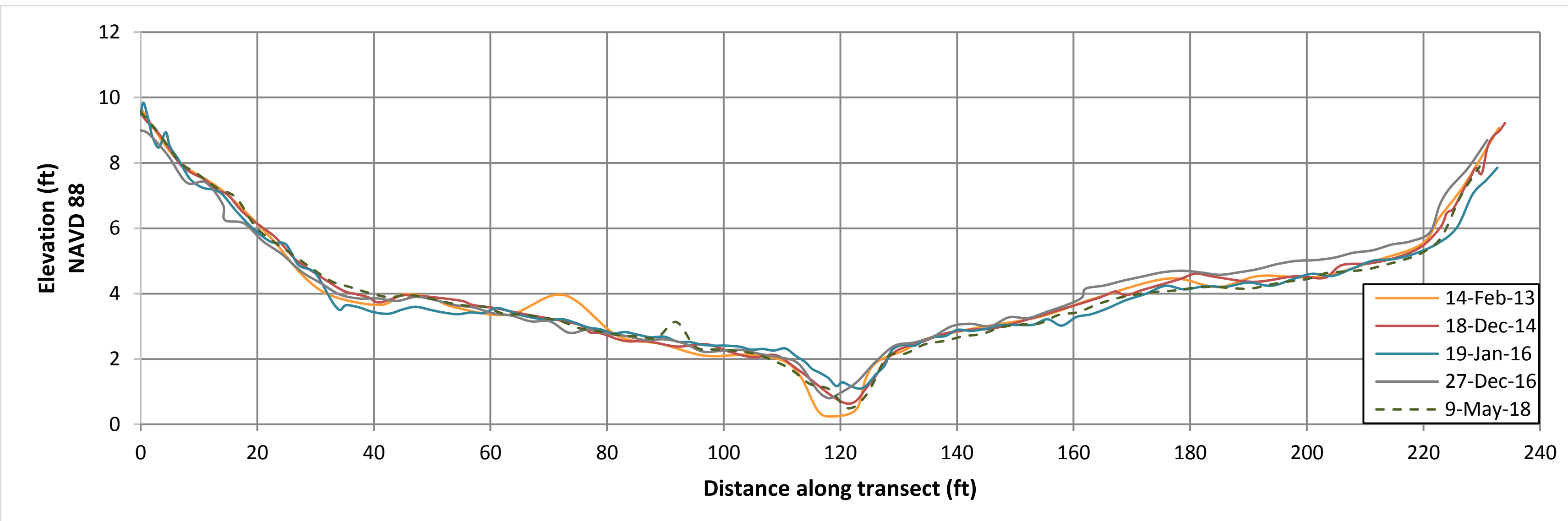



Figure 11. Channel Cross-section Transect 4. Dotted line indicates Year 5 survey.

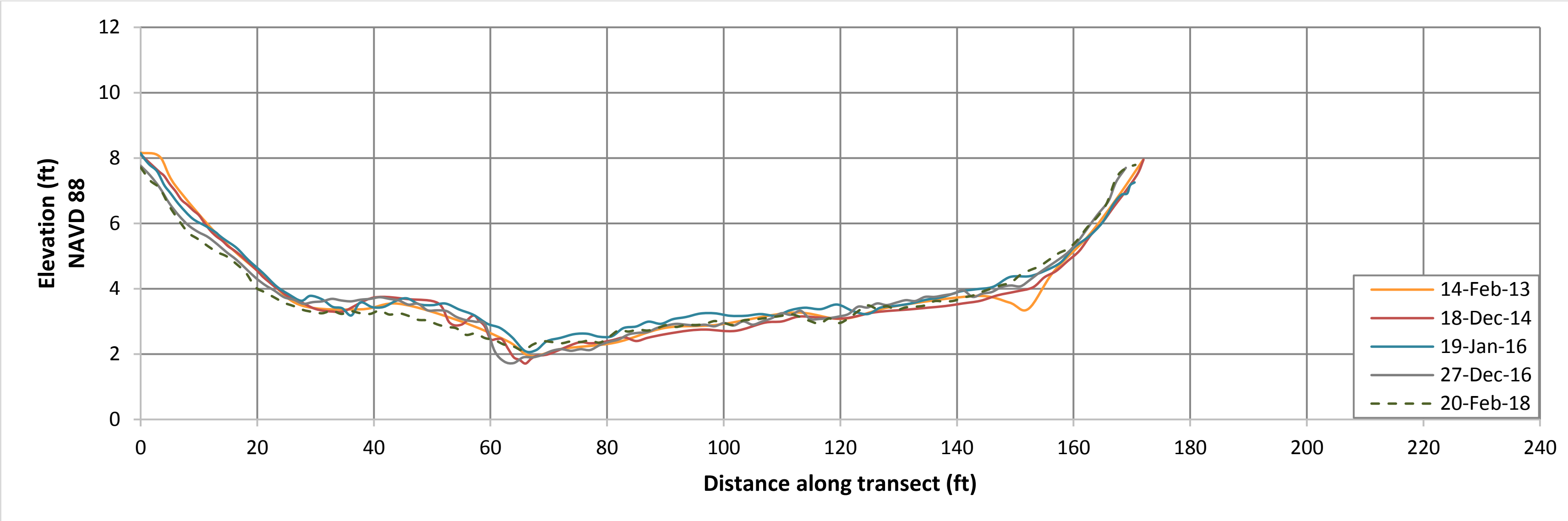



Figure 12. Channel Cross-section Transect 5. Dotted line indicates Year 5 survey.

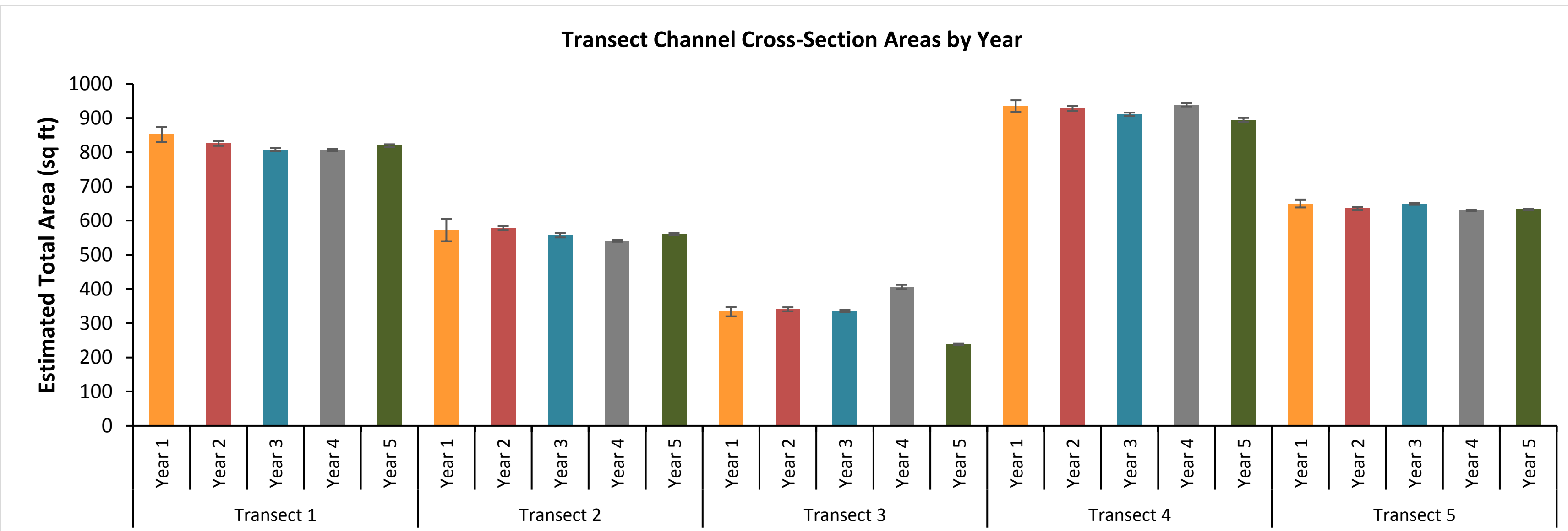



Figure 13. Transect channel cross-section areas by year.

### *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 over time, due to lack of reliability and poor performance of the original YSI sondes; 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 2017 at three permanent post-restoration stations. Dates of deployment varied by station due to probe malfunctions, servicing, biofouling, or calibration glitches. Table 3 displays the reasons for data gaps by date for Year 5. 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. At least one additional year (2018) of data will be collected to meet permit requirements and ensure a full suit of data to analyze.

Data were downloaded, and the sondes were calibrated, cleaned, and redeployed approximately once monthly (Figure 16). YSI calibration instructions (www.ysi.com) or Hydrolab calibration instructions (www.ott.com) were followed for each calibration and each probe. Data 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 (and thus not functioning), 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. Major data gaps in 2017 included sonde malfunctions and power failures, resulting in sondes being returned for maintenance and/or replaced by the manufacturer. During the fall of 2017, 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 5).

| Station | Start Gap | End Gap | Parameter | Reason |
|---|---|---|---|---|
| 2 | 1/6/2017 | 1/21/2017 | ALL | Sensor malfunction, early shutoff |
| | 4/26/2017 | 5/17/2017 | ALL | Sensor malfunction, early shutoff |
| | 7/26/2017 | 7/28/2017 | ALL | Sonde pulled for calibration/service |
| | 8/25/2017 | 9/1/2017 | ALL | Sonde power loss |
| | 9/2/2017 | 9/23/2017 | Depth | Sensor malfunction, possible calibration issue |
| | 9/27/2017 | 10/29/2017 | ALL | Sonde malfunction, early shutoff, pulled for service |
| 5 | 1/18/2017 | 1/21/2017 | ALL | Sensor malfunction, early shutoff |
| | 2/28/2017 | 3/23/2017 | ALL | Sensor malfunction, early shutoff |
| | 5/17/2017 | 5/19/2017 | ALL | Sonde pulled for calibration/service |
| | 7/26/2017 | 7/28/2017 | ALL | Sonde pulled for calibration/service |
| | 10/15/2017 | 10/28/2017 | ALL | Sonde malfunction, autologging disabled |
| | 12/10/2017 | 12/30/2017 | ALL | Sonde pulled for calibration/service |
| 8 | 1/21/2017 | 2/21/2017 | ALL | Sensor malfunction |
| | 2/22/2017 | 3/14/2017 | ALL | Sensor malfunction, possible calibration issue |
| | 3/14/2017 | 3/23/2017 | ALL | Sensor malfunction, early shutoff |
| | 7/26/2017 | 7/28/2017 | ALL | Sonde pulled for calibration/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 following breach event; 19 December 2017.

### *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 (°C) and dissolved oxygen (mg/L). In general, as temperature increased in a closed lagoon scenario, levels of dissolved oxygen decreased as the primary producer communities (algae) consumed the available oxygen. Table 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).

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 | 85.98% | 80.93% | 65.70% | 45.68% |
| 5 | 87.95% | 81.99% | 64.74% | 41.49% |
| 8 | 98.20% | 96.27% | 88.94% | 73.47% |

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 only 10 and 7 consecutive 24-hour periods below 1 mg/L (25% time) for Station 2 and Station 5, respectively. Additionally, results displayed 7 and 2 consecutive 24-hour periods below 1.5 mg/L (50% time) for Station 2 and Station 5, respectively. Station 8 results displayed no 24-hour periods below 1 mg/L (25% time) and 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 Year 5 closed conditions approximately 88% (Station 5) and 98% (Station 8) of the time in Year 5 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 82% (Station 5) and 96% (Station 8) during Year 5, compared to 81% (ML2) and 86% (ML6) during pre-restoration conditions. The overall post-restoration averages of dissolved oxygen readings above 1 mg/L threshold during closed conditions is shown in Table 5 and remain higher than pre-restoration (baseline) averages.

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 (Year 5) | **Post-restoration average** |
|---|---|---|---|---|---|---|---|
| --- | --- | 8 | 95.76% | 53.35% | 95.93% | 98.20% | **88.41%** |
| ML2 | 82.79% | 5 | 96.97% | 74.05% | 84.46% | 87.95% | **87.89%** |
| ML6 | 89.50% | 2 | N/A* | 94.36% | 93.69% | 85.98% | **91.45%** |

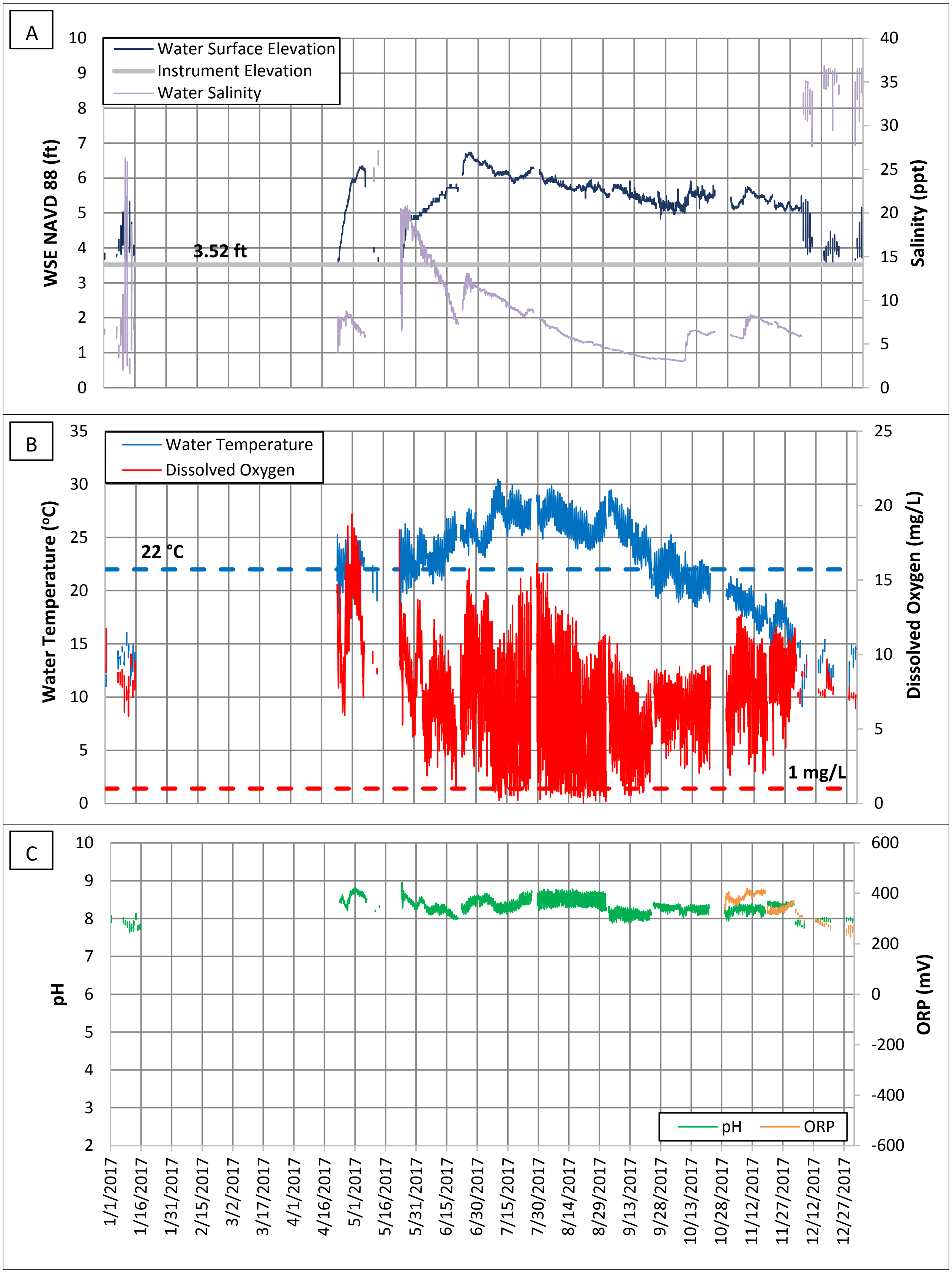



Figure 17. Graphs illustrating continuous water quality parameters from Station 8 (2017).

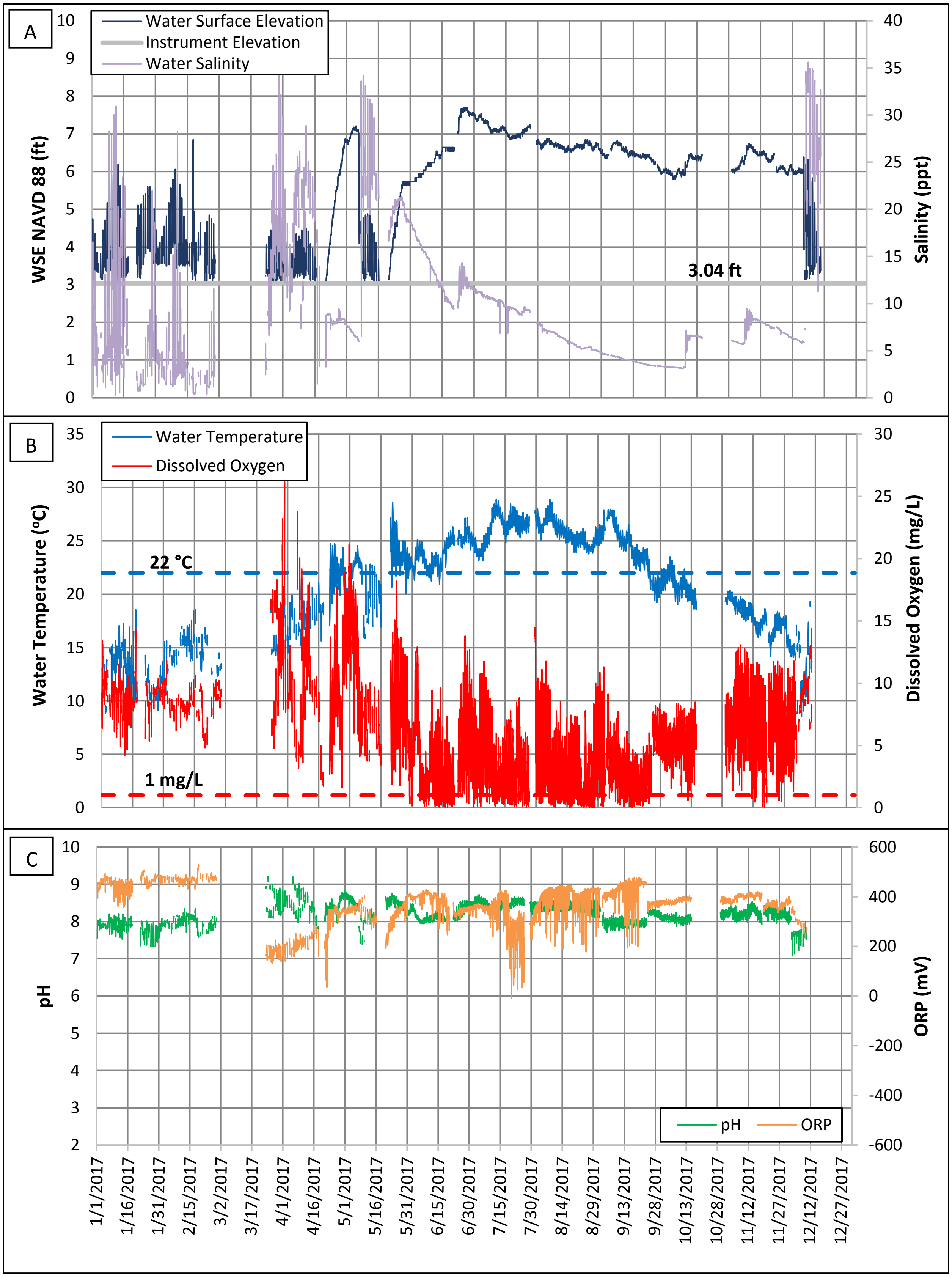



Figure 18. Graphs illustrating continuous water quality parameters from Station 5 (2017).

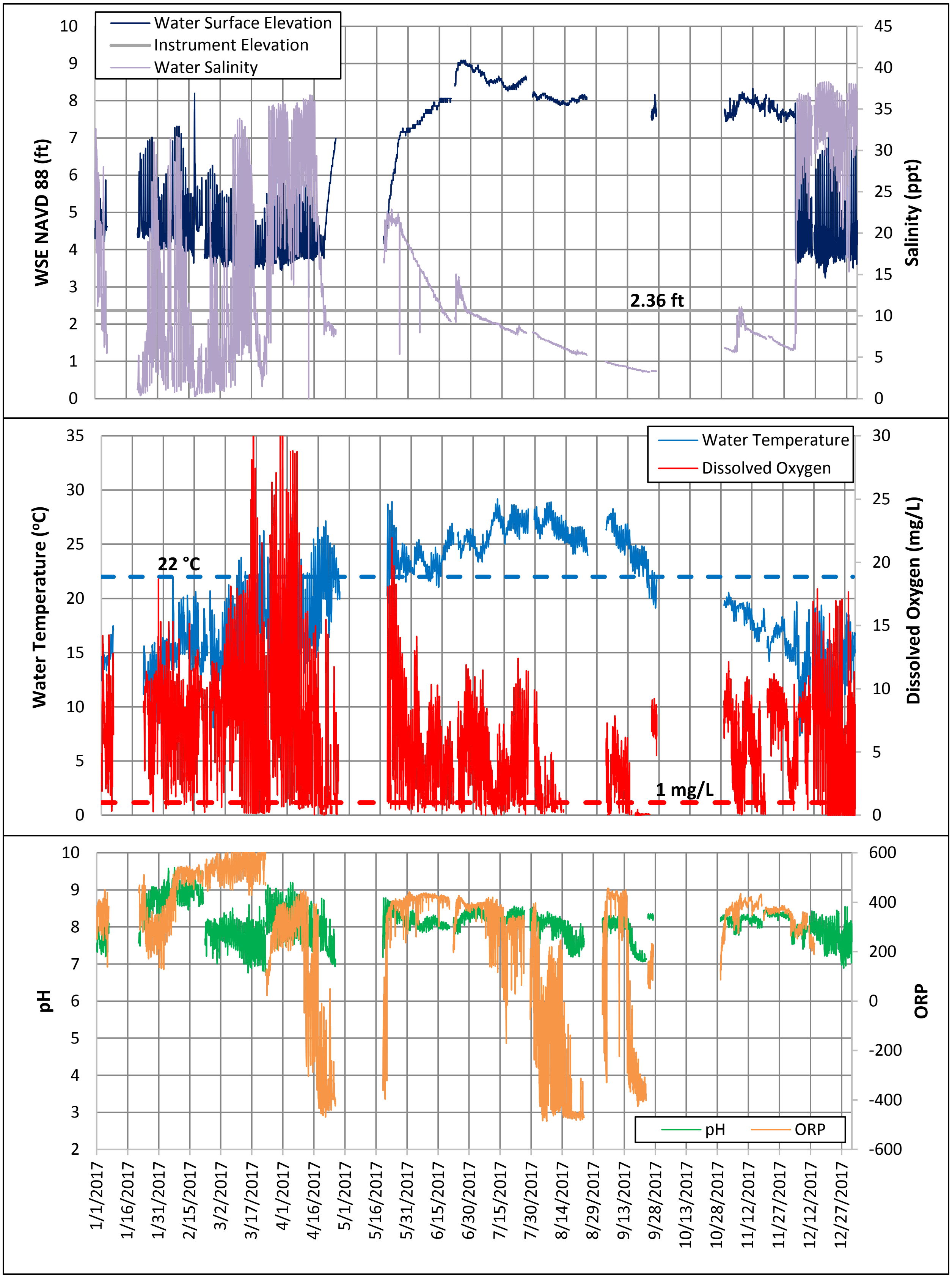



Figure 19. Graphs illustrating continuous water quality parameters from Station 2 (2017).

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

Dissolved oxygen success criteria allow 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 10 and 7 consecutive 24-hour periods below 1 mg/L (25% time) for Station 2 and Station 5, respectively. Additionally, results displayed 7 and 2 consecutive 24-hour periods below 1.5 mg/L (50% time) for Station 2 and Station 5, respectively. Station 8 results displayed no 24-hour periods below 1 mg/L (25% time) and 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'. Year 5 results showed an improvement in the proportion of dissolved oxygen readings above the 1 mg/L threshold for Station 8 and Station 5, while Station 2 showed a slight decrease. Overall, post-restoration averages of the proportion of dissolved readings above the 1 mg/L threshold remain higher than pre-restoration (baseline) conditions. 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, and required the return of sondes for maintenance to the manufacturers. Since the sonde failures caused the missing data, an additional year of data collection (2018) for these parameters is recommended. 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. Additional detailed cleanings are also performed to minimize biofouling.

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 highly 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 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.

Nine 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. Additional supplemental data will be collected during 2018 to provide a full suite of data for 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 |
| 18 August 2017 | Closed | N/A |
| 1 February 2018 | Open | high spring; 6.7 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 and summer sampling events (5 May 2014, 7 May 2015, 12 May 2016, and 18 August 2017), and cooler temperatures occurred during winter sampling events (14 February 2013, 23 December 2014, 15 December 2016, and 1 February 2018) (Figures 20a and 20b). Data in Year 5 displayed both the warmest (26 °C on 18 August 2017) and coolest (13 °C on 1 February 2018) temperatures across the five-year monitoring period.

Salinity data displayed some stratification during the open lagoon condition survey events, with general results indicating a brackish water lens of lower salinity water occurring on the surface of the water column (approximately 5-15 ppt) and more saline, oceanic water occurring towards the bottom of the water column (20-35 ppt; 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, 12 May 2016, and 18 August 2017), little to no salinity stratification occurred (e.g., range of 5.2 – 5.4 ppt in August 2017, and range of 17.4 – 17.9 ppt in May 2016), indicating good mixing. The August 2017 data displayed the lowest salinity values, corresponding to its time frame in the latter part of the summer instead of May. The closed-berm condition 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, 10 mg/L in May 2016, and 6.78 mg/L in August 2017. These closed data contrast with 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).

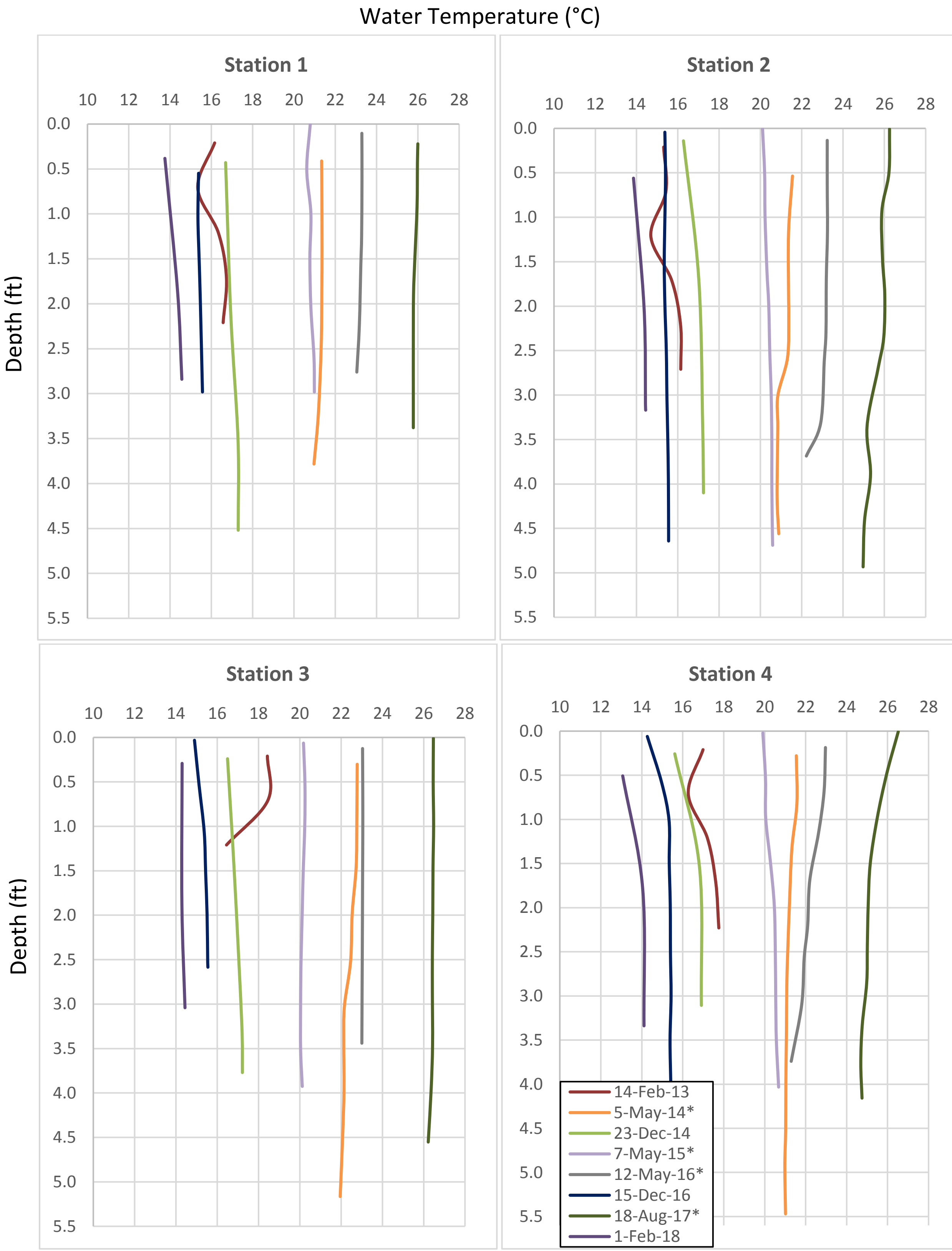



Figure 20a. Post-restoration temperature vertical water quality profiles at Stations 1-4. Asterisk indicates a closed berm condition.

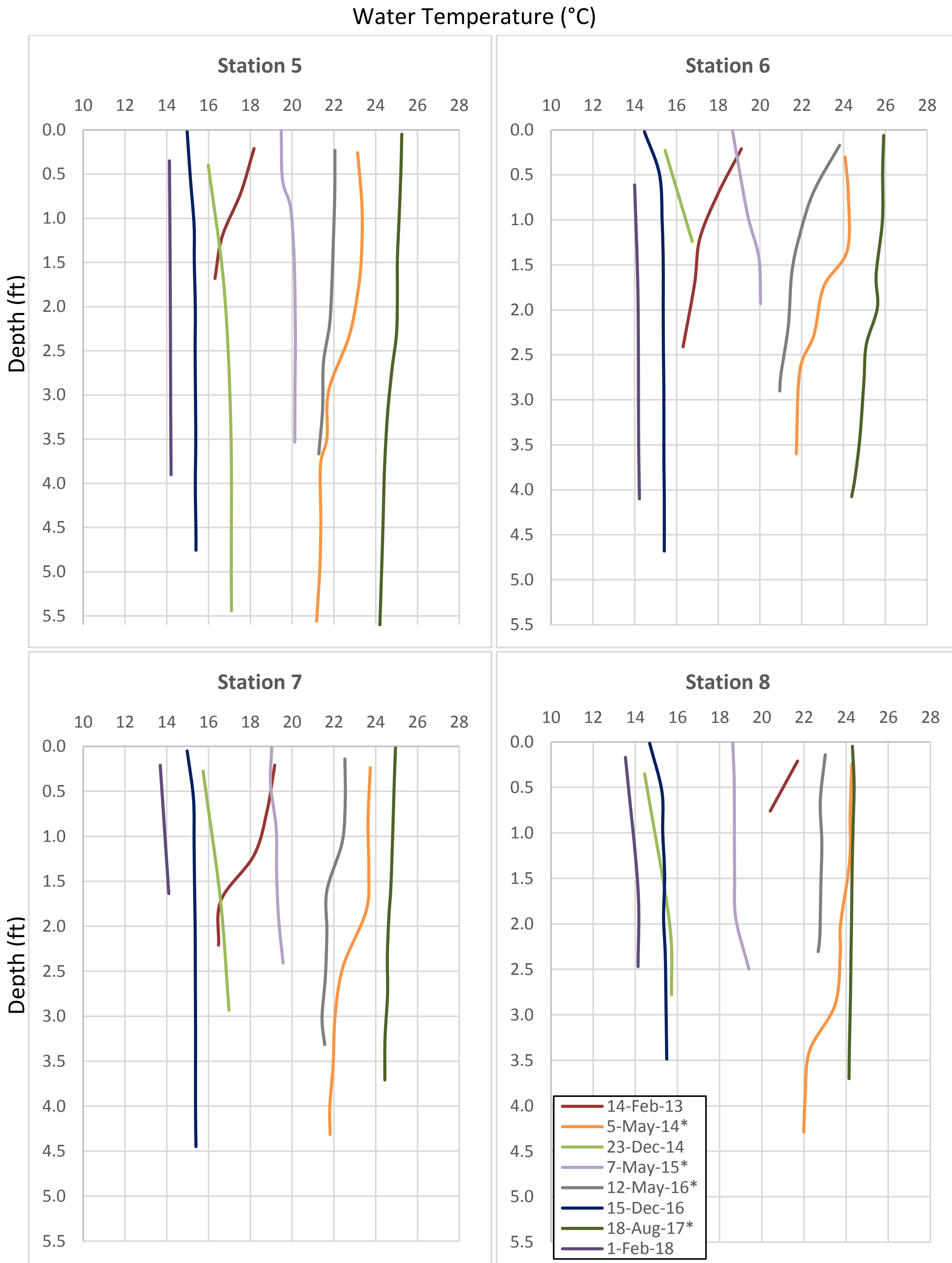



Figure 20b. Post-restoration temperature vertical water quality profiles at Stations 5-8. Asterisk indicates a closed berm condition.

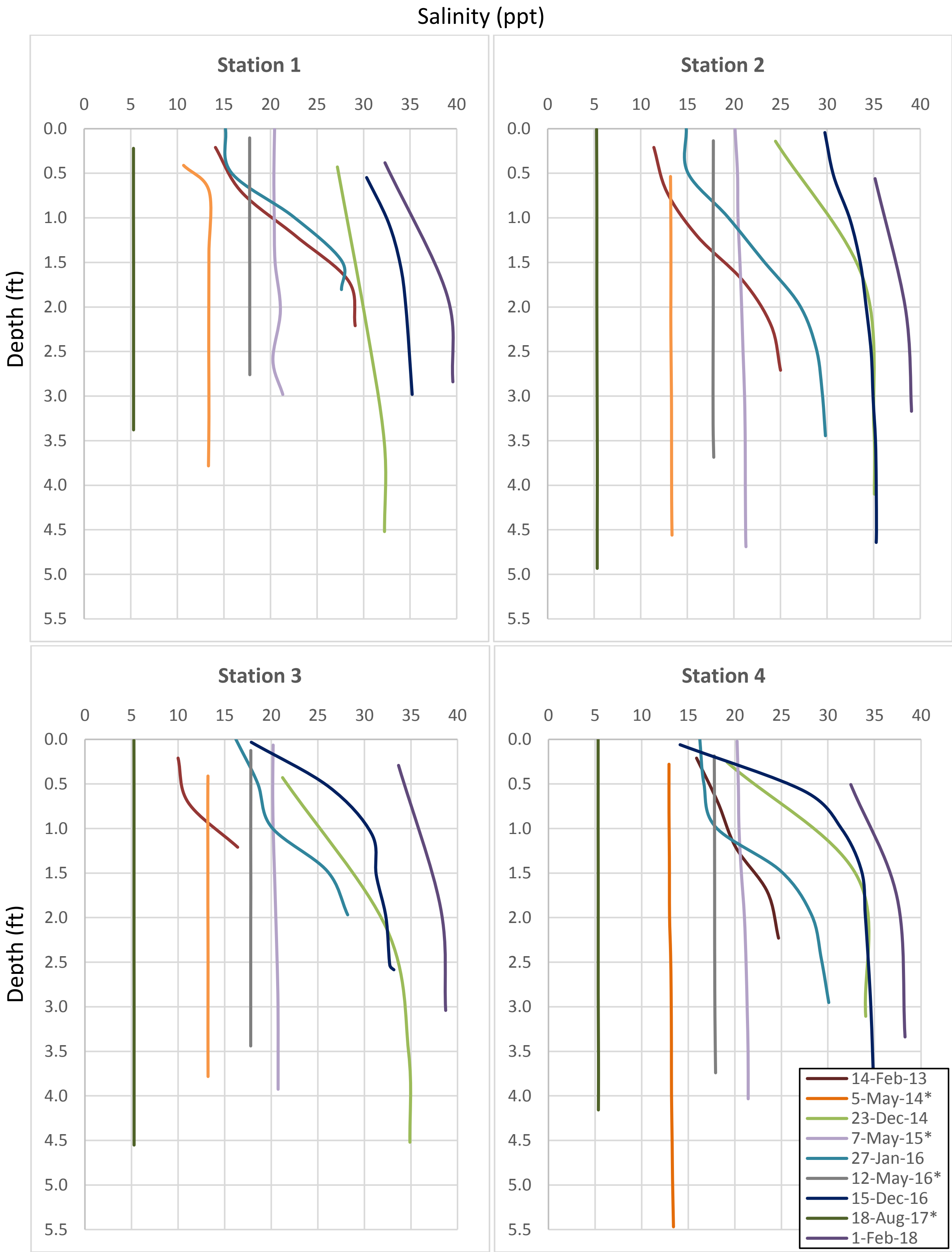



Figure 21a. Post-restoration salinity vertical water quality profiles at Stations 1-4. Asterisk indicates a closed berm condition.

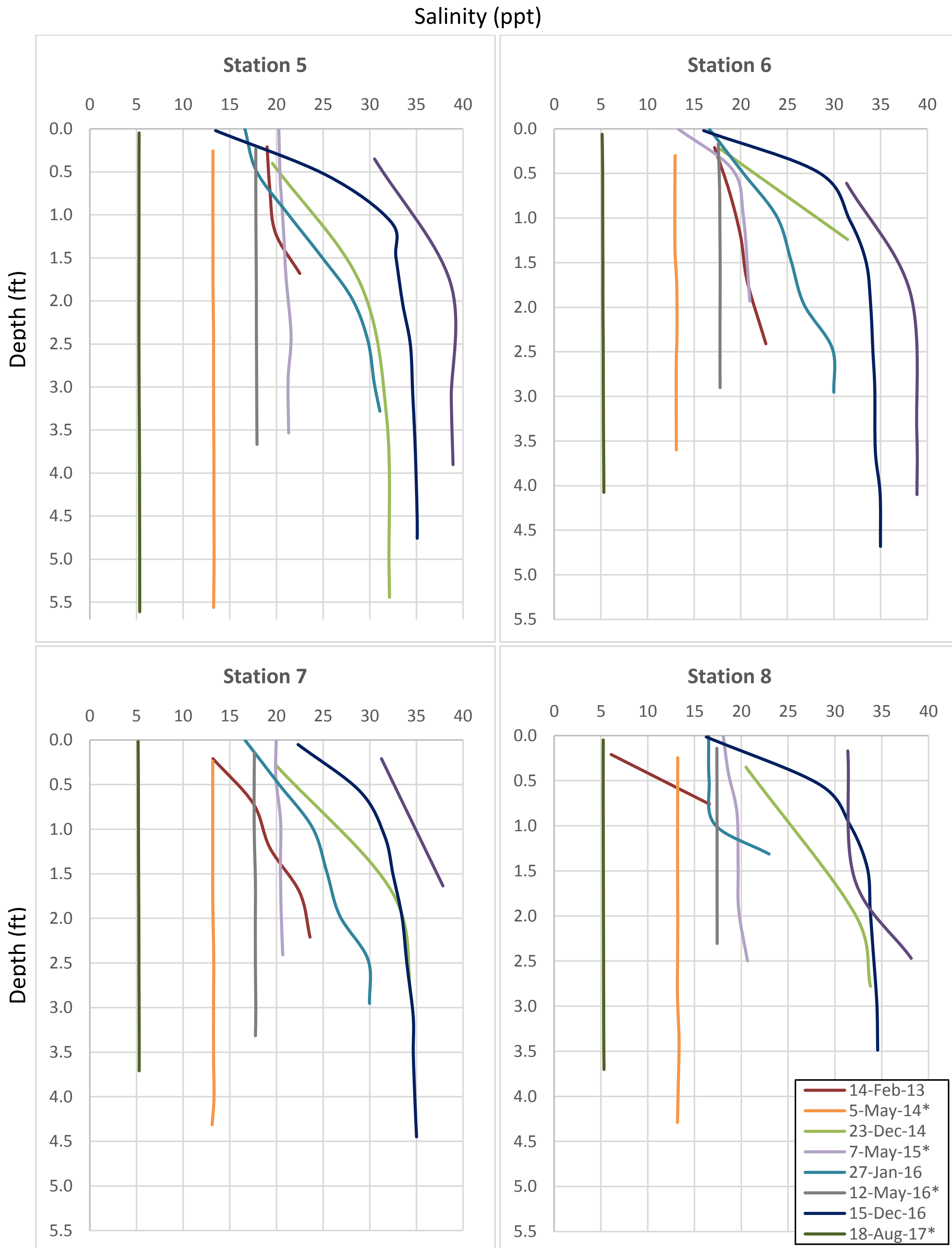



Figure 21b. Post-restoration salinity vertical water quality profiles at Stations 5-8. Asterisk indicates a closed berm condition.

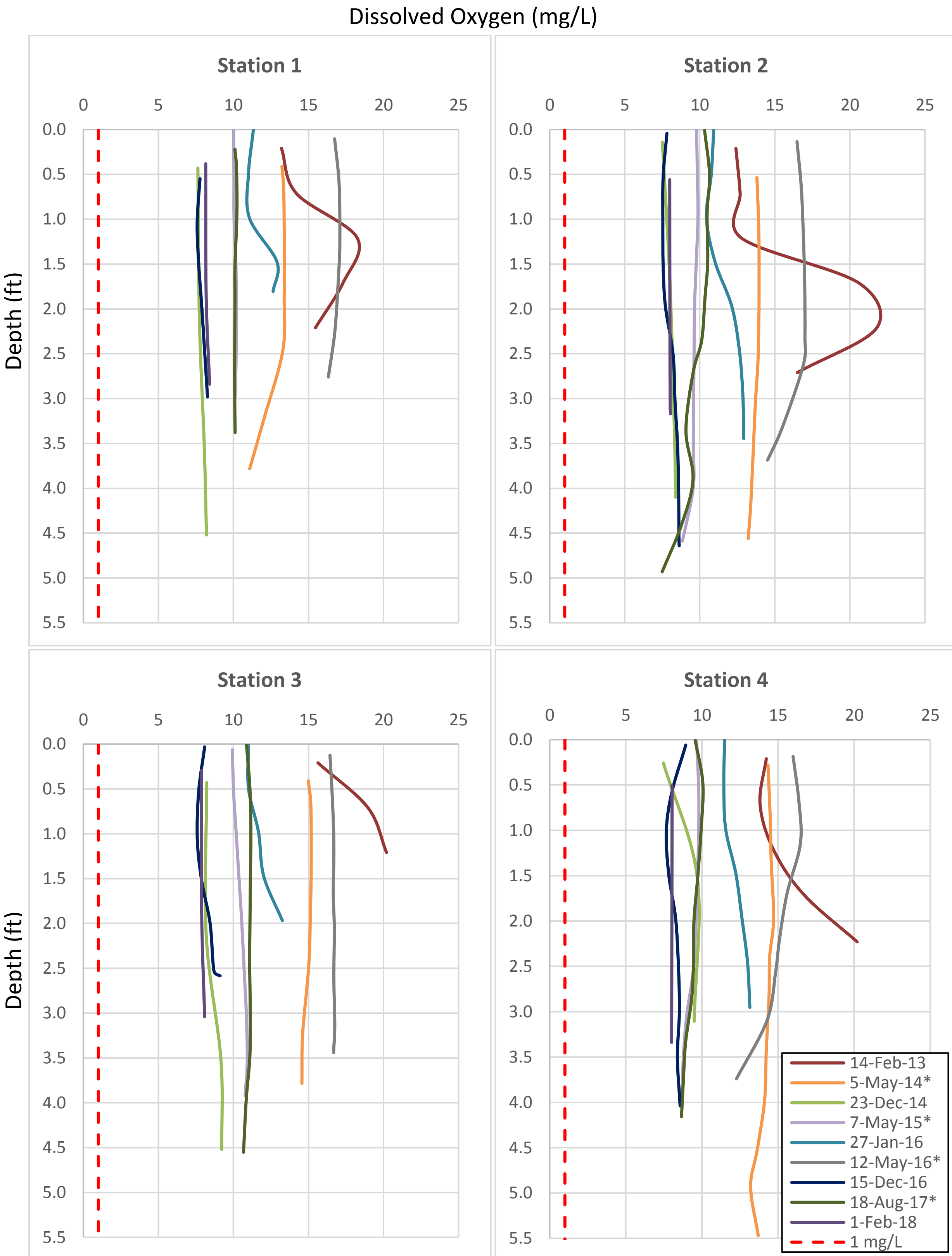



Figure 22a. Post-restoration dissolved oxygen vertical water quality profiles at Stations 1-4 (red line represents 1 mg/L threshold). Asterisk indicates a closed berm condition.

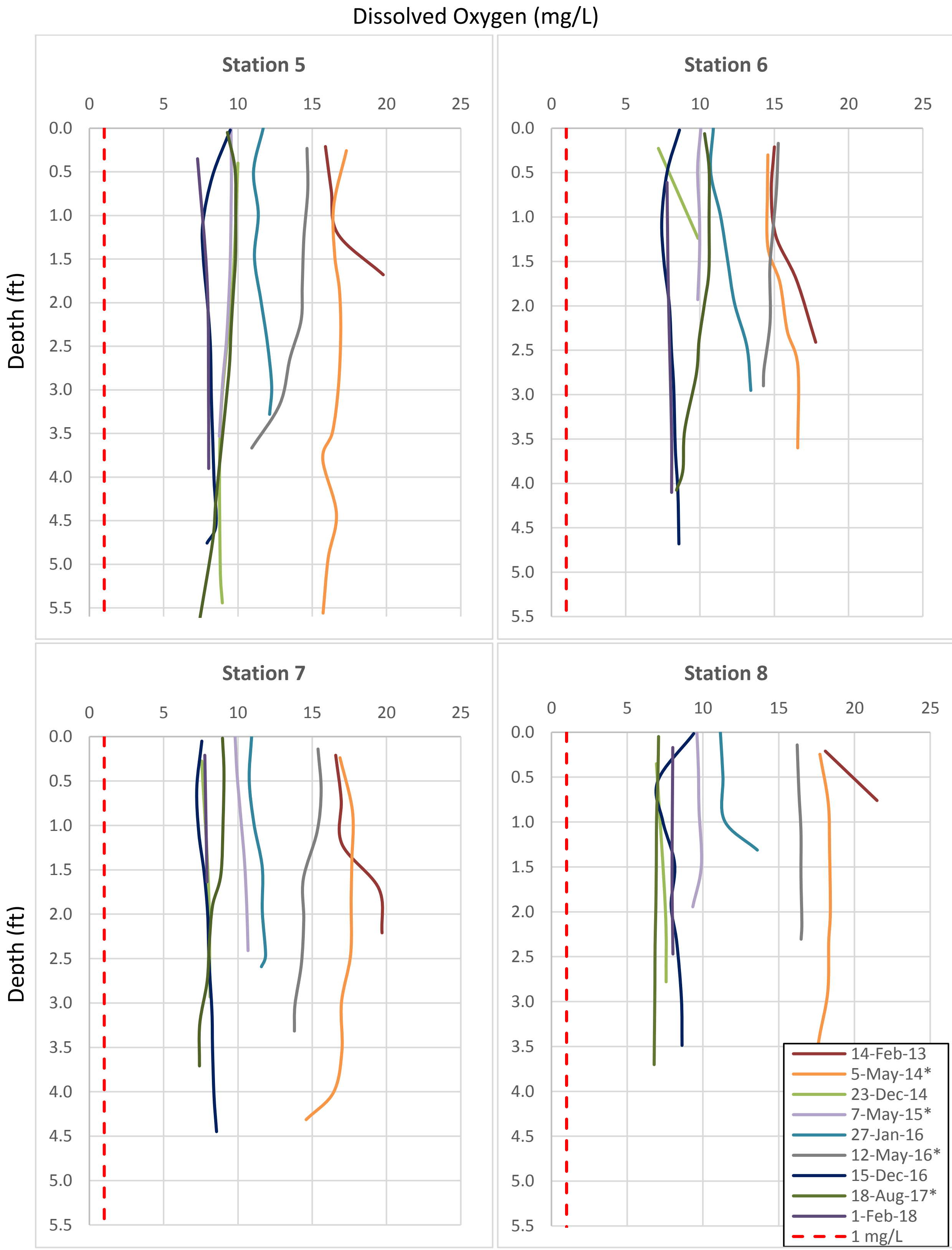



Figure 22b. Post-restoration dissolved oxygen vertical water quality profiles at Stations 5-8 (red line represents 1 mg/L threshold). Asterisk indicates a closed berm condition.

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 |
| 18-Aug-17* | 24.14 | 26.52 | 5.15 | 5.37 | 6.78 | 11.16 | 8.25 | 8.61 |
| 1-Feb-18 | 13.07 | 14.57 | 30.52 | 39.59 | 7.28 | 8.41 | 7.71 | 7.95 |

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 |

| Date | Station | Average Temp (°C) | SE Temp | Average Salinity (ppt) | SE Salinity | Average DO (mg/L) | SE DO | Average pH | SE pH |
|---|---|---|---|---|---|---|---|---|---|
| | 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 |
| 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 | - | - |
| 18-Aug-2017* | 1 | 25.27 | 0.03 | 5.30 | 0.00 | 10.13 | 0.02 | 8.6 | 0.00 |
| | 2 | 25.68 | 0.14 | 5.29 | 0.01 | 9.72 | 0.29 | 8.55 | 0.01 |
| | 3 | 26.42 | 0.02 | 5.27 | 0.00 | 11.02 | 0.05 | 8.59 | 0.00 |

| Date | Station | Average Temp (°C) | SE Temp | Average Salinity (ppt) | SE Salinity | Average DO (mg/L) | SE DO | Average pH | SE pH |
|---|---|---|---|---|---|---|---|---|---|
| | 4 | 25.24 | 0.19 | 5.34 | 0.00 | 9.39 | 0.15 | 8.54 | 0.00 |
| | 5 | 24.78 | 0.11 | 5.29 | 0.01 | 9.14 | 0.21 | 8.49 | 0.00 |
| | 6 | 25.26 | 0.18 | 5.25 | 0.02 | 9.84 | 0.26 | 8.46 | 0.01 |
| | 7 | 24.67 | 0.06 | 5.24 | 0.01 | 8.33 | 0.22 | 8.42 | 0.00 |
| | 8 | 24.25 | 0.03 | 5.27 | 0.01 | 6.90 | 0.03 | 8.31 | 0.01 |
| | | | | | | | | | |
| 01-Feb-2018 | 1 | 14.23 | 0.25 | 36.93 | 2.32 | 8.25 | 0.08 | 7.91 | 0.03 |
| | 2 | 14.27 | 0.14 | 37.91 | 0.47 | 8.03 | 0.01 | 7.92 | 0.01 |
| | 3 | 14.34 | 0.05 | 36.85 | 1.60 | 7.95 | 0.07 | 7.91 | 0.01 |
| | 4 | 13.74 | 0.34 | 36.05 | 1.81 | 8.03 | 0.01 | 7.89 | 0.02 |
| | 5 | 14.18 | 0.02 | 36.70 | 2.38 | 7.82 | 0.18 | 7.90 | 0.02 |
| | 6 | 14.15 | 0.05 | 36.81 | 1.83 | 7.96 | 0.08 | 7.91 | 0.02 |
| | 7 | 13.90 | 0.20 | 34.56 | 3.30 | 7.85 | 0.08 | 7.88 | 0.02 |
| | 8 | 13.93 | 0.20 | 33.88 | 2.15 | 8.00 | 0.02 | 7.76 | 0.03 |

### *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, 10 mg/L in May 2016, and 6.78 mg/L in August 2017. 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 (2$^{nd}$ 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 and summer sampling closed berm condition events 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. Data suggest the restored lagoon represents a brackish water bar-built estuary habitat, with good circulation and dissolved oxygen levels.

## 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 5 semi-annual surface water and bottom water samples were collected at the eight vertical profile Stations (Figure 14) on 6 July 2017 and 1 February 2018, as described in the Monitoring Plan. 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 2008-2017 (data summarized from Heal the Bay's Beach Report Card Report 2017-18).

### *Results*

Graphs displaying data from pre- and post-construction monitoring at all Stations are presented in Figures 23 (bottom) and 24 (surface). The red diamonds on all the right-hand graphs represent the most recent Year 5 survey results (1 February 2018). 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 and low. 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 the Year 3, 4, or 5 surveys. In fact, many of the samples in those years 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. If a particular set of symbols in Figure 23 or 24 is not visible, it is likely due to overlap on the “zero” y-intercept, meaning non-detect for those stations or constituents. 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, 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 via the Heal the Bay. The restoration was completed in May 2013, so the data from 2013-2017 represent “post-restoration years”, though a portion of the 2013 data was collected during the restoration activities. TMDL exceedances were no longer reported on Heal the Bay’s Report Card website (www.beachreportcard.org) or in their Report in 2018, thus no ‘number of TMDL exceedances’ is reported for 2017. Raw data have subsequently been acquired from monitoring agencies in partnership with LMU’s Coastal Research Institute, so additional analyses of bacteria data may be included in the sixth year, final monitoring report.

Table 9. Summary annual AB 411 grade and number of TMDL exceedances from the bacteria Beach Report Card Heal the Bay data (2017-18 Report). 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 |
| 2017 | A | N/A |

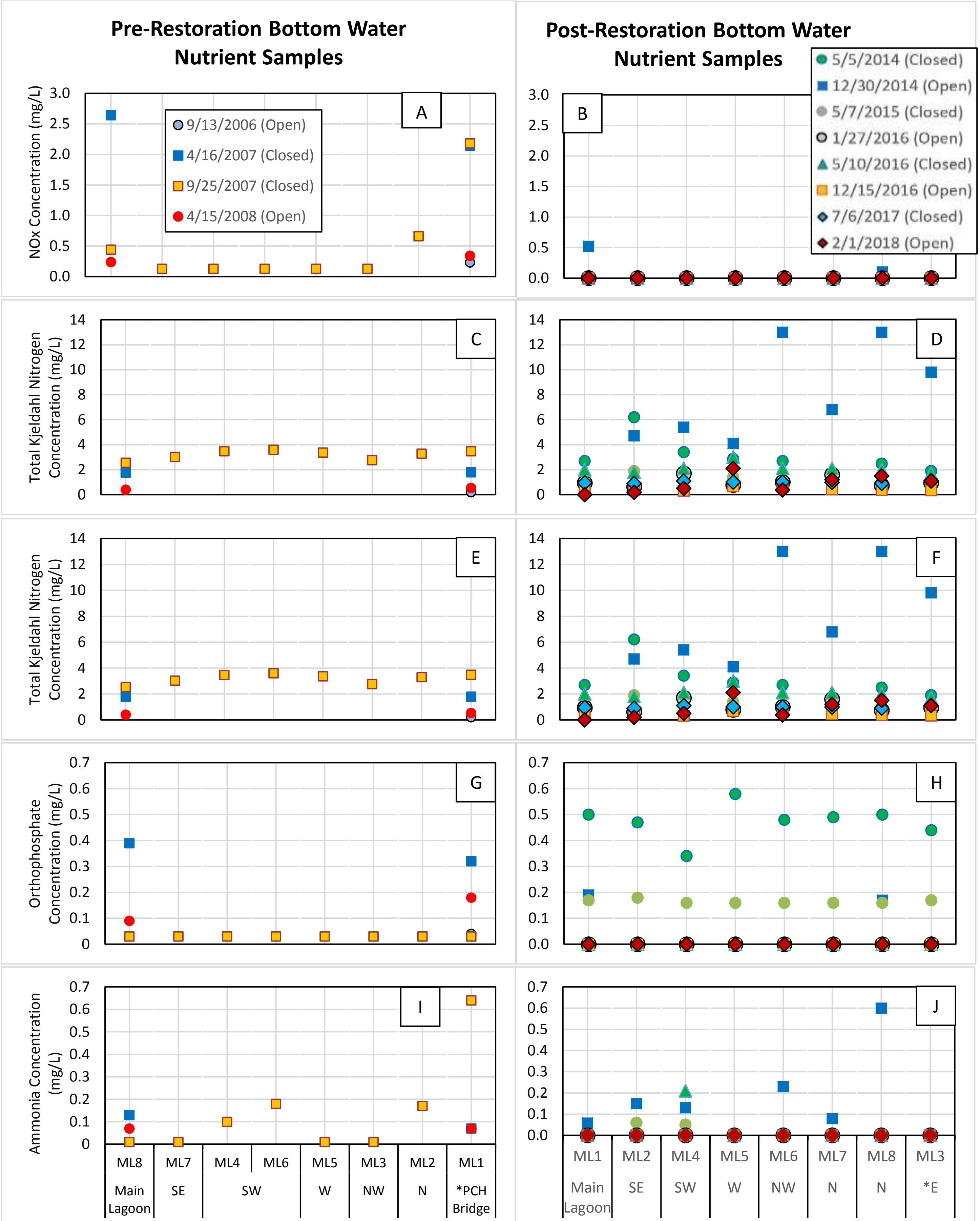
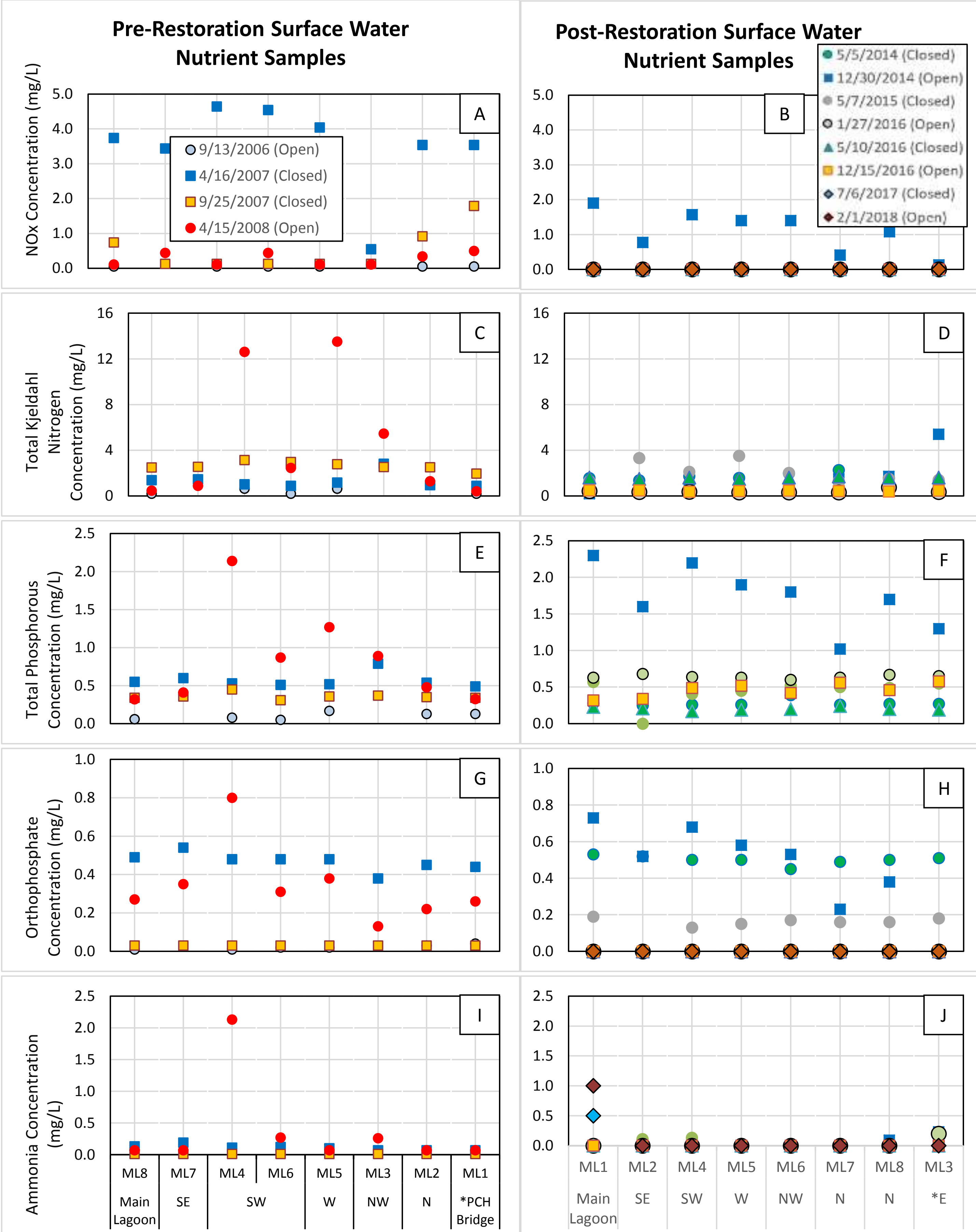



Figure 23. Graphs displaying bottom water nutrient concentration data from pre- (left) and post-restoration (right) (y-axis varies).


Pre-Restoration Surface Water Nutrient Samples
Post-Restoration Surface Water Nutrient Samples
NOx Concentration (mg/L)
Total Kjeldahl Nitrogen Concentration (mg/L)
Total Phosphorous Concentration (mg/L)
Orthophosphate Concentration (mg/L)
Ammonia Concentration (mg/L)
A
B
C
D
E
F
G
H
I
J
9/13/2006 (Open)
4/16/2007 (Closed)
9/25/2007 (Closed)
4/15/2008 (Open)
5/5/2014 (Closed)
12/30/2014 (Open)
5/7/2015 (Closed)
1/27/2016 (Open)
5/10/2016 (Closed)
12/15/2016 (Open)
7/6/2017 (Closed)
2/1/2018 (Open)
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

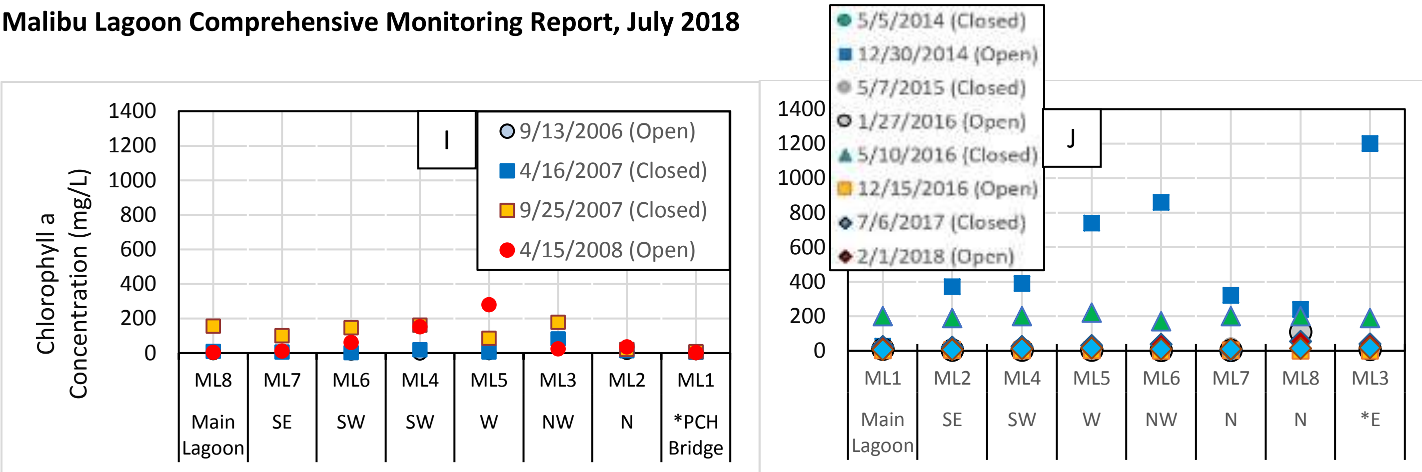



Figure 24. Graphs displaying surface water nutrients concentration data from pre- (left) and post-restoration (right) (y-axis varies).

### *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 5 surveys. Several constituents continued to register as '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, since they are no longer publicly reporting the exceedances, additional analyses of raw data in the final monitoring year may be conducted 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 in subsequent years, 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 all other survey dates. Year 5 samples were collected on 6 July 2017 and 24 January 2018. 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). Laboratory results alternately reported median grain size and dominant grain size, so the right-hand column for Table 10 varies. The 9 March 2017 samples were collected later in the survey year due to significant rain events for several months during the wet season. The samples were not supposed to be collected after 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, March 2017, July 2017, and January 2018 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.

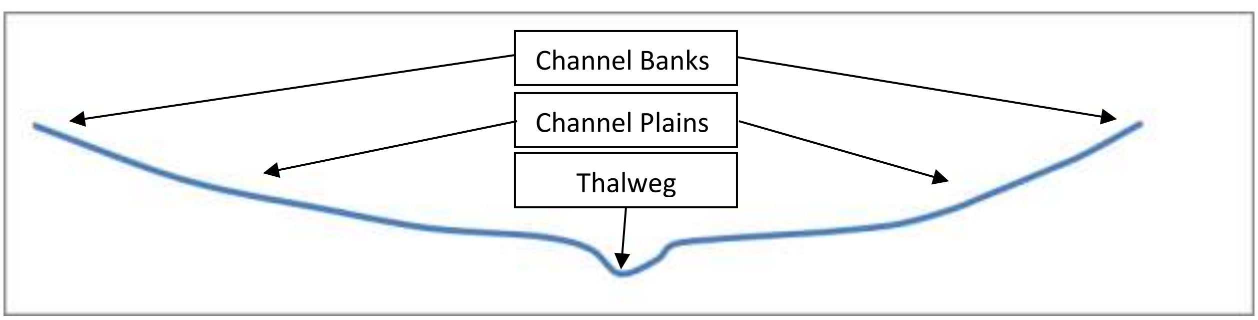



Figure 25. Representative channel cross section displaying the locations of sediment quality collection zones.

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 were integrated to separate silt and clay (< 0.0625 mm), sand (between 0.0625 mm and 2 mm), and gravel (> 2 mm). May 2014, December 2014, May 2015, January 2016, May 2016, March 2017, July 2017, and January 2018 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 and Year 5 data. Station 3 showed an increase in thalweg gravel during the May 2016 survey but was not detected subsequent 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 during closed conditions, indicating good fluctuations.

Table 10. Sediment grain size analysis for all cross sections. 'Channel Banks' and 'Channel Plains' categories 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. Note: sometimes the laboratory provided median grain size and sometimes dominant grain size (far right column).

| | 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 | 34.8 | 56.8 | 8.4 | Silt |
| | | Channel Plains | 56.2 | 36.9 | 6.9 | Silt |
| | | Thalweg | 70.5 | 28.6 | 0.9 | Silt |
| | 2 | Channel Banks | 37.1 | 62.8 | 0.1 | Silt |
| | | Channel Plains | 68.1 | 31.9 | 0.0 | Silt |
| | | Thalweg | 7.2 | 92.4 | 0.5 | Course Sand |
| | 3 | Channel Banks | 11.1 | 76.9 | 12.1 | Course Sand |
| | | Channel Plains | 13.2 | 85.3 | 1.4 | Course Sand |
| | | Thalweg | 4.1 | 81.1 | 14.8 | Course Sand |
| | 4 | Channel Banks | 19.4 | 78.3 | 2.3 | Medium Sand |
| | | Channel Plains | 39.4 | 58.5 | 2.1 | Silt |
| | | Thalweg | 38.8 | 60.0 | 1.2 | Silt |
| | 5 | Channel Banks | 3.2 | 89.7 | 7.1 | Course Sand |
| | | Channel Plains | 6.8 | 87.4 | 5.9 | Very Course Sand |
| | | Thalweg | 0.8 | 79.2 | 20.0 | Very Course Sand |
| | 6 | Channel Banks | 33.0 | 59.8 | 7.1 | Silt |
| | | Channel Plains | 33.7 | 66.3 | 0.0 | Silt |
| | | Thalweg | 36.6 | 57.3 | 6.1 | Silt |
| | 7 | Channel Banks | 4.2 | 87.0 | 8.8 | Course Sand |
| | | Channel Plains | 13.6 | 72.3 | 14.1 | Sand |
| | | Thalweg | 40.7 | 50.1 | 9.1 | Silt |
| | 8 | Channel Banks | 2.7 | 90.7 | 6.6 | Medium Sand |
| | | Channel Plains | 22.3 | 77.7 | 0.0 | Sand |
| | | Thalweg | 1.3 | 85.8 | 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 | 77.0 | 4.1 | Medium Sand |
| | | Thalweg | 4.3 | 93.6 | 2.2 | Fine Sand |
| | 6 | Channel Banks | 22.7 | 55.0 | 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 | 59.0 | 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 | 0.1 | 99.9 | 0.0 | Fine |
| | | Channel Plains | 1.0 | 99.0 | 0.0 | Fine |
| | | Thalweg | 1.1 | 98.9 | 0.0 | Fine |
| | 2 | Channel Banks | 5.0 | 89.8 | 5.2 | Medium |
| | | Channel Plains | 5.2 | 71.9 | 22.9 | Medium |
| | | Thalweg | 27.9 | 66.5 | 5.6 | Fine |
| | 3 | Channel Banks | 12.5 | 83.7 | 3.8 | Medium |
| | | Channel Plains | 20.5 | 76.9 | 2.6 | Fine |
| | | Thalweg | 6.9 | 69.6 | 23.5 | Coarse |
| | 4 | Channel Banks | 11.3 | 88.2 | 0.5 | Fine |
| | | Channel Plains | 23.3 | 76.7 | 0.0 | Fine |
| | | Thalweg | 20.4 | 79.6 | 0.0 | Fine |
| | 5 | Channel Banks | 3.8 | 80.1 | 16.1 | Medium |
| | | Channel Plains | 14.7 | 84.3 | 1.0 | Fine |
| | | Thalweg | 24.8 | 75.2 | 0.0 | Fine |
| | 6 | Channel Banks | 46.4 | 52.9 | 0.8 | Fine |
| | | Channel Plains | 26.2 | 73.5 | 0.3 | Fine |
| | | Thalweg | 31.9 | 67.7 | 0.4 | Fine |
| | 7 | Channel Banks | 2.7 | 78.2 | 19.1 | Medium |
| | | Channel Plains | 20.7 | 65.2 | 14.1 | Medium |
| | | Thalweg | 30.9 | 67.3 | 1.9 | Fine |
| | 8 | Channel Banks | 6.0 | 80.1 | 13.9 | Medium |
| | | Channel Plains | 4.7 | 62.7 | 32.6 | Coarse |
| | | Thalweg | 33.0 | 62.6 | 4.4 | 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 | 1.5 | 98.5 | 0.0 | Fine |
| | | Channel Plains | 0.7 | 89.7 | 9.6 | Medium |
| | | Thalweg | 45.3 | 54.8 | 0.0 | Fine |
| | 2 | Channel Banks | 7.9 | 87.1 | 5.1 | Fine |
| | | Channel Plains | 16.6 | 76.8 | 6.6 | Medium |
| | | Thalweg | 50.9 | 49.1 | 0.0 | Fine |
| | 3 | Channel Banks | 16.3 | 82.9 | 0.8 | Fine |
| | | Channel Plains | 10.2 | 66.1 | 23.8 | Coarse |
| | | Thalweg | 34.2 | 65.8 | 0.0 | Fine |
| | 4 | Channel Banks | 30.3 | 69.8 | 0.0 | Fine |
| | | Channel Plains | 19.4 | 70.9 | 9.7 | Fine |
| | | Thalweg | 39.3 | 60.8 | 0.0 | Fine |
| | 5 | Channel Banks | 6.7 | 75.7 | 17.6 | Medium |
| | | Channel Plains | 3.5 | 79.6 | 16.9 | Medium |
| | | Thalweg | 28.8 | 71.2 | 0.0 | Fine |
| | 6 | Channel Banks | 15.7 | 83.3 | 1.0 | Medium |
| | | Channel Plains | 23.3 | 63.6 | 13.1 | Medium |
| | | Thalweg | 12.5 | 85.0 | 2.5 | Medium |
| | 7 | Channel Banks | 8.3 | 70.7 | 20.9 | Medium |
| | | Channel Plains | 7.4 | 91.1 | 1.6 | Medium |
| | | Thalweg | 11.4 | 88.6 | 0.0 | Medium |
| | 8 | Channel Banks | 34.8 | 43.3 | 21.9 | Medium |
| | | Channel Plains | 8.6 | 68.4 | 23.0 | Medium |
| | | Thalweg | 47.2 | 52.8 | 0.0 | Fine |

| | Station | Location | Total Silt and Clay % (0 to 0.0625 mm) | Sand % (0.0625 mm to 2 mm) | Gravel % (>2 mm) | Dominant Grain Size |
|---|---|---|---|---|---|---|
| July 2017 | 1 | Channel Banks | 0.3 | 99.7 | 0.0 | Medium Sand |
| | | Channel Plains | 29.6 | 70.4 | 0.0 | Very Fine Sand |
| | | Thalweg | 23.5 | 76.5 | 0.0 | Fine Sand |
| | 2 | Channel Banks | 15.9 | 84.1 | 0.0 | Coarse Sand |
| | | Channel Plains | 21.9 | 78.1 | 0.0 | Medium Sand |
| | | Thalweg | 3.3 | 55.2 | 41.5 | Silt |
| | 3 | Channel Banks | 8.5 | 83.5 | 8.0 | Medium / Coarse Sand |
| | | Channel Plains | 68.3 | 31.8 | 0.0 | Fine Sand |
| | | Thalweg | 18.1 | 81.9 | 0.0 | Silt |
| | 4 | Channel Banks | 4.9 | 79.6 | 15.5 | Silt |
| | | Channel Plains | 2.4 | 90.4 | 7.2 | Coarse Sand |
| | | Thalweg | 3.5 | 87.8 | 8.7 | Silt |
| | 5 | Channel Banks | 3.6 | 86.0 | 10.4 | Coarse Sand |
| | | Channel Plains | 16.4 | 83.7 | 0.0 | Coarse Sand |
| | | Thalweg | 33.3 | 66.7 | 0.0 | Coarse Sand |
| | 6 | Channel Banks | 2.2 | 74.2 | 23.6 | Coarse Sand |
| | | Channel Plains | 36.8 | 63.2 | 0.0 | Coarse Sand |
| | | Thalweg | 32.8 | 67.2 | 0.0 | Silt |
| | 7 | Channel Banks | 28.0 | 72.0 | 0.0 | Medium Sand |
| | | Channel Plains | 33.5 | 66.5 | 0.0 | Silt |
| | | Thalweg | 2.3 | 88.5 | 9.3 | Medium Sand |
| | 8 | Channel Banks | 50.5 | 49.5 | 0.0 | Coarse Sand |
| | | Channel Plains | 22.2 | 77.9 | 0.0 | Silt |
| | | Thalweg | 33.1 | 66.9 | 0.0 | Silt |

| | Station | Location | Total Silt and Clay % (0 to 0.0625 mm) | Sand % (0.0625 mm to 2 mm) | Gravel % (>2 mm) | Median Grain Size |
|---|---|---|---|---|---|---|
| January 2018 | 1 | Channel Banks | 1.4 | 98.6 | 0.0 | Coarse Sand |
| | | Channel Plains | 23.0 | 77.0 | 0.0 | Medium Sand |
| | | Thalweg | 21.1 | 74.6 | 4.3 | Medium Sand |
| | 2 | Channel Banks | 2.4 | 84.1 | 13.5 | Very Coarse Sand |
| | | Channel Plains | 1.7 | 76.2 | 22.1 | Very Coarse Sand |
| | | Thalweg | 55.5 | 44.6 | 0.0 | Fine Sand |
| | 3 | Channel Banks | 42.8 | 57.2 | 0.0 | Fine Sand |
| | | Channel Plains | 43.4 | 56.6 | 0.0 | Fine Sand |
| | | Thalweg | 61.8 | 38.3 | 0.0 | Very Fine Sand |
| | 4 | Channel Banks | 26.7 | 73.3 | 0.0 | Medium Sand |
| | | Channel Plains | 32.1 | 68.0 | 0.0 | Medium Sand |
| | | Thalweg | 69.5 | 30.5 | 0.0 | Very Fine Sand |
| | 5 | Channel Banks | 3.0 | 75.5 | 21.5 | Very Coarse Sand |
| | | Channel Plains | 39.7 | 60.3 | 0.0 | Fine Sand |
| | | Thalweg | 51.5 | 48.5 | 0.0 | Fine Sand |
| | 6 | Channel Banks | 3.0 | 65.2 | 31.8 | Very Coarse Sand |
| | | Channel Plains | 2.8 | 79.8 | 17.5 | Very Coarse Sand |
| | | Thalweg | 4.7 | 76.0 | 19.3 | Very Coarse Sand |
| | 7 | Channel Banks | 4.2 | 64.8 | 31.0 | Very Coarse Sand |
| | | Channel Plains | 2.5 | 66.0 | 31.5 | Very Coarse Sand |
| | | Thalweg | 62.6 | 37.4 | 0.0 | Very Fine Sand |
| | 8 | Channel Banks | 1.7 | 87.9 | 10.5 | Very Coarse Sand |
| | | Channel Plains | 2.9 | 88.1 | 9.0 | Coarse Sand |
| | | Thalweg | 55.2 | 44.9 | 0.0 | Coarse Sand |

### 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 low during the July 2017 Year 5 surveys. In fact, all samples recorded as 'non-detect' for N in July 2017. Several spikes were seen in January 2018 in N, though other constituents remained low. On the whole, across all Stations and survey years, 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, and remained consistently low in both Year 5 surveys (Table 12), and lower, relatively, than pre-restoration data.

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 |
| | 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 | 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 |

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

| | Station | Location | Nitrate + Nitrite, as N (mg/kg) | TN (mg/kg) | TKN (mg/kg) | TP (mg/kg) |
|---|---|---|---|---|---|---|
| | | Channel Plain | ND | 760.00 | 760.00 | 200.00 |
| | | Thalweg | ND | 84.00 | 84.00 | 190.00 |
| | 3 | Channel Bank | ND | 1500.00 | 1500.00 | 220.00 |
| | | Channel Plain | ND | 460.00 | 460.00 | 210.00 |
| | | Thalweg | ND | 210.00 | 210.00 | 170.00 |
| | 4 | Channel Bank | ND | 460.00 | 460.00 | 270.00 |
| | | Channel Plain | ND | 520.00 | 520.00 | 210.00 |
| | | Thalweg | ND | 460.00 | 410.00 | 210.00 |
| | 5 | Channel Bank | 0.60 | 280.00 | 280.00 | 270.00 |
| | | Channel Plain | ND | 360.00 | 360.00 | 230.00 |
| | | Thalweg | ND | 210.00 | 210.00 | 210.00 |
| | 6 | Channel Bank | ND | 480.00 | 480.00 | 180.00 |
| | | 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 |

| | Station | Location | Nitrate + Nitrite, as N (mg/kg) | TN (mg/kg) | TKN (mg/kg) | TP (mg/kg) |
|---|---|---|---|---|---|---|
| | | 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 |
| | | | | | | |
| 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 |

| | Station | Location | Nitrate + Nitrite, as N (mg/kg) | TN (mg/kg) | TKN (mg/kg) | TP (mg/kg) |
|---|---|---|---|---|---|---|
| | 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 |
| | 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 |
| | | | | | | |
| July 2017 | 1 | Channel Bank | ND | 760.00 | 760.00 | 420.00 |
| | | Channel Plain | ND | 56.00 | 56.00 | 200.00 |
| | | Thalweg | ND | 1100.00 | 1100.00 | 420.00 |
| | 2 | Channel Bank | ND | 460.00 | 460.00 | 300.00 |
| | | Channel Plain | ND | 880.00 | 880.00 | 350.00 |
| | | Thalweg | ND | 560.00 | 560.00 | 260.00 |
| | 3 | Channel Bank | ND | 340.00 | 340.00 | 320.00 |
| | | Channel Plain | ND | 690.00 | 690.00 | 350.00 |
| | | Thalweg | ND | 610.00 | 610.00 | 270.00 |
| | 4 | Channel Bank | ND | 340.00 | 340.00 | 310.00 |
| | | Channel Plain | ND | 610.00 | 610.00 | 300.00 |
| | | Thalweg | ND | 500.00 | 500.00 | 220.00 |
| | 5 | Channel Bank | ND | 690.00 | 690.00 | 350.00 |
| | | Channel Plain | ND | 640.00 | 640.00 | 230.00 |
| | | Thalweg | ND | 540.00 | 540.00 | 240.00 |

| | Station | Location | Nitrate + Nitrite, as N (mg/kg) | TN (mg/kg) | TKN (mg/kg) | TP (mg/kg) |
|---|---|---|---|---|---|---|
| | 6 | Channel Bank | ND | 910.00 | 910.00 | 310.00 |
| | | Channel Plain | ND | 520.00 | 520.00 | 250.00 |
| | | Thalweg | ND | 580.00 | 580.00 | 270.00 |
| | 7 | Channel Bank | ND | 690.00 | 690.00 | 390.00 |
| | | Channel Plain | ND | 770.00 | 770.00 | 380.00 |
| | | Thalweg | ND | 410.00 | 410.00 | 200.00 |
| | 8 | Channel Bank | ND | 680.00 | 680.00 | 270.00 |
| | | Channel Plain | ND | 650.00 | 650.00 | 280.00 |
| | | Thalweg | ND | 650.00 | 650.00 | 160.00 |
| | | | | | | |
| January 2018 | 1 | Channel Bank | ND | 51.00 | 51.00 | 290.00 |
| | | Channel Plain | ND | 140.00 | 140.00 | 210.00 |
| | | Thalweg | ND | 360.00 | 360.00 | 280.00 |
| | 2 | Channel Bank | 7.00 | 300.00 | 290.00 | 400.00 |
| | | Channel Plain | ND | 350.00 | 350.00 | 390.00 |
| | | Thalweg | 4.00 | 540.00 | 540.00 | 320.00 |
| | 3 | Channel Bank | ND | 330.00 | 330.00 | 540.00 |
| | | Channel Plain | ND | 390.00 | 390.00 | 520.00 |
| | | Thalweg | ND | 590.00 | 590.00 | 390.00 |
| | 4 | Channel Bank | 4.20 | 350.00 | 350.00 | 610.00 |
| | | Channel Plain | ND | 280.00 | 280.00 | 420.00 |
| | | Thalweg | ND | 240.00 | 240.00 | 280.00 |
| | 5 | Channel Bank | ND | 300.00 | 300.00 | 600.00 |
| | | Channel Plain | ND | 160.00 | 160.00 | 370.00 |
| | | Thalweg | 2.60 | 260.00 | 260.00 | 270.00 |
| | 6 | Channel Bank | 2.50 | 170.00 | 170.00 | 640.00 |
| | | Channel Plain | ND | 390.00 | 390.00 | 510.00 |
| | | Thalweg | 3.40 | 170.00 | 170.00 | 270.00 |
| | 7 | Channel Bank | ND | 330.00 | 330.00 | 510.00 |
| | | Channel Plain | ND | 400.00 | 300.00 | 570.00 |
| | | Thalweg | 6.90 | 170.00 | 160.00 | 280.00 |
| | 8 | Channel Bank | 2.30 | 450.00 | 450.00 | 430.00 |
| | | Channel Plain | ND | 550.00 | 550.00 | 390.00 |
| | | Thalweg | ND | 400.00 | 400.00 | 340.00 |

### *Performance Evaluation*

As the deposition and fluctuation of fine-grained sediments is a predictable occurrence in variable water energy conditions, the fluctuations based on open and closed condition of the grain size sediments is an expected trend due to movement of the lagoon waters. 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 trajectories 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. Similarly, nutrients are often more associated with fine-grained sediments, and with the "flushing" of the fine grains regularly out of the lagoon, it may support the lower nutrient data results.

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. 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 and Year 5 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 5 of the monitoring program, and several parameters 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, 8 March 2017, and 24 January 2018 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 and their subcontractors. 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 41 taxa across 7 phyla and 12 classes represented in the post-restoration surveys, including the benthic core (31 taxa) and the net sweep (20 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 January 2018 (Year 5). 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 100.0% in January 2018 for benthic core invertebrates (Figures 27a and 28a), and a decrease in the percent abundance of the pollution-tolerant taxa, e.g. from over 91% in 2007 for both survey types pre-restoration to 0.0% and 9.4% in the benthic core and net sweep survey types, respectively. Post-restoration net sweep data were consistently dominated by oligochaetes, with a pollution tolerance value of 5 (indicating this class is sensitive to pollution), along with the presence of various taxa of insects, bivalves and gastropods. Post-restoration benthic core data were also frequently dominated by oligochaetes, with additional gastropod molluscs and others. All post-restoration years (1-5) show a reduction in pollution-tolerant abundances of invertebrate taxa as compared to pre-restoration survey abundances.

The percentage of the number of pollution sensitive taxa in the benthic cores was also 100% for the January 2018 surveys, with 0.0% number of taxa in the pollution tolerant category. A similar trend of more pollution sensitive species, albeit less dramatic, was expressed by the percentages of the numbers of taxa in the net sweep samples, which showed a slight increase in sensitive (pollution-intolerant) species use of the site as a trend on the post-restoration surveys, and a slight decrease in the percent of number of pollution tolerant taxa (Figures 27b and 28b). Both survey types for the most recent data in January 2018 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. The May 2014 surveys were conducted in a closed berm condition.

| Phylum | Class | Order | Family | Lowest Possible Taxon | Benthic Cores | | | | | Net Sweeps | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | May 2014 | Dec 2014 | Jan 2016 | Mar 2017 | Jan 2018 | May 2014 | Dec 2014 | Jan 2016 | Mar 2017 | Jan 2018 |
| Annelida | Oligochaeta | | | Oligochaeta | | | | | | X | X | X | X | X |
| Annelida | Oligochaeta | Haplotaxida | Tubicidae | Tubicidae | X | | | | | | | | | |
| Annelida | Oligochaeta | Haplotaxida | Tubificidae | Tubificidae | | X | X | X | X | | | | | |
| Annelida | Polychaeta | Sedentaria | Capitellidae | *Capitella capitata* complex | | X | 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 | X | | | | | |
| Arthropoda | Insecta | Coleoptera | Dytiscidae | Hydroporinae | X | | | | | | | | | |
| Arthropoda | Insecta | Coleoptera | Hydrophilidae | *Enochrus sp.* | X | | | | | X | | | | |
| Arthropoda | Insecta | Coleoptera | Hydrophilidae | *Hydrochus sp.* | X | | | | | | | | | |
| Arthropoda | Insecta | Coleoptera | Staphylinidae | Staphylinidae | | | | | X | | | | | |
| Arthropoda | Insecta | Diptera | Ceratopogonidae | Ceratopogon | | | | | | | | | X | |
| Arthropoda | Insecta | Diptera | Ceratopogonidae | Dasyhelea | | | | | | X | | | | X |
| Arthropoda | Insecta | Diptera | Chironomidae | Chronomini | X | X | X | | | X | X | X | X | |
| Arthropoda | Insecta | Diptera | Chironomidae | Orthocladiinae | | | | X | | | | | | X |
| Arthropoda | Insecta | Diptera | Chironomidae | Tanytarsini | | | | | | | | | X | |
| Arthropoda | Insecta | Diptera | Diptera | *Dasyhelea sp.* | | X | | | | | | | | |
| Arthropoda | Insecta | Diptera | Dolichopodidae | Dolichopodidae | X | X | | X | X | X | | | X | |
| Arthropoda | Insecta | Diptera | Ephydridae | Ephydridae | | | | | X | | | | X | 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 | |

| Phylum | Class | Order | Family | Lowest Possible Taxon | Benthic Cores | | | | | Net Sweeps | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | May 2014 | Dec 2014 | Jan 2016 | Mar 2017 | Jan 2018 | May 2014 | Dec 2014 | Jan 2016 | Mar 2017 | Jan 2018 |
| Arthropoda | Malacostraca | Amphipoda | Corophiidae | *Monocorophium insidiosum* | | | | X | | | | | | |
| Arthropoda | Malacostraca | Amphipoda | Gammaridae | *Gammarus sp.* | | X | | | X | | | | | |
| Arthropoda | Malacostraca | Amphipoda | Hyalellidae | Hyalella | | | | | | | | | X | X |
| Arthropoda | Malacostraca | Amphipoda | Talitridae | *Traskorchestia sp.* | | | | X | X | | | | | |
| Arthropoda | Maxillopoda | Calanoida | | Calanoida | X | | X | | | | | | | |
| Arthropoda | Maxillopoda | Harpactacoida | | Harpactacoida | | | X | | | | | | | |
| Arthropoda | Ostracoda | | | Ostracoda | | | | | | | X | X | X | X |
| Arthropoda | Ostracoda | Podocopida | | Podocopida | X | X | X | X | | X | | | | |
| Arthropoda | Ostracoda | Podocopida | Cypridoidea | Cypridoidea | | | | | X | | | | | |
| Arthropoda | Ostracoda | Podocopida | Dawinulocopina | Dawinulocopina | | | | | X | | | | | |
| Chordata | Osteichthys | | | Fish egg/larva | X | | | | | | | | | |
| Mollusca | Bivalvia | Veneroida | Corbiculidae | *Corbicula sp.* | | | | | | | | | | X |
| Mollusca | Gastropoda | | | Gastropoda | | | | | | | | | | X |
| Mollusca | Gastropoda | Cephalaspidea | Haminoeidae | *Haminoea vesicula* | | | | | X | | | | | |
| Mollusca | Gastropoda | Saccoglosa | Hermaeidae | *Alderia willowi* | X | | | | X | | | | | X |
| Nematoda | Adenophorea | Mermithida | Mermithidae | Mermithidae | X | X | X | | | | | | | |
| Nemertea | Anopla | Paleonemertea | | Paleonemertea | X | | | | | | | | | |
| Platyhelminthes | Turbellaria | Rhabdocoela | | Rhabdocoela | X | | | | | | | | | |

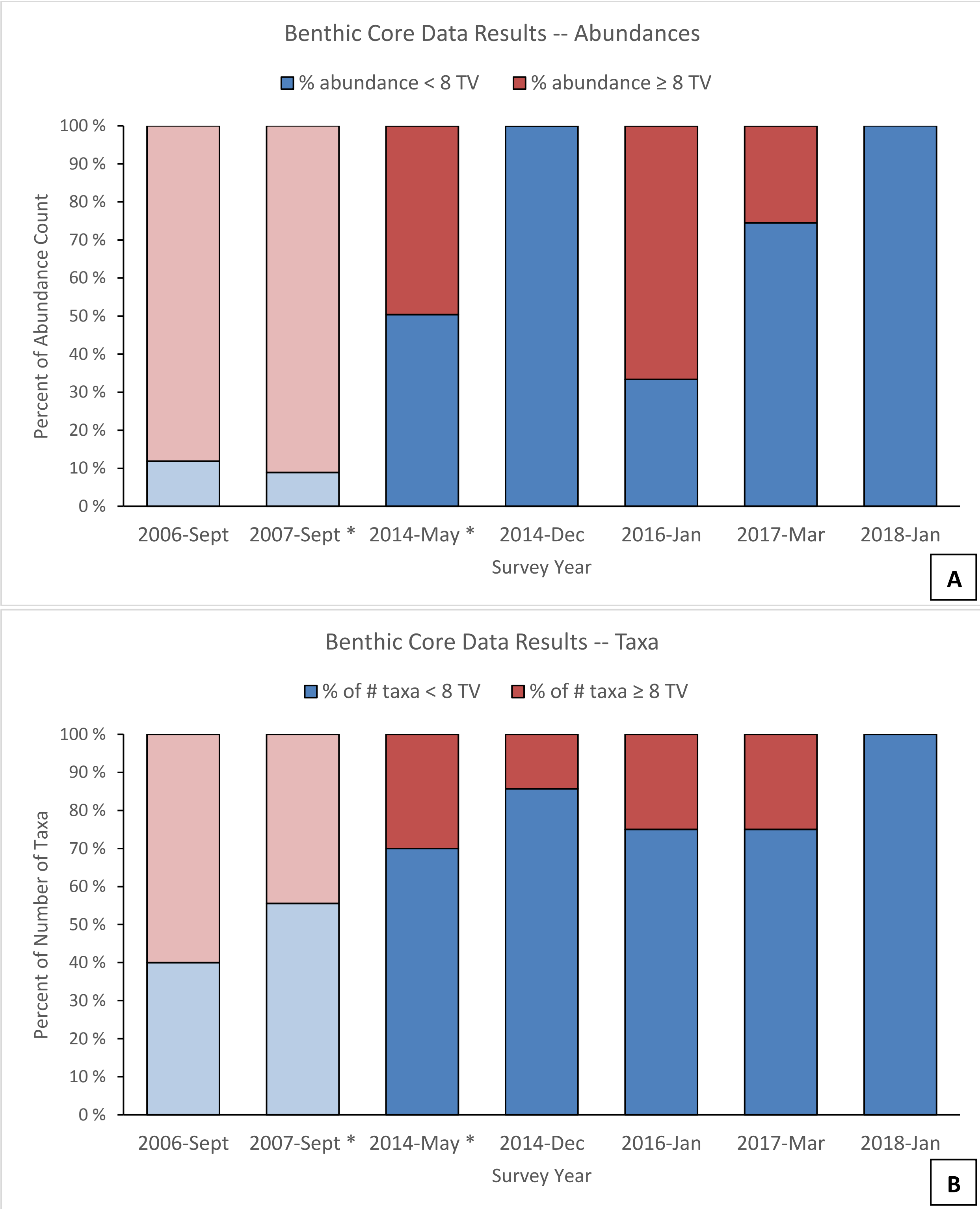



Figure 27. Benthic invertebrate core data results organized by (A) percent of abundance count data with pollution tolerance values (TV) below 8, and (B) percent of number of taxa with TV below 8. Asterisks indicate a closed berm condition. Light colors represent pre-restoration survey data.

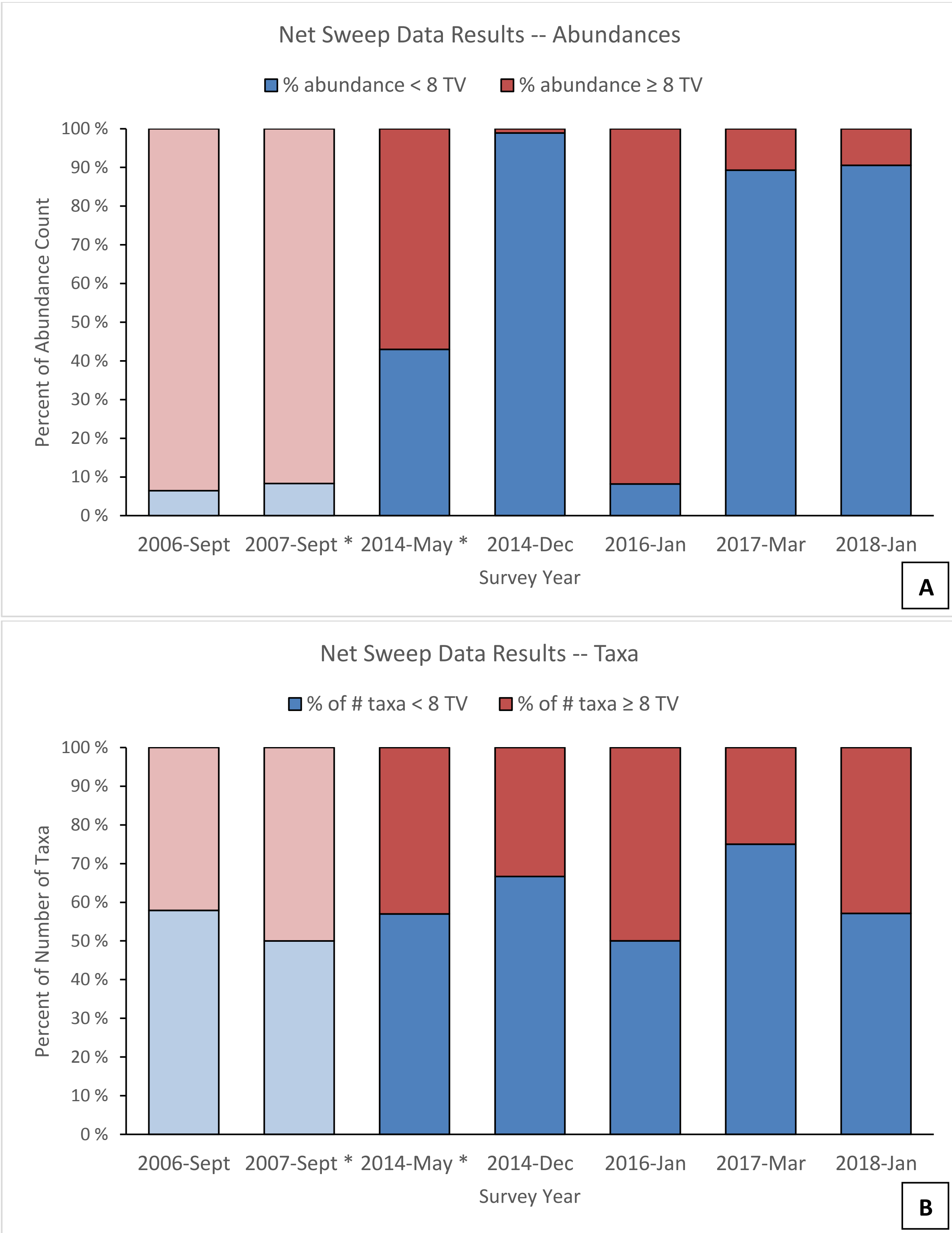



Figure 28. Net sweep invertebrate data results organized by (A) percent of abundance count data with pollution tolerance values (TV) below 8, and (B) percent of number of taxa with TV below 8. Asterisks indicate a closed berm condition. Light colors represent pre-restoration survey data.

### *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 and 2018 data results, even showing 100% pollution sensitive abundances and number of taxa for the benthic core data in 2018. 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 final monitoring report for next year to have a full evaluation of trends over time. Invertebrate populations are also likely to have been affected by El Niño (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 and several additional taxa in 2018 as well, including a new bivalve.

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 2018 results for the net sweep data, two gastropod taxa did not have a pollution tolerance value assigned. For the 2018 benthic core invertebrate data, nine taxa making up a little over 12% 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 and submerged vegetation community both continue to develop, establish more complexity, and vary seasonally over time.

## 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 (July 2017 and January 2018).

### *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, 3 March 2017, 25 July 2017 (Year 5), and 30 January 2018 (Year 5). Surveys were 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. On 25 July 2017 and 30 January 2018, spot surveys returned to the usual protocol, focused on the eastern end of the beach.

In May 2015 and July 2017, 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 continued to be inaccessible; therefore, Site 2a was surveyed again for Year 5 surveys (similarly to previous surveys) to comply with monitoring plan requirements. The lagoon (berm) was closed to the ocean for the July 2017 survey, but it was open for the January 2018 survey.


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

Figure 30. Representative photograph of fish surveys being conducted at Site 1 on 30 January 2018 (credit: 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, and 2017). 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 an increasing abundance of invasive non-native fishes. Post-restoration surveys have documented a range of native and non-native fish and invertebrate species, with the added function of a nursery habitat, based on the presence of many juvenile and larval fish.

Table 14. Species captured or observed during each of the fish survey events. Asterisk indicates closed berm condition. Note: 2005 survey highlighted in orange 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 | Jul 2017 * | Jan 2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | X | X |
| Northern anchovy | *Engraulis mordax* | | X | | X | | X | X | | X | |
| Opaleye | *Girella nigricans* | X | | | | | | | | X | |
| Southern steelhead trout | *Oncorhynchus mykiss* | | | X | | | | | | | |
| Spotted turbot | *Pleuronichthys ritteri* | | | | | | | | | | X |
| Staghorn sculpin | *Leptocottus armatus* | | X | X | | | X | X | X | X | X |
| Striped mullet | *Mugil cephalus* | | | X | X | X | X | X | X | X | X |
| Tidewater goby | *Eucyclogobius newberryi* | X | X | X | | X | | X | X | X | |
| Topsmelt | *Atherinops sp.* | X | X | X | X | X | X | X | X | X | X |
| Topsmelt larva (< 5 cm) | *Atherinops sp.* | | | X | | X | X | X | X | X | X |
| Unidentified goby larva (<5cm) | ---- | | | | | | | | | X | X |
| Unidentified fish larva (< 5 cm) | ---- | | | X | | 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 | | X | X |
| Mosquitofish | *Gambusia affinis* | X | X | X | X | X | X | X | X | X | |
| Carp | *Cyprinus carpio* | X | | 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=1,289), 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 across several sites (Figure 31). Due to time constraints, spot surveys were not conducted 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, n=132), followed by topsmelt (adult n=49, juvenile n=35). Notably, only one non-native mosquitofish was captured across all sites.

**July 2017 Survey**

A total of 10 tidewater gobies were captured across several sites along with 8 goby larvae. Tidewater gobies were identified in the restoration seines, but not the beach spot seines. Striped mullet were observed jumping throughout the lagoon. The dominant species surveyed and identified was topsmelt (larvae n=2,618, juveniles n=132, adult n=56), followed by Mississippi silversides (n=663), and northern anchovy (n=662). Seventeen longjawed mudsuckers were also counted.

**January 2018 Survey**

One tidewater goby larva was captured during a spot seine near the berm. It was approximately 2 mm long and very difficult to conclusively identify. It was released, rather than vouchered. Striped mullet were observed jumping throughout the lagoon; one adult (66 cm in length) was captured at Site 3. The dominant species surveyed and identified was topsmelt (larva n=179, juveniles n=20, adult n=0). Three longjawed mudsucker larvae were also observed. The majority of individuals collected were extremely young larval or juvenile fish, which suggests that Malibu Lagoon is currently serving as a nursery site for both lagoon and ocean species.

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. A total of 14 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, January 2016, and January 2018 post-construction surveys reflect the winter, marine influenced conditions, as compared to the native fish species observed in the May and summer 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. 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. The Year 5 surveys followed similar trends, with the addition of spotted turbot as a species previously unrecorded on surveys.

## Avian Community Surveys

### *Introduction*

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

### *Methods*

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

Post-restoration surveys were conducted on the project site by Cooper Ecological Monitoring, Inc. on: 11-12 February, 18-19 April, 22-23 July, and 28-29 October 2013; 6-7 January, 21-22 April, 22-23 July, and 28-29 October 2014; 6-7 January, 21 April (two surveys completed on this date), 9-10 July, and 26-27 October 2015; 11-12 January, 26-27 April, 25-26 July and, 25-26 October 2016; 17-18 January, 24 and 26 April, 13-14 July, and 30-31 October 2017. 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, similar to the 2017 Year 4 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*

Interpretations of increases and declines in abundances or species richness should be made with caution, as birds are highly variable over space and time, and counts are indicative of a snapshot only. The total number of birds identified as part of Year 5 surveys was 6,310 individuals, representing the lowest post-restoration total thus far. The 2012-16 average cumulative total was 9,690. Year 4 surveys had identified the highest total number of birds, post-restoration, at 11,736 individuals, representing an approximately 46% increase for Year 4 over the pre-restoration average. The cumulative number of species and identifiable subspecies detected in all five post-restoration years is 155, with four new species identified in 2017: Canada Goose, Ross's Goose, Reddish Egret, and Merlin.

In the five years since restoration, 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 shallower and narrower, prior to the restoration. A comparison of 22 common waterbirds in the Western Channels shows continuing high species richness in 2017, but a dip in counts of individuals since 2014. Both post-restoration total number of individuals and total species richness by year still remain higher for the western channel analysis as compared to pre-restoration data.

Again, comparison of sheer numbers and species richness totals are of limited interpretive use for bird data, 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 in 2017 were similar to 2016 (and to the years following the 2013 restoration); it appears that 2015 was likely an unusually good year for open-country species, in particular Western Meadowlark (Table 15). Counts of scrub/woodland species are higher than 2013 immediately post-restoration, but are still less than half counts pre-restoration, probably because the vegetation (both scrub and riparian) is still growing in and may take decades to reach the density and maturity of the site prior to restoration.

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. Urban species were recorded in exactly the same numbers in 2017 as in 2016, and are still less than half pre-restoration levels, suggesting the site is still relatively less appealing to urban-adapted birds, and its avifauna is arguably more "wild."

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, from multiple observers between 2015-2017, shows stable numbers 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

Large waders and, particularly, fish-eaters, were found in higher numbers than prior years (including pre-restoration years), suggesting that the lagoon is functioning well for those groups. Freshwater marsh birds surged in 2017, particularly Great-tailed Grackle and Common Yellowthroat, which favor reeds for breeding and wintering. While the two rail species found at the site pre-restoration no longer occur regularly (i.e. Sora and Virginia Rail), these two are readily seen across the street at Legacy Park, where reedbeds are far more extensive (D. Cooper, pers. obs.; eBird data supported).

After a few low years, shorebird use of the lagoon appears to be rising, with counts of many species approaching pre-restoration numbers, and overall shorebird numbers double that of 2016, and triple that of 2015. Qualitatively, there seem to be more shorebirds in general roosting on the islands toward the main lagoon than in prior years, regardless of time of day, tide, etc. Some species have been fairly stable in recent years, such as Least Sandpiper, while others such as Marbled Godwit have clearly increased, especially in fall, when dozens of shorebirds roost at the edge of the main lagoon. Additionally in 2017, federally threatened Western Snowy Plovers successfully nested on the beach adjacent to the restoration area (see separate subsection below).

Counts of marine bird continued to decline in 2017, but this was largely due to the continuing slide in numbers of two abundant species, Brown Pelican and Elegant Tern, which are seeing their breeding success in Mexico hampered by recent increases in ocean water temperature. This has led to lower numbers of young dispersing north up the coast of California in summer/fall, and presumably smaller pre-breeding aggregations of adults in spring.

### Western Channels Analysis (restoration area only)

In the five years since restoration, 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 shallower and narrower, prior to the restoration. A comparison of 22 common waterbirds in the western channels shows continuing high species richness in 2017 (n=20), but a dip in counts of individuals since 2014 (Figure 33, Table 17). Both post-restoration total number of individuals and total species richness by year still remain higher for the western channel analysis as compared to pre-restoration data (n=174, 11, respectively, Table 17). Again, since these common waterbird species include Brown Pelican and Elegant Tern, the dearth of both these species since 2014 likely affected trends in numbers in the western channels in recent years. In addition, the fact that a handful of species are not dominating in terms of numbers may also be seen as a positive outcome for species diversity (which remains high relative to pre-restoration years). Finally, there may be an upper limit for how many individual birds can actually use the western channels given its limited size, which means that the site may be re-settling into a kind of equilibrium in terms of numbers of individuals.

### Western Snowy Plover and Other Sensitive Bird Species

Only a handful of special-status species regularly occur at Malibu, including 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. There were three reports of individual Belding's Savannah Sparrows (state threatened) from Malibu Lagoon in 2017 (eBird), but no photographs were posted to confirm the species identification.

Of the special-status species, the Brown Pelican and Western Snowy Plover make heavy usage of the site and are present most of the year. Both continued to utilize the site in 2017, occurring almost exclusively on the sand spit separating the main lagoon from the beach. In 2017, a handful of pairs of Western Snowy Plovers attempted to breed at Malibu Lagoon for the first time in modern history (no prior records), with at least one chick successfully fledging (S. Vigallon, via email on 7 July, 2017), owing to a well-coordinated effort between California State Parks, Los Angeles Audubon Society, US Fish and Wildlife Service, and others to install protective fencing, wire mesh enclosures, daily monitoring, and other protective measures. This represents the first successful nesting by this species in Los Angeles or Orange Counties in almost 70 years.

California Least Tern bred at Malibu Lagoon in early summer (2017), with more than 20 active nests May – July, and multiple young fledged (S. Vigallon, via email on 7 July, 2017). Birds were observed foraging in the lagoon (including in the far western portions of the restored channels), though most were seen overflying the lagoon to feed offshore to the west. This marks the third time in recent years this species has attempted nesting at the lagoon, indicating its importance as an alternate nesting site away from larger and more established colonies to the north and south.

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) | 2017 (Year 4) |
| Open country | American Pipit | X | X | | X | | |
| | Killdeer | X | X | X | X | X | X |
| | Savannah Sparrow | X | X | X | X | X | X |
| | Say's Phoebe | X | X | X | X | X | X |
| | Western Kingbird | X | | | X | | |
| | Western Meadowlark | | X | X | X | X | X |
| Scrub/Woodland | Allen's Hummingbird | X | X | X | X | X | X |
| | American Robin | | X | | | | |
| | Anna's Hummingbird | X | | X | X | | |
| | Bewick's Wren | X | X | X | X | X | X |
| | Bushtit | X | X | X | X | X | X |
| | California Scrub-Jay | | | | | X | X |
| | California Towhee | X | X | X | X | X | X |
| | Cedar Waxwing | X | | | | | |
| | Hermit Thrush | | | X | X | X | |
| | House Wren | X | X | X | X | X | X |
| | Lincoln's Sparrow | X | | X | X | | X |
| | Oak Titmouse | X | | | X | X | X |
| | Orange-crowned Warbler | X | | X | X | X | X |
| | Ruby-crowned Kinglet | X | X | X | X | X | X |
| | Song Sparrow | X | X | X | X | X | X |
| | Spotted Towhee | X | | X | X | | X |
| | Townsend's Warbler | | | | X | | |
| | Wilson's Warbler | X | | | X | | |
| | Yellow Warbler | X | | | X | | |
| Urban | American Crow | X | X | X | X | X | X |
| | Black Phoebe | X | X | X | X | X | X |
| | Brewer's Blackbird | X | | | | | X |
| | Brown-headed Cowbird | X | X | X | X | X | |
| | European Starling | X | X | X | X | X | X |
| | Hooded Oriole | X | X | | | | |
| | House Finch | X | X | X | X | X | X |
| | Rock Pigeon | | | | | X | X |
| | Northern Mockingbird | X | 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) | 2017 (Year 5) |
| Freshwater Marsh | Common Yellowthroat | X | X | X | X | X | X |
| | Great-tailed Grackle | X | X | X | X | X | X |
| | Marsh Wren | X | | | X | X | X |
| | Red-winged Blackbird | X | | | X | X | X |
| | Sora | X | | | | X | |
| | Virginia Rail | X | | | | | |
| Marine/Beach | Black Oystercatcher | X | X | | | | |
| | Bonaparte's Gull | X | X | X | X | X | X |
| | Brant | X | X | | X | X | |
| | Brown Pelican | X | X | X | X | X | X |
| | Caspian Tern | X | X | X | X | X | X |
| | Double-crested Cormorant | X | X | X | X | X | X |
| | Elegant Tern | X | 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 | X |
| | Herring Gull | X | X | X | X | X | X |
| | Horned Grebe | X | | | X | | |
| | Least Tern | X | | | X | | X |
| | Mew Gull | X | | X | | | |
| | Red-breasted Merganser | X | X | X | X | X | X |
| | Red-throated Loon | | X | X | | | |
| | Royal Tern | | X | X | X | X | X |
| | Ruddy Turnstone | X | X | X | X | X | X |
| | Sanderling | X | X | X | X | X | X |
| | Snowy Plover | X | X | X | X | X | X |
| | Surfbird | | | X | | | |
| | Western Grebe | | X | X | X | X | X |
| | Western Gull | X | X | X | X | X | X |
| Shorebirds | American Avocet | X | X | | | | |
| | Black-bellied Plover | X | X | X | X | X | X |
| | Black-necked Stilt | | | | X | | |
| | Dunlin | X | X | X | | | X |
| | Greater Yellowlegs | X | X | | | X | X |
| | Least Sandpiper | X | 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) | 2017 (Year 5) |
| | Long-billed Curlew | X | | | | | |
| | Long-billed Dowitcher | X | | | X | X | |
| | Marbled Godwit | X | X | X | X | X | X |
| | Semipalmated Plover | X | X | X | X | X | X |
| | Spotted Sandpiper | X | X | X | X | X | X |
| | Western Sandpiper | X | X | X | X | X | X |
| | Whimbrel | X | X | X | X | X | X |
| | Willet | X | X | X | X | X | X |
| | Wilson's Phalarope | | | | X | | |
| Waders | Black-crowned Night Heron | X | X | X | X | | X |
| | Great Blue Heron | X | X | X | X | X | X |
| | Great Egret | X | X | X | X | X | X |
| | Green Heron | X | | X | X | | |
| | Snowy Egret | X | X | X | X | X | X |
| Waterfowl | American Coot | X | X | X | X | X | X |
| | American Wigeon | X | X | X | X | X | X |
| | Blue-winged Teal | X | | | X | X | X |
| | Bufflehead | X | X | X | X | X | X |
| | Cinnamon Teal | X | | | X | X | |
| | Eared Grebe | X | X | X | X | X | X |
| | Gadwall | X | X | X | X | X | X |
| | Green-winged Teal | X | X | X | X | X | X |
| | Hooded Merganser | | | | X | | X |
| | Lesser Scaup | X | X | X | | | X |
| | Mallard | X | X | X | X | X | X |
| | Northern Pintail | X | | X | X | X | X |
| | Northern Shoveler | X | X | X | X | X | |
| | Pied-billed Grebe | X | X | X | X | X | X |
| | Ruddy Duck | X | 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 | | X |
| | California Brown Pelican | X | X | X | X | X | X |
| | Caspian Tern | X | X | X | X | X | X |
| | Double-crested Cormorant | X | X | X | X | X | X |
| | Forster's Tern | X | X | | X | | |
| | Great Blue Heron | X | X | X | X | X | X |
| | Great Egret | X | 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) | 2017 (Year 5) |
| | Green Heron | X | | X | | | |
| | Hooded Merganser | | | | X | | X |
| | Least Tern | X | | | X | | X |
| | Osprey | X | | | | X | X |
| | Pied-billed Grebe | X | X | X | X | X | X |
| | Red-breasted Merganser | X | X | X | X | X | X |
| | Red-throated Loon | | X | X | | | |
| | Royal Tern | | X | X | X | X | X |
| | Snowy Egret | X | X | X | X | X | X |

Figure 32. Photograph of restoration area with birds in flight (credit: R. Abbott, TBF, 3 December 2017).

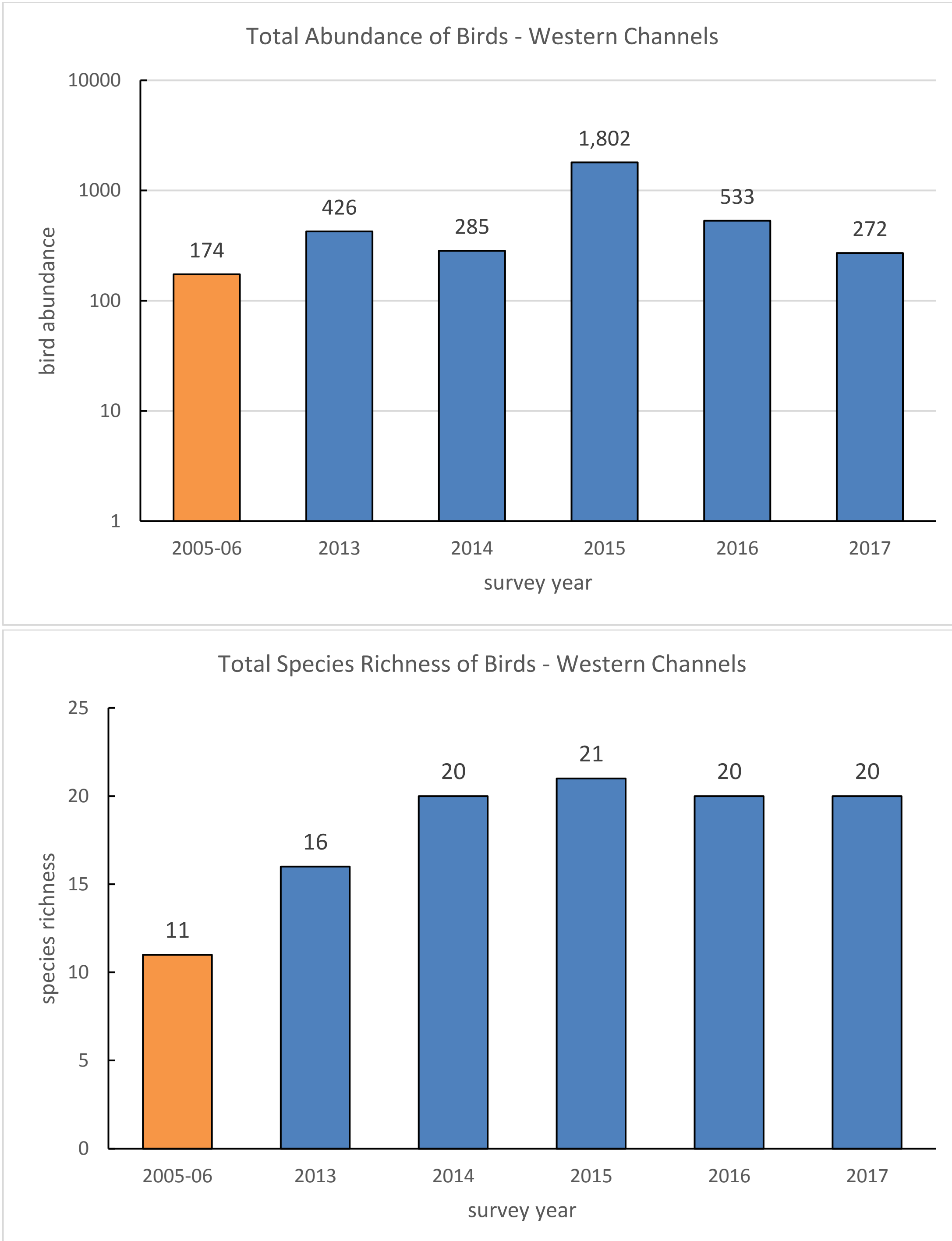



Figure 33. Comparison of total bird numbers (top) and species richness (bottom) in restoration area only (western channels) of Malibu Lagoon during surveys (2005-2017). Note the log scale on the top graph.

Table 17. Selected waterbird use of the restoration area only (western channels) of Malibu Lagoon, 2005-2017, during surveys. Note: pre-restoration 2005-06 column highlighted in orange.

| | Pre-restoration | Post-restoration | | | | |
|---|---|---|---|---|---|---|
| **Species** | **2005-06** | **2013** | **2014** | **2015** | **2016** | **2017** |
| American Wigeon | | 30 | 2 | 1 | 7 | 8 |
| Black-bellied Plover | | | 6 | 60 | 22 | 49 |
| Brown Pelican | | | 3 | 1106 | 1 | 4 |
| Caspian Tern | 3 | 1 | 2 | 8 | 8 | 7 |
| Double-cr. Cormorant | | 15 | 5 | 45 | 40 | 5 |
| Eared Grebe | | 24 | 25 | 15 | 3 | 2 |
| Elegant Tern | | | | 5 | 250 | |
| Gadwall | 27 | 104 | 59 | 114 | 27 | 49 |
| Great Blue Heron | 9 | 14 | 5 | 11 | 9 | 13 |
| Great Egret | 5 | 9 | 2 | 5 | 4 | 12 |
| Green-winged Teal | 70 | 28 | 15 | 61 | 20 | 17 |
| Killdeer | 6 | 28 | 9 | 34 | 18 | 10 |
| Least Sandpiper | 26 | 6 | 3 | | | 11 |
| Marbled Godwit | | | 37 | 6 | 17 | 1 |
| Northern Shoveler | 5 | 82 | 13 | 9 | 26 | |
| Pied-billed Grebe | 2 | 16 | 3 | 4 | 12 | 8 |
| Red-breasted Merganser | | 4 | 1 | 5 | 9 | 12 |
| Ruddy Duck | | 24 | 47 | 226 | 3 | 7 |
| Snowy Egret | 19 | 38 | 36 | 53 | 44 | 43 |
| Western Grebe | | 3 | | 7 | 8 | 5 |
| Whimbrel | 2 | | 6 | 17 | | 1 |
| Willet | | | 6 | 10 | 5 | 8 |
| **Total # of Individuals** | **174** | **426** | **285** | **1,802** | **533** | **272** |
| **Species Richness** | **11** | **16** | **20** | **21** | **20** | **20** |

### *Performance Evaluation*

Several patterns have emerged after five 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 5 continue to make heavy use of the site, in particular the beach and lower lagoon area (e.g. Brown Pelican and Snowy Plover). While overall bird counts for the 2017 year were low, the restoration area analyses continued to show improvements in both abundances and species richness data.

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, 15 December 2016, 18 August 2017, and 6 February 2018 (Year 5). Note that the August 2017 survey was conducted during a closed berm condition to attempt to target a warm summer month that could have the potential for higher algal cover. 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, SE). All stations were subsequently averaged together to determine the grand mean total cover by year (± SE). In cases where deep water obscured visibility, that area was not surveyed and was subtracted from the total transect length.

### *Results*

The average cover results of algae and SAV can be broken down into several categories, including: wrack, *Cladophora,* and *Ruppia.* 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*, *Cystoseira*, and woody debris. '*Cladophora'* is the genus for small, attached, turf-like green alga. Since January 2016, surveys have also identified *Ruppia sp.*, or ditchgrass, which is an attached submerged aquatic vegetation (SAV) species. Algae, wrack, and SAV all function very differently with regards to nutrient uptake and sequestration as well as dissolved oxygen cycling, so are thus evaluated separately. In the most recent Year 5 survey (6 February 2018), the average *Ruppia* cover was 0.83% ± 0.13, average algae cover was 0.71% ± 0.17, and average wrack cover was 0.27% ± 0.11 (Figure 34).

Tables 18 and 19 display average cover across all six surveys. The grand mean total algal and SAV cover (± SE) for all surveys on 6 February 2018 was 1.81% ± 0.33. (Table 18). *Ruppia* was found to be very high on the 18 August 2017 survey during closed conditions and was the only algae or SAV identified (range of 0.82% ± 0.82 to 91.63% ± 3.79). 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.

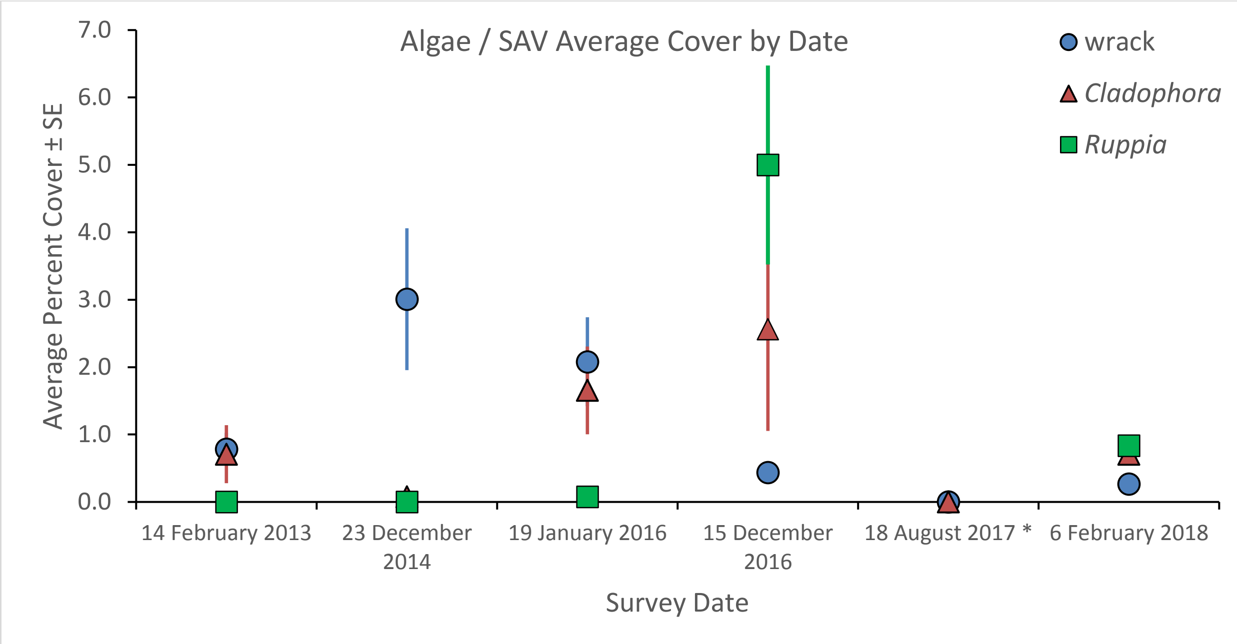



Figure 34. Graph indicating average algae and SAV cover (± SE) by survey date and category of algae/SAV. Asterisk indicates *Ruppia* data excluded as an outlier from the graph; see *Ruppia* totals in Table 19.

Table 18. Total percent cover ± standard error for the six post-restoration surveys conducted across eight stations. Total cover includes both algae (e.g. wrack, *Cladophora*) and SAV (e.g. *Ruppia*). Asterisk indicates closed berm.

| | 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 | 0.00 ± 0.00 | 3.84 ± 1.50 | 3.64 ± 1.58 | 6.53 ± 1.30 |
| Station 6 | 0.00 ± 0.00 | 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** |

| | 18 Aug 2017 * | 6 Feb 2018 |
|---|---|---|
| Station 1 | 0.82 ± 0.82 | 2.33 ± 0.06 |
| Station 2 | 87.13 ± 3.27 | 4.96 ± 0.12 |
| Station 3 | 82.67 ± 2.23 | 6.05 ± 0.10 |
| Station 4 | 88.25 ± 4.96 | 1.59 ± 0.03 |
| Station 5 | 75.9 ± 12.46 | 4.21 ± 0.10 |
| Station 6 | 84.71 ± 14.22 | 4.33 ± 0.10 |
| Station 7 | 91.63 ± 3.79 | 11.45 ± 0.24 |
| Station 8 | 87.08 ± 3.12 | 8.56 ± 0.19 |
| **Grand Mean** | **74.77 ± 5.61** | **5.43 ± 0.12** |

Table 19. Algae data as station average wrack and *Cladophora* percent cover ± standard error for the six 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 | 0.00 ± 0.00 |
| Station 3 | 0.20 ± 0.20 | 0.67 ± 0.67 | 0.95 ± 0.53 | 0.00 ± 0.00 | 1.32 ± 0.53 | 1.21 ± 1.01 | 0.21 ± 0.21 |
| Station 4 | 1.67 ± 0.33 | 0.43 ± 0.30 | 1.12 ± 0.29 | 0.17 ± 0.07 | 0.72 ± 0.40 | 0.10 ± 0.10 | 0.00 ± 0.00 |
| Station 5 | 0.00 ± 0.00 | 0.00 ± 0.00 | 3.84 ± 1.50 | 0.00 ± 0.00 | 0.06 ± 0.02 | 3.42 ± 1.48 | 0.16 ± 0.16 |
| Station 6 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.18 ± 0.05 | 0.05 ± 0.05 | 0.29 ± 0.03 | 0.00 ± 0.00 | 0.11 ± 0.11 |
| Station 7 | 0.36 ± 0.06 | 0.11 ± 0.00 | 0.29 ± 0.11 | 0.00 ± 0.00 | 0.31 ± 0.12 | 1.88 ± 0.29 | 0.00 ± 0.00 |
| Station 8 | 0.68 ± 0.52 | 4.40 ± 2.42 | 0.25 ± 0.11 | 0.00 ± 0.00 | 2.44 ± 1.80 | 0.00 ± 0.00 | 0.12 ± 0.08 |

| | 12/15/2016 | | | 8/18/2017 * | | |
|---|---|---|---|---|---|---|
| | wrack | *Cladophora* | *Ruppia* | wrack | *Cladophora* | *Ruppia* |
| Station 1 | 2.59 ± 0.2 | 1.56 ± 0.38 | 4.69 ± 1.45 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.82 ± 0.82 |
| Station 2 | 0.38 ± 0.27 | 6.73 ± 4.16 | 4.02 ± 1.25 | 0.00 ± 0.00 | 0.00 ± 0.00 | 87.13 ± 3.27 |
| Station 3 | 0.13 ± 0.13 | 7.07 ± 5.72 | 2.49 ± 2.09 | 0.00 ± 0.00 | 0.00 ± 0.00 | 82.67 ± 2.23 |
| Station 4 | 0.10 ± 0.10 | 1.22 ± 0.85 | 1.94 ± 0.98 | 0.00 ± 0.00 | 0.00 ± 0.00 | 88.25 ± 4.96 |
| Station 5 | 0.02 ± 0.02 | 0.96 ± 0.45 | 5.54 ± 1.69 | 0.00 ± 0.00 | 0.00 ± 0.00 | 75.90 ± 12.46 |
| Station 6 | 0.26 ± 0.02 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 84.71 ± 14.22 |
| Station 7 | 0.01 ± 0.01 | 2.96 ± 0.51 | 10.17 ± 2.32 | 0.00 ± 0.00 | 0.00 ± 0.00 | 91.63 ± 3.79 |
| Station 8 | 0.00 ± 0.00 | 0.00 ± 0.00 | 11.14 ± 2.02 | 0.00 ± 0.00 | 0.00 ± 0.00 | 87.08 ± 3.12 |

| | 2/6/2018 | | |
|---|---|---|---|
| | wrack | algae | *Ruppia* |
| Station 1 | 0.13 ± 0.11 | 0.65 ± 0.12 | 0.00 ± 0.00 |
| Station 2 | 0.89 ± 0.56 | 0.08 ± 0.02 | 0.68 ± 0.26 |
| Station 3 | 0.99 ± 0.12 | 0.70 ± 0.25 | 0.32 ± 0.05 |
| Station 4 | 0.07 ± 0.04 | 0.10 ± 0.03 | 0.36 ± 0.04 |
| Station 5 | 0.00 ± 0.00 | 0.37 ± 0.02 | 1.03 ± 0.27 |
| Station 6 | 0.00 ± 0.00 | 0.45 ± 0.14 | 0.99 ± 0.24 |
| Station 7 | 0.03 ± 0.03 | 1.27 ± 0.29 | 2.52 ± 0.09 |
| Station 8 | 0.03 ± 0.03 | 2.05 ± 0.45 | 0.77 ± 0.08 |

### *Performance Evaluation*

There was significant and excessive algal growth in the Lagoon pre-restoration; algae cover was one of the key indicators of eutrophication to the system. The surveys and data were difficult to collect due to the massive amounts of organic matter and unconsolidated fine-grained sediments causing an inability to deploy transects. While no pre-restoration "baseline" was identified due to high variability in cover ($2^{nd}$ 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 five 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. One algal bloom occurred in summer 2013 following the restoration and lasted for a duration of approximately two weeks, quickly dispersing via wind-driven circulation. Pre-restoration algal blooms would occur often and last several months, impacting dissolved oxygen levels throughout the lagoon. 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. The closed condition algae survey (August 2017) only identified *Ruppia* as present in high cover ratios. This was also likely influenced by the fact that the majority of most transects were not visible (underwater); therefore, the cover assessments were within a smaller area. *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*

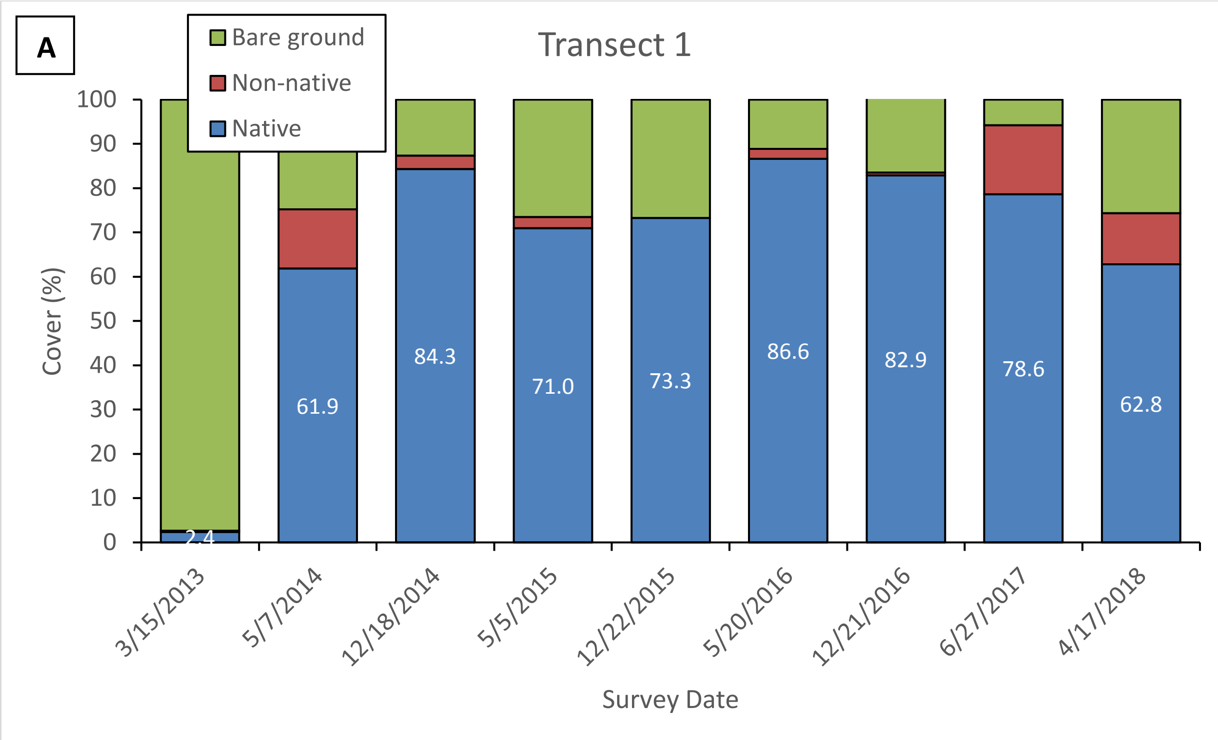
Data for absolute percent cover of native/nonnative vegetation species were collected along three, 50-meter transects (Figure 35) using the line-intercept method on 15 March 2013, 7 May 2014, 18 December 2014, 5 May 2015, 22 December 2015, 20 May 2016, 21 December 2016, 27 June 2017 (Year 5), and 17 April 2018 (Year 5). 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. At least one more vegetation cover assessment will be conducted.

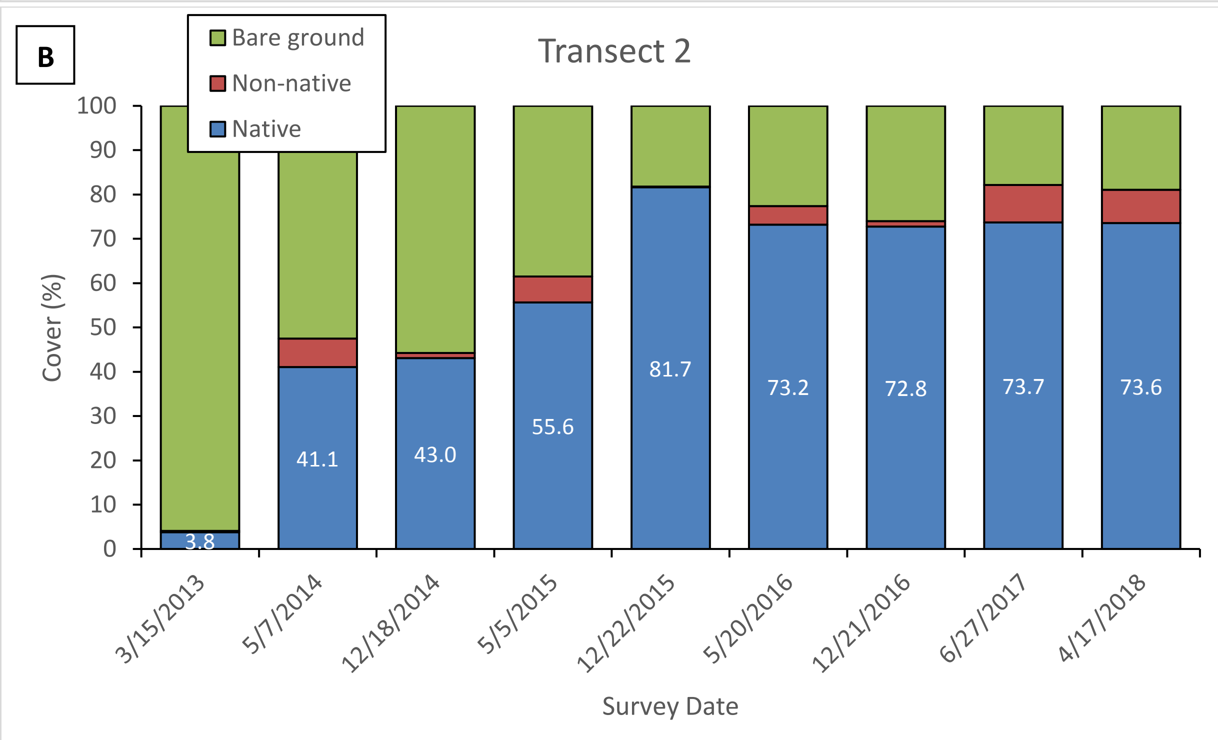
Each transect location was recorded with a submeter global positioning system (GPS) unit and photographed at each end. Absolute cover data were calculated based on the total distance for each species within each transect. Species data were collected to an accuracy of 0.01 m along each 50-meter transect.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

In the fifth monitoring year, the average (± standard error) native cover across all transects was 66.8 ± 9.5% and 59.7 ± 9.1%, respectively. The average non-native cover was less than 10% across both Year 5 survey dates. The relative native cover ranged between 83.4 – 90.7%. Cover for native vegetation species along an individual transect in the most recent survey was the highest on Transect 2, at 73.6% (with a relative native cover of 90.7%) and lowest on Transect 3 at 42.6%, but with a relative native cover of 87.8% (Figure 36). Native cover remained high on Transect 1 and 2, with some non-native invasion which was subsequently removed in community restoration events. All transects have shown a general trend over time of increasing native vegetation cover and decreasing bare ground over time, with slight fluctuations depending on season and survey year. Additionally, the range in non-native cover for the most recent survey (2018) was 5.9 – 11.5%. The highest cover for non-native vegetation is usually seen in the spring surveys (still low, relatively speaking) which capture annual non-natives, but which are then subsequently weeded out during restoration events. Since both Year 5 surveys were in the warmer months of 2017 and 2018, there was higher non-native cover represented. Lastly, the species richness at a transect level is higher post-restoration, often with 8-10 native plant species represented of a variety of plant types including ground cover, subshrubs, and overstory canopy.


A
Transect 1
Bare ground
Non-native
Native
Cover (%)
0
10
20
30
40
50
60
70
80
90
100
2.4
61.9
84.3
71.0
73.3
86.6
82.9
78.6
62.8
3/15/2013
5/7/2014
12/18/2014
5/5/2015
12/22/2015
5/20/2016
12/21/2016
6/27/2017
4/17/2018
Survey Date


B
Transect 2
Bare ground
Non-native
Native
Cover (%)
0
10
20
30
40
50
60
70
80
90
100
3.8
41.1
43.0
55.6
81.7
73.2
72.8
73.7
73.6
3/15/2013
5/7/2014
12/18/2014
5/5/2015
12/22/2015
5/20/2016
12/21/2016
6/27/2017
4/17/2018
Survey Date

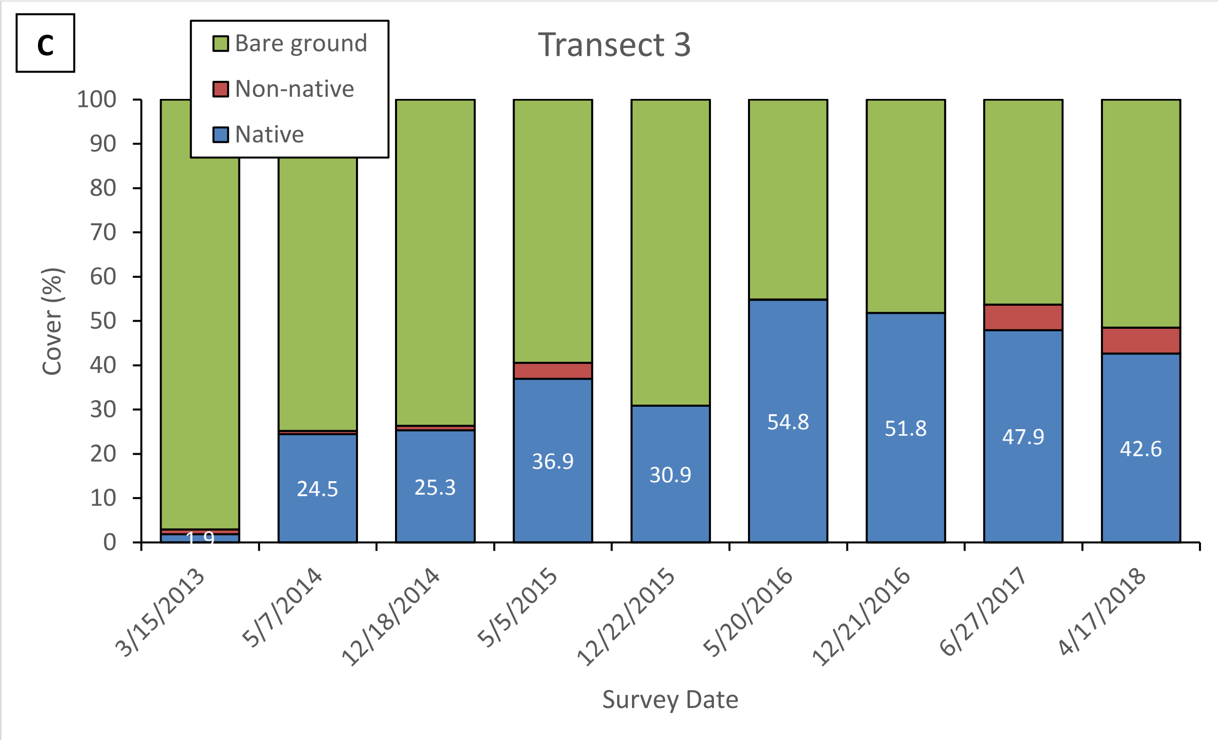



Figure 36. Graphs displaying absolute cover of vegetation across each Transect: (A) 1, (B) 2, and (C) 3.

### *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. Reductions or variability in non-native cover are likely the result of extensive weeding and non-native species removal efforts during monthly restoration events led by The Bay Foundation. The average native vegetation cover is above the success criteria (i.e. > 50%), and the average non-native cover is also meeting the success criteria (i.e. < 10%). One final monitoring year will be surveyed and compared against the Year 5 success criteria for the vegetation cover requirements. Similarly, the CRAM biotic metric continued increasing across the monitoring years, supplementing the vegetation cover assessment that the community continues to develop and become more complex over time. Continued observation and monitoring is recommended, especially for the area surrounding Transect 3. At least one additional plant survey is planned for the sixth monitoring year.

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, 27 December 2016, and 27 June 2017 (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 | $155^o$ | 8:15 AM | 1 |
| | Photo Point 2 | $300^o$, $75^o$ | 8:30 AM | 2 |
| | Photo Point 3 | $220^o$, $100^o$ | 8:46 AM | 2 |
| 7 May 2014 | Photo Point 1 | $155^o$ | 11:22 AM | 1 |
| | Photo Point 2 | $300^o$, $75^o$ | 11:13 AM | 2 |
| | Photo Point 3 | $220^o$, $100^o$ | 11:08 AM | 2 |
| 18 December 2014 | Photo Point 1 | $155^o$ | 12:47 PM | 1 |
| | Photo Point 2 | $300^o$, $75^o$ | 12:41 PM | 2 |
| | Photo Point 3 | $220^o$, $100^o$ | 12:37 PM | 2 |
| 5 May 2015 | Photo Point 1 | $155^o$ | 3:00 PM | 1 |
| | Photo Point 2 | $300^o$, $75^o$ | 2:59 AM | 2 |
| | Photo Point 3 | $220^o$, $100^o$ | 2:56 PM | 2 |
| 22 December 2015 | Photo Point 1 | $155^o$ | 3:40 PM | 1 |
| | Photo Point 2 | $300^o$, $75^o$ | 3:49 PM | 2 |
| | Photo Point 3 | $220^o$, $100^o$ | 3:49 PM | 2 |

| Date | Station | Approximate Bearing | Time | Number of Photos |
|---|---|---|---|---|
| 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 |
| 27 June 2017 | Photo Point 1 | 155° | 2:47 PM | 1 |
| | Photo Point 2 | 300°, 75° | 2:54 PM | 2 |
| | Photo Point 3 | 220°, 100° | 3:01 PM | 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 eight 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 in 2014, photographs from Years 3-5 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; (D) 5 May 2015.

Figure 38 (*continued*). Photograph of Photo Point 1, bearing 155° on (E) 22 December 2015; (F) 16 May 2016; (G) 27 December 2016; (H) 27 June 2017.

Figure 39. Photograph of Photo Point 1, bearing 300° on (A) 15 March 2013; (B) 7 May 2014; (C) 18 December 2014; (D) 5 May 2015.

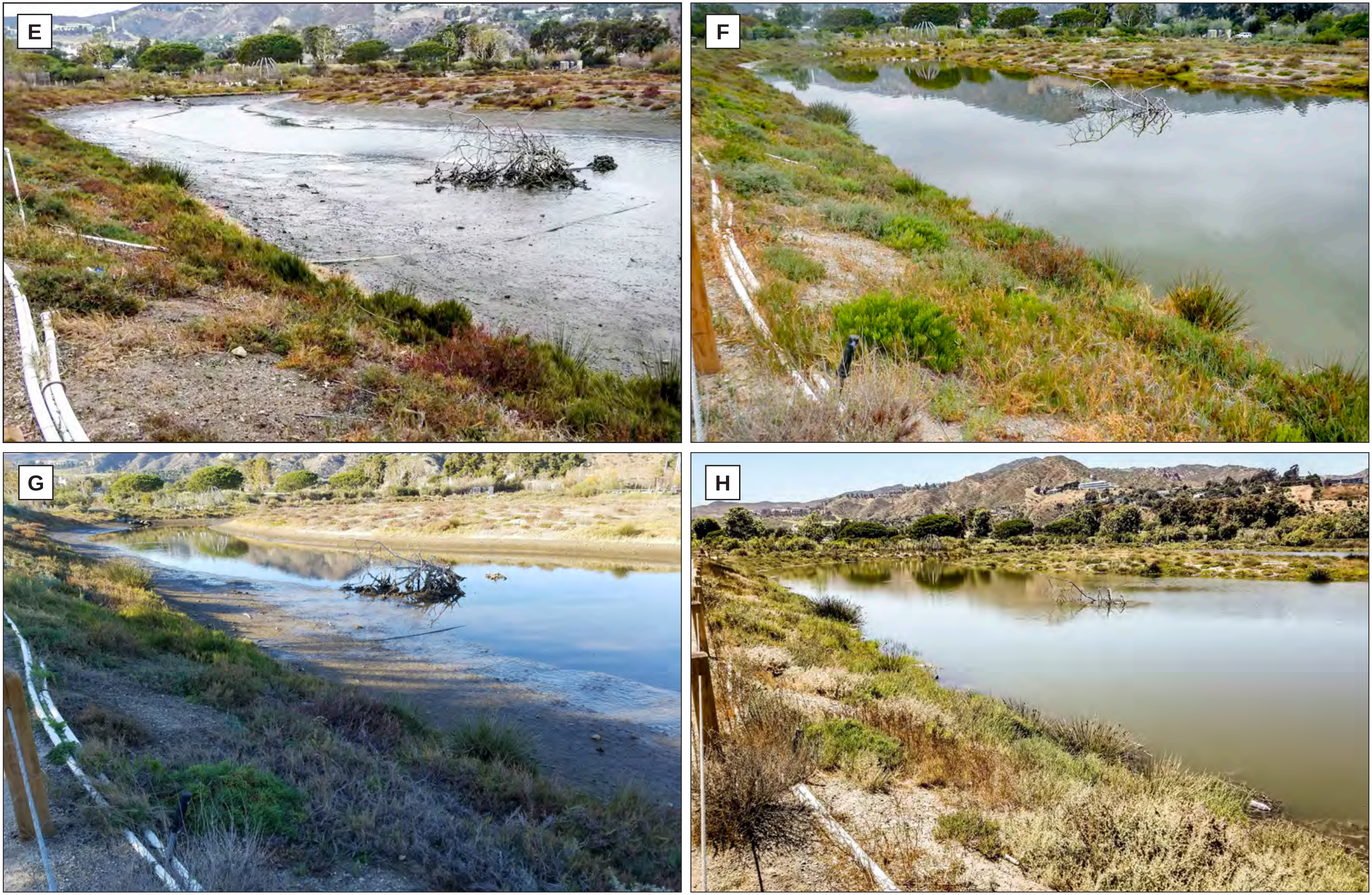


Figure 39 (*continued*). Photograph of Photo Point 1, bearing 155° on (E) 22 December 2015; (F) 16 May 2016; (G) 27 December 2016; (H) 27 June 2017.

Figure 40. Photograph of Photo Point 1, bearing 75° on (A) 15 March 2013; (B) 7 May 2014; (C) 18 December 2014; (D) 5 May 2015.

Figure 40 (*continued*). Photograph of Photo Point 1, bearing 75° on (E) 22 December 2015; (F) 16 May 2016; (G) 27 December 2016; (H) 27 June 2017.

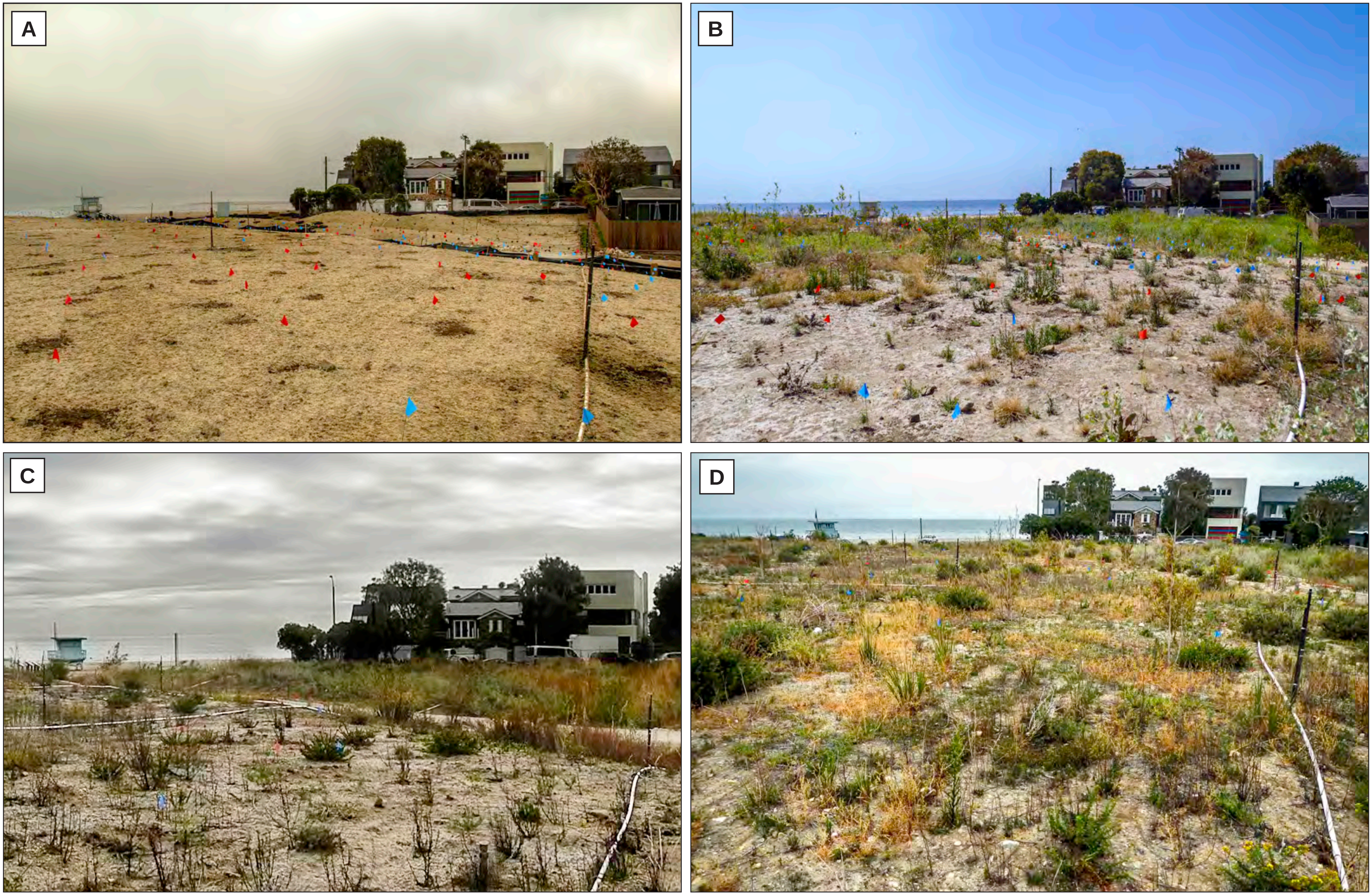


Figure 41. Photograph of Photo Point 1, bearing 100° on (A) 15 March 2013; (B) 7 May 2014; (C) 18 December 2014; (D) 5 May 2015.

Figure 41 (*continued*). Photograph of Photo Point 1, bearing 10° on (E) 22 December 2015; (F) 16 May 2016; (G) 27 December 2016; (H) 27 June 2017.

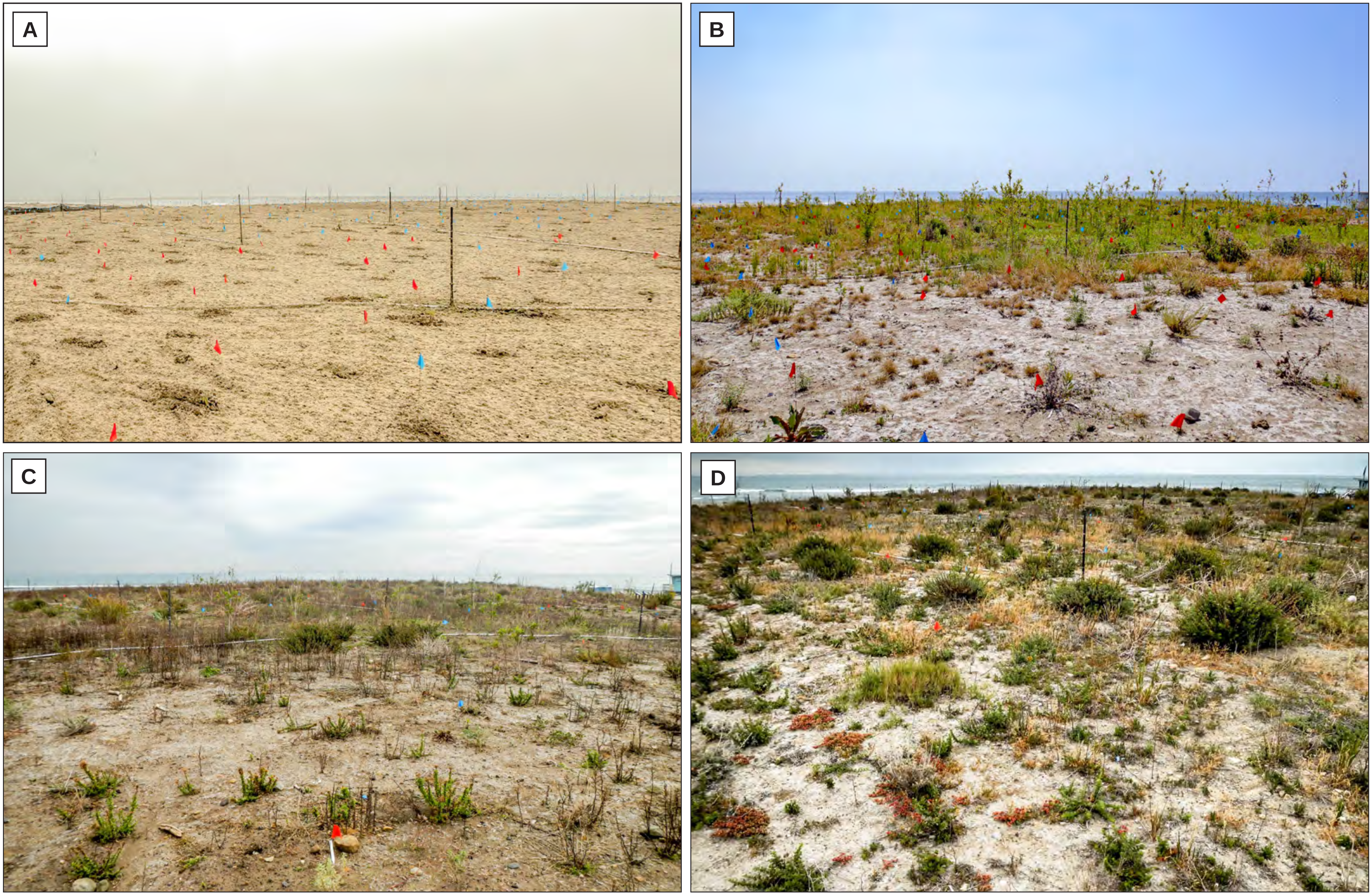



Figure 42. Photograph of Photo Point 1, bearing 100° on (A) 15 March 2013; (B) 7 May 2014; (C) 18 December 2014; (D) 5 May 2015.

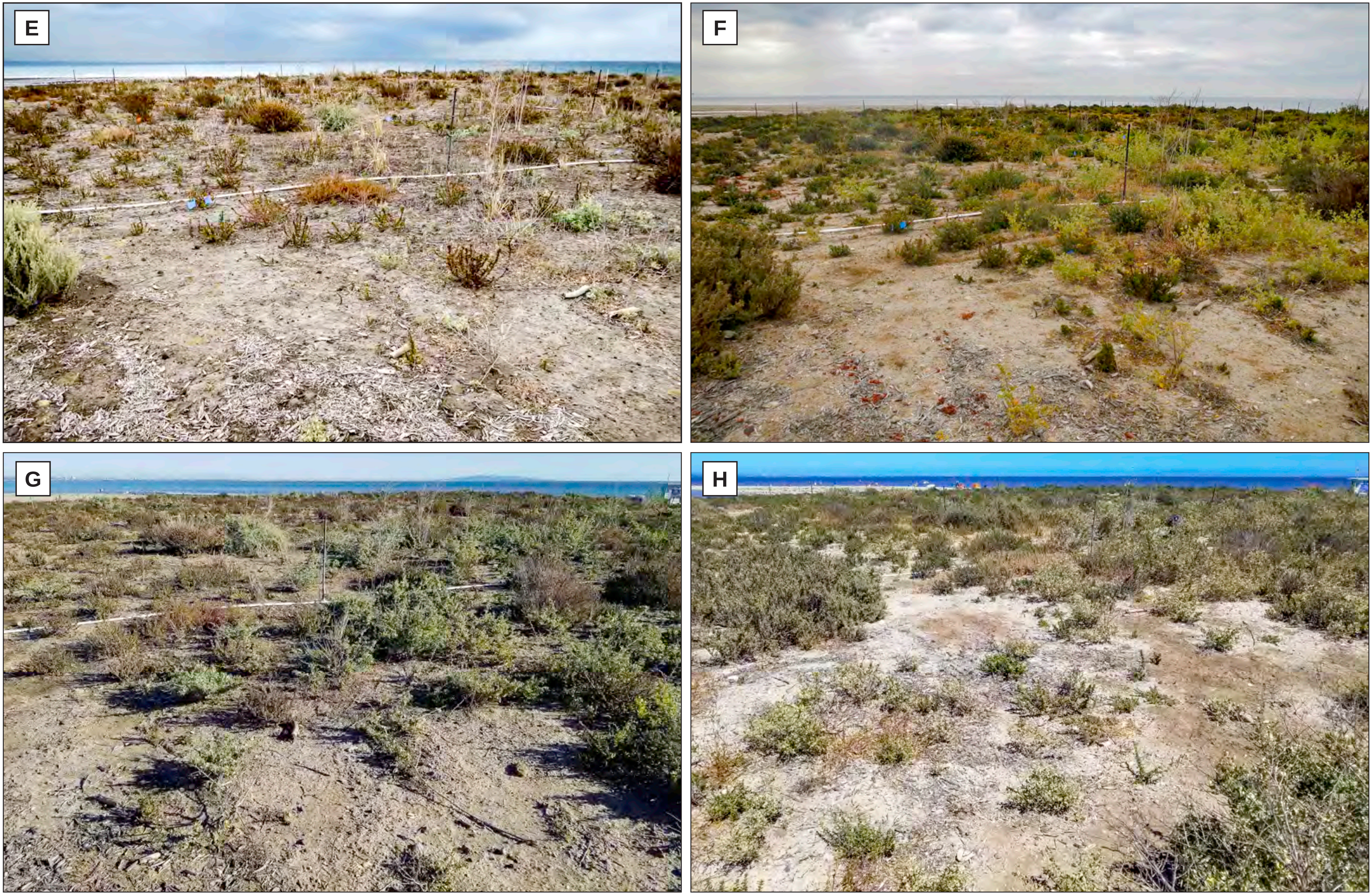


Figure 42 (*continued*). Photograph of Photo Point 1, bearing 10° on (E) 22 December 2015; (F) 16 May 2016; (G) 27 December 2016; (H) 27 June 2017.

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# Appendix 1. Malibu Lagoon Post-Restoration Fish Survey Results: July 2017 (Prepared by R. Dagit)

# Malibu Lagoon
# Post Construction Fish Survey July 2017

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

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**July 2017**

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## EXECUTIVE SUMMARY

A post-construction fish survey of Malibu Lagoon was conducted on Wednesday 25 July 2017 by a team from the RCD of the Santa Monica Mountains with assistance from CDPR, Santa Monica Bay Foundation staff, USFWS staff and volunteers Alexander Prescott and Jai Lin from UCB.

Malibu Lagoon was closed to the ocean since late May 2017, with some continued overwash during high tides. We were not able to seine to depletion due to high water and air temperatures that posed a threat to the fish. Instead, for consistency sake, a total of 10 seine pulls were completed in each of the six permanent sites. High tide was at 5:21 pm (1.6' elevation) and the moon was full on 23 July. 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 series of spot surveys along the eastern end of the beach between the enclosures for the snowy plovers and the Adamson house.

A total of 10 federally endangered tidewater gobies (*Eucyclogobius newberryi)* were captured in several sites along with 8 goby larva. Striped mullet (*Mugil cephalus*) were observed jumping throughout the lagoon. The dominant species surveyed and identified was topsmelt (*Atherinops affinis, lara = 2,618, juveniles =132, adult = 56*), followed by Mississippi silversides (*Menida beryllina* = 663) and Northern Anchovy (*Engraulis mordax* = 662). A total of 17 longjawed mudsuckers (*Gillichthys mirabilis*) were also observed.

Species captured or observed during the July 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* |
| Northern Anchovy | *Engraulis mordax* |

**Non-Native Fish Species**

| | |
|---|---|
| Mosquitofish | *Gambusia affinis* |
| Mississippi Silversides | *Menidia beryllina* |
| Carp | *Cyprinus carpio* |

**Invertebrates**

| | |
|---|---|
| Oriental shrimp | *Palaemonetes sp.* |
| Hemigraspus crab | *Hemigraspus sp.* |
| Water boatman | |

## 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 from the Santa Monica Bay Foundation, Alexander Prescott and Jai Lin from UC Santa Barbara Bren School were also most helpful.

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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.

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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.

The eighth survey occurred on 26 July 2017. The lagoon level was 7'8" based on the ramp markers, with some overwash evident at the east side of the berm. The weather was hot and sunny, with a SW wind increasing during the course of the day. Air temperatures were in the 80'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.

Due to high water levels and extremely warm water and air temperatures, as well as high numbers of juvenile topsmelt and Mississippi silversides, we did 10 seine pulls within the blocking nets and then checked the blocking nets. **WE DID NOT FISH TO DEPLETION.**

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 |

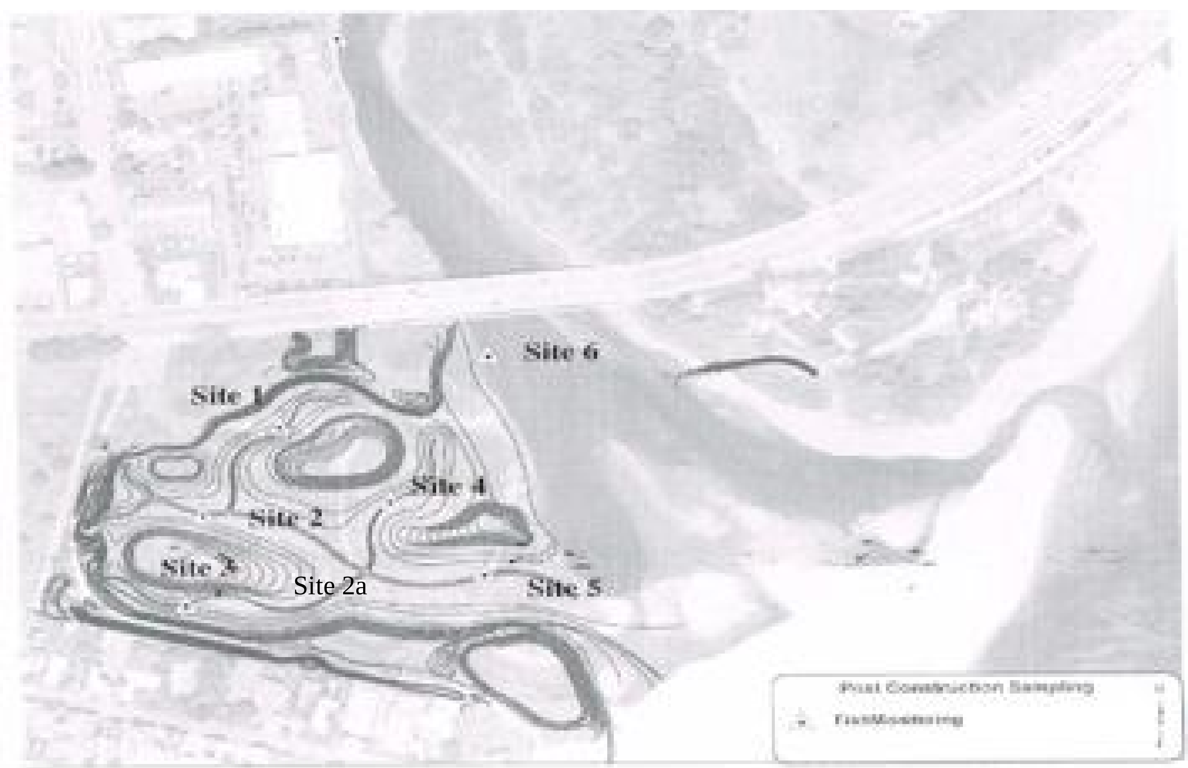


**Figure 1. Map of the Permanent Monitoring Sites, Malibu Lagoon Restoration (Established in January 2013 and revised in May 2014)**

# RESULTS

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

Table 2. Water Quality and site conditions at the permanent monitoring sites 26 July 2017

| **Variable** | **Site 1** | **Site 2** | **Site 2a** | **Site 3** | **Site 5** | **Site 6** |
|---|---|---|---|---|---|---|
| Avg depth (cm) | 100 | 120 | 40 | 160 | 180 | 60 |
| Water T ($^oC$) | 28.8 | 27.5 | 27.7 | 28.3 | 28.2 | 27.7 |
| Air T ($^oC$) | | | | | | |
| Salinity ppt | 5 | 6 | 6 | 6 | 6 | 5 |
| DO mg/l | 7.54 | 12.55 | 5.85 | 6.54 | 7.47 | 5.3 |
| pH | 8.4 | 8.3 | 8.3 | 8.2 | 8.2 | 8.2 |
| Conductivity | 15.5 | 15 | 15.6 | 15.3 | 13.2 | 15.4 |
| % Floating Algae cover | 0 | 0 | 0 | 0 | 0 | 0 |
| % Submerged/ Attached Algae cover | 100 | 50 | 10 | 50 | 25 | 60 |
| % emergent vegetation bank cover | 100 | 100 | 100 | 100 | 100 | 90 |
| Emergent Vegetation type | Jaumea, Distichlis, Salicornia, Juncus | Jumea, Distichlis, Salicornia | Jaumea, Distichlis, Salicornia, Juncus | Jaumea, Distichlis, Salicornia | Jaumea, Distichlis, Salicornia | Jaumea, Distichlis, Salicornia |
| Dominant Substrate | Sand and mud | muck | Sand and muck | Sand and muck | Sand and muck | cobble |
| Time start | 15:20 | 13:55 | 16:15 | 13:00 | 11:05 | 14:30 |

Table 3. Summary of Fish and Invertebrates captured/observed 26 July 2017

| **Lagoon-ocean connection conditions** | **closed** | **Site 1** | **Site 2** | **Site 2a** | **Site 3** | **Site 5** | **Site 6** | **Spot 1 beach** | **Spot 2 beach** | **Spot 3 beach** | **TOTALS** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Native Fish Species** | | | | | | | | | | | 0 |
| Steelhead trout | *Onchorhynchus mykiss* | | | | | | | | | | 0 |
| Unidentified goby larva (<5 cm) | | | | | | 8 | | | | | 8 |
| Tidewater goby (<5 cm) | *Eucyclogobius newberryi* | 1 | 4 | | 3 | | 2 | | | | 10 |
| 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* | | | | | | | | | | 0 |
| CA killifish juveniles (5-10 cm) | *Fundulus parvipinnis* | | | | | | | | | | 0 |
| Long-jawed mudsucker (<5 cm) | *Gillichthys mirabilis* | | | | 1 | 3 | | | | | 4 |
| Long-jawed mudsucker (5-10 cm) | *Gillichthys mirabilis* | 1 | 1 | | 3 | 6 | 1 | | | 1 | 13 |
| Topsmelt larva (<5 cm) | *Atherinops affinis* | 12 | 765 | 163 | 221 | 472 | 13 | 365 | 27 | 580 | 2618 |
| Topsmelt juvenile (6-15 cm) | *Atherinops affinis* | 12 | 18 | 89 | 191 | 129 | 16 | 194 | 10 | 274 | 933 |
| Topsmelt adult (>15 cm) | *Atherinops affinis* | | | 1 | 3 | 48 | | 2 | 1 | 1 | 56 |
| Unidentified smelt larva (<5 cm) | *Atherinops sp* | | | | | | | | | | 0 |
| Staghorn sculpin (<5 cm) | *Leptocottus armatus* | | 1 | | | | | | | | 1 |
| Staghorn sculpin (5-10 cm) | *Leptocottus armatus* | | 1 | | | 1 | | | | | 2 |
| Staghorn sculpin (10-15 cm) | *Leptocottus armatus* | | | | 1 | | 1 | | | | 2 |
| Opaleye | *Girella nigricans* | | | | | | | | | | 0 |
| Diamond turbot | *Hypsopsetta guttulata* | | | | | | | | | | 0 |
| Garabaldi (28 cm FL) dead dropped by birds | *Hypsypops rubicundus* | | | | | | | | | | 0 |
| Northern anchovy <5 cm | *Engraulis mordax* | | | | | 10 | | 5 | 63 | 345 | 423 |
| Northern anchovy (5-10 cm) | *Engraulis mordax* | | 1 | | | 29 | | 2 | 143 | 64 | 239 |
| striped mullet | *Mugil cephalus* | | | | | | | | | | 0 |
| Unidentified larva (<1cm) | | | | 52 | | | | | | | 52 |
| **Non-Native Fish Species** | | | | | | | | | | | 0 |
| Mosquitofish juveniles (<5cm) | *Gambusia affinis* | 245 | | 1 | 7 | 8 | 10 | | | | 271 |
| Mosquitofish adults (5-10 cm) | *Gambusia affinis* | | | | | | 3 | | | | 3 |
| Carp | *Cyprinus carpio* | | | | | | 1 | | | | 1 |
| Mississippi silversides (<5 cm) | *Menida audens* | 67 | 4 | 36 | 18 | | 525 | | | | 650 |
| Mississippi silversides (5-10cm) | *Menida audens* | 6 | | 1 | 6 | | | | | | 13 |
| | | | | | | | | | | | 0 |
| **Invertebrates** | | | | | | | | | | | 0 |
| Oriental shrimp | *Shrimp sp.* | 79 | 19 | 7 | 47 | 73 | 55 | | | | 280 |
| Hemigraspus crabs | | | | | 1 | | 1 | | | | 2 |
| Water boatman juveniles | | 14 | | | | | | | | | 14 |
| 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 | | | | | | | | | | | 0 |
| Dragonfly | | 16 | | | | | | | | | 16 |
| Caddisfly | | 8 | | | | | | | | | 8 |

**SUMMARY**

The July2017 post-construction fish survey was completed in one day with a team of 11 people.

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

A total of six native fish species were observed in July 2017.

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

| | | Survey | Relocation | Survey | Survey | Survey | Survey | Survey | Survey | Survey | Survey |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 6/1/2005 | 6/1/2012 | 1/8/2013 | 5/15/2014 | 12/11/2014 | 5/27/2015 | 1/12/2016 | 6/1/2016 | 3/3/2017 | 7/26/2017 |
| | | open | open | open | closed | open | closed | open | closed | open | closed |
| **Native Fish Species** | | | | | | | | | | | |
| Steelhead trout | *O.mykiss* | | | | 1 observed | | | | | 0 | 0 |
| Unidentified goby larva (<5 cm) | | | 2 | | 500~ | | | | 0 | 0 | 8 |
| Tidewater goby larva (<5cm) | *Eucyclogobius newberryi* | | | | 13 | | | | 17 | 12 | 10 |
| Tidewater goby adult (6-8cm) | *Eucyclogobius newberryi* | 473 | 8 | | 0 | | 41 | | 0 | 0 | 0 |
| Arrow goby (<5 cm) | *Cleavlandia ios* | | | | 5 | | | | 0 | 0 | 0 |
| Bay goby? | *Lepidogobius lepidus* | | | | 2 | | | | 0 | 0 | 0 |
| CA Halibut | *Paralichthys californicus* | | | | | | | | 2 | 0 | 0 |
| CA killifish juveniles (<5cm) | *Fundulus parvipinnis* | | 306 | | 0 | | | | 1 | 1 | 0 |
| CA killifish (5-10 cm) | *Fundulus parvipinnis* | 46 | 16 | | 5 | | | | 0 | 0 | 0 |
| Long-jawed mudsucker (<5 cm) | *Gillichthys mirabilis* | 1 | 8 | | 5 | | 3 | | 11 | 2 | 4 |
| Long-jawed mudsucker (5-10 cm) | *Gillichthys mirabilis* | | 11 | | | | 22 | 5 | 52 | 0 | 13 |
| Topsmelt larva (<5 cm) | *Atherinops sp* | | 1 | 3 | | | 176 | 6 | 1289 | 35 | 2618 |
| Topsmelt juvenile (6 cm) | *Atherinops sp* | 244 | 0 | | 24 | | 60 | | 133 | 48 | 933 |
| Topsmelt adult (16 cm) | *Atherinops sp* | | 0 | | | | 6 | | 0 | 0 | 56 |
| Unidentified smelt larva (<5 cm) | *Atherinops sp* | | 101 | | 15,293 | | 2244 | 64 | | 0 | 0 |
| Staghorn sculpin (<5 cm) | *L. armatus* | | | 17 | 11 | | | 1 | | 130 | 1 |
| Staghorn sculpin (5-10 cm) | *L.armatus* | | 3 | | | | | | 5 | 4 | 2 |
| Staghorn sculpin (10-15 cm) | | | | | | | | | | | 2 |
| Opaleye | *Girella nigricans* | | | | | | | | | 0 | 0 |
| Diamond turbot | *Hypsopsetta guttulata* | | | 7 | 1 | | | | 5 | 0 | 0 |
| Garabaldi (28 cm FL) dead dropped by birds | *Hypsypops rubicundus* | | | | | | | | | 0 | 0 |
| Northern anchovy <5 cm | *Engraulis mordax* | | 5 | | | | | 180 | 1 | 0 | 423 |
| Northern anchovy (5-10 cm) | | | | | | | | | | | 239 |
| Striped mullet | *Mugil cephalus* | observed | | observed | observed | 7 | 1 | | observed | observed | 0 |
| Unidentified fish larva | | | | | | | 991 | | 3 | 0 | 52 |
| **Non-Native Fish Species** | | | | | | | | | | | 0 |
| Mosquitofish Juveniles (<5cm) | *Gambusia affinis* | | | | | | 13 | 6 | 10 | 1 | 271 |
| Mosquitofish Adults (5-10cm) | *Gambusia affinis* | 65 | 4072 | | | 2 | 3 | | | 0 | 3 |
| *Carp* | *Cyprinus carpio* | 1 | | | observed | | | | | 0 | 1 |
| Mississippi silversides (<5 cm) | *Menida audens* | | | 1 | 0 | 970 | 9 | 15 | 16 | 0 | 650 |
| Mississippi silversides (5-10 cm) | *Menida audens* | | | | | | | | | 0 | 13 |
| | | | | | | | | | | | 0 |
| **Invertebrates** | | | | | | | | | | 0 | 0 |
| Oriental shrimp | *Palaemonetes sp.* | | | 37 | 209 | 43 | 10 | 5 | 58 | 89 | 280 |
| Hemigraspus crabs | | | 6 | | 8 | 1 | 20 | 1 | 1 | 2 | 2 |
| Water boatman juveniles | | | 6,000+ | | 2504 | | | | | 0 | 14 |
| Amphipods | | | 2500+ | | | | | | | 0 | 0 |
| Isopods | | | 2500+ | | | | | | | 0 | 0 |
| Ctenophore sp (<2 cm) | | | | 3 | | | | | | 0 | 0 |
| Salp sp (<2 cm) | | | | 3 | | | | | | 0 | 0 |
| Sea hare (5-10 cm) | *Aplysia californica* | | | 2 | | | | | | 0 | 0 |
| Segmented worm <2 cm) | | | | 3 | | | | | | 0 | 0 |
| Gastropoda | | | | | | | 4 | | | 0 | 0 |
| Water scavenger larva | Hydrophilidae | | | | | | 1 | | | 0 | 0 |
| Dragonfly | | | | | | | | | | 0 | 16 |
| Caddisfly | | | | | | | | | | 0 | 8 |
| Crayfish | *Procambarus clarkii* | | | | | | | | | 1 | 0 |

# Appendix A. Photographs of fish species

Staghorn sculpin

Tidewater goby

Topsmelt

Long-jawed mudsucker

# Appendix B. Site Photos

Site 1

Site 3

Site 2

Site 5

Site 2a

Site 6

**Spot Seine at beach**

# Appendix 2. Malibu Lagoon Post-Restoration Fish Survey Results: January 2018 (Prepared by R. Dagit)

# Malibu Lagoon
# Post Construction Fish Survey January 2018

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

**Prepared by:**
**Danielle Alvarez, Russell Dauksis, Brianna Demirci, and Rosi Dagit**
**RCD of the Santa Monica Mountains**
**540 S. Topanga Canyon Blvd.**
**Topanga, CA 90290**

**January 2018**

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# EXECUTIVE SUMMARY

A post-construction fish survey of Malibu Lagoon was conducted on Tuesday 30 January 2018 by a team from the RCD of the Santa Monica Mountains with assistance from CDPR, The Bay Foundation staff, CA Science Center staff, and volunteers.

Malibu Lagoon was open to the ocean since early December 2017, with lagoon levels changing with the tide. We were able to seine to depletion at all sites though low water levels reduced the area available to pull the seines. High tide was at 7:43 am (6.9' elevation) and the moon was full on 31 January. 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 series of spot surveys along the eastern end of the beach along the open berm and up the eastern bank past the PCH bridge.

A total of 1 suspected larval federally endangered tidewater goby (*Eucyclogobius newberryi)* was captured during a spot seine near the berm. It was approximately 2 mm long and very difficult to conclusively identify. We decided to release it, rather than collect as a voucher for identification. Striped mullet (*Mugil cephalus*) were observed jumping throughout the lagoon and we captured and measured one 26 inch adult at site 3. The dominant species surveyed and identified was topsmelt (*Atherinops affinis, larva = 179, juveniles =20, adult = 0*), followed by Oriental Shrimp (*Palaemonetes spp.* = 3). A total of 3 longjawed mudsucker larva (*Gillichthys mirabilis*) were also observed.

The majority of individuals collected were extremely young larval or juvenile fish, which suggests that Malibu Lagoon is currently serving as a nursery site for both lagoon and ocean species.

Species captured or observed during the January 2018 survey include:

| | |
|---|---|
| **Native Fish Species** | |
| Tidewater goby | *Eucyclogobius newberryi* |
| Topsmelt | *Atherinops affinis* |
| Staghorn sculpin | *Leptocottus armatus* |
| Striped mullet | *Mugil cephalus* |
| Longjawed mudsucker | *Gillithys mirabilis* |
| Spotted Turbot | *Pleuronichtys rittere* |
| | |
| **Non-Native Fish Species** | |
| Mississippi Silversides | *Menidia beryllina* |
| | |
| **Invertebrates** | |
| Oriental shrimp | *Palaemonetes sp.* |
| Isopods | |

## 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. Chuck Kopczak and Maria Loberg, curator and aquarist staff with the California Science Center, Rod Abbott and Chris Enyart from The Bay Foundation, and volunteers Sydney Hughes and Angela Madsen 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, Stream Team
Garrett Nichols, Stream Team

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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 2017, the lagoon was surveyed open in March and closed in July.

### 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.

The eighth survey occurred on 26 July 2017. The lagoon level was 7'8" based on the ramp markers, with some overwash evident at the east side of the berm. The weather was hot and sunny, with a SW wind increasing during the course of the day. Air temperatures were in the 80's F.

The ninth survey occurred on 30 January 2018. The lagoon was breached and we started on a high tide. Lagoon levels lowered as the day progressed, reflecting the outgoing tide, staying below the levels on the ramp completely. The weather was mild and sunny with consistent high cloud cover. A light NE wind persisted throughout the day and air temperatures were in the low 70's F. The full moon on 31 January was not only a super moon due to apogee, but also a blue moon and blood moon, with full lunar eclipse visible around 0530. This was the most extreme tide of the month.

## 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.

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

-ziplock baggies
- fish measuring boards (2)
- fish id books
- camera
- GPS

- data sheets
- ice chest for voucher specimens
- hand sanitizer
- 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 |

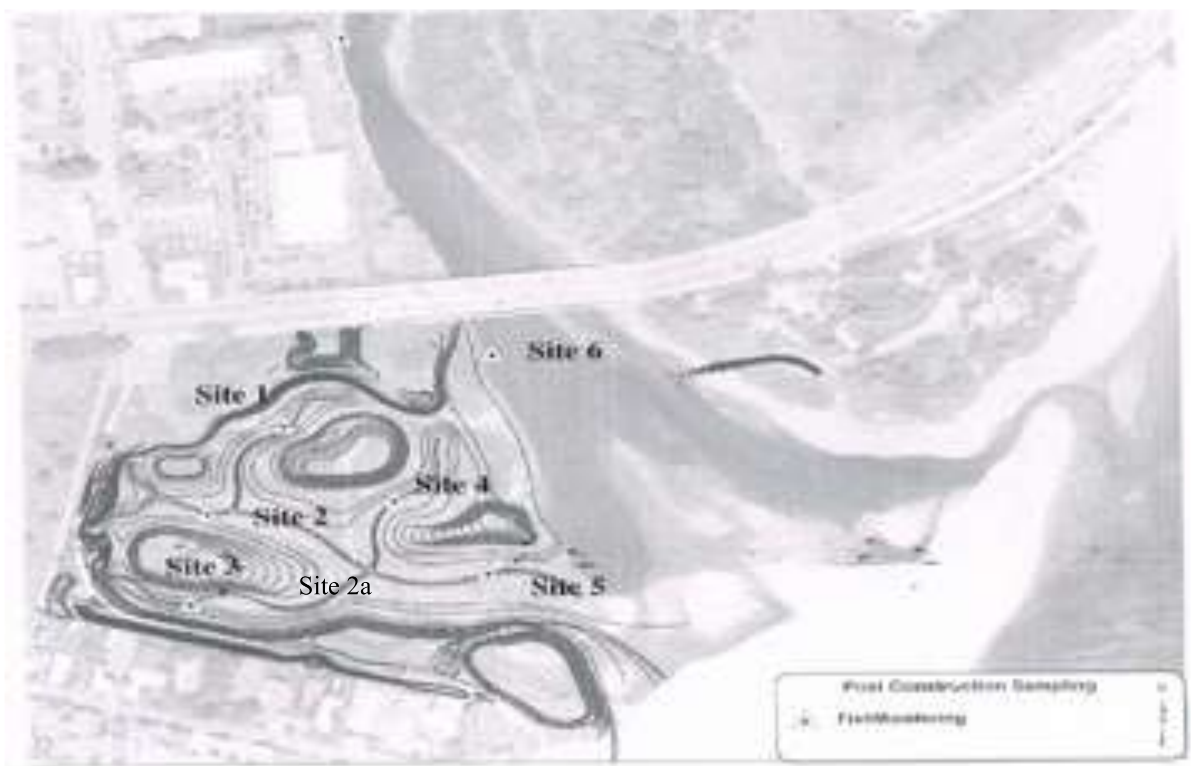


**Figure 1. Map of the Permanent Monitoring Sites, Malibu Lagoon Restoration (Established in January 2013 and revised in May 2014)**

# RESULTS

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

Table 2. Water Quality and site conditions at the permanent monitoring sites 30 January 2018

| Variable | Site 1 | Site 2 | Site 2a | Site 3 | Site 5 | Site 6 |
|---|---|---|---|---|---|---|
| Avg depth (cm) | 45 | 65 | 10 | 110 | 35 | 50 |
| Water T (ºC) | 13.2 | 13.4 | 13.4 | 13.4 | 15.4 | 13.6 |
| Air T (ºC) | 22 | 20 | 20 | 20 | 22 | 20 |
| Salinity ppt | 31 | 25 | 26 | 25 | 30 | 26 |
| DO mg/l | 7.6 | 8.2 | 8.02 | 8.35 | 10.95 | 8.2 |
| pH | 8.2 | 8.1 | 8.1 | 8.1 | 8.3 | 8.2 |
| Conductivity | ND | ND | ND | ND | ND | ND |
| % Floating Algae cover | 0 | 0 | 0 | 0 | 0 | 0 |
| % Submerged/ Attached Algae cover | 0 | 0 | 0 | 0 | 0 | 0 |
| % emergent vegetation bank cover | 100 | 25 | 0 | 100 | 0 | 50 |
| Emergent Vegetation type | Jaumea, Distichlis, Juncus | Jumea, Distichlis, Salicornia | None | Jaumea, Distichlis, Juncus | None | Jaumea, Distichlis |
| Dominant Substrate | Mud/silt | Sand and cobble | Sand and cobble | Sand and gravel | Sticky mud | cobble |
| Time start | 09:10 | 09:50 | 09:35 | 10:15 | 12:40 | 08:35 |

Table 3. Summary of Fish and Invertebrates captured/observed 30 January 2018.

| **Lagoon-ocean connection conditions** | **OPEN** | **Site 1** | **Site 2** | **Site 2a** | **Site 3** | **Site 5** | **Site 6** | **Spot Seines** | **TOTALS** |
|---|---|---|---|---|---|---|---|---|---|
| **Seine pull total to depletions** | | 12 | 9 | 10 | 15 | 16 | 15 | 16 | 77 |
| **Native Fish Species** | | | | | | | | | 0 |
| Steelhead trout | *O.mykiss* | | | | | | | | 0 |
| Unidentified goby larva (<5 cm) | | | | | | | | 1 | 0 |
| Tidewater goby larva (<5cm) | *Eucyclogobius newberryi* | | | | | | | | 0 |
| Tidewater goby adult (6-8cm) | *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* | | | | | | | | 0 |
| CA killifish (5-10 cm) | *Fundulus parvipinnis* | | | | | | | | 0 |
| Long-jawed mudsucker (<5 cm) | *Gillichthys mirabilis* | | | | | | 3 | | 3 |
| Long-jawed mudsucker (5-10 cm) | *Gillichthys mirabilis* | | | | | | | | 0 |
| **Topsmelt larva (<5 cm)** | *Atherinops sp* | 14 | 48 | | 46 | 51 | 20 | 97 | 179 |
| Topsmelt juvenile (6 cm) | *Atherinops sp* | | | | 16 | 1 | 3 | 244 | 20 |
| Topsmelt adult (16 cm) | *Atherinops sp* | | | | | | | | 0 |
| Unidentified smelt larva (<5 cm) | *Atherinops sp* | | | | | | | | 0 |
| Staghorn sculpin (<5 cm) | *L. armatus* | | | | | 1 | | 7 | 1 |
| Staghorn sculpin (5-10 cm) | *L.armatus* | | | | | | | | 0 |
| Staghorn sculpin (10-15cm) | *L.armatus* | | | | | | | | 0 |
| Opaleye | *Girella nigricans* | | | | | | | | 0 |
| Diamond turbot | *Hypsopsetta guttulata* | | | | | | | | 0 |
| Spotted turbot | *Pleuronichthys ritteri* | | | | | 2 | | 10 | 2 |
| Garabaldi (28 cm FL) dead dropped by birds | *Hypsypops rubicundus* | | | | | | | | 0 |
| Northern anchovy <5 cm | *Engraulis mordax* | | | | | | | | 0 |
| Northern anchovy (5-10 cm) | *Engraulis mordax* | | | | | | | | 0 |
| Striped mullet | *Mugil cephalus* | | | | 1 | | | | 1 |
| Unidentified fish larva | | | | | | | | | 0 |
| **Non-Native Fish Species** | | | | | | | | | 0 |
| Mosquitofish Juveniles (<5cm) | *Gambusia affinis* | | | | | | | | 0 |
| Mosquitofish Adults (5-10cm) | *Gambusia affinis* | | | | | | | | 0 |
| Carp | *Cyprinus carpio* | | | | | | | | 0 |
| Mississippi silversides <5cm | *Menida audens* | | | | | 1 | | | 1 |
| *Mississippi silversides (5-10cm)* | *Menida audens* | | | | | | | | 0 |

| **Lagoon-ocean connection conditions** | **OPEN** | **Site 1** | **Site 2** | **Site 2a** | **Site 3** | **Site 5** | **Site 6** | **Spot Seines** | **TOTALS** |
|---|---|---|---|---|---|---|---|---|---|
| **Invertebrates** | | | | | | | | | 0 |
| Oriental shrimp | *Palaemonetes sp.* | | 2 | | 2 | 1 | | 2 | 5 |
| Hemigraspus crabs | | | | | | | | | 0 |
| Water boatman juveniles | | | | | | | | | 0 |
| Amphipods | | | | | | | | | 0 |
| Isopods | | | | | 3 | | | | 3 |
| Ctenophore sp (<2 cm) | | | | | | | | | 0 |
| Salp sp (<2 cm) | | | | | | | | | 0 |
| Sea hare (5-10 cm) | *Aplysia californica* | | | | | | | | 0 |
| Segmented worm <2 cm) | | | | | | | | | 0 |
| Gastropoda | | | | | | | | | 0 |
| Water scavenger larva | Hydrophilidae | | | | | | | | 0 |
| Dragonfly | | | | | | | | | 0 |
| Caddisfly | | | | | | | | | 0 |
| Crayfish | *Procambarus clarkii* | | | | | | | | 0 |

## SUMMARY

The January 2018 post-construction fish survey was completed in one day with a team of 13 people.

Table 4 provides a summary comparing abundance of species documented in Malibu Lagoon prior to restoration (2005), species relocated during restoration (2012), and nine post-construction surveys (2013-2018).

A total of five native fish species were observed in January 2018.

Table 4. Summary of Fish and Invertebrates captured/observed 2005 – 2018

| | | Survey | Relocation | Survey | Survey | Survey | Survey | Survey | Survey | Survey | Survey | Survey |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **6/1/2005** | **June 2012** | **1/8/2013** | **5/15/2014** | **12/11/2014** | **5/27/2015** | **1/12/2016** | **6/1/2016** | **3/3/2017** | **7/26/2017** | **1/30/2018** |
| | | **open** | **open** | **open** | **closed** | **open** | **closed** | **open** | **closed** | **open** | **closed** | **open** |
| **Native Fish Species** | | | | | | | | | | | | |
| Steelhead trout | *O.mykiss* | | | | 1 obs. | | | | | 0 | 0 | 0 |
| Unidentified goby larva (<5 cm) | | | 2 | | 500~ | | | | 0 | 0 | 8 | 1 |
| Tidewater goby larva (<5cm) | *Eucyclogobius newberryi* | | | | 13 | | | | 17 | 12 | 10 | 0 |
| Tidewater goby adult (6-8cm) | *Eucyclogobius newberryi* | 473 | 8 | | 0 | | 41 | | 0 | 0 | 0 | 0 |
| Arrow goby (<5 cm) | *Cleavlandia ios* | | | | 5 | | | | 0 | 0 | 0 | 0 |
| Bay goby? | *Lepidogobius lepidus* | | | | 2 | | | | 0 | 0 | 0 | 0 |
| CA Halibut | *Paralichthys californicus* | | | | | | | | 2 | 0 | 0 | 0 |
| CA killifish juveniles (<5cm) | *Fundulus parvipinnis* | | 306 | | 0 | | | | 1 | 1 | 0 | 0 |
| CA killifish (5-10 cm) | *Fundulus parvipinnis* | 46 | 16 | | 5 | | | | 0 | 0 | 0 | 0 |
| Long-jawed mudsucker (<5 cm) | *Gillichthys mirabilis* | 1 | 8 | | 5 | | 3 | | 11 | 2 | 4 | 3 |
| Long-jawed mudsucker (5-10 cm) | *Gillichthys mirabilis* | | 11 | | | | 22 | 5 | 52 | 0 | 13 | 0 |
| Topsmelt larva (<5 cm) | *Atherinops sp* | | 1 | 3 | | | 176 | 6 | 1289 | 35 | 2618 | 276 |
| Topsmelt juvenile (6 cm) | *Atherinops sp* | 244 | 0 | | 24 | | 60 | | 133 | 48 | 933 | 264 |
| Topsmelt adult (16 cm) | *Atherinops sp* | | 0 | | | | 6 | | 0 | 0 | 56 | 0 |
| Unidentified smelt larva (<5 cm) | *Atherinops sp* | | 101 | | 15,293 | | 2244 | 64 | | 0 | 0 | 0 |
| Staghorn sculpin (<5 cm) | *L. armatus* | | | 17 | 11 | | | 1 | | 130 | 1 | 8 |
| Staghorn sculpin (5-10 cm) | *L.armatus* | | 3 | | | | | | 5 | 4 | 2 | 0 |
| Opaleye | *Girella nigricans* | | | | | | | | | 0 | 2 | 0 |
| Diamond turbot | *Hypsopsetta guttulata* | | | 7 | 1 | | | | 5 | 0 | 0 | 0 |
| Spotted turbot | *Pleuronichthys ritteri* | | | | | | | | | | | 12 |

| | | Survey | Relocation | Survey | Survey | Survey | Survey | Survey | Survey | Survey | Survey | Survey |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **6/1/2005** | **June 2012** | **1/8/2013** | **5/15/2014** | **12/11/2014** | **5/27/2015** | **1/12/2016** | **6/1/2016** | **3/3/2017** | **7/26/2017** | **1/30/2018** |
| | | **open** | **open** | **open** | **closed** | **open** | **closed** | **open** | **closed** | **open** | **closed** | **open** |
| **Native Fish Species** | | | | | | | | | | | | |
| Garabaldi (28 cm FL) dead dropped by birds | *Hypsypops rubicundus* | | | | | | | | | 0 | 0 | 0 |
| Northern anchovy <5 cm | *Engraulis mordax* | | 5 | | | | | 180 | 1 | 0 | 423 | 0 |
| Northern anchovy 5-10 cm | *Engraulis mordax* | | | | | | | | | | 239 | 0 |
| Striped mullet | *Mugil cephalus* | obs. | | obs. | obs. | 7 | 1 | | obs. | obs. | 0 | 1 |
| Unidentified fish larva | | | | | | | 991 | | 3 | 0 | 52 | 0 |
| **Non-Native Fish Species** | | | | | | | | | | | 0 | 0 |
| Mosquitofish Juveniles (<5cm) | *Gambusia affinis* | | | | | | 13 | 6 | 10 | 1 | 271 | 0 |
| Mosquitofish Adults (5-10cm) | *Gambusia affinis* | 65 | 4072 | | | 2 | 3 | | | 0 | 3 | 0 |
| Carp | *Cyprinus carpio* | 1 | | | obs. | | | | | 0 | 1 | 0 |
| Mississippi silversides | *Menida audens* | | | 1 | 0 | 970 | 9 | 15 | 16 | 0 | 650 | 1 |
| | | | | | | | | | | | 13 | 0 |
| **Invertebrates** | | | | | | | | | | 0 | | 0 |
| Oriental shrimp | *Palaemonetes sp.* | | | 37 | 209 | 43 | 10 | 5 | 58 | 89 | 280 | 7 |
| Hemigraspus crabs | | | 6 | | 8 | 1 | 20 | 1 | 1 | 2 | 2 | 0 |
| Water boatman juveniles | | | 6,000+ | | 2504 | | | | | 0 | 14 | 0 |
| Amphipods | | | 2500+ | | | | | | | 0 | 0 | 0 |
| Isopods | | | 2500+ | | | | | | | 0 | 0 | 3 |
| Ctenophore sp (<2 cm) | | | | 3 | | | | | | 0 | 0 | 0 |
| Salp sp (<2 cm) | | | | 3 | | | | | | 0 | 0 | 0 |
| Sea hare (5-10 cm) | *Aplysia californica* | | | 2 | | | | | | 0 | 0 | 0 |
| Segmented worm <2 cm) | | | | 3 | | | | | | 0 | 0 | 0 |
| Gastropoda | | | | | | | 4 | | | 0 | 0 | 0 |
| Water scavenger larva | Hydrophilidae | | | | | | 1 | | | 0 | 0 | 0 |
| Dragonfly | | | | | | | | | | | 16 | 0 |
| Caddisfly | | | | | | | | | | | 8 | 0 |
| Crayfish | *Procambarus clarkii* | | | | | | | | | 1 | 0 | 0 |

# Appendix A. Photographs of fish species


Striped mullet


Mississippi silverside


Staghorn sculpin


Spotted turbot


Topsmelt

## Appendix B. Site Photos


Site 1


Site 3


Site 2


Site 5


Site 2a


Site 6

**Spot Seine upstream of PCH Bridge**

**Spot seine near beach face close to breach**

**Spot seine by upper PCH Bridge**

**Along east bank of lagoon by Adamson House**

# Appendix 3. Avian Usage of Post-Restoration Malibu Lagoon: Year 5 (2017) (Prepared by D. Cooper)

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# Avian Usage of Post-restoration Malibu Lagoon Year 5 (2017)

## Malibu Lagoon State Beach

## Malibu, California

*Prepared for:*
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March 20, 2018

## Summary

The Year 5 (2017) quarterly surveys recorded 6,310 individual birds (pooled across two-day counts), which is just over half that recorded the prior year (11,738 individuals), with 2016 being an unusually high year for total individual birds. Following restoration in 2013, birds favoring urban habitats and freshwater marsh, as well as shorebirds and waders, have increased, while marine species and waterfowl have declined in numbers. However, numbers of urban species and shorebirds are lower now than on pre-restoration counts, and numbers of fish-eaters are somewhat higher now. Species diversity in the "Western Channels," where the restoration was focused, is higher now than on the pre-restoration counts, though numbers of individuals have leveled-off to those found pre-restoration. Finally, two special-status species, Western Snowy Plover and California Least Tern, successfully bred at Malibu Lagoon in 2017 for the first time in recorded history, which marks the first Los Angeles County nesting success for Snowy Plover in roughly 70 years, and one of just a handful of successful breeding sites for Least Tern in the County. Four species detected in 2017 were new for the quarterly survey: Canada Goose, Ross's Goose, Reddish Egret, and Merlin, bringing the cumulative number of species and identifiable subspecies detected on quarterly surveys in all five years to 155 (excluding fly-overs not using the habitat and hybrids).

## 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[1]. Here I analyze five years of data, each with quarterly surveys: pre-restoration (2005-06) and post-restoration (2013-2017), conducted on the following dates[2]:

Pre-restoration dates:

- 28-29 October 2005
- 09 and 11 January 2006
- 26-27 April 2006
- 22-23 July 2006

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

[2] 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.

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
- 17-18 January 2017
- 24 and 26 April 2017
- 13-14 July 2017
- 30-31 October 2017

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, I omitted most raptors from the analysis, which are typically seen flying over the site and rarely lingering, with the exception of Osprey, which regularly use the site for foraging.

I 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 evolving 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, as 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 average daily estimate[3].

## Results

The Year 5 (2017) survey recorded 6,310 individuals, the lowest total yet, and just over half the number recorded the year prior (11,738). The 2012-2016 average cumulative total was

[3] 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.

9,690, so this year's count (of individual birds using the site) is well below that[4]. The cumulative number of species and identifiable subspecies detected in all five years is 155, with two species new for 2017, Canada Goose, Ross's Goose, Reddish Egret, and Merlin (singles of each). Species richness, which dropped in the first two years post-restoration, rebounded somewhat by 2015, and has held relatively steady (119 in 2005-06, then 88 (2013), 87 (2014), 100 (2015), 88 (2016) and 87 (2017). However, as noted above, these comparisons 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 and further analysis[5]. Table 1a summarizes counts of selected groupings by ecological guilds of species from 2005 (pre-restoration) to 2017 (post-restoration); more detailed counts are found in Tables A1 and A2.

Results from the quarterly surveys may be compared with sightings submitted to eBird from hundreds of visits by birders (see Appendix, below).

Table 1a. Summary of quarterly bird counts (total count/# species), by guild, at Malibu Lagoon, 2005-2017. Please refer to Tables A1 and A2 for species used in analysis.

| **Guild** | **2005-06** | **2013** | **2014** | **2015** | **2016** | **2017** |
|---|---|---|---|---|---|---|
| Open country | 61 (4) | 48 (5) | 50 (4) | 105 (5) | 43 (4) | 37 (4) |
| Scrub/woodland | 276 (15) | 97 (8) | 116 (12) | 129 (16) | 156 (11) | 128 (12) |
| Urban | 320 (8) | 54 (7) | 42 (6) | 67 (6) | 153 (7) | 153 (7) |
| Freshwater marsh | 181 (6) | 57 (2) | 17 (2) | 76 (4) | 96 (5) | 245 (4) |
| Marine/beach | 2311 (19) | 2054 (21) | 5672 (18) | 4404 (19) | 3879 (16) | 1237 (15) |
| Shorebird | 917 (13) | 398 (11) | 282 (9) | 183 (11) | 334 (10) | 664 (10) |
| Waders | 124 (5) | 121 (4) | 105 (5) | 97 (5) | 94 (3) | 160 (4) |
| Waterfowl | 1267 (15) | 1790 (11) | 962 (12) | 909 (15) | 735 (13) | 859 (13) |
| Fish-eaters | 371 (12) | 498 (12) | 303 (12) | 369 (13) | 301 (10) | 524 (12) |

<u>Landbirds</u>

Treating landbirds first (see Table A1, below), 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.

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

[5] Because several pre-restoration surveys (2005-06) were conducted by another surveyor (not D.S. 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).

Addressing each ecological guild separately, counts of open country species in 2017 were similar to 2016 (and to the years following the 2013 restoration); it is now clear that 2015 was likely an unusually good year for open-country species, in particular Western Meadowlark.

Counts of scrub/woodland species are higher than 2013 immediately post-restoration, but are still less than half counts pre-restoration, probably because the vegetation (both scrub and riparian) is still growing in, and may take decades to reach the density and maturity of the site prior to restoration. These observations may be compared to a much larger database of birders' reports to the eBird database (www.ebird.org); Figure A1 presents counts of one representative scrub-dwelling species, the Song Sparrow, from multiple observers 2015-2017, which shows stable numbers 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.

Urban species were recorded in exactly the same numbers as in 2016, and are still less than half pre-restoration levels, suggesting the site is still relatively less appealing to urban-adapted birds, and its avifauna is arguably more "wild."

Waterbirds

For waterbirds (Table A2), 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/omnivores.

Freshwater marsh birds surged in 2017, particularly Great-tailed Grackle and Common Yellowthroat, which favor reeds for breeding and wintering. While the two rail species found at the site pre-restoration no longer occur regularly (Sora and Virginia Rail), these two are readily seen across the street at Legacy Park (eBird), where reedbeds are far more extensive (pers. obs.).

Counts of marine bird continued to decline in 2017, but this was largely due to the continuing slide in numbers of two abundant species, Brown Pelican and Elegant Tern, which are seeing their breeding success in Mexico hampered by recent increases in ocean water temperature. This has led to lower numbers of young dispersing north up the coast of California in summer/fall, and presumably smaller pre-breeding aggregations of adults in spring.

After a few low years, shorebird use of the lagoon appears to be rising, with counts of many species approaching pre-restoration numbers, and overall shorebird numbers double that of 2016, and triple that of 2015. Qualitatively, there seem to be more shorebirds in general roosting on the islands toward the main lagoon than in prior years, regardless of time of day, tide, etc. (pers. obs.). Some species have been fairly stable in recent years, such as Least Sandpiper, while others such as Marbled Godwit have clearly increased, especially in fall, when dozens of shorebirds roost at the edge of the main lagoon (Figure A2).

Large waders and, particularly, fish-eaters, were found in higher numbers than prior years (including pre-restoration years), suggesting that the lagoon is functioning well for those groups. The continuation of breeding by large waders across PCH at Malibu Country Mart through 2017 has probably contributed to numbers at the lagoon, particularly in spring and summer (recent tree-trimming of the colony trees may affect this). Figure A3 shows counts of Snowy Egret from eBird, which have been relatively stable in recent years.

Waterfowl continue to show mixed trends, with counts of individuals and species roughly similar the past three years, but lower (both in numbers and richness) to pre-restoration totals. Reasons for this are not clear; waterfowl numbers in southern California seem particularly dependent on early-winter storms, which may push them south if they materialize, or if they don't, may "retain" birds north in places like the Sacramento Valley. Figure A4 illustrates how certain waterfowl, such as Northern Shoveler, have not been using the lagoon, while others, like American Wigeon, continue to do so. Changes in salinity and aquatic plant growth could also be impacting these numbers.

Intra-site Changes in Avian Usage

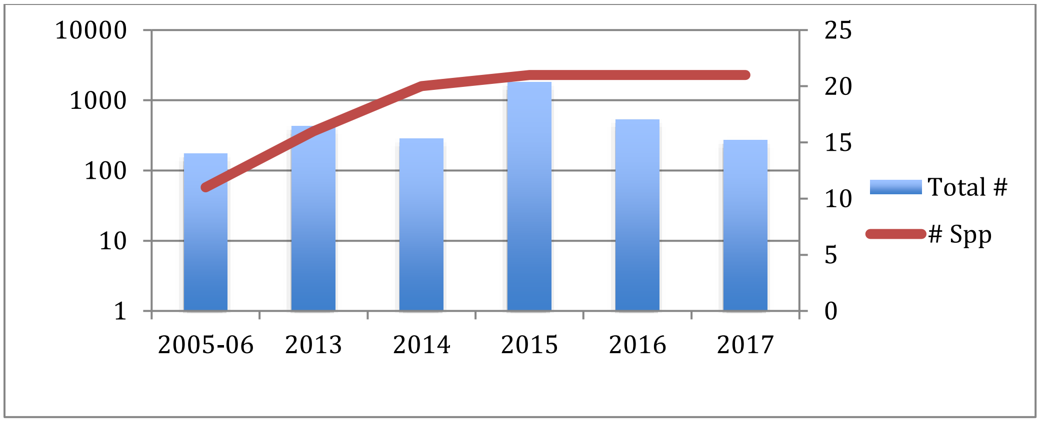
In the five years since restoration, certain bird species have been able to use more of the site, particularly waterbirds using the aquatic habitats in the western portion of the lagoon, which had been shallower and narrower, but more thickly vegetated overall, prior to the restoration. A comparison of 22 common waterbirds in the Western Channels (Table 1b, Figure 1) shows continuing high species richness in 2017, but a dip in counts of individuals since 2014, approaching pre-restoration levels. Again, since these common waterbird species include Brown Pelican and Elegant Tern, the dearth of both these species since 2014 likely affected trends in numbers in the Western Channels in recent years. In addition, the fact that a handful of species are not dominating in terms of numbers may also be seen as a positive outcome for species diversity (which remains high relative to pre-restoration years). Finally, there may be an upper limit for how many individual birds can actually use the Western

Channels given its limited size, which means that the site may be re-settling into a kind of equilibrium in terms of numbers of individuals.

Table 1b. Selected Waterbird Usage of "Western Channels" Portion of Malibu Lagoon, 2005-Present.

| **Species** | **2005-06** | **2013** | **2014** | **2015** | **2016** | **2017** |
|---|---|---|---|---|---|---|
| American Wigeon | 0 | 30 | 2 | 1 | 7 | 8 |
| Black-bellied Plover | 0 | 0 | 6 | 60 | 22 | 49 |
| Brown Pelican | 0 | 0 | 3 | 1106 | 1 | 4 |
| Caspian Tern | 3 | 1 | 2 | 8 | 8 | 7 |
| Double-cr. Cormorant | 0 | 15 | 5 | 45 | 40 | 5 |
| Eared Grebe | 0 | 24 | 25 | 15 | 3 | 2 |
| Elegant Tern | 0 | 0 | 0 | 5 | 250 | 0 |
| Gadwall | 27 | 104 | 59 | 114 | 27 | 49 |
| Great Blue Heron | 9 | 14 | 5 | 11 | 9 | 13 |
| Great Egret | 5 | 9 | 2 | 5 | 4 | 12 |
| Green-winged Teal | 70 | 28 | 15 | 61 | 20 | 17 |
| Killdeer | 6 | 28 | 9 | 34 | 18 | 10 |
| Least Sandpiper | 26 | 6 | 3 | 0 | 0 | 11 |
| Marbled Godwit | 0 | 0 | 37 | 6 | 17 | 1 |
| Northern Shoveler | 5 | 82 | 13 | 9 | 26 | 0 |
| Pied-billed Grebe | 2 | 16 | 3 | 4 | 12 | 8 |
| Red-breasted Merganser | 0 | 4 | 1 | 5 | 9 | 12 |
| Ruddy Duck | 0 | 24 | 47 | 226 | 3 | 7 |
| Snowy Egret | 19 | 38 | 36 | 53 | 44 | 43 |
| Western Grebe | 0 | 3 | 0 | 7 | 8 | 5 |
| Whimbrel | 2 | 0 | 6 | 17 | 0 | 1 |
| Willet | 0 | 0 | 6 | 10 | 5 | 8 |
| **Total #** | **174** | **426** | **285** | **1802** | **533** | **272** |
| **# Spp** | **11** | **16** | **20** | **21** | **20** | **20** |

Figure 1. Comparison of total individuals ("Total #") and annual species richness (# Spp.") in Western Channels area of Malibu Lagoon on quarterly surveys, 2005-2017.




Sensitive species

Only a handful of special-status species regularly occur at Malibu, including 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. There were three reports of individual State Threatened Belding's Savannah Sparrows from Malibu Lagoon in 2017 (eBird), none accompanied by a photograph or details that would support a conclusive identification.

Of the special-status species, the Brown Pelican and Snowy Plover make heavy usage of the site, and are present most of the year. Both continued to utilize the site in 2017, occurring almost exclusively on the sand spit separating the main lagoon from the beach (which was not affected by the restoration). In 2017, a handful of pairs of Snowy Plovers attempted to breed at Malibu Lagoon for the first time in modern history (no prior records), with at least one chick successfully fledging (S. Vigallon, via email, July 7, 2017), owing to a well-coordinated effort between California State Parks, Los Angeles Audubon Society, and others to install protective fencing, wire mesh enclosures, daily monitoring, and others protective measures. This represents the first successful nesting by this species in Los Angeles County in roughly 70 years.

The California Least Tern again attempted to breed in early summer (2017), with more than 20 active nests May – July, and multiple young fledged (S. Vigallon, via email, July 7, 2017). Birds were observed foraging in the lagoon (including in the far western portions of the restored channels), though most were seen overflying the lagoon to feed offshore to the west. This marks the third time in recent years this species has attempted nesting at the lagoon, indicating its importance as an alternate nesting site away from larger and more established colonies to the north and south[6]. This nesting success, and its significance, will be discussed in future publications.

[6] Least Terns attempted to breed here (unsuccessfully) in 2013, and then in 2016, when 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).

**APPENDIX. Additional Tables and Figures.**

Table A1. Landbird guilds (excludes aerial foragers[7]).

| Guild | Species | 2005-06 | 2013 | 2014 | 2015 | 2016 | 2017 | Trend |
|---|---|---|---|---|---|---|---|---|
| OPEN COUNTRY[8] | | | | | | | | |
| | American Pipit | 10[9] | 3 | 0 | 5 | 0 | 0 | |
| | Killdeer | 48 | 31 | 14 | 36 | 30 | 28 | |
| | Savannah Sparrow | 2 | 3 | 5 | 8 | 3 | 2 | |
| | Say's Phoebe | 1 | 6 | 4 | 1 | 4 | 2 | |
| | Western Meadowlark | 0 | 5 | 27 | 55 | 6 | 5 | |
| Total open country (# species) | | 61 (4) | 48 (5) | 50 (4) | 105 (5) | 43 (4) | 37 (4) | Mixed |
| SCRUB/WOODLAND[10] | | | | | | | | |
| | Allen's Hummingbird | 38 | 10 | 10 | 13 | 15 | 7 | |
| | American Robin | 0 | 3 | 0 | 0 | 0 | 0 | |
| | Anna's Hummingbird | 21 | 0 | 3 | 2 | 0 | 0 | |
| | Bewick's Wren | 15 | 1 | 1 | 1 | 2 | 6 | |
| | Bushtit | 70 | 22 | 35 | 24 | 65 | 50 | |
| | California Scrub-Jay | 0 | 0 | 0 | 0 | 4 | 1 | |
| | California Towhee | 18 | 9 | 7 | 6 | 7 | 5 | |
| | Cedar Waxwing | 14 | 0 | 0 | 0 | 0 | 0 | |
| | Hermit Thrush | 0 | 0 | 2 | 8 | 2 | 0 | |
| | House Wren | 5 | 2 | 3 | 4 | 12 | 11 | |
| | Lincoln's Sparrow | 5 | 0 | 2 | 2 | 0 | 1 | |
| | Oak Titmouse | 1 | 0 | 0 | 5 | 5 | 5 | |
| | Orange-crowned Warbler | 11 | 0 | 3 | 4 | 4 | 3 | |
| | Ruby-crowned Kinglet | 5 | 3 | 8 | 12 | 3 | 1 | |
| | Song Sparrow | 51 | 47 | 40 | 38 | 37 | 37 | |
| | Spotted Towhee | 15 | 0 | 2 | 1 | 0 | 1 | |
| | Townsend's Warbler | 0 | 0 | 0 | 4 | 0 | 0 | |
| | Wilson's Warbler | 3 | 0 | 0 | 2 | 0 | 0 | |
| | Yellow Warbler | 4 | 0 | 0 | 3 | 0 | 0 | |
| Total scrub/woodland (# species) | | 276 (15) | 97 (8) | 116 (12) | 129 (16) | 156 (11) | 128 (12) | Decline/ some recovery |
| URBAN | | | | | | | | |
| | American Crow | 49 | 16 | 6 | 8 | 18 | 16 | |
| | Black Phoebe | 28 | 17 | 11 | 7 | 20 | 11 | |
| | Brewer's Blackbird | 27 | 0 | 0 | 0 | 0 | 1 | |
| | Brown-headed Cowbird | 14 | 5 | 1 | 1 | 3 | 0 | |
| | European Starling | 123 | 1 | 2 | 28 | 4 | 27 | |
| | Hooded Oriole | 7 | 1 | 0 | 0 | 0 | 0 | |
| | House Finch | 65 | 11 | 17 | 19 | 96 | 85 | |
| | Rock Pigeon | 0 | 0 | 0 | 0 | 7 | 8 | |
| | Northern Mockingbird | 7 | 3 | 5 | 4 | 6 | 5 | |
| Total urban (# species) | | 320 (8) | 54 (7) | 42 (6) | 67 (6) | 153 (7) | 153 (7) | Decline/ some "recovery" |

[7] We omit the "aerial insectivore" from the analysis; species such as swifts and swallows were irregularly recorded during the surveys, but no distinction was made as to whether they were actually utilizing the habitat on the ground. Western Kingbird was omitted from this analysis in 2017 as it appears to be a rare migrant.
[8] 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.
[9] Might have included fly-over birds, discarded from totals in subsequent years
[10] 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 A2. Waterbird guilds.

| Guild | Species | 2005-06 | 2013 | 2014 | 2015 | 2016 | 2017 | Trend |
|---|---|---|---|---|---|---|---|---|
| FRESHWATER MARSH | | | | | | | | |
| | Common Yellowthroat | 63 | 16 | 12 | 22 | 41 | 46 | |
| | Great-tailed Grackle | 20 | 41 | 5 | 43 | 25 | 134 | |
| | Marsh Wren | 3 | 0 | 0 | 6 | 8 | 10 | |
| | Red-winged Blackbird | 84 | 0 | 0 | 5 | 21 | 55 | |
| | Sora | 5 | 0 | 0 | 0 | 1 | 0 | |
| | Virginia Rail | 6 | 0 | 0 | 0 | 0 | 0 | |
| Total freshwater marsh (# species) | | 181 (6) | 57 (2) | 17 (2) | 76 (4) | 96 (5) | 245 (4) | Decline/ increase |
| MARINE/BEACH | | | | | | | | |
| | Black Oystercatcher | 3 | 1 | 0 | 0 | 0 | 0 | |
| | Bonaparte's Gull | 1 | 2 | 11 | 9 | 2 | 6 | |
| | Brant | 4 | 6 | 0 | 6 | 6 | 0 | |
| | Brown Pelican | 862 | 167 | 4142 | 2821 | 374 | 144 | |
| | Caspian Tern | 83 | 13 | 26 | 19 | 20 | 22 | |
| | Double-cr. Cormorant | 109 | 310 | 142 | 193 | 107 | 173 | |
| | Elegant Tern | 258 | 219 | 310 | 781 | 2880 | 332 | |
| | Forster's Tern | 2 | 6 | 0 | 4 | 0 | 0 | |
| | Glaucous-winged Gull | 1 | 2 | 4 | 10 | 1 | 0 | |
| | Heermann's Gull | 216 | 30 | 466 | 176 | 43 | 34 | |
| | Herring Gull | 1 | 4 | 2 | 18 | 2 | 3 | |
| | Horned Grebe | 3 | 0 | 0 | 2 | 0 | 0 | |
| | Least Tern | 30 | 0 | 0 | 2 | 0 | 84 | |
| | Mew Gull | 2 | 0 | 1 | 0 | 0 | 0 | |
| | Red-breasted Merganser | 7 | 8 | 4 | 12 | 9 | 27 | |
| | Red-throated Loon | 0 | 2 | 1 | 0 | 0 | 0 | |
| | Royal Tern | 0 | 7 | 12 | 26 | 51 | 26 | |
| | Ruddy Turnstone | 10 | 34 | 21 | 8 | 24 | 22 | |
| | Sanderling | 58 | 460 | 48 | 8 | 115 | 10 | |
| | Snowy Plover | 52 | 202 | 137 | 16 | 76 | 91 | |
| | Surfbird | 0 | 0 | 4 | 0 | 0 | 0 | |
| | Western Grebe | 0 | 3 | 16 | 9 | 9 | 10 | |
| | Western Gull | 608 | 576 | 325 | 284 | 160 | 253 | |
| Total marine/beach (# species) | | 2311 (19) | 2054 (21) | 5672 (18) | 4404 (19) | 3879 (16) | 1237 (15) | Mixed/decline |

Table A2. (continued)

| Guild | Species | 2005-06 | 2013 | 2014 | 2015 | 2016 | 2017 | Trend |
|---|---|---|---|---|---|---|---|---|
| SHOREBIRDS[11] | | | | | | | | |
| | American Avocet | 9 | 6 | 0 | 0 | 0 | 0 | |
| | Black-bellied Plover | 287 | 224 | 169 | 73 | 202 | 288 | |
| | Black-necked Stilt | 0 | 0 | 0 | 4 | 0 | 0 | |
| | Dunlin | 5 | 2 | 1 | 0 | 0 | 1 | |
| | Greater Yellowlegs | 8 | 1 | 0 | 0 | 1 | 1 | |
| | Least Sandpiper | 71 | 33 | 4 | 1 | 18 | 17 | |
| | Long-billed Curlew | 2 | 0 | 0 | 0 | 0 | 0 | |
| | Long-b. Dowitcher | 14 | 0 | 0 | 1 | 1 | 0 | |
| | Marbled Godwit | 54 | 15 | 63 | 19 | 38 | 134 | |
| | Semipalmated Plover | 27 | 16 | 3 | 10 | 13 | 9 | |
| | Spotted Sandpiper | 11 | 6 | 7 | 8 | 2 | 3 | |
| | Western Sandpiper | 197 | 21 | 11 | 6 | 26 | 68 | |
| | Whimbrel | 20 | 27 | 9 | 21 | 13 | 22 | |
| | Willet | 212 | 47 | 15 | 38 | 20 | 121 | |
| | Wilson's Phalarope | 0 | 0 | 0 | 2 | 0 | 0 | |
| Total shorebirds (# species) | | 917 (13) | 398 (11) | 282 (9) | 183 (11) | 334 (10) | 664 (10) | Decline/ recovery |
| WADERS | | | | | | | | |
| | Black-cr. Night-heron | 31 | 5 | 3 | 5 | 0 | 2 | |
| | Great Blue Heron | 24 | 26 | 9 | 17 | 13 | 30 | |
| | Great Egret | 13 | 13 | 5 | 8 | 10 | 35 | |
| | Green Heron | 1 | 0 | 1 | 1 | 0 | 0 | |
| | Snowy Egret | 55 | 77 | 87 | 66 | 71 | 93 | |
| Total waders (# species) | | 124 (5) | 121 (4) | 105 (5) | 97 (5) | 94 (3) | 160 (4) | Mixed/increase |
| WATERFOWL | | | | | | | | |
| | American Coot | 628 | 1096 | 562 | 239 | 461 | 525 | |
| | American Wigeon | 16 | 49 | 17 | 10 | 13 | 22 | |
| | Blue-winged Teal | 6 | 0 | 0 | 4 | 3 | 1 | |
| | Bufflehead | 46 | 26 | 10 | 4 | 1 | 16 | |
| | Cinnamon Teal | 16 | 0 | 0 | 3 | 1 | 0 | |
| | Eared Grebe | 10 | 27 | 74 | 29 | 5 | 10 | |
| | Gadwall | 94 | 164 | 107 | 143 | 54 | 102 | |
| | Green-winged Teal | 147 | 48 | 42 | 66 | 33 | 32 | |
| | Hooded Merganser | 0 | 0 | 0 | 2 | 0 | 16 | |
| | Lesser Scaup | 2 | 1 | 1 | 0 | 0 | 2 | |
| | Mallard | 170 | 98 | 28 | 99 | 97 | 88 | |
| | Northern Pintail | 8 | 0 | 2 | 2 | 6 | 4 | |
| | Northern Shoveler | 47 | 163 | 31 | 18 | 40 | 0 | |
| | Pied-billed Grebe | 14 | 28 | 12 | 13 | 14 | 14 | |
| | Ruddy Duck | 55 | 90 | 76 | 276 | 7 | 27 | |
| | Snow Goose | 8 | 0 | 0 | 1 | 0 | 0 | |
| Total waterfowl (# species) | | 1267 (15) | 1790 (11) | 962 (12) | 909 (15) | 735 (13) | 859 (13) | Mixed |
| FISH-EATERS[12] | | | | | | | | |
| | Belted Kingfisher | 0 | 3 | 1 | 2 | 2 | 0 | |
| | Black-cr. Night-heron | 31 | 5 | 3 | 5 | 0 | 2 | |
| | Caspian Tern | 83 | 13 | 26 | 19 | 20 | 22 | |
| | Double-cr. Cormorant | 109 | 310 | 142 | 193 | 107 | 173 | |

[11] Excludes marine-associated species such as Sanderling.
[12] 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).

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Forster's Tern | 2 | 6 | 0 | 4 | 0 | 0 | |
| | Great Blue Heron | 24 | 26 | 9 | 17 | 13 | 30 | |
| | Great Egret | 13 | 13 | 5 | 8 | 10 | 35 | |
| | Green Heron | 1 | 0 | 1 | 0 | 0 | 0 | |
| | Hooded Merganser | 0 | 0 | 0 | 2 | 0 | 16 | |
| | Least Tern | 30 | 0 | 0 | 2 | 0 | 85 | |
| | Osprey | 2 | 0 | 0 | 0 | 4 | 1 | |
| | Pied-billed Grebe | 14 | 28 | 12 | 13 | 14 | 14 | |
| | Red-br. Merganser | 7 | 8 | 4 | 12 | 9 | 27 | |
| | Red-throated Loon | 0 | 2 | 1 | 0 | 0 | 0 | |
| | Royal Tern | 0 | 7 | 12 | 26 | 51 | 26 | |
| | Snowy Egret | 55 | 77 | 87 | 66 | 71 | 93 | |
| Total fish-eaters (# species) | | 371 (12) | 498 (12) | 303 (12) | 369 (13) | 301 (10) | 524 (12) | Increase |

Figure A1. Average counts of Song Sparrow at Malibu Lagoon, Jan. 2015 – Dec. 2017 (eBird data).

Figure A2. Counts of Least Sandpiper (top) and Marbled Godwit (bottom) at Malibu Lagoon, Jan. 2015 – Dec. 2017 (eBird data).

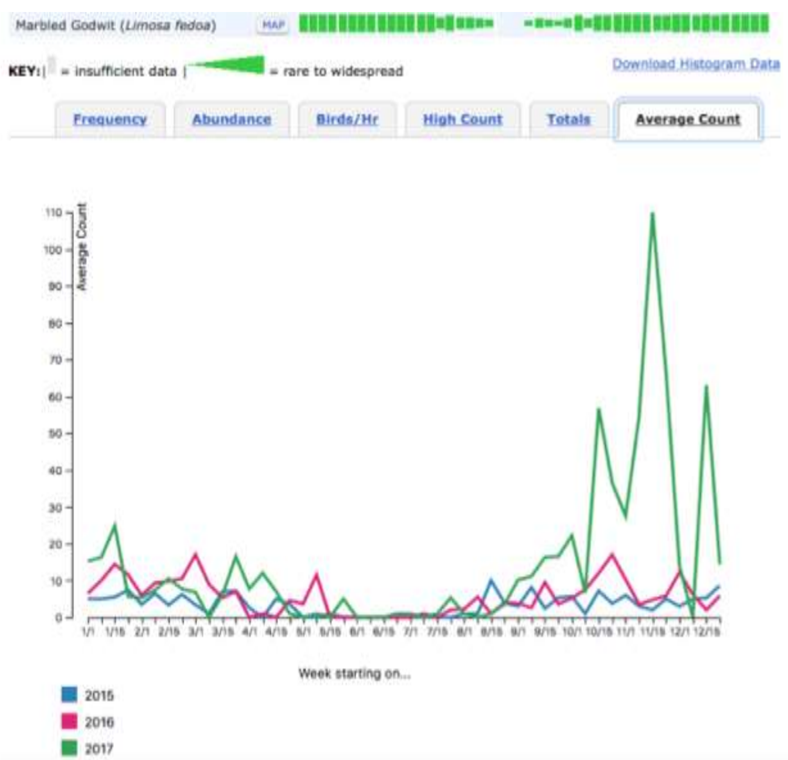



Figure A3. Counts of Snowy Egret at Malibu Lagoon, Jan. 2015 – Dec. 2017 (eBird data).

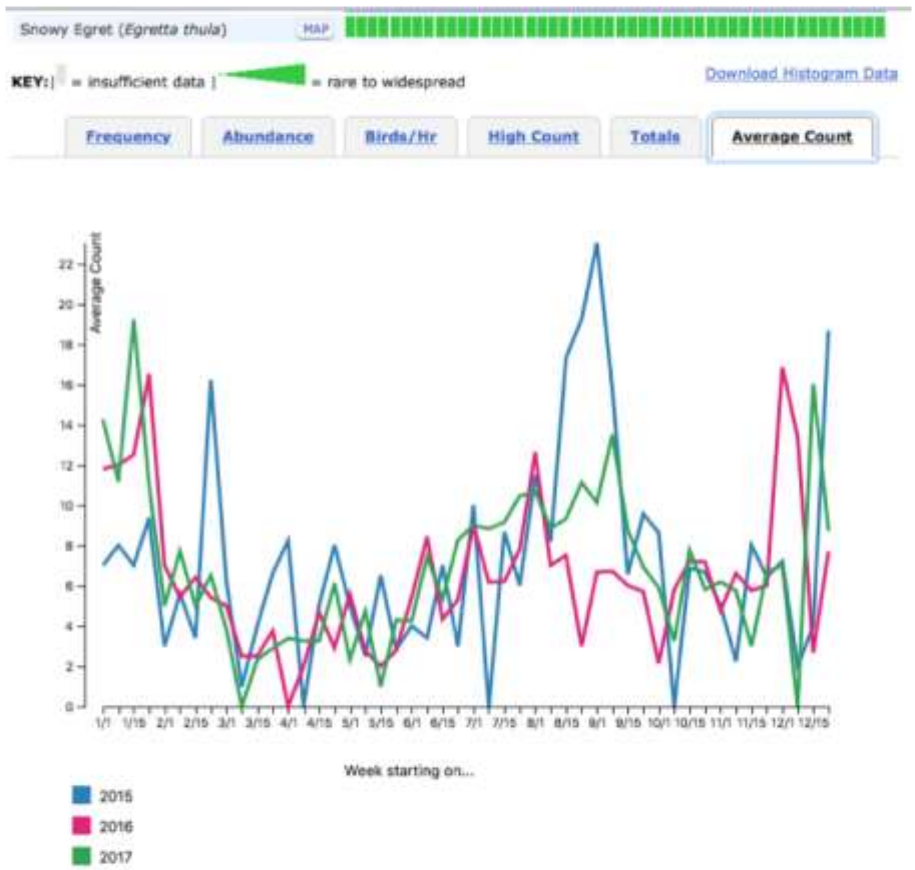


Figure A4. Counts of Northern Shoveler (top) and American Wigeon (bottom) at Malibu Lagoon, Jan. 2015 – Dec. 2017 (eBird data).