Malibu Lagoon Restoration and Enhancement Project

Final Comprehensive Monitoring Report (Year 6)

August 2019

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Final Comprehensive Monitoring Report (Year 6)

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Executive Summary

The Malibu Lagoon Restoration and Enhancement Project was completed on 31 March 2013. This report assesses the post-restoration conditions of Malibu Lagoon across approximately six years of monitoring by evaluating a suite of parameters. An evaluation of post-restoration conditions, through detailed physical, chemical, and biological monitoring components has resulted in several overarching trends. The restoration project has been determined to be wholly successful as assessed against defined project goals, performance standards, and success criteria (Table ES-1) outlined in California Coastal Commission CDP No. 4-07-098 and supporting documentation, including monitoring plans. No supplemental habitat restoration and enhancement plan is recommended for the project.

A clear pattern in the water quality data indicates that lowering the lagoon elevation, creating a wider single main channel directed more towards the incoming tide, orienting channel configurations in line with prevailing wind patterns, and removing the pinch points (i.e., bridges) led to an increase in circulation both in an open and closed berm lagoon condition. Vertical profile mixing was an additional water quality indicator of a well-functioning post-restoration system. California Rapid Assessment Method (CRAM) surveys were 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, along with the 5-year success criteria for each survey type and the criteria evaluation details or results (Table ES-1). Detailed analyses by parameter are in the subsections below the summary table and integrate each set of results and data across survey years. Summary conclusions can be found at the end of the Executive Summary and with additional detail at the end of this report.

When compared to pre-restoration data, post-restoration results show improved water quality, improved circulation, removal of dead zones and excess sedimentation issues, and a diverse native ecosystem resilient to impacts. This report contains detailed results and analyses for each parameter surveyed, including comparisons to pre-restoration data as well as trends across the entire monitoring period to track changes over time. These results show that the site is meeting the overall project goals.

Table ES-1. Summary of 5-year success criteria results by survey type.

Survey Category	Survey Type	5-Year Success Criteria Summary	Meeting 5-Year Criteria?	Criteria Evaluation Details
L2 Rapid Assessment	California Rapid Assessment Method	None identified.	N/A	Although there were no specific quantitative success metrics identified for the CRAM scores, the final trend is above pre-restoration scores, with a consistent increase over time, suggesting support for a healthy and robust wetland community.
Physical	Channel Cross-Sections	Lack of a continual occurrence of sandbar formation and sedimentation in the form of a sandbar that isolates the western restoration area from the main channel three times over a six-year period during open lagoon conditions.	Yes	No isolation of the western restoration area and channels has occurred during the six-year assessment period; thus, the restoration is meeting the project success criteria. Additionally, the lack of sedimentation suggests that the restored lagoon is experiencing improved circulation as compared to pre-restoration conditions.
Water Quality	Automated Sonde Sampling	Locations within the western channel shall not have persistent dissolved oxygen levels below 1.5 mg/L for a sustained period of more than 12 hours a day over two closed lagoon periods of more than 60 days; or consistently low dissolved oxygen levels below 1.0 mg/L that occur for more than 6 hours a day over the course of 30 days during closed conditions.	Yes	Dissolved oxygen average data across all post-restoration years exceeded all project success criteria at all stations during closed conditions. No dissolved oxygen levels were below the identified thresholds for the sustained periods. Additionally, the assessments of trends across all years suggest higher dissolved oxygen post-restoration as compared to pre-restoration conditions, as well as a lack of 'dead zones' that occurred prior to restoration.
	Vertical Profiles	Water quality monitoring should not indicate persistent stratification of lagoon waters and depressed bottom water dissolved oxygen during closed conditions; restored lagoon should show improvements in water circulation and tidal flushing.	Yes	Dissolved oxygen was well above the success criteria threshold (i.e., > 1 mg/L) for all samples collected across all stations and all surveys. Data suggest the restored lagoon represents a brackish water bar-built estuary habitat, with good circulation and dissolved oxygen levels.
	Surface and Bottom Water Constituents	None identified.	N/A	Although there were no specific quantitative success criteria identified for the water constituent sampling, six years of monitoring did not identify any areas of concern. Additionally, post-restoration bacteria data show higher annual "grades".
Sediment Quality	Sediment Grain Size and Constituents	(1) Grain size distribution at each sampling station should increase from the baseline monitoring conditions; (2) Increased sediment nutrient sequestration should not occur over three consecutive years.	Yes	The trajectories of grain size distributions over the course of the six survey years were found to meet project success criteria, which specifies that grain size distribution should increase from the baseline monitoring conditions. Similarly, the restoration area was also meeting the sediment nutrient success criteria by not sequestering excess nutrients as compared to the pre-restoration conditions.

Survey Category	Survey Type	5-Year Success Criteria Summary	Meeting 5-Year Criteria?	Criteria Evaluation Details
Biological	Benthic Invertebrates	Increasing the diversity and species richness of benthic invertebrates and the number of species and individual taxa with lower pollution tolerance values in Malibu Lagoon.	Yes	The abundances and numbers of pollution sensitive benthic invertebrate taxa are higher than pre-restoration conditions and did not exhibit decreases across multiple years; thus, the benthic community is meeting the project success criteria.
	Fish Community	Abundance and species richness of native fish shall not decrease; maintain at or above pre-restoration levels.	Yes	Both the native fish species richness' and the overall native fish abundances are higher in all six of the post-restoration summer surveys than in the pre-restoration summer survey, which indicates the site is meeting the project success criteria.
	Bird Community	Utilization of restoration area for roosting and foraging.	Yes	Many species of birds utilize the site for roosting, foraging, and breeding. Although not part of the success criteria, post-restoration numbers of birds, species richness, and diversity (Shannon Index) remain higher on average for the western channels (restored areas) as compared to pre-restoration data.
	SAV and Algae Cover	Decrease in % SAV; decrease in eutrophication impacts.	Yes	Post-restoration data indicate a reduction in algae cover as compared to pre-restoration data, especially in the form of floating algal mats, thus the site is meeting the success criteria. Algal cover shifted from pre-restoration floating mats that decomposed to create 'dead zones', to post-restoration cover dominated by wrack or submerged seagrasses.
	Plant Cover	90% native plant cover in seeded or planted areas by Year 5; 10% or less non-native plant cover.	Yes	Vegetation cover as assessed for both native and non-native species is meeting the restoration success criteria. Relative native vegetation cover was 96-100%, with average absolute native vegetation cover across all transects between 78-80% cover for Year 6, and non-native cover less than 1%.
	Photo Point	Vegetation establishment.	Yes	The vegetation community has continued to establish over time within the restoration area as demonstrated by the photo point series. Non-native, invasive vegetation was removed through community restoration events.

California Rapid Assessment Method: Although there were no quantitative success metrics identified for the CRAM scores, the final trend is above pre-restoration scores, with a consistent increase over time, suggesting support for a healthy and robust wetland community. The overall CRAM score increased from 50 pre-restoration to 77 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 defined in the CRAM Technical Bulletin (2018), the condition class represented by wetland tertiles went from the "poor" category in pre-restoration conditions to the highest tertile classified as "good" in the most recent survey. As predicted, the biotic structure attribute continued to increase as the vegetation community increased in overall cover and complexity over time. The overall CRAM final score is likely to remain consistently above the pre-restoration assessment final score.

Physical Monitoring – Channel Cross-Sections: Overall, channel cross sections remained stable and did not exhibit any large-scale changes between survey dates. No isolation of the western restoration area and channels has occurred during the six-year assessment period; thus, the restoration is meeting the project success criteria. Additionally, the lack of sedimentation suggests that the restored lagoon is experiencing improved circulation as compared to pre-restoration conditions. 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. Slight shifts in the profiles are likely attributed to natural morphological variability due to tidal waters and may continue with post-Woolsey fire sediment moving through the system. Sediment moved in accordance with predicted tidal and closed berm water regimes.

Water Quality – Automated Water Quality Monitoring: During Year 6, dissolved oxygen data exceeded all success criteria at all stations during closed conditions. Overall, the averages of dissolved oxygen data over all post-restoration monitoring years exceeded all success criteria at all stations during closed conditions. No open condition success criteria were set as part of the permitting process. 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. Variability may be due to any number of factors, including biofouling, temperature fluctuations, and variability in other physical or climatic factors.

Sonde probe failure and equipment malfunctions, primarily unexplained early shutoffs, led to periods of missing data during the cooler closed bar conditions, and required the return of sondes for maintenance to the manufacturers. There are no comparative pre-restoration data to the back-channel station due to the inability to install sonde equipment given the sedimentation, anoxia, and "muck" conditions that dominated the pre-restoration back channels; thus, the comparative estimates from post-restoration are likely to be conservative.

Water Quality – Vertical Profiles: Dissolved oxygen was well above the success criteria threshold (i.e., > 1 mg/L) for all samples collected across all stations and all surveys. Data suggest the restored lagoon represents a brackish water bar-built estuary habitat, with good circulation and dissolved oxygen levels. Minimal to no haloclines observed during closed conditions indicated good mixing. Post-restoration improvements in circulation in both open and closed berm conditions were indicated by the presence of high levels of dissolved oxygen throughout the site, especially in the back channels, which were previously severely impacted by extremely low dissolved oxygen and anoxic conditions. Dissolved oxygen 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, 6.78 mg/L in August 2017, and 4.07 mg/L in May 2018. 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. Data indicate good circulation throughout the 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: Although there were no specific quantitative success criteria identified for the water constituent sampling, six years of monitoring did not identify any areas of concern. 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 and trends over time. Consistent low concentrations of nutrients remained present through the Year 6 surveys. Additionally, based on Heal the Bay Beach Report Card data, the post-restoration trend appears to be declining numbers of TMDL exceedances and an increased "grade", post-restoration.

Sediment Quality – Sediment Constituent Sampling: The trajectories of grain size distributions over the course of the six survey years were found to meet project success criteria, which specifies that grain size distribution should increase from the baseline monitoring conditions. Similarly, the restoration area was also meeting the sediment nutrient success criteria by not sequestering excess nutrients as compared to the pre-restoration conditions. 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 were consistent with the project goals.

Sediment nutrient averages were higher in pre-restoration surveys, especially for Total Kjeldahl Nitrogen and Total Nitrogen, than 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. Additionally, nutrients may have been sequestered into SAV, rather than deposited into the sediments.

Biological Monitoring – Benthic Invertebrates: The abundances and numbers of pollution sensitive benthic invertebrate taxa are higher than pre-restoration conditions and did not exhibit decreases across multiple years; thus, the benthic community is meeting the project and permitting success criteria. 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 has fluctuated slightly over the years, depending on conditions during that sampling year. However, the overall community exhibited a trend back towards pollution-sensitive taxa in the 2017 and both sets of 2018 data results, showing 100% pollution-sensitive abundances and number of taxa for both benthic core data in 2018 (i.e., January and April data).

Biological Monitoring – Fish Community Surveys: Both the native fish species richness' and the overall native fish abundances were higher in all six of the post-restoration summer surveys than in the pre-restoration summer survey, which indicates the site is meeting the permitting success criteria. 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. 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 were generally 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. Additionally, juvenile gobies have been observed, indicating a functioning nursey habitat for the endangered gobies throughout multiple survey years.

Biological Monitoring – Avian Community Surveys: Many species of birds utilize the site for roosting, foraging, and breeding, thus meeting the broad restoration success criteria. Although not part of the success criteria, post-restoration numbers of birds, species richness, and diversity (Shannon Index) remain higher on average for the restored western channels as compared to pre-restoration data. Several patterns have emerged after six years of post-restoration bird monitoring, and they provide an indication of how the site's avifauna are responding to the restoration overall. Individual species and guild patterns were variable but suggested a shift in the bird community from urban, scrub, and country guilds towards marine and fish-eating guilds, with mixed results for other communities

Notably, special-status species in Year 6 continue to make heavy use of the site, in particular the beach and lower lagoon area (e.g., Brown Pelican and Western Snowy Plover). Seven Western Snowy Plover nests were documented across 2017 and 2018, including at least four fledglings; 39 California Least Tern nests were documented across the six post-restoration monitoring years (2013-2018), including at least 13 fledglings. Neither species had previously been identified nesting in almost 70 years in the region.

Vegetation – SAV / Algae Percent Cover Monitoring: Post-restoration data indicate a reduction in algae cover as compared to pre-restoration data, especially in the form of floating algal mats; thus, the site is meeting the success criteria. Algal cover shifted from pre-restoration floating mats that decomposed to create 'dead zones', to post-restoration cover dominated by wrack or submerged seagrasses. 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 as well as seagrasses. After six years, the floating algal mats remained well below a 10% grand mean total cover and well within the success criteria recommendations. Small amounts of wrack do not cause eutrophication and often provide food and habitat for invertebrate species.

Additionally, wind-driven circulation in the post-restoration channels tended to disperse any algae mats, thereby reducing any potential impacts from the algae becoming trapped in one location. Lastly, submerged aquatic vegetation (SAV) seagrasses are longer-living species which uptake and fix nutrients, reducing eutrophication. Living SAV was present in the form of *Ruppia sp.* in several locations within the restoration area across multiple surveys, and *Phyllospadix sp.* found in a cobble portion of the main channel. 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 as assessed for both native and non-native species is meeting the restoration success criteria. In Year 6, relative native vegetation cover was 96-100%, with average absolute native vegetation cover across all transects between 78-80% cover and non-native cover less than 1%. Vegetation cover has shown a relative increase over time, with a large increase after the initial post-restoration baseline survey. Vegetation complexity (e.g., density, additional plant layers), in restoration projects can continue to develop for decades after initial plantings. Similarly, the CRAM biotic metric continued increasing across the monitoring years, and the photo-monitoring surveys visually confirmed the trend, supplementing the vegetation cover assessment that the community continues to develop and become more complex over time. Post-restoration surveys indicated a range of approximately 8 to 16 native plant species identified immediately adjacent to the transects (within about 10 meters), compared to an average of six or fewer dominant species pre-restoration. Reductions or variability in non-native cover are the result of weeding and non-native species removal efforts, in part. Periodic non-native maintenance may still be required in future years and should be evaluated qualitatively for need in the spring of each year prior to annual non-native species going to seed.

Vegetation – Photo-Point Monitoring: The vegetation community has continued to establish over time within the restoration area as demonstrated by the photo point series. Non-native, invasive vegetation was removed through community restoration events. 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 survey.

Final Restoration Assessment and Conclusions

This report assessed the post-restoration conditions of Malibu Lagoon across approximately six years of monitoring by evaluating a suite of parameters as part of the long-term monitoring plan of the Malibu Lagoon Restoration and Enhancement Project. The goals of the restoration project were to: (1) increase circulation of water in the lagoon during both open mouth and closed mouth conditions to improve water quality and decrease eutrophication; (2) to restore the lagoon habitat by re-establishing suitable soil conditions and native plant species and removing non-native species; and to (3) evaluate, record, and analyze existing and changing ecological conditions of the lagoon using physical, chemical, and biological parameters to measure restoration success (CCC Staff Report, CDP No. 4-07-098). The restoration project has been determined to be wholly successful as assessed against defined project goals, performance standards, and success criteria (Table ES-1) outlined in California Coastal Commission CDP No. 4-07-098 and supporting documentation, including monitoring plans.

An evaluation of post-restoration conditions, through detailed physical, chemical, and biological monitoring components has resulted in several overarching trends. Year 6 data support the long-term trend of increasing health and recovery of Malibu Lagoon following the restoration effort in 2013. All monitoring components have met or exceeded established success criteria set by the project documents and the California Coastal Commission, and adaptive management measures are not recommended. However, it is recommended to annually qualitatively assess the growth of non-natives along the perimeter access trails in areas likely to be exposed to non-native seed dispersal through human activity. If found, non-native plants should be removed before going to seed. Educational tour groups like those frequently led by Audubon Society and RCDSMM could also provide updates to State Parks if invasive vegetation is identified during the course of educational activities. If funding is available, additional surveys such as biennial CRAM or cross-section transects would continue to inform long-term monitoring trends to further support the six-year assessments and analyses.

The rapid wetland condition indicator score (CRAM) increased in each post-restoration year, and the site-intensive data supported those results. The vegetation community continued to become more complex over time, and as this establishment continued, 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 were significantly reduced post-restoration, and well below established criteria limits. Similarly, dissolved oxygen, vertical profiles, and other indicators showed that the improved circulation has resulted in enhanced water quality throughout the site. Overall, post-restoration monitoring surveys have identified the distinct recovery and establishment of many important chemical and biological wetland functions supporting a healthy, stable, predominantly native ecosystem that was resilient to several external stressors during the course of this assessment.

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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 (State Parks) 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 17 July 2019.

During the Year 6 monitoring period, the Lagoon berm breached on 26 November 2018, and the ‘open condition monitoring’ occurred between the date of the breach and June 2019 according to the protocols and during appropriate tidal conditions. The lagoon berm closed in July 2019.

An aerial overview of Malibu Lagoon highlighting the restoration and monitoring areas in relation to the main lagoon and Surfrider Beach is displayed in Figure 1. The subsequent series of photographs display aerial photographs of the western channels prior to restoration (Figure 2), during construction (Figures 3 and 4), and post-restoration (Figures 5 through 8).

Figure 1. Map of project location site (Western Channels) and environs several years after the restoration (credit: Google Earth, 19 Nov 2018).

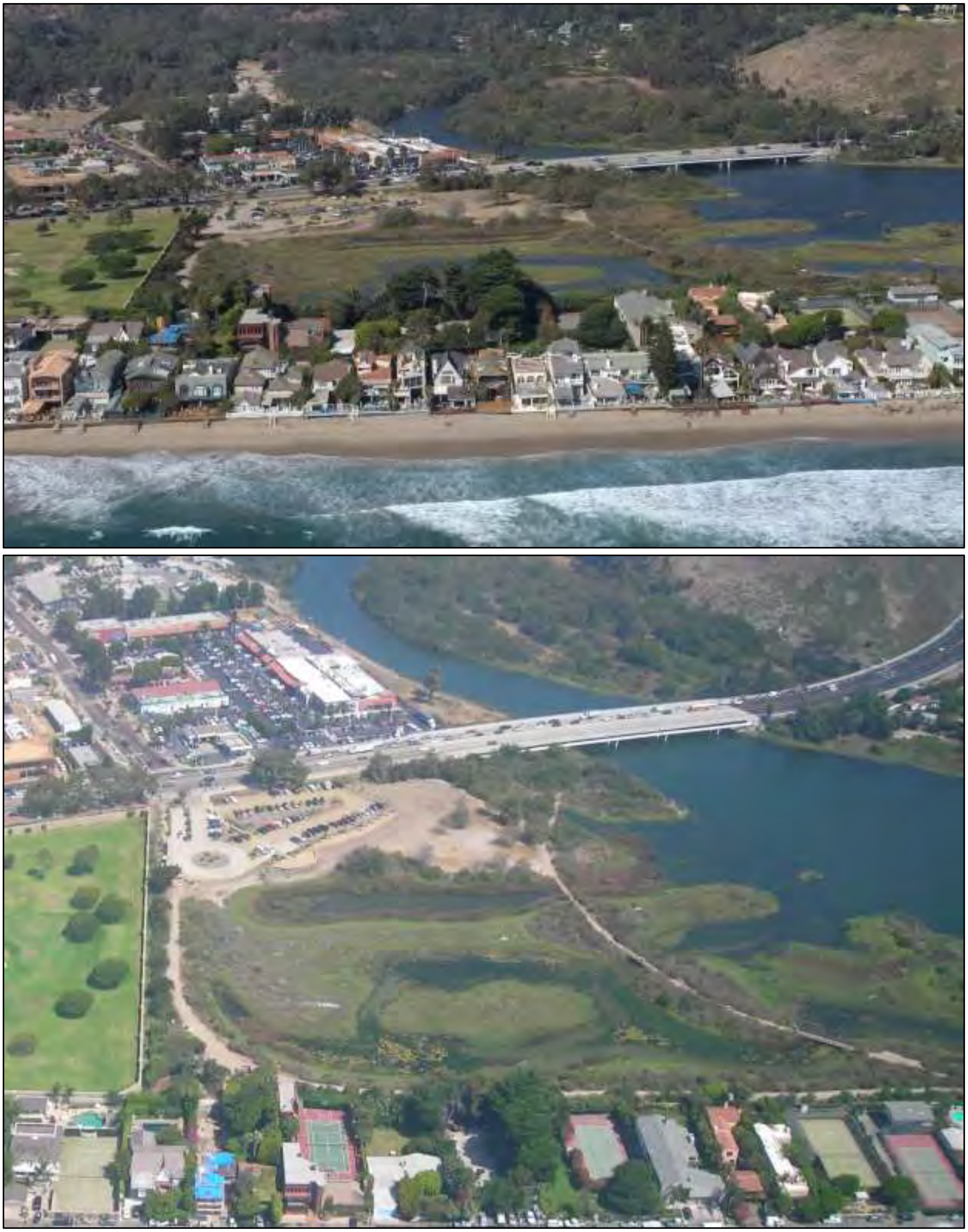


Figure 2. Aerial view of pre-restoration Malibu Lagoon from a Lighthawk flight in September 2008 (top) and March 2009 (bottom) (credit: TBF and Lighthawk).

Figure 3. Aerial view of Malibu Lagoon during restoration construction activities from a Lighthawk flight in July 2012 (credit: TBF and Lighthawk).

Figure 4. Aerial view of Malibu Lagoon during restoration construction activities from a Lighthawk flight in August 2012 (credit: TBF and Lighthawk).

Figure 5. Aerial view of Malibu Lagoon post-restoration in December 2013 during an open berm condition (credit: TBF and Lighthawk).

Figure 6. Aerial view of Malibu Lagoon post-restoration in December 2014 during an open berm condition (credit: TBF and Lighthawk).

Figure 7. Aerial view of Malibu Lagoon post-restoration in June 2016 during a closed berm condition (credit: TBF and Lighthawk).

Figure 8. Aerial view of post-restoration Malibu Lagoon from a Lighthawk flight on 11 Dec 2018 with an open berm condition (credit: M. Grubbs, The Bay Foundation, and Lighthawk).

Comprehensive Monitoring Report Goals

This Year 6 Comprehensive Monitoring Report (report) focuses on summarizing data results since the completion of the restoration project (2013), with an outline of methods implemented to obtain the data. 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 July 2019. The report also comprehensively assesses the conditions of the post-restoration area as compared to the defined success criteria and available pre-restoration data (SMBRF 2012).

Methods and sampling dates 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 aquatic vegetation and algae, vegetation cover, and photo point surveys. Detailed individual fish and bird reports are also included as appendices. An additional section was added for this report with details about the Woolsey Fire, which burned much of the Malibu Creek Watershed in November 2018 and had the potential to impact results from several of the monitoring protocols implemented in post-fire conditions. Table 1 summarizes the monitoring plan associated with this report, required survey details, notes on cumulative survey efforts since the restoration was completed, survey dates, and number of surveys. Permits required a total of 85 surveys across many parameters including biological, chemical, and physical surveys. The post-restoration cumulative total number of surveys conducted across six years of effort was 119.

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, 2017, and 2018. For detailed methods, refer to the referenced monitoring literature. Detailed citations are available in this report prior to the Appendices.

Table 1. Summary of monitoring plan, implementation schedule, and cumulative monitoring survey notes.

Survey Category	Survey Type	Post-Restoration Dates	Post-Restoration Cumulative Total	Required Survey Count	Survey Count Difference	Required Survey Details on Permit	Notes on Conducted Sampling -- Cumulative
L2 Rapid Assessment	California Rapid Assessment Method	2/14/13, 10/4/13, 5/7/14, 12/23/14, 5/5/15, 1/19/16, 12/27/16, 6/26/17, 12/4/18	9	N/A	+ 4	None required, annual requested by CCC (5).	While not required by the permit, CRAM was conducted nine (9) times in post-restoration conditions across six years.
Physical	Channel Cross-Sections	2/14/13, 12/18/14, 1/19/16, 12/21/16, 2/20/18, 2/26/19; Note: some surveys required multiple days	6	10	- 4	Four channel cross-sections surveyed twice annually for five years post-restoration (10): end of rainy season (open) and in Sept (closed); 40 transects total.	Closed condition surveys were not possible due to the amount of water in the lagoon, thus leading to inaccurate elevation results. Therefore, six (6) open-condition cross-section surveys were conducted over six years across five stations for a total of 30 transects.
Water Quality	Automated Sonde Sampling	May 2013 - June 2019; missing data identified in report	N/A	N/A	N/A	Automated sampling should be conducted approx. from April through mid-October or first rain event of the year, annually for five years.	Automated sampling conducted year-round with breaks due to probe or sonde failure, calibration issues, maintenance requirements, and other reasons (see report chapter for details).
	Vertical Profiles	2/14/13, 5/5/14, 12/23/14, 5/7/15, 1/27/16, 5/12/16, 12/15/16, 8/18/17, 2/1/18, 5/23/18, 6/25/19	11	10	+ 1	Six stations surveyed twice annually for a total of ten (10) surveys for vertical profiles of ancillary water quality parameters.	Eight stations were surveyed twice annually for vertical profiles across six years for a total of eleven surveys (11).
	Surface and Bottom Water Constituents	5/5/14, 12/30/14, 5/7/15, 1/27/16, 5/10/16, 12/15/16, 7/6/17, 2/1/18	10	10	----	Four stations surveyed twice annually (open and closed conditions) for five years for a total of ten (10) surveys.	Eight stations surveyed twice annually (open and closed conditions) for five (5) years for a total of ten (10) surveys.
Sediment Quality	Sediment Grain Size and Constituents	5/5/14, 12/30/14, 5/7/15, 1/21/16, 5/10/16, 3/9/17, 7/6/17, 1/24/18, 7/12/18, 1/29/19	10	10	----	Six stations surveyed twice annually (open and closed conditions) for five years for a total of ten (10) surveys.	Eight stations surveyed twice annually (open and closed conditions) for five (5) years for a total of ten (10) surveys.

Survey Category	Survey Type	Post-Restoration Dates	Post-Restoration Cumulative Total	Required Survey Count	Survey Count Difference	Required Survey Details on Permit	Notes on Conducted Sampling -- Cumulative
Biological	Benthic Invertebrates	5/5/14, 12/30/14, 1/21/16, 3/8/17, 1/24/18, 4/13/18, 4/26/19	7 (+)	5	+ 2	Annual surveys across eight stations for five (5) years in open berm conditions.	Seven (7) full benthic invertebrate and net sweep surveys were conducted across six years at eight stations; two additional closed surveys were conducted in summer 2018.
	Fish Community	1/8/13, 5/15/14, 12/11/14, 5/27/15, 1/12/16, 6/1/16, 3/3/17, 7/25/17, 1/30/18, 6/19/18, 2/20/19, 7/17/19	12	5	+ 7	Summer sampling annually at six stations for five (5) years.	Biannual (twice annually) surveys conducted across six years for a total of twelve (12) surveys (six open and six closed berm surveys) at six stations with additional spot surveys conducted.
	Bird Community	See report for all dates	24	20	+ 4	Quarterly surveys for five years for a total of twenty (20) surveys.	Quarterly surveys were conducted for a period of six years post-restoration for a total of twenty-four (24) avian surveys.
	SAV/Algae Cover	2/14/13, 12/23/14, 1/19/16, 12/15/16, 8/18/17, 2/6/18, 7/12/18, 4/11/19	8	5	+ 3	Submerged Aquatic Vegetation (SAV) and macroalgae surveyed at eight stations annually during the fall (open berm) for five (5) years.	Submerged Aquatic Vegetation (SAV) and macroalgae surveyed at eight stations annually during the fall (open berm) for five (5) years, with the following supplemental added surveys: one (1) open berm warm season survey, two (2) closed berm warm season surveys, and two (2) qualitative visual cover surveys.
	Plant Cover	3/15/13, 5/7/14, 12/18/14, 5/5/15, 12/22/15, 5/20/16, 12/21/16, 6/27/17, 4/17/18, 7/12/18, 12/4/18	11 (+)	5	+ 6	Three permanent vegetation transects surveyed annually for five (5) years post-restoration.	Three permanent vegetation transects were surveyed biannually (twice annually) for six years post-restoration for a total of eleven (11) surveys and one supplemental survey in June 2019.
	Photo Point	3/15/13, 5/7/14, 12/18/14, 5/5/15, 12/22/15, 5/16/16, 12/27/16, 6/27/17, 5/23/18, 12/4/18, 6/25/19	11	5	+ 6	Three permanent photo monitoring locations will visually document the establishment of vegetation in spring for five (5) years.	Three permanent photo monitoring locations with five total bearings were monitored twice annually for six years for a total of eleven (11) surveys.
Total Number of Surveys		----	**119**	**85**			

Woolsey Fire

The Woolsey Fire started on 8 November 2018, burning almost 100,000 acres of land and destroying over 1,500 structures in Los Angeles and Ventura Counties (Figures 9 and 10). Santa Ana winds pushed the fire through the Santa Monica Mountains and towards the coast. A large portion of the burn area was determined to be moderate soil burn severity, increasing the potential for runoff, debris flows, and other potential hazards. This significant event had the potential to detrimentally impact the Malibu Lagoon in multiple ways, including water quality, sedimentation, impacts to the biotic communities, and others. A post-fire collaborative stakeholder group was formed to consolidate and prioritize monitoring efforts throughout the region as well as communicating with agencies and municipalities to coordinate recovery efforts. Members of this collaborative include representatives from groups such as TBF, NOAA, state waterboards, NPS, State Parks, NGOs, and many universities.

To inform potential impacts to the Malibu Lagoon, spot monitoring was conducted in the months after the fire in addition to the long-term monitoring program. Specifically, site checks were performed to assess sedimentation, detrital input to the system, and impacts to vegetation or wildlife (Figure 11). Monitoring results are included in each of the chapters below, but in summary, the lagoon was resilient to the fire and subsequent sediment moving down the watershed. Circulation within the lagoon retained some of the detritus for a period of several weeks, after which most of the burned debris was flushed out of the system by tidal action and well-circulated waters.

Figure 9. Screenshot of the Woolsey Fire burning near Pepperdine on 9 November 2018, courtesy CBSLA.com.

Figure 10. Map of the Woolsey Fire burn area (red outline) and the surrounding area (map replicated from CSUCI).

Figure 11. Photographs of organic detritus from the Woolsey Fire in the Malibu Lagoon (4 December 2018).

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 or summer), as well as annual biological sampling for multiple parameters during the appropriate monitoring seasons. The monitoring occurred for more than 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 sought 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 assessed post-restoration water quality and habitat conditions over time. The overarching goal of the hydrological section of this report was to detect observable improvements in the chemical conditions that facilitate biological stability by the reestablishment and persistence of native species beyond the five years following construction.

Specific objectives of the physical and water quality monitoring of the Malibu Lagoon were 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; and
- Provide timely identification of any problems or challenges with the physical or chemical development of the lagoon.

Specific water quality and physical parameters that were assessed in this report included: 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. CRAM surveys included physical and hydrological components in addition to the biotic metrics.

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

Nine 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, 26 June 2017, and 4 December 2018 (Figure 3). 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. However, it was determined that additional surveys would serve to assess the trend over time more completely. 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 (AA, 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, with the assumption well within the CRAM error margin. 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 2). The attributes are all averaged to quantify a final assessment score for each wetland module and AA analyzed.

Table 2. 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 12 displays a landscape photo of a portion of the CRAM AA taken on the 4 December 2018 survey. Figure 13 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, fitted specifically to wetland habitats as defined by the Manual.

Figure 12. Landscape photo of a portion of the CRAM AA at Malibu on the most recent survey, 4 December 2018.

Figure 13. 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 3 and Figure 14, with the pre-restoration data (2012) also included for comparison. The overall CRAM score increased from 50 pre-restoration to 77 based on the latest survey, surpassing the threshold for the highest, or “good”, condition class as defined by the CRAM Technical Bulletin (2018) (Figure 15). The wetland was classified in the “poor” condition category prior to restoration for many impacts and factors leading to its degradation, including impacted hydrology, physical characteristics, and biological support metrics.

While the overall CRAM score and each of the attribute scores are much higher in the most recent post-restoration survey than pre-restoration, 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. Monthly volunteer restoration and maintenance events held throughout the years have contributed to maintaining a reduction in non-native, invasive vegetation across the site.

Table 3. 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 (2012)	14 Feb '13	4 Oct '13	7 May '14 *	23 Dec '14	5 May '15 *	19 Jan '16	27 Dec '16	26 Jun '17 *	4 Dec '18
Attribute 1: Buffer and Landscape Context	38	38	38	38	53	53	53	53	53	57
Attribute 2: Hydrology Attribute	50	58	58	58	58	58	58	67	75	67
Attribute 3: Physical Structure Attribute	50	88	75	75	88	88	88	100	88	100
Attribute 4: Biotic Structure Attribute	61	39	56	53	64	64	72	75	83	83
Overall AA Score	**50**	**56**	**57**	**56**	**66**	**66**	**68**	**74**	**75**	**77**

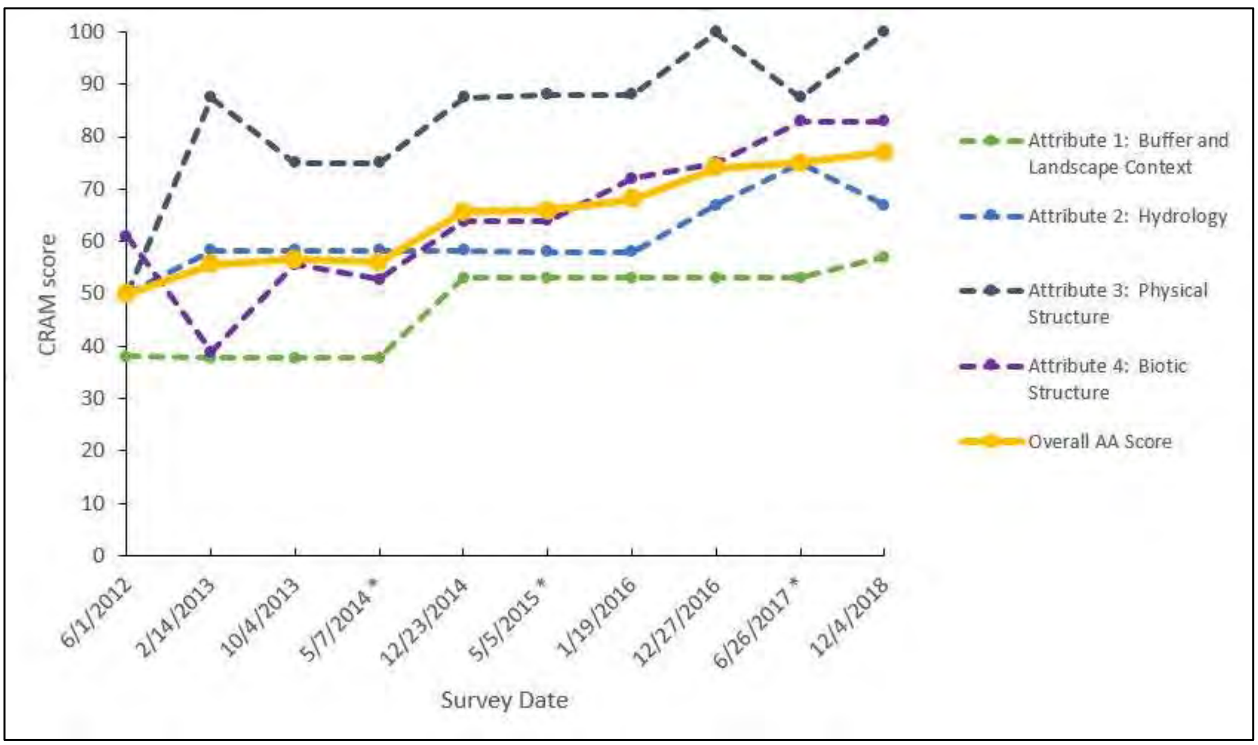


Figure 14. Graph of CRAM attribute and overall scores over time. Note: the 2012 survey date is pre-restoration and the asterisks indicate closed-berm condition surveys.

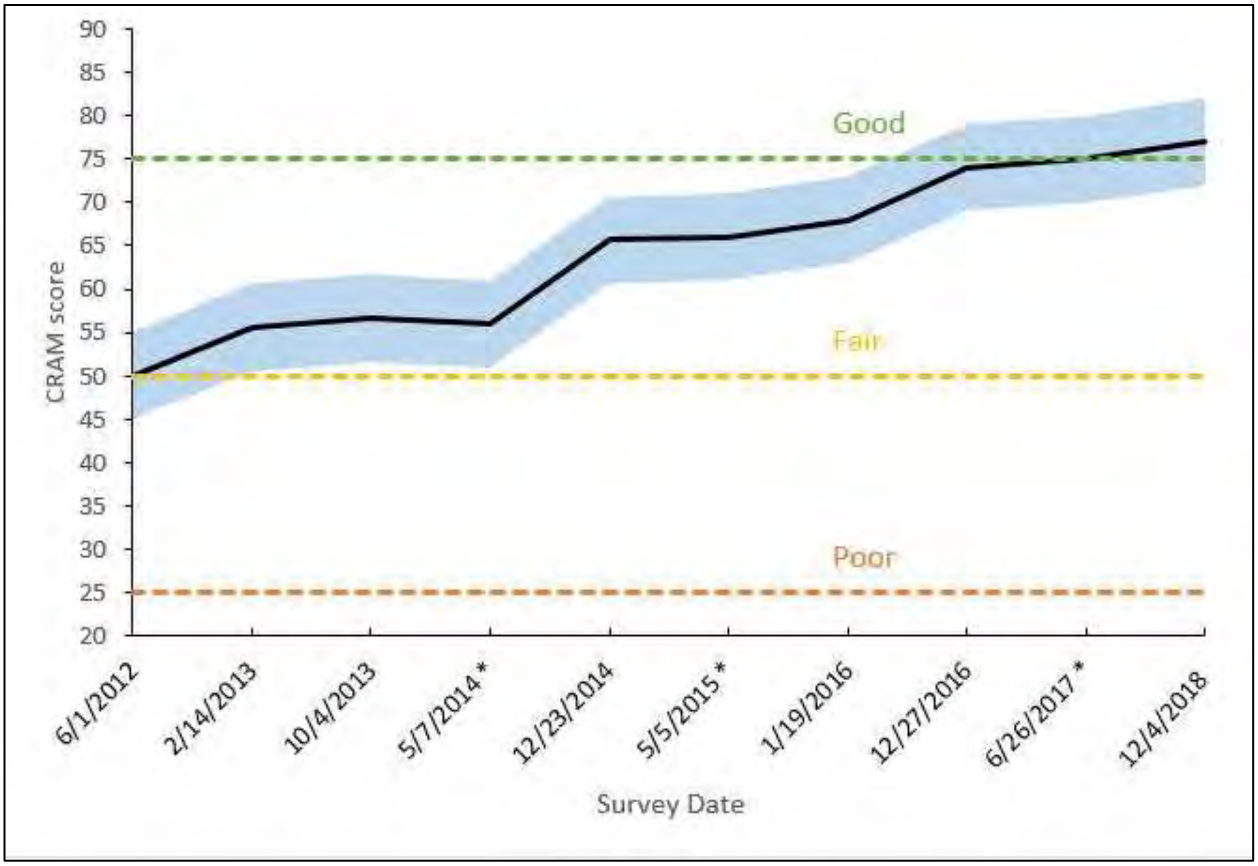


Figure 15. Graph of CRAM attribute and overall scores over time. "Poor, Fair, and Good" represent the generic wetland condition tertiles to define the condition classes per the CRAM Technical Bulletin (2018).

Figures 16, 17, and 18 contain representative geotagged photographs including bearing from the most recent CRAM survey within the AA on 4 December 2018 during a low outgoing spring tide. Figure 16 contains photographs from the southern portion of the AA facing towards wetland habitats at 29° NE (top) and 94° E (bottom). Figure 17 contains photographs from the central portion of the AA facing towards wetland habitats at 137° SE (top) and 90° E (bottom). Figure 18 contains photographs from the northern portion of the AA facing towards wetland habitats at 66° NE (top) and 135° SE (bottom). Detailed global positioning system (GPS) and bearing data are included as a watermark stamp on each photograph for ease of reference.

Figure 16. Geotagged photographs taken within the AA (southern portion) on 4 December 2018.

Figure 17. Geotagged photographs taken within the AA (central portion) on 4 December 2018.

Figure 18. Geotagged photographs taken within the AA (northern portion) on 4 December 2018.

Performance Evaluation

Although there were no quantitative success metrics identified for the CRAM scores, the final trend is above pre-restoration scores, with a consistent increase over time, suggesting support for a healthy and robust wetland community.

Post-restoration surveys showed a consistent increase in final CRAM scores over time, culminating with the highest scores in the most recent surveys (Figures 14 and 15). Scores indicate 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. Although there were no quantitative success metrics identified for the CRAM scores, the final trend is above pre-restoration scores, with a consistent increase over time, suggesting support for a healthy and robust wetland community. The photographs serve to further illustrate the wetland vegetation community.

Figure 19. Geotagged photograph taken facing south (166°) on 4 December 2018.

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 six 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, 9 May 2018, and 26 February 2019 (Figures 6 and 7). Horizontal and vertical locations of cross-section end-points were fixed by permanent monuments; however, in Year 5 and 6, field leaders were unable to locate several monuments which may have been inadvertently 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 and 6 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 20. Cross-channel elevation survey at Malibu Lagoon on 22 February 2019.

Figure 21. Map of cross-channel elevation transect locations.

Results

Results were calculated for all six post-restoration cross-section transects comparatively across all survey dates (Figures 23-27, dotted lines indicate Year 6 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 23-27). 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 are shown in Figure 28.

During Year 6, the Malibu Lagoon experienced external stressor inputs through the Woolsey fire, which occurred in November 2018, followed by a heavier rain year with associated sediment flows from the watershed. However, Year 6 cross-section diagrams and area calculations continued to show no significant evidence of sediment deposition, even after post-Woolsey fire assessments. In Year 6, Transect 4 closest to the main channel recorded minor sediment shifts in the thalweg area, which was confirmed through in-field observations while maintaining the sonde casing located on the transect thalweg. Transects 3 and 5 had minor changes to the western banks, likely due to a combination of flow of burned material from winter storms post-Woolsey fire and natural morphological variability. Overall, these transects show minimal impacts from the threat of sedimentation directly caused by post-Woolsey fire flow from the watershed and down Malibu Creek. Organic (burned) sediment was observed along channel banks during field visits post-Woolsey fire and post-storm events (Figure 22); however, the cross-sections taken in 2019 showed minimal sedimentation within the channels. Like most fires of this magnitude, it was expected that there would be post-Woolsey fire effects for years to come. Observations of the Year 6 cross-section data indicated that the channels were stable, and most of the sediment that came down the watershed during initial storms following the Woolsey fire likely exited through the breach and into the ocean through tidal action during open berm conditions. Slight variations in cross-section profiles throughout the previous post-restoration monitoring years were mainly attributed to natural morphological variability due to lagoon tidal flow and/or survey location variability due to the inadvertent removal of reference monuments for those transects.

Figure 22. Photos of burn material from the Woolsey fire on the lagoon's west banks following a storm event (8 December 2019).

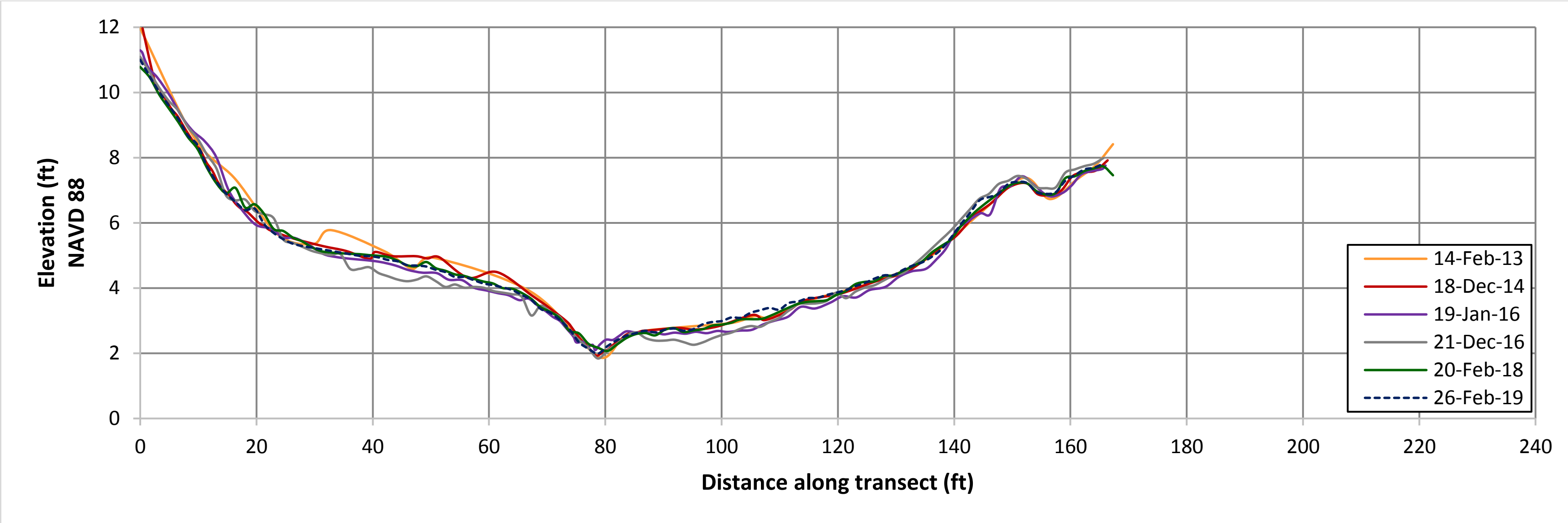


Figure 23. Channel Cross-section Transect 1. Dotted line indicates Year 6 survey.

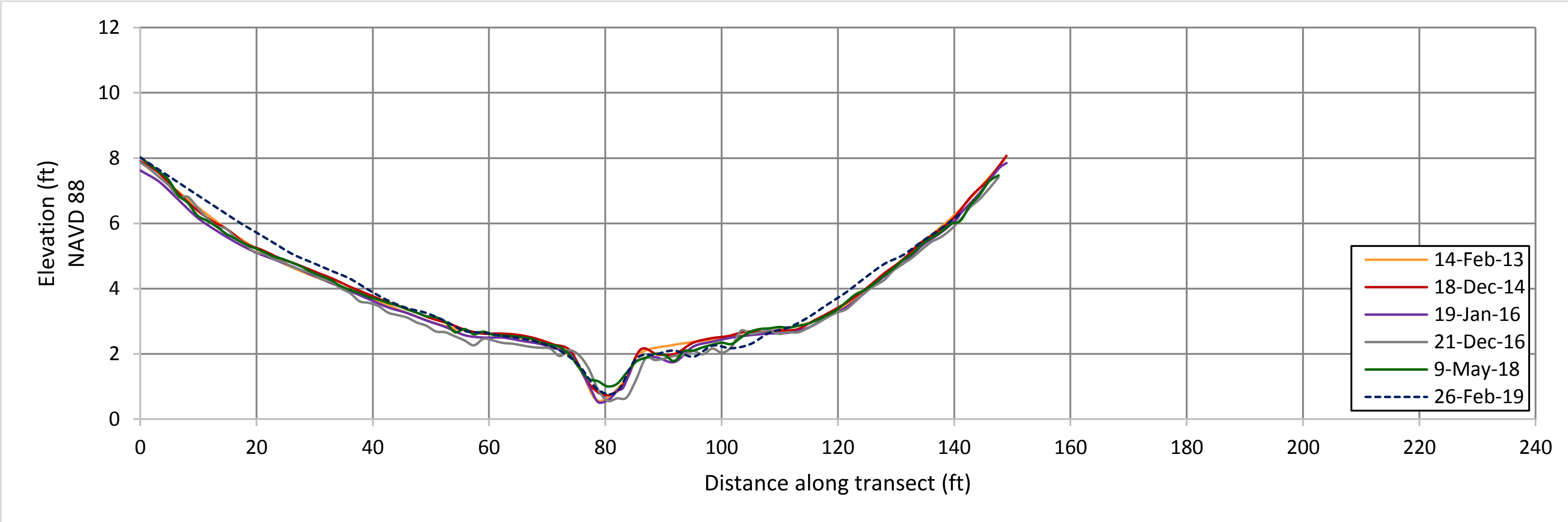


Figure 24. Channel Cross-section Transect 2. Dotted line indicates Year 5 survey.

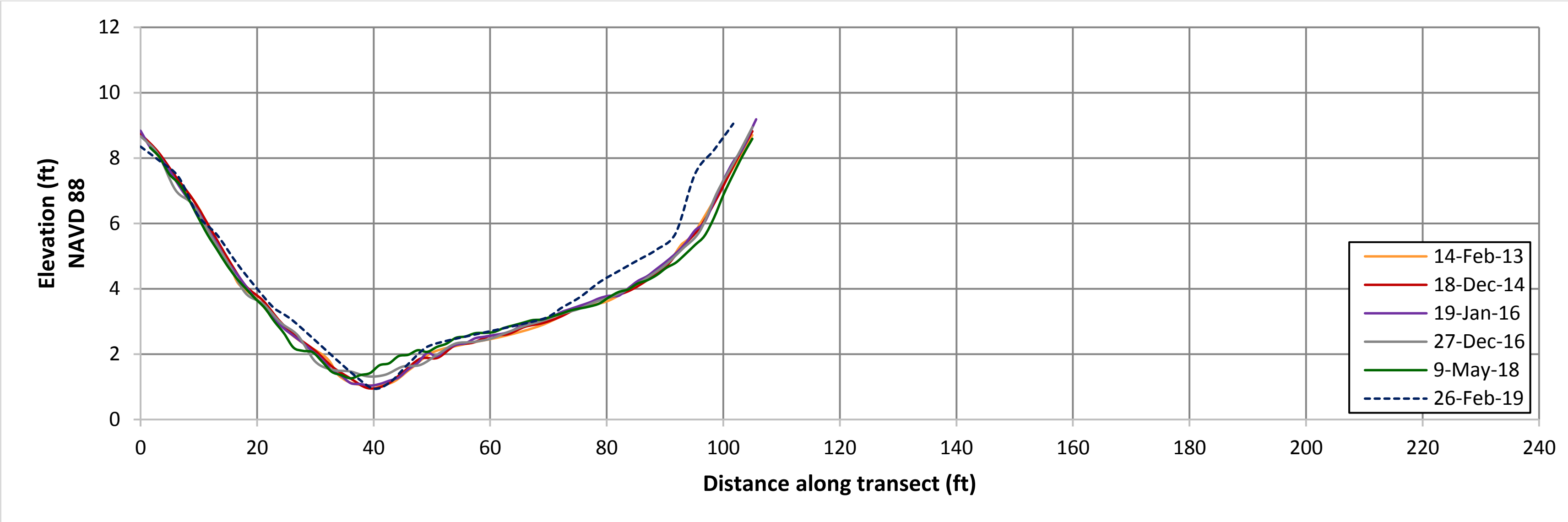


Figure 25. Channel Cross-section Transect 3. Dotted line indicates Year 5 survey.

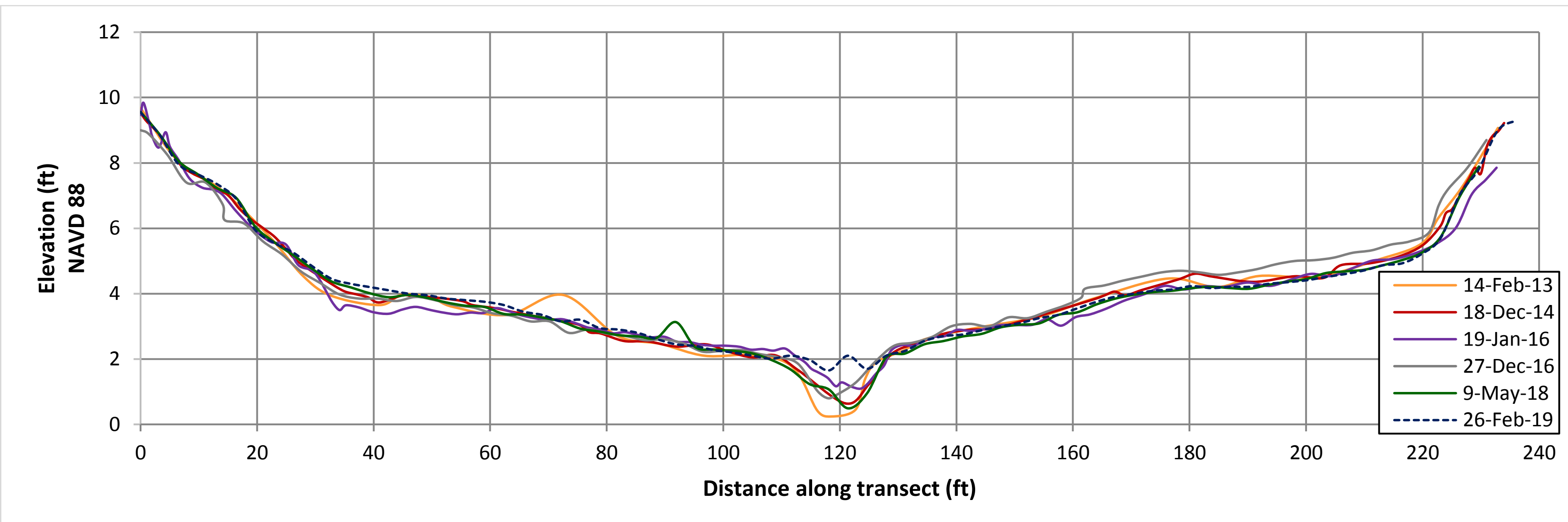


Figure 26. Channel Cross-section Transect 4. Dotted line indicates Year 5 survey.

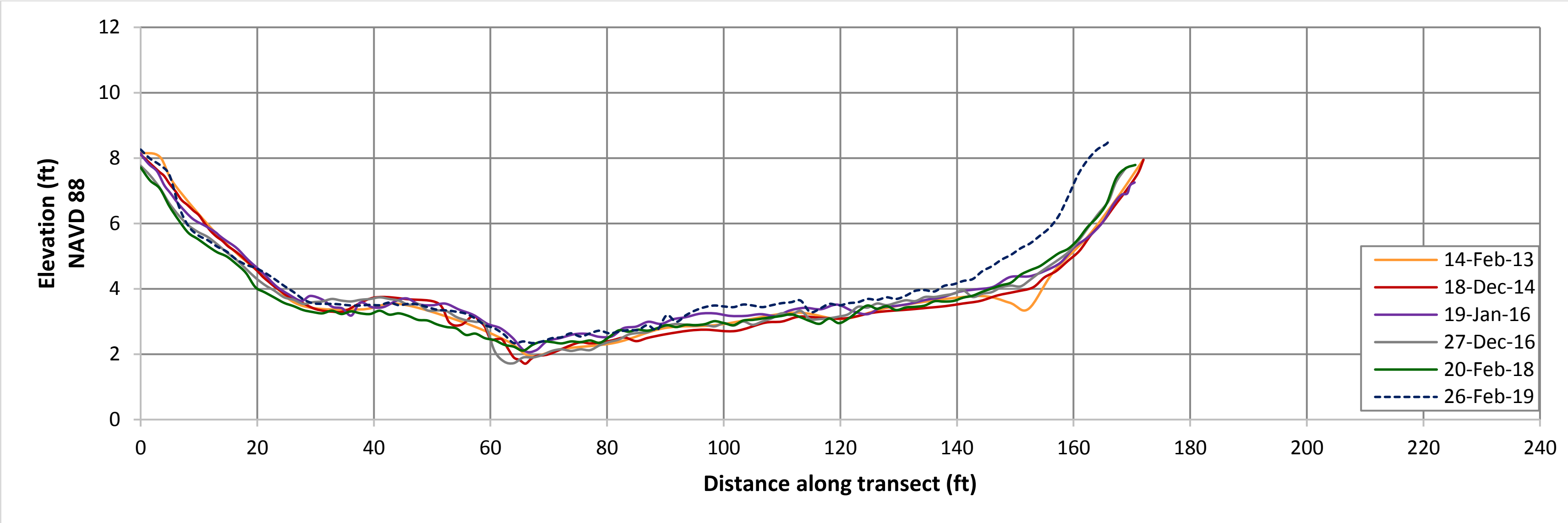


Figure 27. Channel Cross-section Transect 5. Dotted line indicates Year 5 survey.

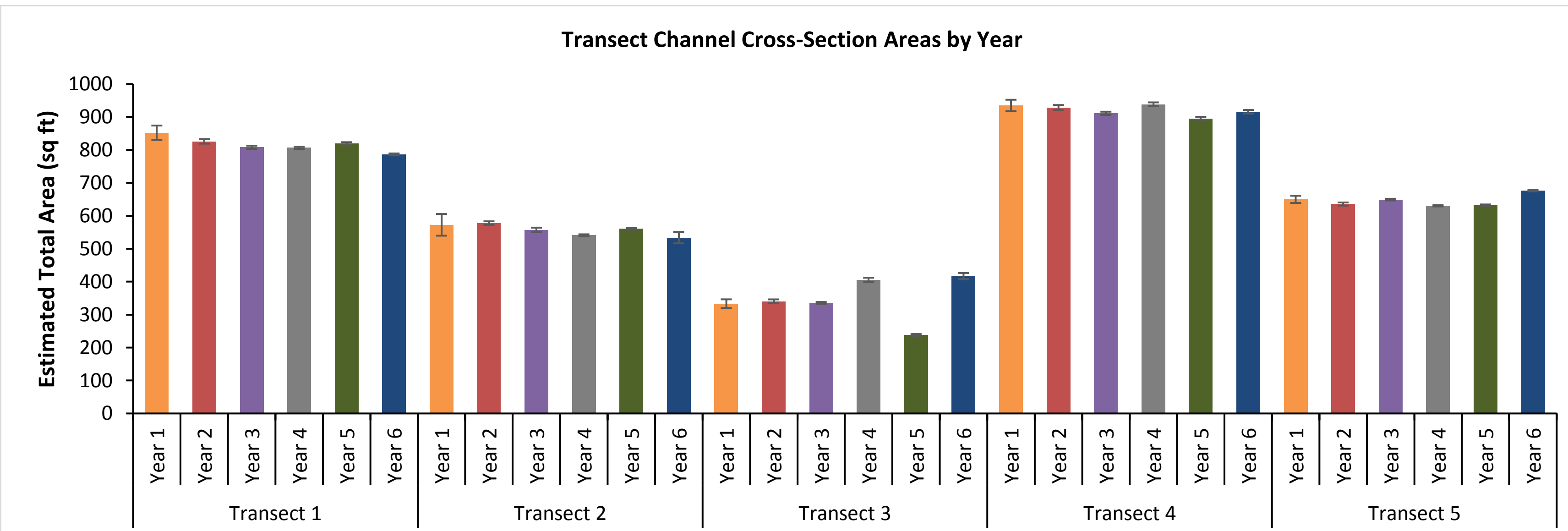


Figure 28. Transect channel cross-section areas by year.

Performance Evaluation

No isolation of the western restoration area and channels has occurred during the six-year assessment period; thus, the restoration is meeting the project success criteria. Additionally, the lack of sedimentation suggests that the restored lagoon is experiencing improved circulation as compared to pre-restoration conditions.

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, even after significant external factors (Woolsey fire followed by heavy rains) caused an increase in sediment to move down the watershed. 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. While the lagoon showed minimal effects of sedimentation following the Woolsey fire, a fire of this magnitude could have potentially long-lasting effects to the overall watershed. The most recent data showed that the initial flush of burn material largely bypassed entering the lagoon, and the sediment that did enter was either subsequently flushed out directly through the breach into the ocean or carried out by the tidal prism. This demonstrates that one of the key goals of the restoration was 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 project. Based on the Year 6 survey conducted after the fire and rains, the restoration area appears fairly resilient to excess sediment coming down the watershed, with improved post-restoration functions related to circulation and tidal exchange. Subsequent surveys in future years would confirm this initial post-fire assessment.

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, Hydrolab ML7, and Yellow Springs Instruments (YSI) 600XLM multi-parameter data loggers. The YSI 600XLM data loggers were phased out and replaced with Hydrolab DS5X and Hydrolab ML7 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. 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 June 2019 at three permanent post-restoration stations. Dates of deployment varied by station due to probe malfunctions, servicing, biofouling, or calibration glitches. Table 4 displays the reasons for data gaps by date for Year 6. 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 29). When possible, data were compared to pre-restoration data collected from hydrologically similar back channels (ML2 and ML6) (Figure 30). Pre-restoration data were collected between October 2006 and June 2012.

Data were downloaded, and the sondes were calibrated, cleaned, and redeployed approximately once monthly (Figure 31). 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 2018/19 included sonde malfunctions and power failures, resulting in sondes being returned for maintenance and/or replaced by the manufacturer. 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. Additionally, when one sonde was malfunctioning or pulled for service, priority was given to reallocate and deploy sondes to the back channel stations (Station 8 and Station 5). Thus, Station 2 had the largest data gaps. Lastly, during the winter following the Woolsey fire, the main channel sonde (Station 2), was pulled for several months because of sediment issues inside the sonde casing. The back channel sondes did not have any issues with sediment.

Table 4. Reasons for data gaps due to malfunction, servicing, or calibration issues with the sondes (Year 6+).

Station	Start Gap	End Gap	Parameter	Reason
2	1/1/2018	8/22/2018	ALL	Sonde not deployed, pulled for service
	9/12/2019	10/2/2019	DO	Sensor malfunction
	10/2/2018	10/23/2018	ALL	Sonde not deployed, pulled for service
	12/20/2018	2/2/2019	DO	Intermittent sensor malfunction, potential sediment in sonde housing
	2/2/2019	2/26/2019	Temp, Salinity, pH/ORP, DO	Sensor malfunction, sediment in sonde housing
	2/26/2019	6/20/2019	ALL	Sonde not deployed due to sediment in sonde housing
5	1/1/2018	8/22/2018	ALL	Sonde not deployed, out to for service
	8/23/2018	9/12/2018	pH/ORP	Sensor malfunction
	9/12/2018	9/26/2018	DO	Intermittent sensor malfunction, biofouling issues
	10/8/2018	10/12/2018	DO	Sensor malfunction
	10/12/2018	10/23/2018	ALL	Sensor malfunction, power loss
	11/19/2018	11/21/2018	DO	Intermittent malfunction, biofouling issues
	11/21/2018	11/26/2018	ALL	Sensor malfunction, power loss
	11/27/2018	1/28/2019	ALL	Sonde not deployed, pulled for service
	1/28/2019	2/26/2019	pH/ORP	Sensor malfunction
	5/22/2019	6/20/2019	pH/ORP	Sensor malfunction
8	1/1/2018	8/22/2018	ALL	Sonde not deployed, pulled for service
	8/31/2018	9/12/2018	Depth	Calibration issue, sensor malfunction
	9/23/2018	9/25/2018	DO	Sensor malfunction
	10/2/2018	10/18/2018	Depth	Calibration issue, sensor malfunction
	5/14/2019	6/20/2019	pH/ORP	Sensor malfunction

Figure 29. 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 30. Map of pre-restoration water quality monitoring stations. ML2 and ML6 are the locations of the pre-restoration permanently-deployed YSI data sondes.

Figure 31. In-field sonde calibration on 23 October 2018.

Results

Graphs displaying data from post-construction monitoring at Stations 2, 5, and 8 are presented in Figures 32-34. Figures 32a, 33a, and 34a 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 32b, 33b, and 34b demonstrate the relationship between temperature (°C) and dissolved oxygen (mg/L). In general, as temperature increased in a closed lagoon scenario, levels of dissolved oxygen decreased as the primary producer communities (algae) consumed the available oxygen. Table 5 summarizes the overall percentage of dissolved oxygen readings above each specified threshold from August 2018 to June 2019. Figures 32c, 33c, and 34c illustrate the relationship between pH and oxidation reduction potential (ORP).

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

	Dissolved Oxygen Threshold (mg/ L)			
Station	1	1.5	3	5
2	81.35%	78.65%	70.12%	59.07%
5	88.84%	86.13%	79.98%	71.76%
8	95.28%	94.15%	90.46%	80.41%

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 seven and five consecutive 24-hour periods below 1 mg/L (25% time) for Stations 2 and 5, respectively. Additionally, results displayed three and two consecutive 24-hour periods below 1.5 mg/L (50% time) for Stations 2 and 5, respectively. Station 8 results displayed five consecutive 24-hour periods below 1 mg/L (25% time) and seven consecutive 24-hour periods below 1.5 mg/L (50% time). Results were well below established success criteria maximums.

Data from the back channel sondes (Stations 5 and 8) displayed a high percentage of readings above dissolved oxygen thresholds. The post-restoration back channel sondes were above 1 mg/L dissolved oxygen during Year 6 closed conditions 88.84% (Station 5) and 95.28% (Station 8) of the time in Year 6 compared to 82.79% (ML2) during pre-restoration deployment (Table 6). The percentage of post-restoration closed condition readings above 1.5 mg/L dissolved oxygen were 86.13% (Station 5) and 94.15% (Station 8) during Year 6 (Table 5), compared to 81% (ML2) 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 6; those average data were also higher than pre-restoration (baseline) averages, with annual fluctuations. Pre-restoration baseline stations were shifted for this final report to better compare pre-and post-restoration conditions, i.e., ML2 (pre-restoration) was the most similar to a back channel (Station 8, post-restoration), given that the actual pre-restoration back channels were too silted in and full of 'muck' to place a permanent sonde.

Table 6. Pre- and post-restoration proportion of dissolved oxygen readings above 1 mg/L threshold.

Survey	Station		
	Pre-restoration: ML2 Post-restoration: 8	Pre-restoration: N/A Post-restoration: 5	Pre-restoration: ML6 Post-restoration: 2
Pre-restoration (Baseline)	82.79%	----	89.50%
Post-restoration (Year 2)	95.76%	96.97%	---
Post-restoration (Year 3)	53.35%	74.05%	94.36%
Post-restoration (Year 4)	95.93%	84.46%	93.69%
Post-restoration (Year 5)	98.20%	87.95%	85.98%
Post-restoration (Year 6)	95.28%	88.84%	81.35%
Post-restoration average	**89.07%**	**87.95%**	**90.27%**

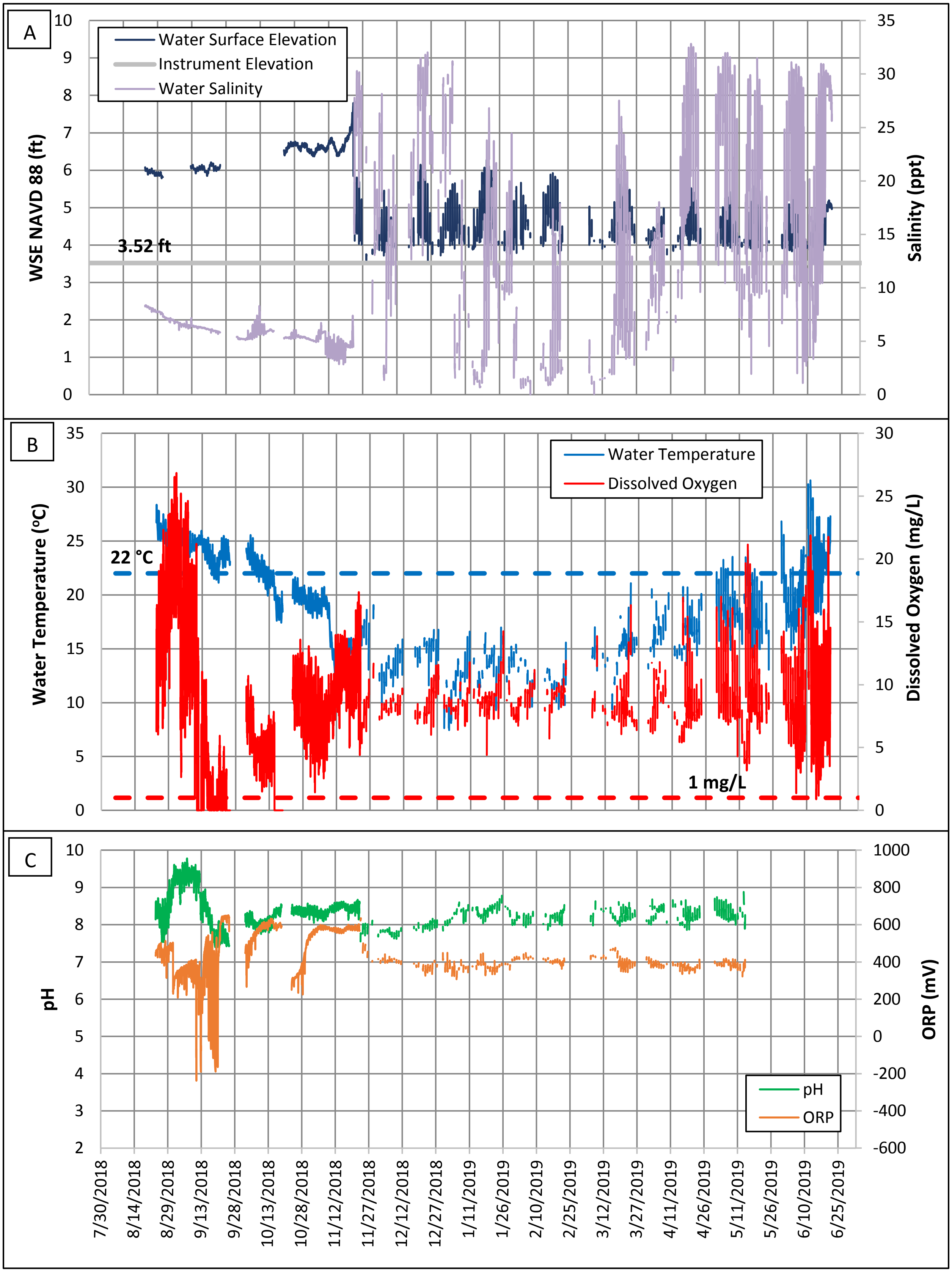


Figure 32. Graphs illustrating continuous water quality parameters from Station 8 (2018-2019).

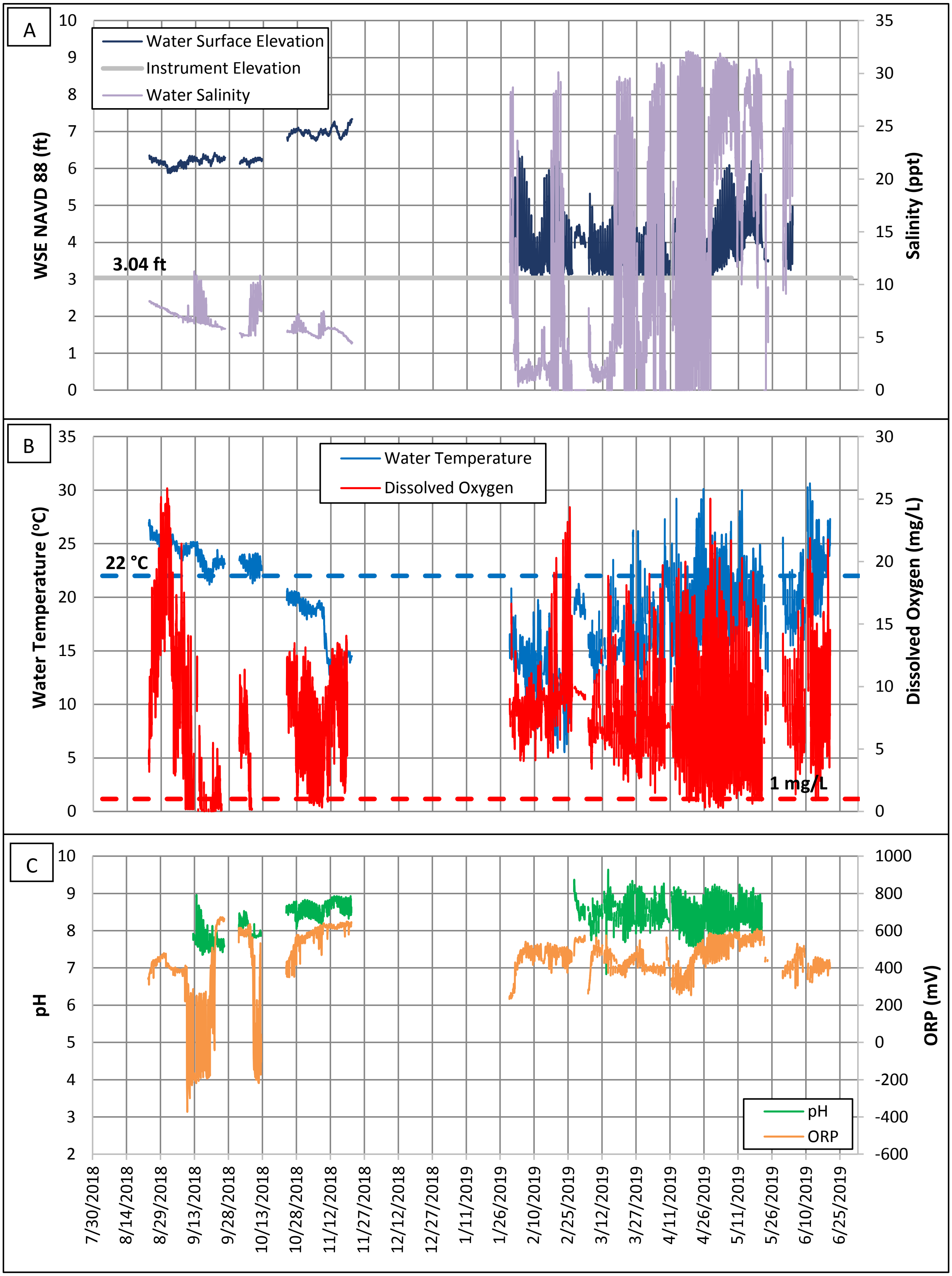


Figure 33. Graphs illustrating continuous water quality parameters from Station 5 (2018-2019).

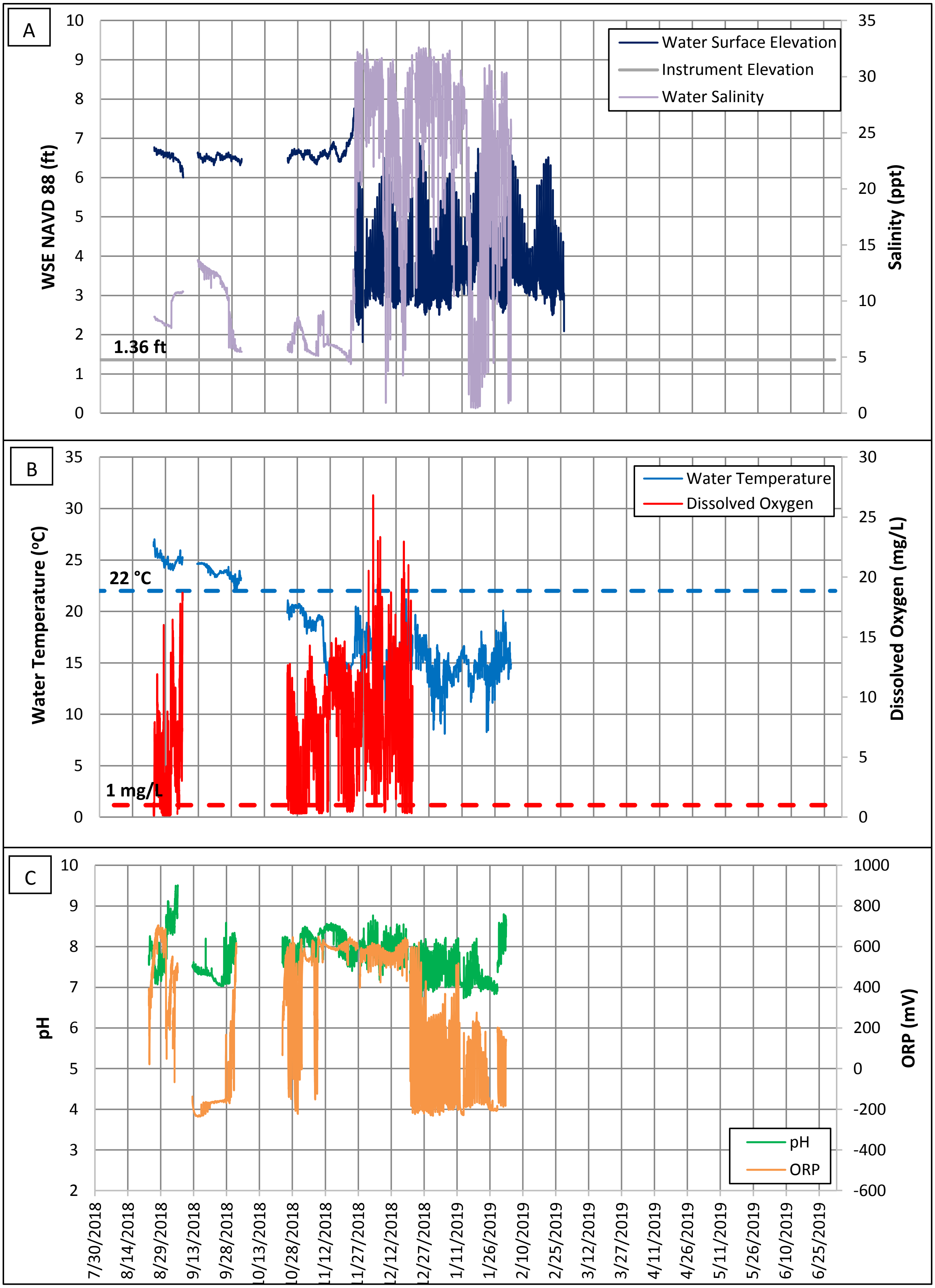


Figure 34. Graphs illustrating continuous water quality parameters from Station 2 (2018-2019).

Performance Evaluation

During Year 6, dissolved oxygen data exceeded all success criteria at all stations during closed conditions. Overall, the averages of dissolved oxygen data over all post-restoration monitoring years exceeded all success criteria at all stations during closed conditions.

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. 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 for Year 6 displayed only seven and five consecutive 24-hour periods below 1 mg/L (25% time) for Station 2 and Station 5, respectively. Additionally, results displayed three and two consecutive 24-hour periods below 1.5 mg/L (50% time) for Station 2 and Station 5, respectively. Station 8 results displayed five consecutive 24-hour periods below 1 mg/L (25% time) and seven consecutive 24-hour periods 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).

Additionally, sondes were pulled for service and malfunctioning frequently from January to August 2018, which led to a large data gap during closed conditions. The sondes were able to be redeployed during the later portion of the summer and during closed conditions, a period where dissolved oxygen is historically at the lowest (thus the results are conservative). The sonde readings during the closed condition in late summer of Year 6 showed dissolved oxygen readings meeting all success criteria.

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. Year 6 results showed a high number of dissolved oxygen readings above the 1 mg/L threshold even with data gaps during the beginning of the closed condition and potential effects post-Woolsey fire. Overall, post-restoration averages of the proportion of dissolved readings above the 1 mg/L threshold remain higher than pre-restoration (baseline) conditions. Dissolved oxygen data variability may be due to any number of factors, including biofouling, temperature fluctuations, and El Niño effects.

Cumulatively, post-restoration automated water quality monitoring data spans from May 2013 to June 2019. The sondes were deployed year-round. Data gaps due to sonde calibration, servicing, sensor and mechanical issues, and additional reasons were documented in monitoring reports. The Hydrologic and

Biological Project Monitoring Plan specified a minimum of three multi-parameter data loggers to be deployed in the lagoon from April through the first storm of the Fall (October or November) for a period of five years following the implementation of the restoration project. The time period from Spring to Fall is typical for closed berm conditions, a period when water fills up in the lagoon and dissolved oxygen can decrease when temperature rises. The average data coverage of all three sondes deployed from April to November for five seasons was 82%; for the back channels (Station 5 and 8), the data coverage was 93%. The main channel sonde (Station 2) had the least amount of data coverage, primarily due to the priority reallocation of sondes to the back channels when one sonde was down and had to be sent for service. As of July 2019, two sondes are still deployed in the back channel stations, and TBF will coordinate with State Parks to continue data collection for the remainder of the 2019 closed condition season at minimum.

Lastly, sonde probe failure and equipment malfunctions, primarily unexplained early shutoffs, led to periods of missing data during the cooler closed bar conditions, and required the return of sondes for maintenance to the manufacturers. Additionally, sondes tend to ‘drift’ prior to failure, where collected data encounter sporadic errors becoming more frequent with time.

There were no good 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 over six years during a high tide (N = 6) or closed condition (N = 5) using a YSI 600 XLM hand-held water quality instrument or equivalent for a total of eleven surveys (Table 7). The vertical profiles provide a spatial expansion of the continuous data sonde loggers to the whole water column in addition to providing quality control checks for the continuous datasets. In-depth descriptions of the specifications and operation manual of this instrument can be found at www.ysi.com.

Eleven 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 35). The water temperature and pH parameters experienced sensor malfunctions on 27 January 2016, and the temperature sensor malfunctioned on 25 June 2019; 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. All eleven surveys are analyzed together in the results section and compared to data from pre-restoration surveys.

Table 7. Dates and lagoon conditions for vertical profile surveys. Tide heights are reported as Mean Sea Level.

Date	Lagoon Condition	Tide
14 February 2013	Open	high neap; 3.9 ft MSL
5 May 2014	Closed	N/A
23 December 2014	Open	high spring; 6.6 ft MSL
7 May 2015	Closed	N/A
27 January 2016	Open	high spring; 4.9 ft MSL
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
23 May 2018	Closed	N/A
25 June 2019	Open	high neap; 4.4 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.

Figure 35. Photographs taken of LMU's Coastal Research Institute internship student and TBF staff collecting water quality vertical profile data on 25 June 2019.

Results

Results suggest fairly consistent temperature data throughout the water column with little to no stratification occurring, especially during closed conditions. The warmest temperatures occurred during the spring and summer closed berm sampling events (e.g., August 2017 and May 2016), and cooler temperatures occurred during winter open berm sampling events (e.g., February 2018 and December 2016) (Figures 36a and 36b). Overall, temperature followed expected patterns, exhibiting seasonal variability in range. Data in Year 5 displayed both the warmest (26 °C in August 2017) and coolest (13 °C in February 2018) temperatures across the six-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 37a and 37b). 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, 18 August 2017, and 23 May 2018), 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; 2nd Nature 2010).

Dissolved oxygen (DO) data showed consistently high values across 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 38a and 38b). Similarly to other parameters measured such as temperature, DO exhibited little to no stratification, especially in the closed berm conditions. The vertical profile dissolved oxygen levels never fell below 4 mg/L at any of the stations during all post-restoration sampling events. Even in the May 2018 survey where the DO hit a minimum reading of 4.07 (across all survey years), the average reading across all stations was still 6.89 mg/L. 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, 6.78 mg/L in August 2017, and 4.07 mg/L in May 2018. 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 (2nd Nature 2010). Additionally, in pre-restoration conditions there were many areas of the back channels where the water was so filled with unconsolidated sediments that water quality profiles were not even possible.

Average, maximum, and minimum values for each of the parameters measured (i.e., salinity, water temperature, and pH) were all consistent with water quality parameter goals of the restoration project (Tables 8 and 9).

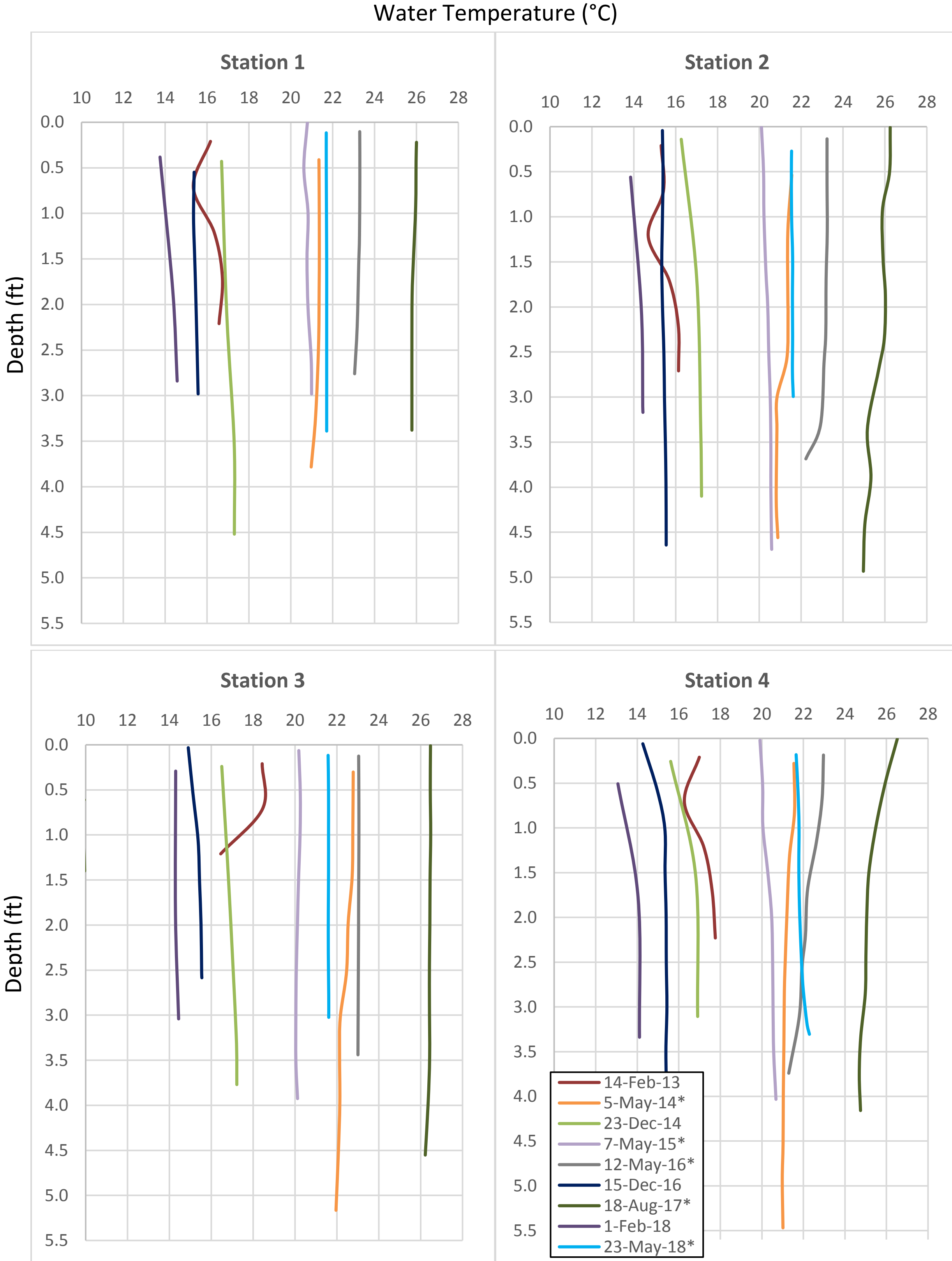


Figure 36a. Post-restoration temperature vertical water quality profiles at Stations 1-4. Asterisk indicates a closed berm condition.

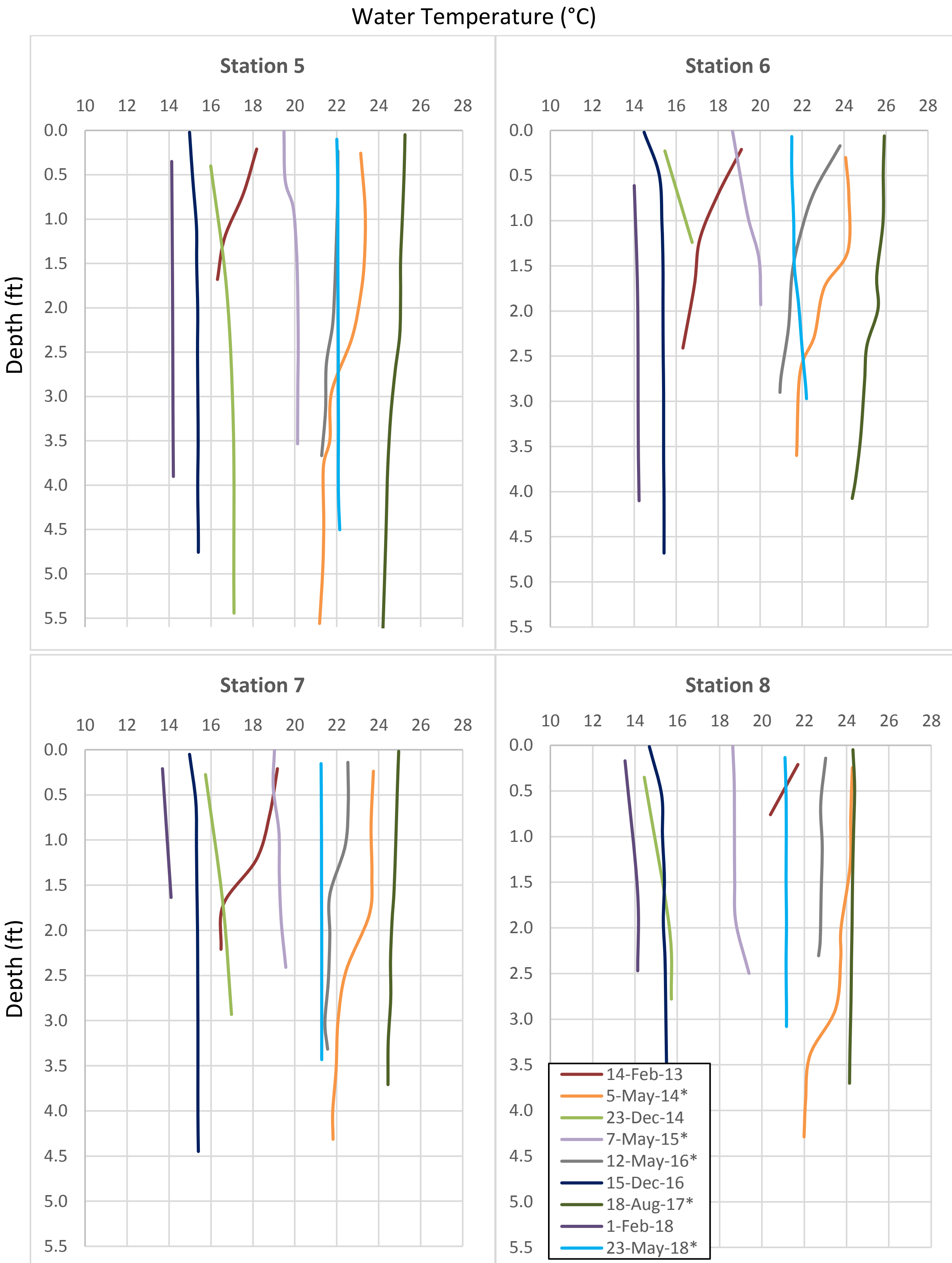


Figure 36b. Post-restoration temperature vertical water quality profiles at Stations 5-8. Asterisk indicates a closed berm condition.

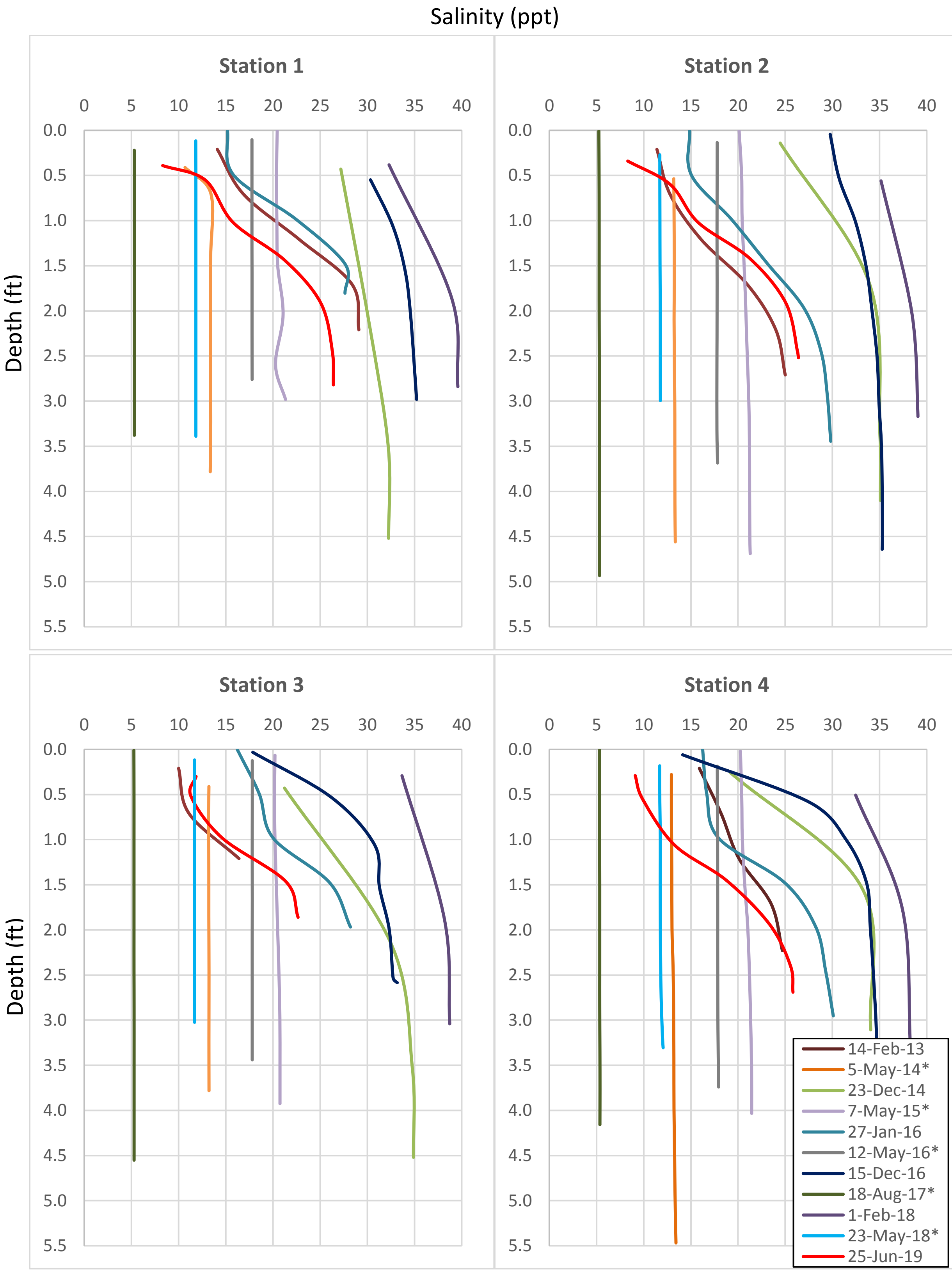


Figure 37a. Post-restoration salinity vertical water quality profiles at Stations 1-4. Asterisk indicates a closed berm condition.

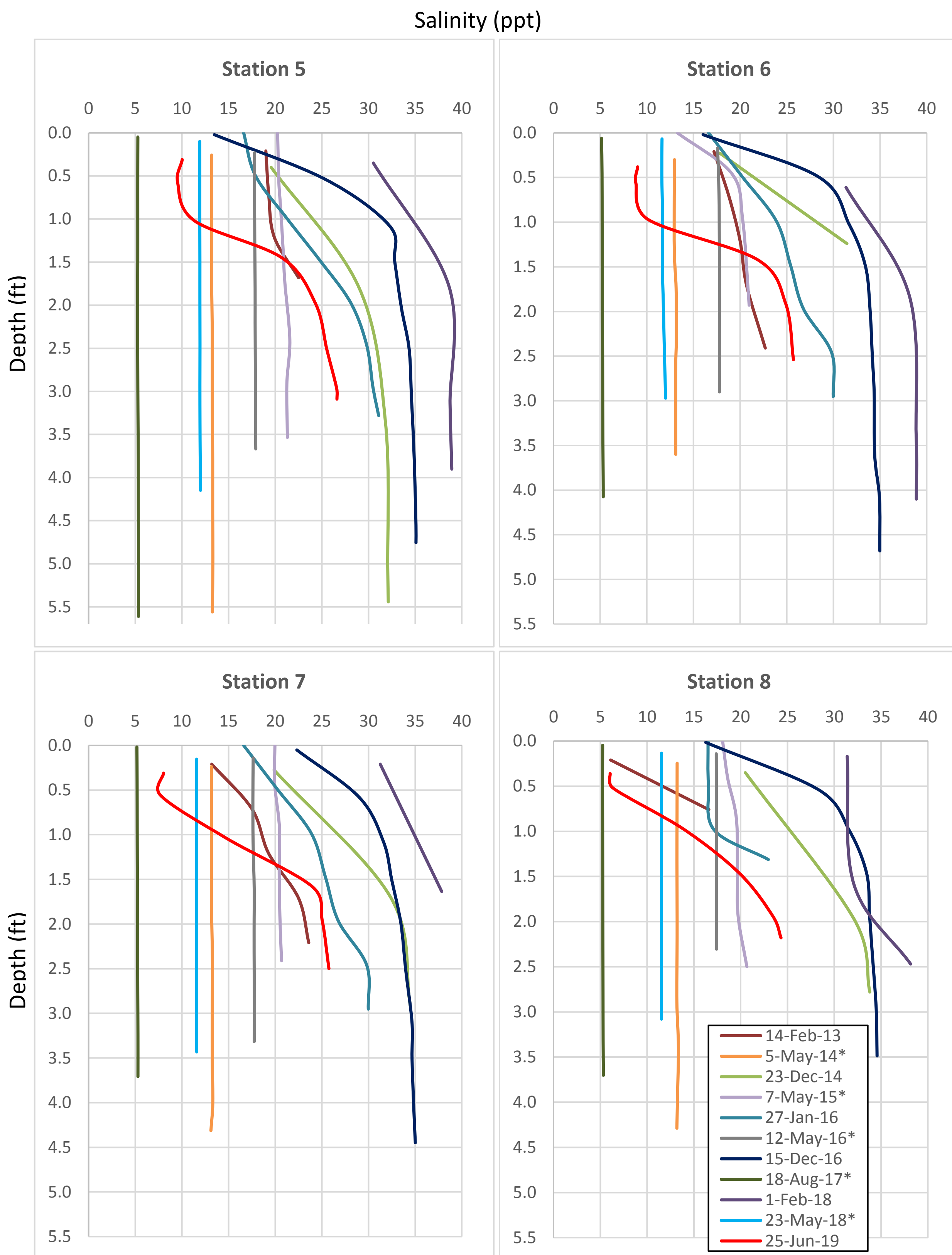


Figure 37b. Post-restoration salinity vertical water quality profiles at Stations 5-8. Asterisk indicates a closed berm condition.

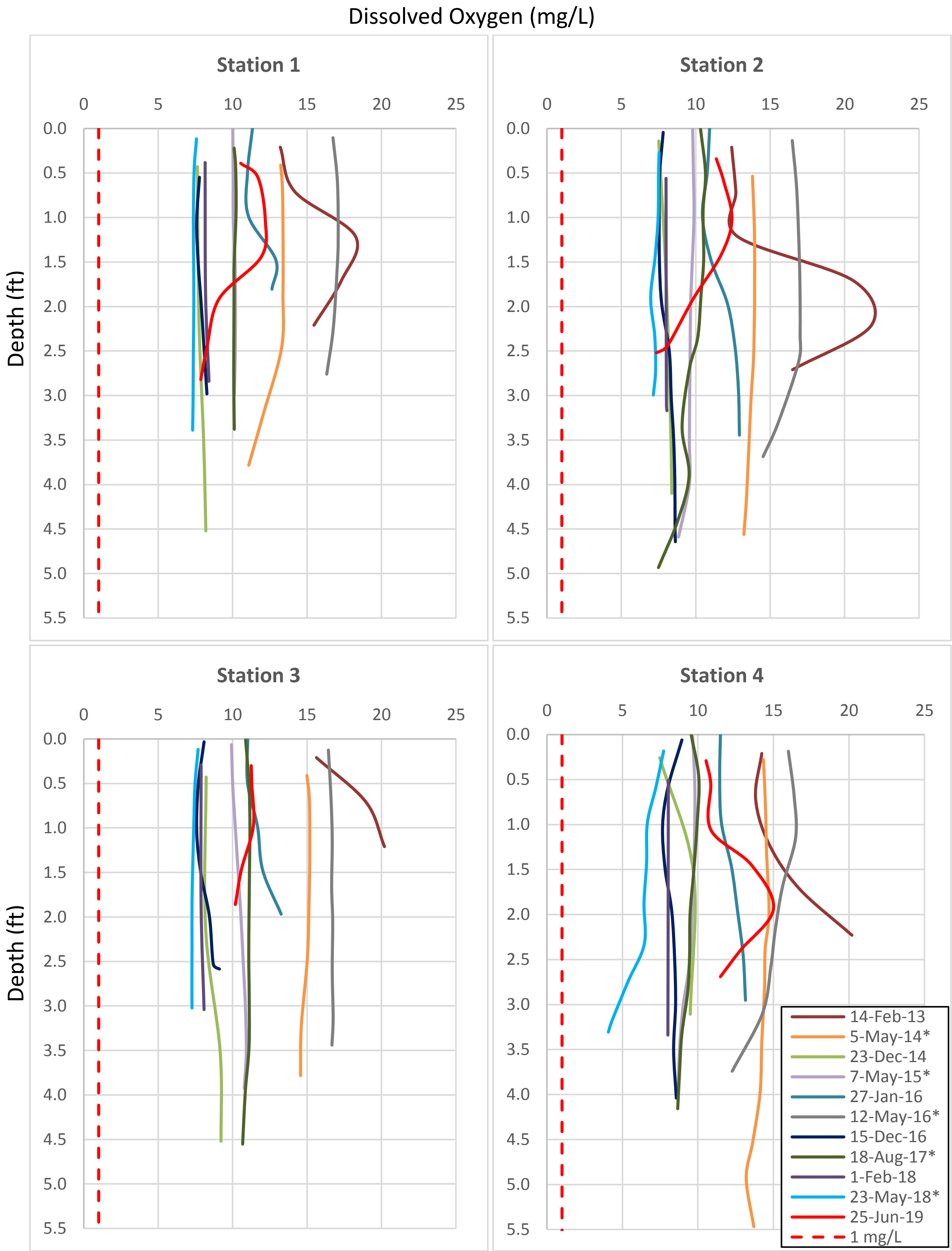


Figure 38a. Post-restoration dissolved oxygen vertical water quality profiles at Stations 1-4 (red line represents 1 mg/L threshold). Asterisk indicates a closed berm condition.

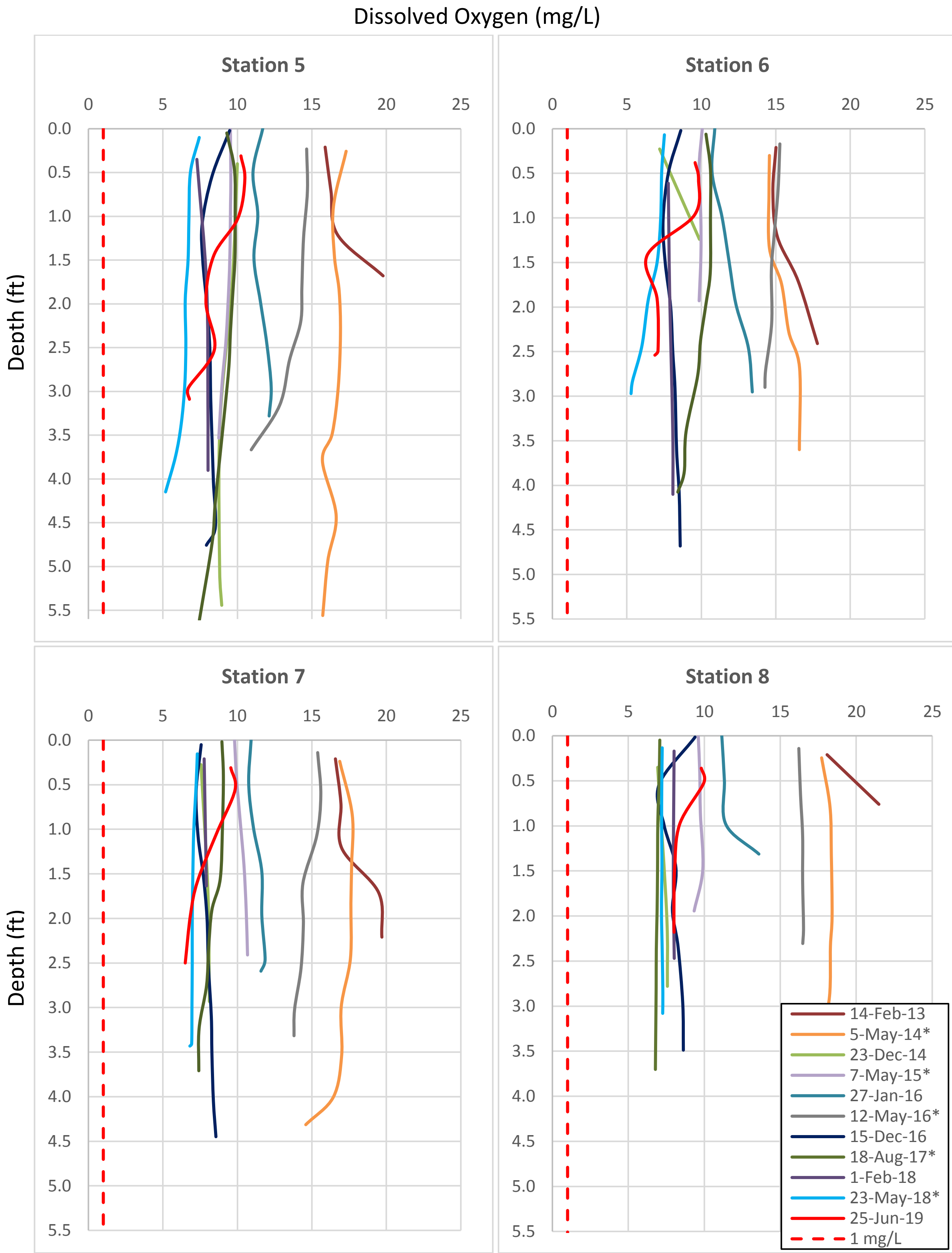


Figure 38b. Post-restoration dissolved oxygen vertical water quality profiles at Stations 5-8 (red line represents 1 mg/L threshold). Asterisk indicates a closed berm condition.

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

Survey Date	Temperature (°C)		Salinity (ppt)		Dissolved Oxygen (mg/L)		pH	
	Min	Max	Min	Max	Min	Max	Min	Max
14-Feb-13	14.69	21.70	6.10	29.10	12.41	21.80	8.00	8.55
5-May-14 *	20.81	24.27	10.68	13.42	11.08	18.41	9.03	9.33
23-Dec-14	14.44	17.30	17.82	35.08	6.93	10.00	7.24	8.06
7-May-15 *	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
23-May-18*	21.09	22.29	8.22	12.06	4.07	7.73	8.22	8.33
25-Jun-19	N/A	N/A	6.05	26.62	6.36	15.00	8.06	8.50

Table 9. 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

Date	Station	Average Temp (°C)	SE Temp	Average Salinity (ppt)	SE Salinity	Average DO (mg/L)	SE DO	Average pH	SE pH
	5	16.80	0.21	28.91	2.41	9.25	0.24	7.93	0.06
	6	16.11	0.65	24.64	6.82	8.54	1.33	7.77	0.02
	7	16.43	0.36	28.92	4.56	7.90	0.17	7.66	0.04
	8	15.26	0.41	28.80	4.18	7.34	0.21	7.29	0.05
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	-	-

Date	Station	Average Temp (°C)	SE Temp	Average Salinity (ppt)	SE Salinity	Average DO (mg/L)	SE DO	Average pH	SE pH
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
	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
23-May-2018*	1	21.70	0.00	11.83	0.00	7.39	0.03	8.30	0.00
	2	21.58	0.01	11.74	0.01	7.20	0.13	8.30	0.00
	3	21.60	0.00	11.69	0.00	7.37	0.05	8.31	0.00
	4	21.90	0.07	11.82	0.04	6.09	0.44	8.27	0.01
	5	22.06	0.01	11.60	0.40	6.26	0.30	8.27	0.01
	6	21.81	0.10	11.78	0.06	6.53	0.32	8.28	0.01
	7	21.27	0.00	11.59	0.00	7.03	0.05	8.28	0.00
	8	21.14	0.01	11.54	0.00	7.22	0.01	8.26	0.00
25-June-2019	1	-	-	19.41	2.55	10.23	0.64	8.34	0.02
	2	-	-	19.82	2.19	10.38	0.71	8.38	0.04
	3	-	-	16.35	1.88	10.94	0.19	8.36	0.02
	4	-	-	17.96	2.56	12.16	0.59	8.38	0.04
	5	-	-	19.34	2.73	8.63	0.53	8.25	0.03
	6	-	-	18.02	2.91	8.04	0.54	8.20	0.03
	7	-	-	17.55	3.00	8.12	0.50	8.18	0.02
	8	-	-	15.67	2.90	8.70	0.33	8.21	0.02

Performance Evaluation

Dissolved oxygen was well above the success criteria threshold (i.e., > 1 mg/L) for all samples collected across all stations and all surveys. Data suggest the restored lagoon represents a brackish water bar-built estuary habitat, with good circulation and dissolved oxygen levels.

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 4 mg/L at any of the stations during all post-restoration sampling events across all six years of surveys. 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, 6.78 mg/L in August 2017, and 4.07 mg/L in May 2018. These data contrast the pre-restoration closed berm sampling event (26 September 2007), where the dissolved oxygen vertical profile data dropped below the 1 mg/L threshold multiple times, especially at increased depths (2nd Nature 2010). Data indicate post-restoration mixing during closed conditions, meeting the project goal tied specifically to increased circulation. Little to no stratification of dissolved oxygen occurred during any of the sampling events across all stations. Of note are the bottom DO readings, which were consistently higher than pre-restoration conditions.

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 6 semi-annual surface water and bottom water samples were collected at the eight vertical profile Stations (Figure 29) on 23 May 2018 (closed berm) and 19 March 2019 (open berm), as described in the Monitoring Plan. Samples were processed by TestAmerica, including: nitrate plus nitrite as N (TN), Total Kjeldahl Nitrogen (TKN), Total Phosphorous (TP), orthophosphate, ammonia, and chlorophyll a (surface samples only). Previous sampling years included the following dates: 5 May 2014 (closed), 30 December 2014 (open), 7 May 2015 (closed), 27 January 2016 (open), 10 May 2016 (closed), 15 December 2016 (open), 6 July 2017 (closed), and 1 February 2018 (open). Summary results from a targeted post-fire water quality survey conducted by USGS after a rainstorm on 5 March 2019 are also included in the results section. 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 2008-2018 (data summarized from Heal the Bay's Beach Report Card Report).

Additionally, precipitation was calculated by downloading daily total precipitation from the Thousand Oaks (1CA9) station across all post-restoration survey years (i.e., 2013-2019) and summed by wet season (1 November through 31 March). The 1CA9 station was geographically the closest to Malibu Lagoon based on available data. Note that precipitation may have occurred outside of the calculated total dates, but the graph was intended to capture the majority of the wet season available data. Data were provided by AccuWeather Premium.

Results

Total wet season precipitation by year following the implementation of the restoration is shown in Figure 39. Precipitation varied considerably by year. Note that the 2018-19 wet season also included the Woolsey Fire in November 2018 with subsequent rain events washing sediment down the watershed. The three wet seasons immediately following the restoration had lower total precipitation amounts, ranging from a low of 4.4 (2013-14) to a high of 18.8 cm (2014-15), than the subsequent three wet seasons, ranging from a low of 25.3 (2018-19) to a high of 38.6 cm (2016-17).

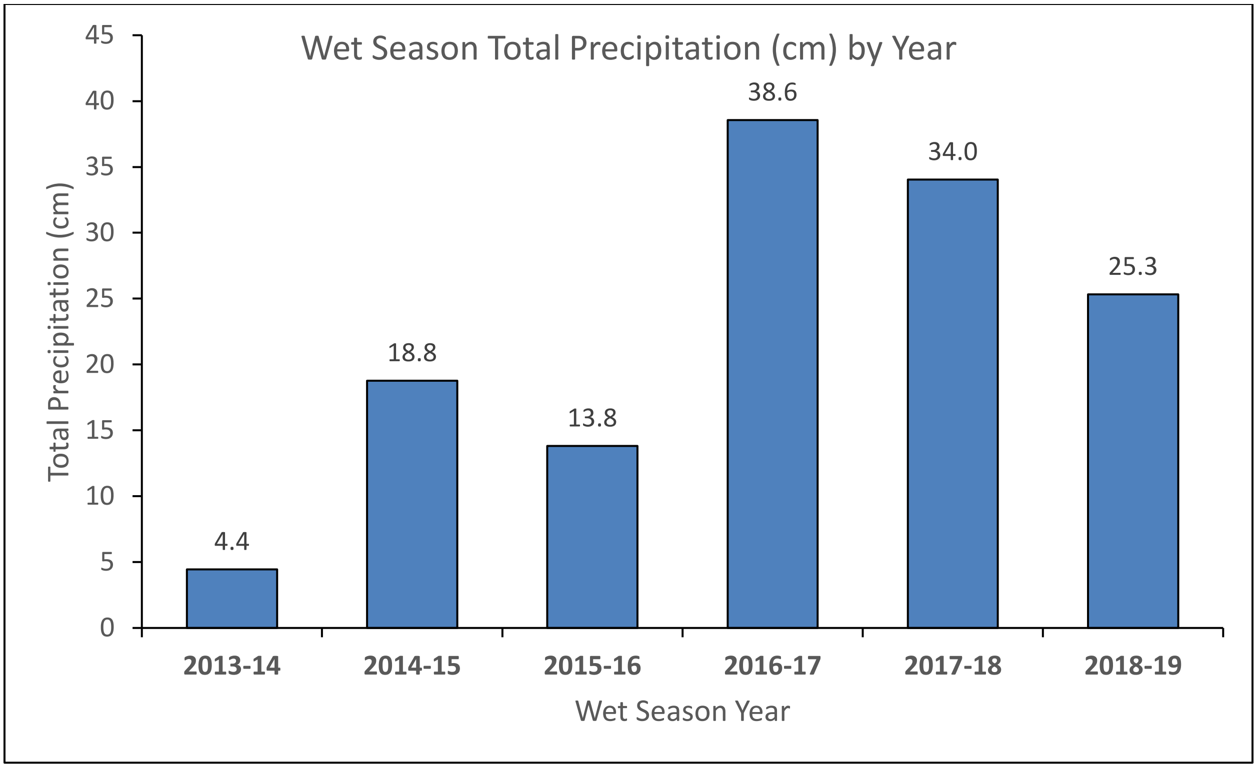


Figure 39. Graph displaying post-restoration precipitation data (cm) by year for wet season (1 Nov – 31 Mar).

Graphs displaying data from pre- and post-construction water quality bottom sample and surface sample monitoring at all Stations are presented in Figures 40-50. Figures were set up such that each page focused on one constituent (e.g., total phosphorous). The top graphs of each page summarize the four pre-restoration water quality sampling events conducted from 2006-2008 (open and closed); the middle graphs of each page summarize the post-restoration closed berm condition results; and the bottom graphs of each page summarize the post-restoration open berm condition results. Bottom water grab sample results are presented first, followed by surface water grab sample results.

Figures 40 and 45 displays the values of nitrate plus nitrite as N (NO_x) concentrations for pre- and post-restoration surveys. Figures 41 and 46 display the values of Total Kjeldahl Nitrogen (TKN) concentrations for pre- and post-restoration surveys. Figures 42 and 47 display the values of Total Phosphorous (TP) concentrations for pre- and post-restoration surveys. Figures 43 and 48 display the values for orthophosphate concentrations for pre- and post-restoration surveys. Figures 44 and 49 display the values for ammonia concentrations for pre- and post-restoration surveys. Figure 50 displays 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. For example, NO_x concentrations for all post-restoration closed berm surveys (surface and bottom samples) were zeroes, thus, the colored markers overlap on the “zero” y-axis intercept. The y-axes vary based on constituent.

Overall, the post-restoration nutrient concentrations remained relatively constant and low. The exception found in the 30 December 2014 samples (Year 2 Report), which showed higher nutrient concentrations across multiple parameters, were not identified in the subsequent four years of monitoring. 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 is not visible, it is due to overlap on the "zero" y-intercept, meaning non-detect for those stations or constituents.

Summary bacteria data from Heal the Bay suggest an overall decrease in Total Maximum Daily Load (TMDL) exceedances, post-restoration (Table 10), especially as compared to the highest exceedance years, which occurred pre-restoration (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, A and A, respectively) than the years preceding the restoration (D, C, B, and F, respectively). Table 10 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 starting in 2017, thus no 'number of TMDL exceedances' is reported for 2017 or 2018.

Table 10. Summary annual AB 411 grade and number of TMDL exceedances from the bacteria Beach Report Card (Heal the Bay). Note: gray cells display pre-restoration data, and 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
2018	A	N/A

A supplemental post-fire survey was conducted by USGS on 5 March 2019 directly after a rain event with the goal of assessing for evidence of impacted septic systems or other fire-related water quality impacts (Joseph Domagalski, USGS, pers. comm. 2019). Summary results suggested slightly elevated dissolved organic carbon and total dissolved nitrogen, but with a lack of evidence of an anthropogenic signature. Some evidence of humic material (e.g., burnt soils) was evident, but no significant signatures of wastewater impacts (J. Domagalski, USGS).

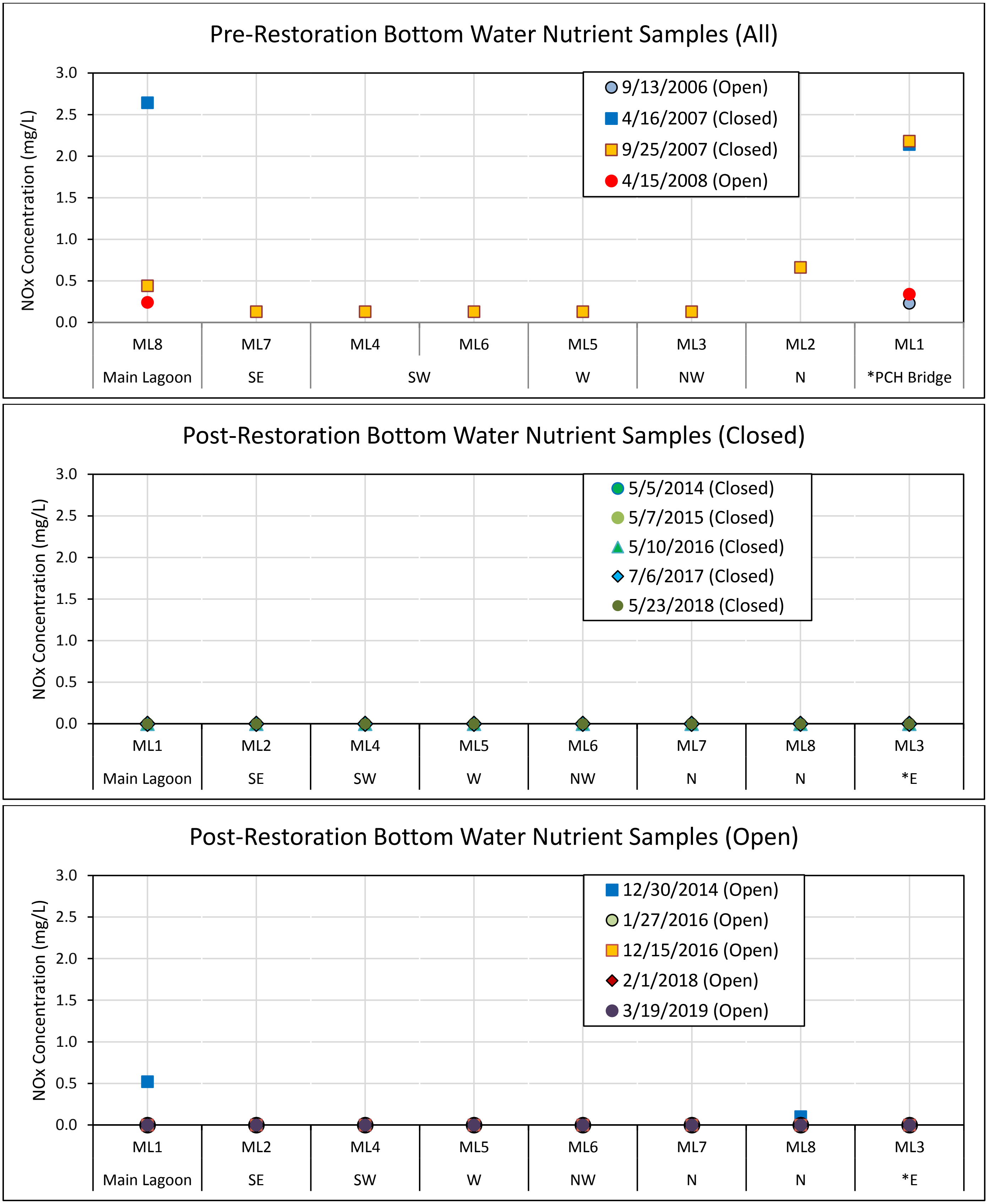
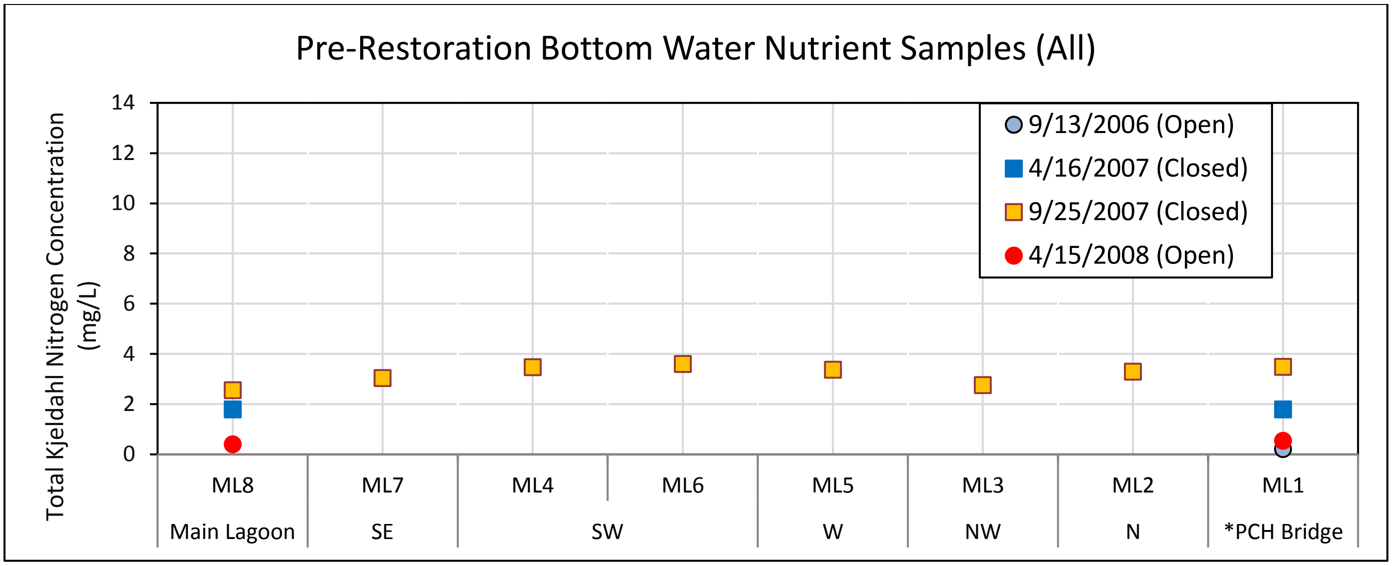
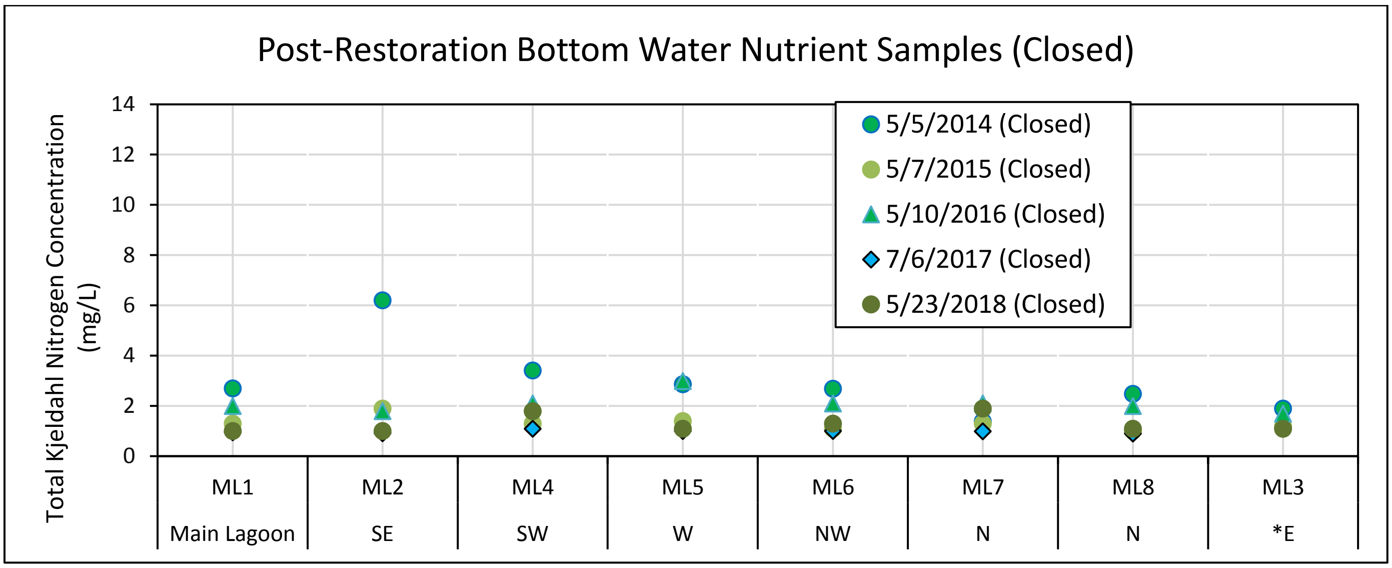


Figure 40. Pre-restoration bottom water nutrient samples (top graph), post-restoration closed (middle graph), and post-restoration open condition (bottom graph) bottom water nutrient samples for NOx concentration (mg/L).





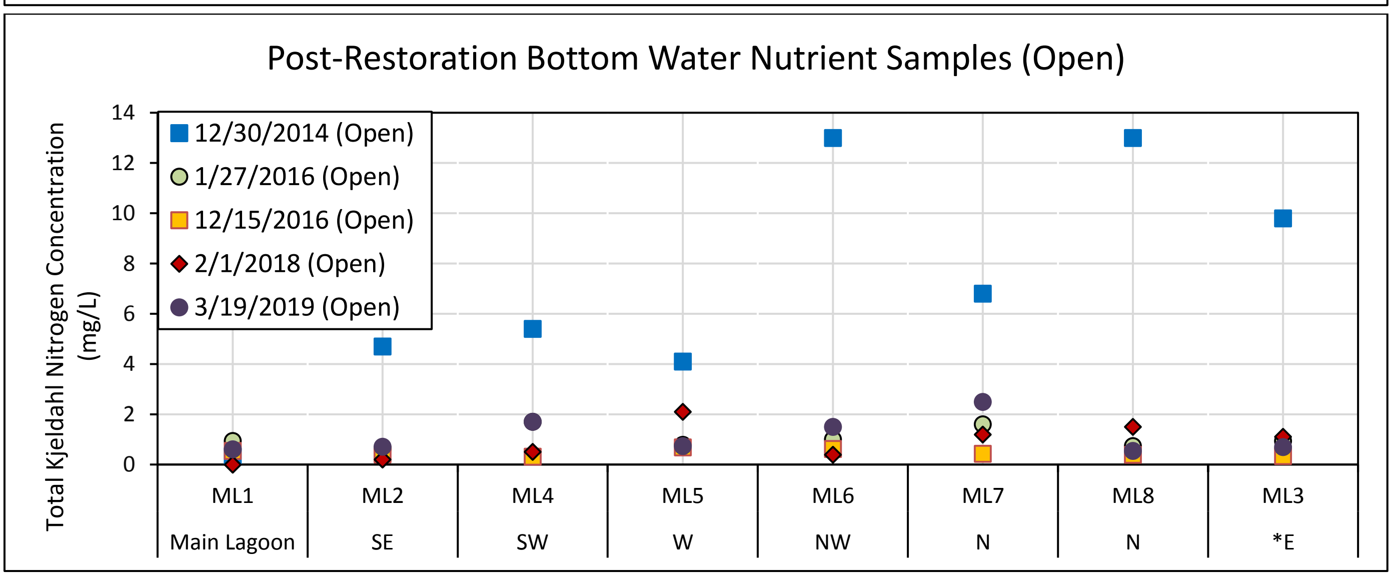
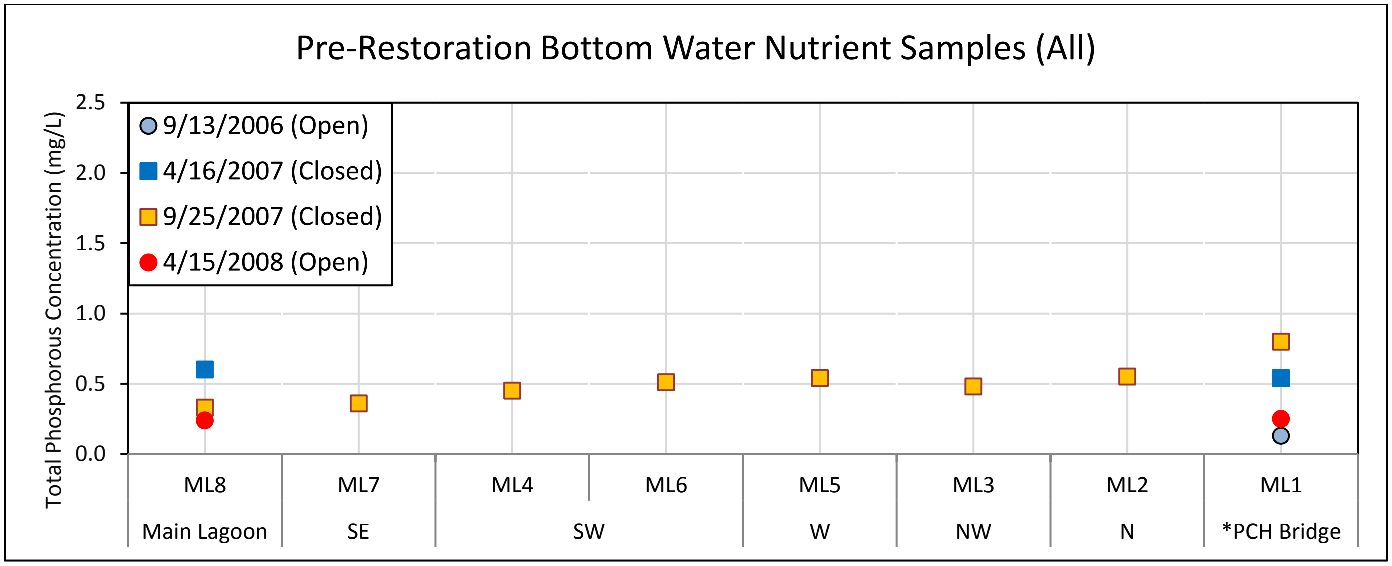
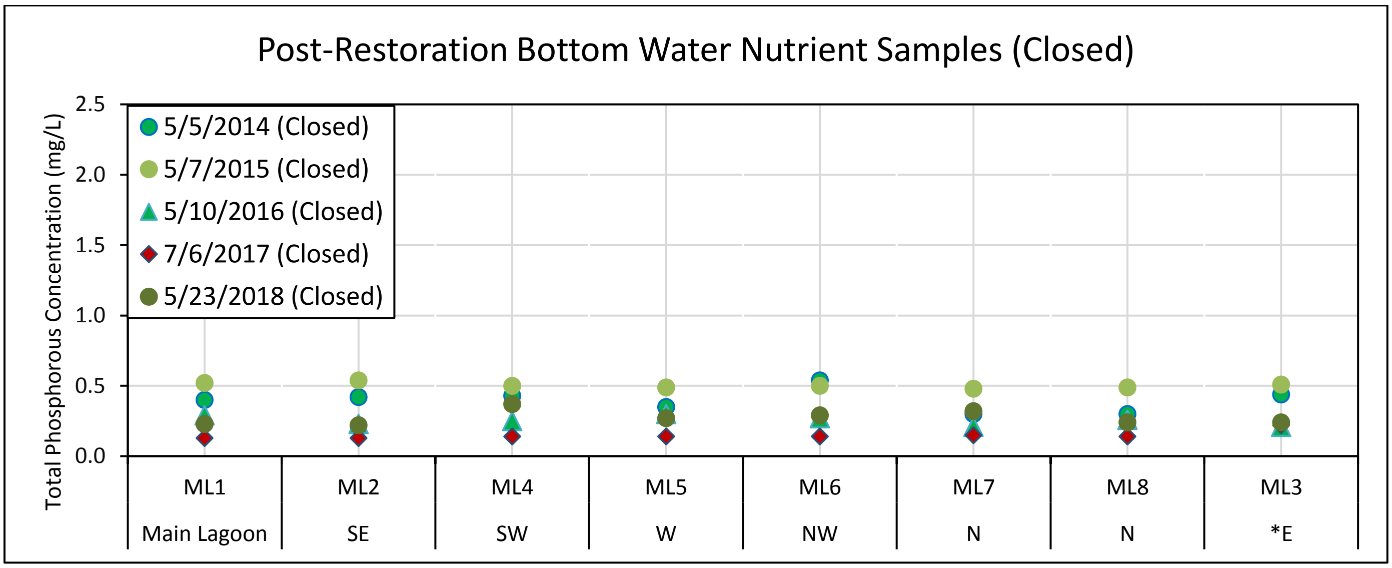


Figure 41. Pre-restoration bottom water nutrient samples (top graph), post-restoration closed (middle graph), and post-restoration open condition (bottom graph) bottom water nutrient samples for Total Kjeldahl Nitrogen (mg/L).





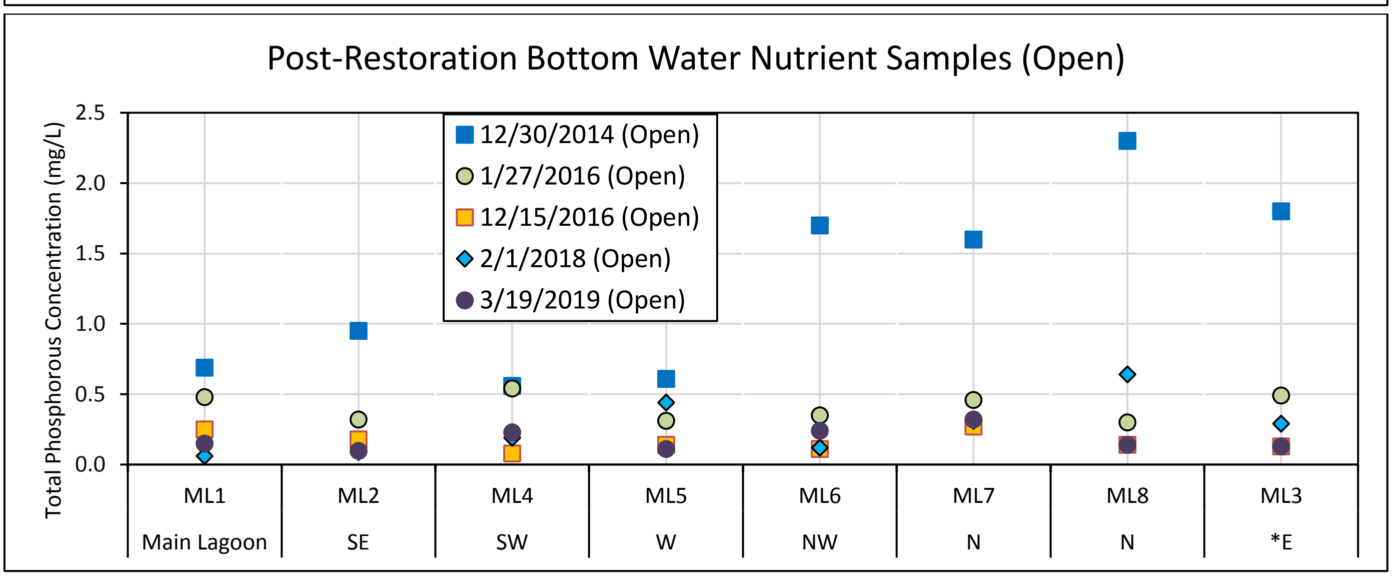
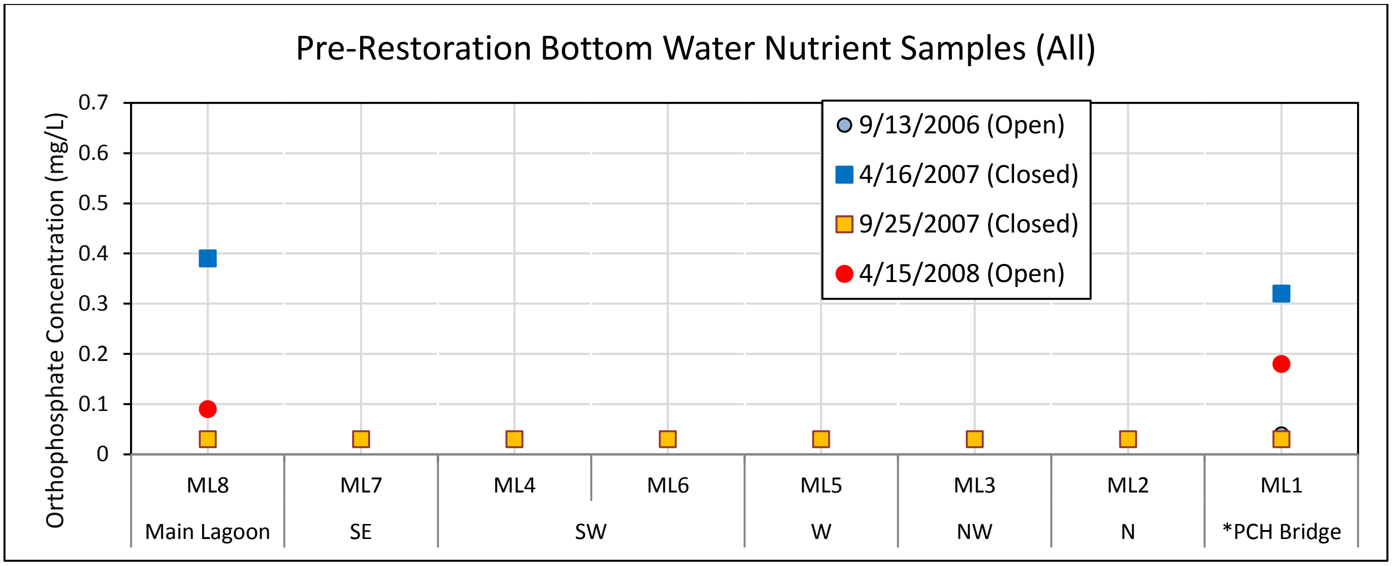
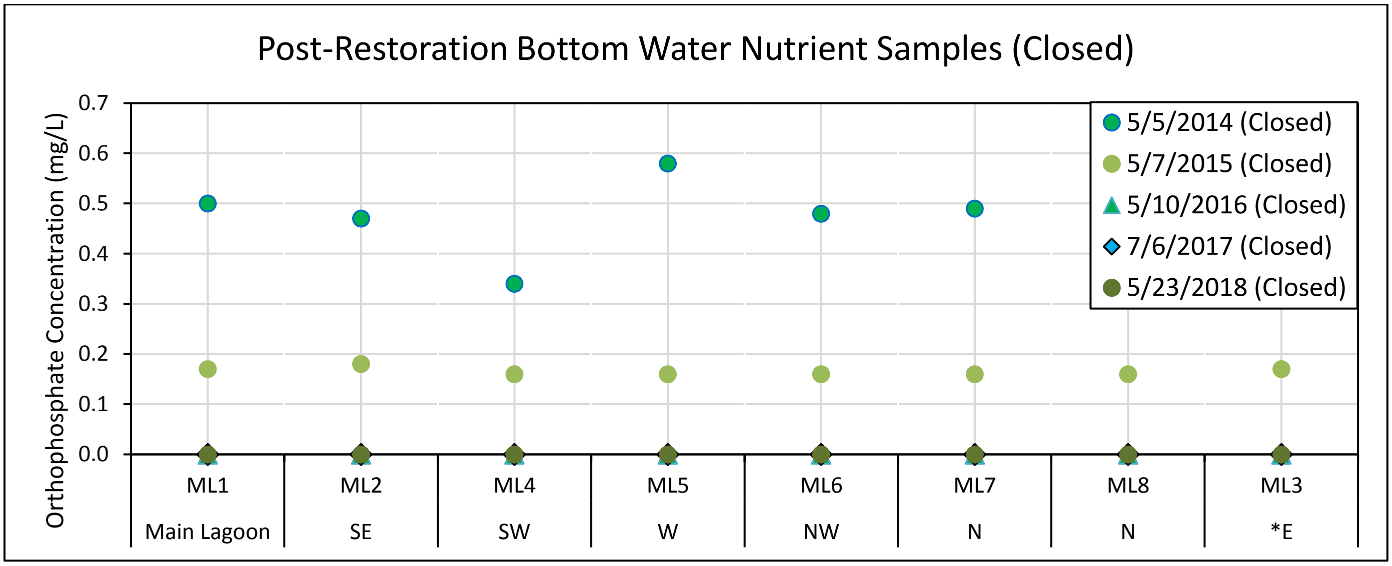


Figure 42. Pre-restoration bottom water nutrient samples (top graph), post-restoration closed (middle graph), and post-restoration open condition (bottom graph) bottom water nutrient samples for Total Phosphorous (mg/L).





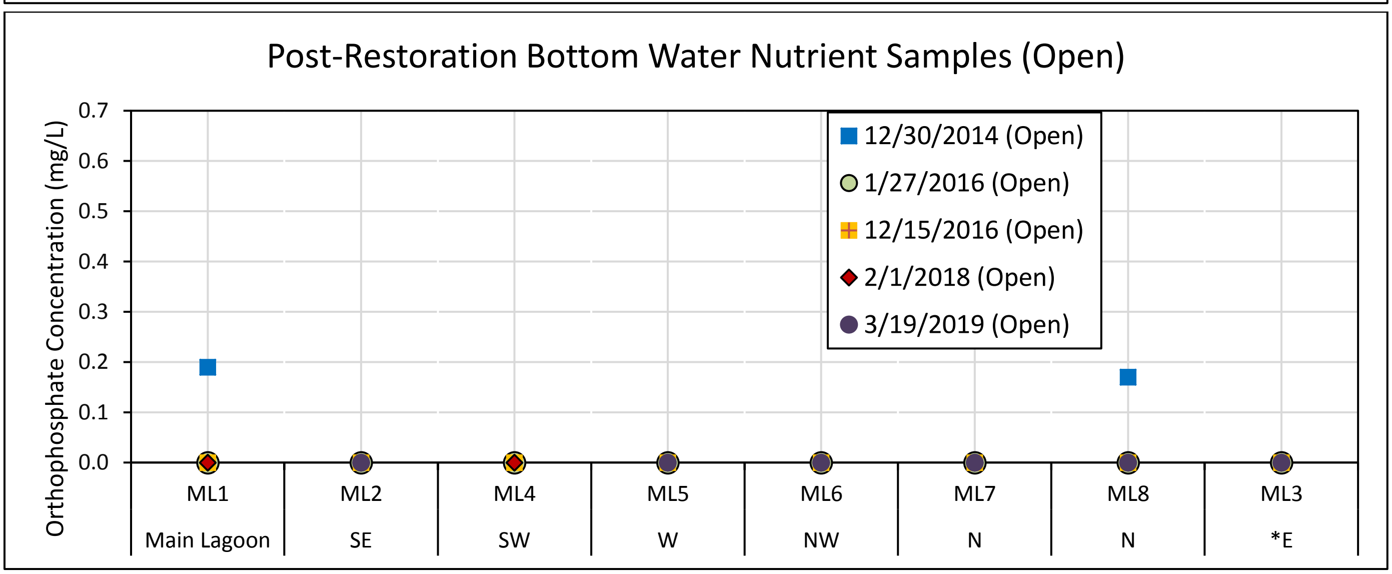


Figure 43. Pre-restoration bottom water nutrient samples (top graph), post-restoration closed (middle graph), and post-restoration open condition (bottom graph) bottom water nutrient samples for Orthophosphate (mg/L).

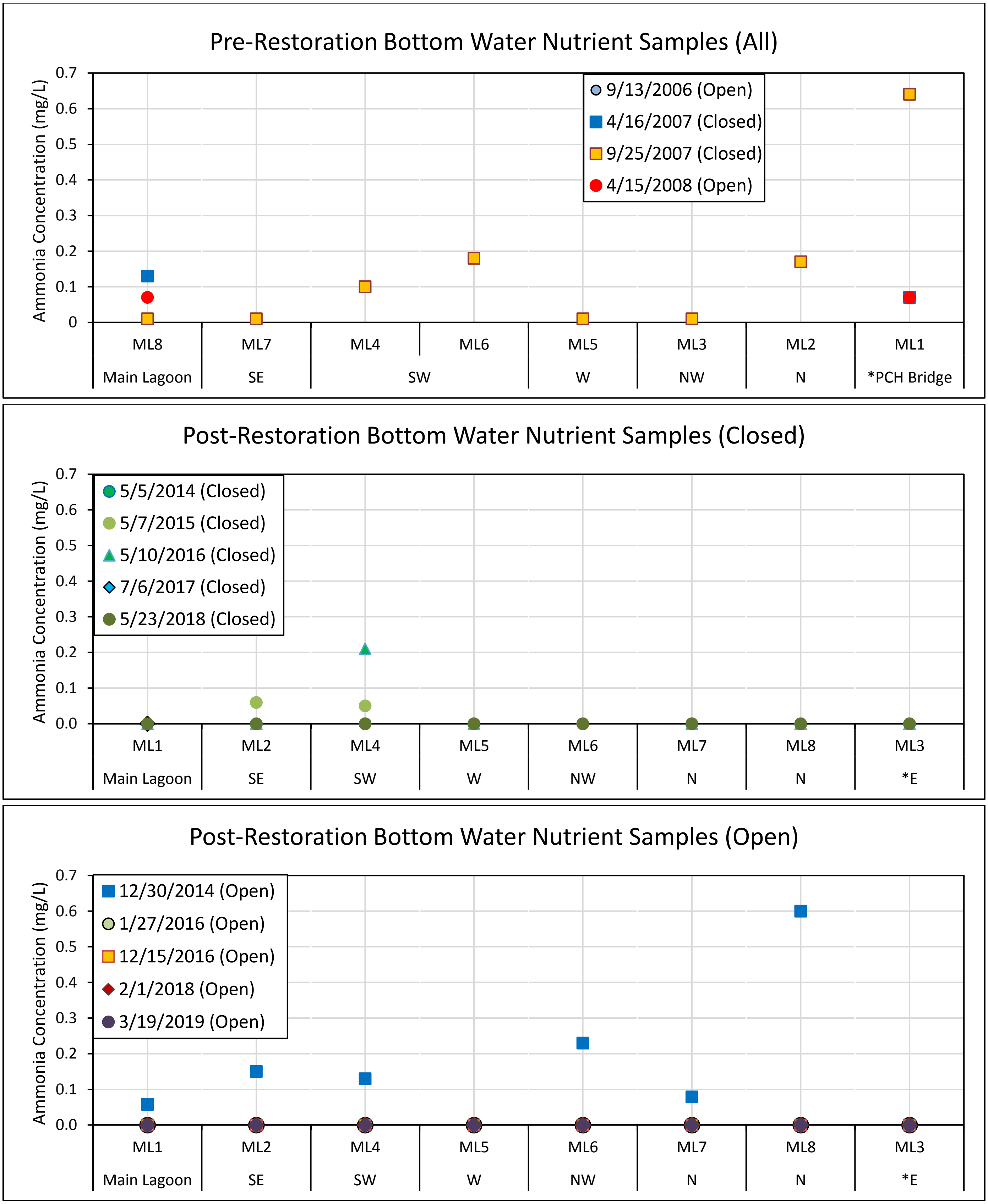


Figure 44. Pre-restoration bottom water nutrient samples (top graph), post-restoration closed (middle graph), and post-restoration open condition (bottom graph) bottom water nutrient samples for Ammonia (mg/L).

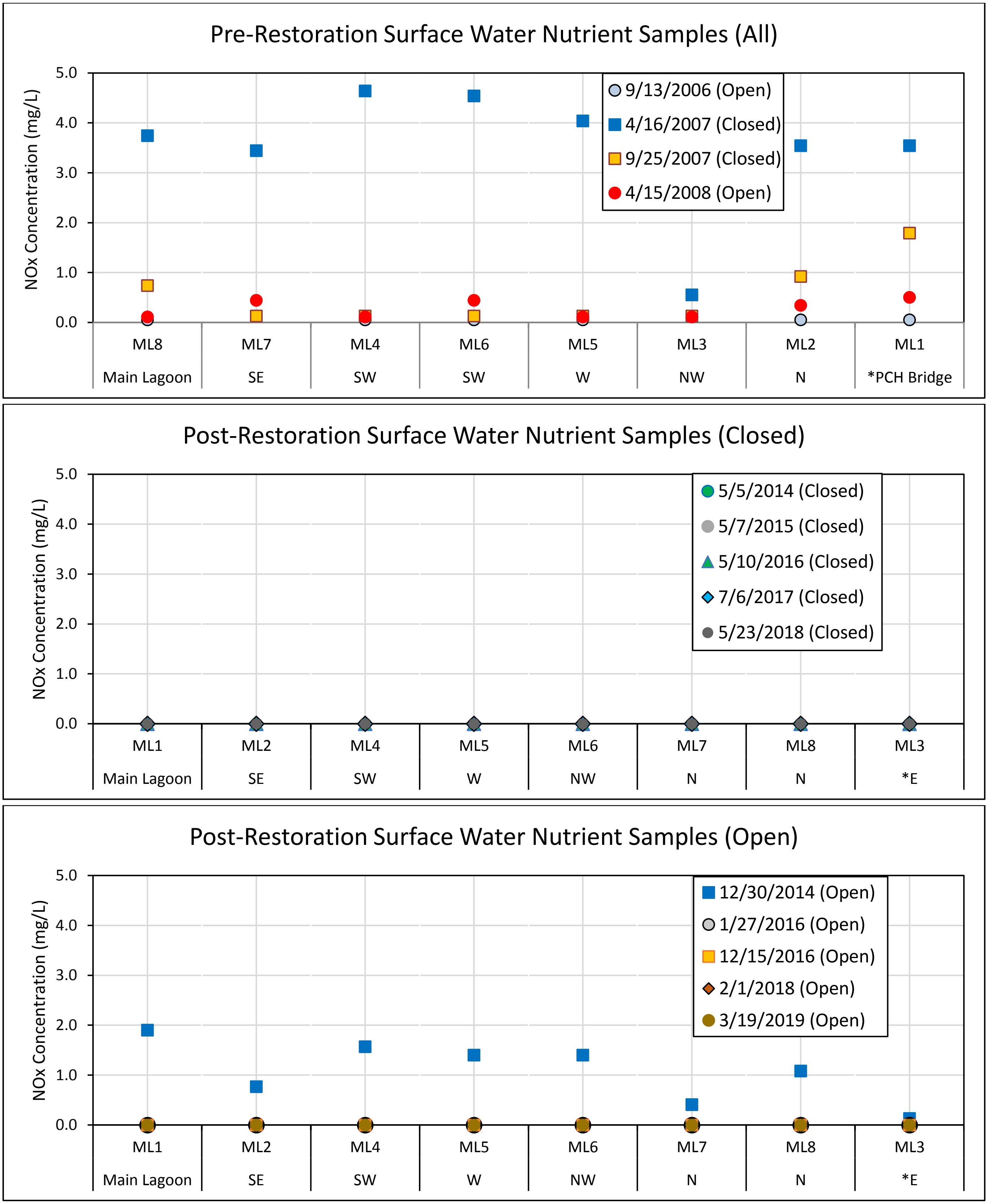


Figure 45. Pre-restoration surface water nutrient samples (top graph), post-restoration closed (middle graph), and post-restoration open condition (bottom graph) surface water nutrient samples for NOx Concentration (mg/L).

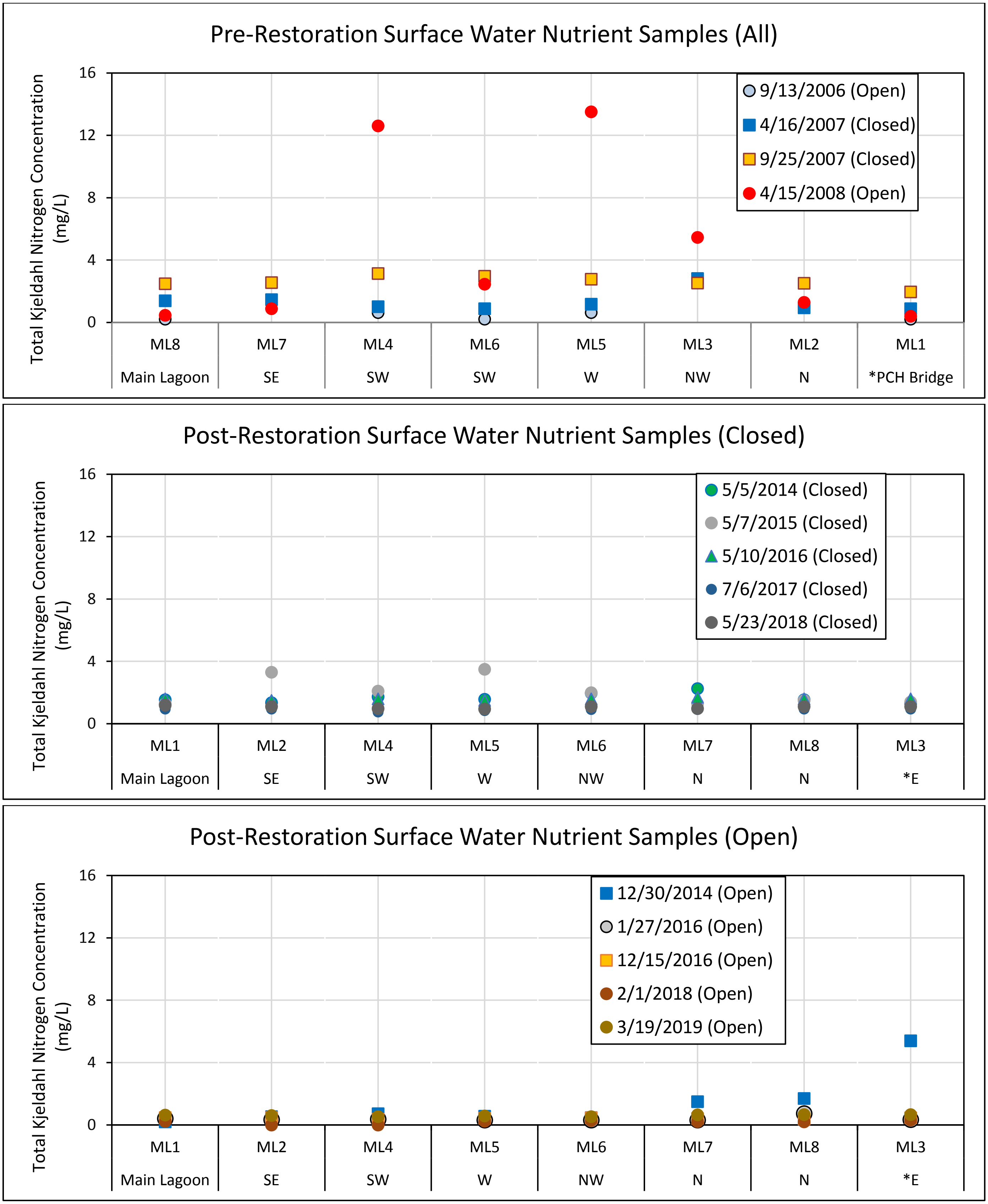


Figure 46. Pre-restoration surface water nutrient samples (top graph), post-restoration closed (middle graph), and post-restoration open condition (bottom graph) surface water nutrient samples for Total Kjeldahl Nitrogen (mg/L).

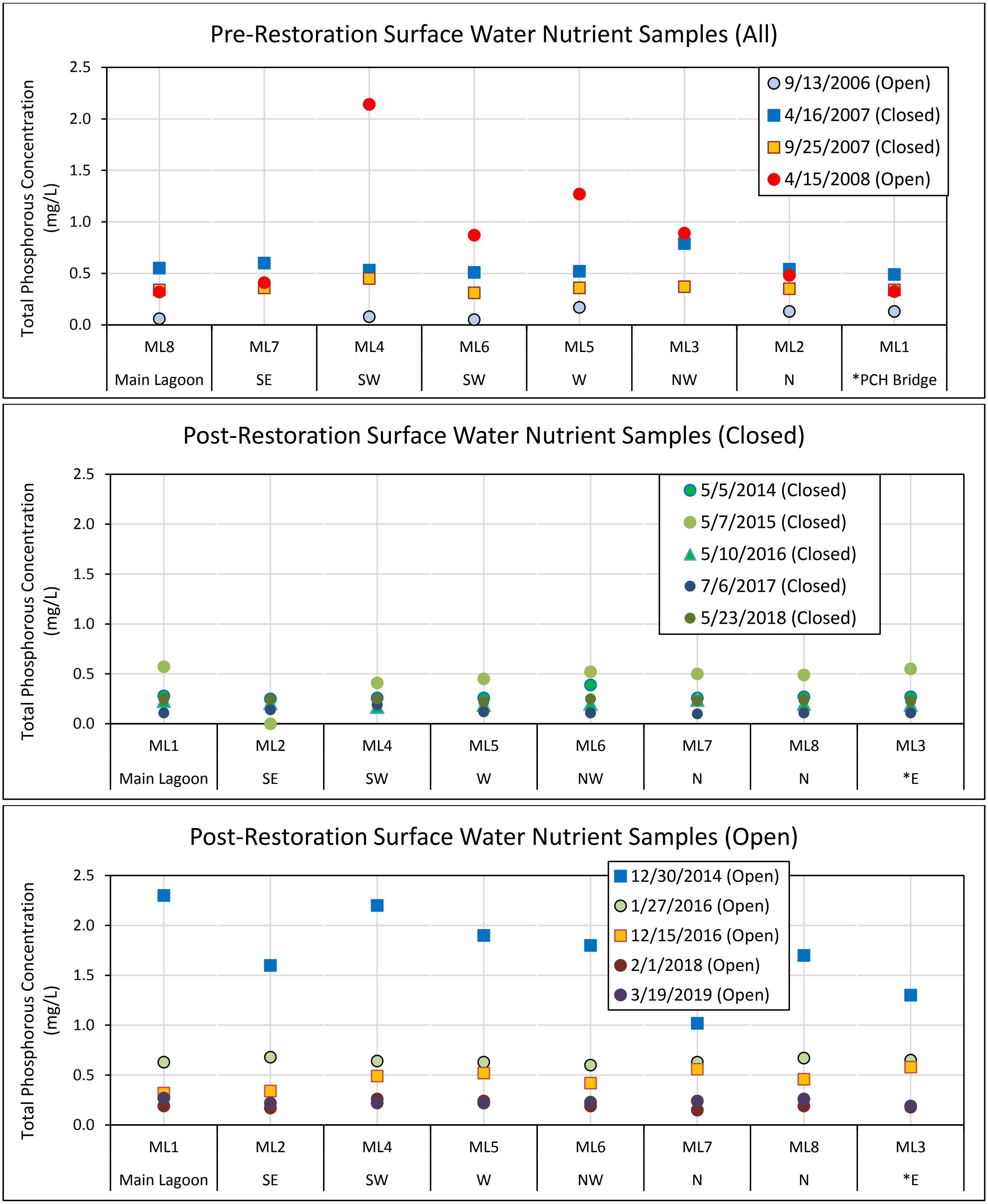


Figure 47. Pre-restoration surface water nutrient samples (top graph), post-restoration closed (middle graph), and post-restoration open condition (bottom graph) surface water nutrient samples for Total Phosphorous (mg/L).

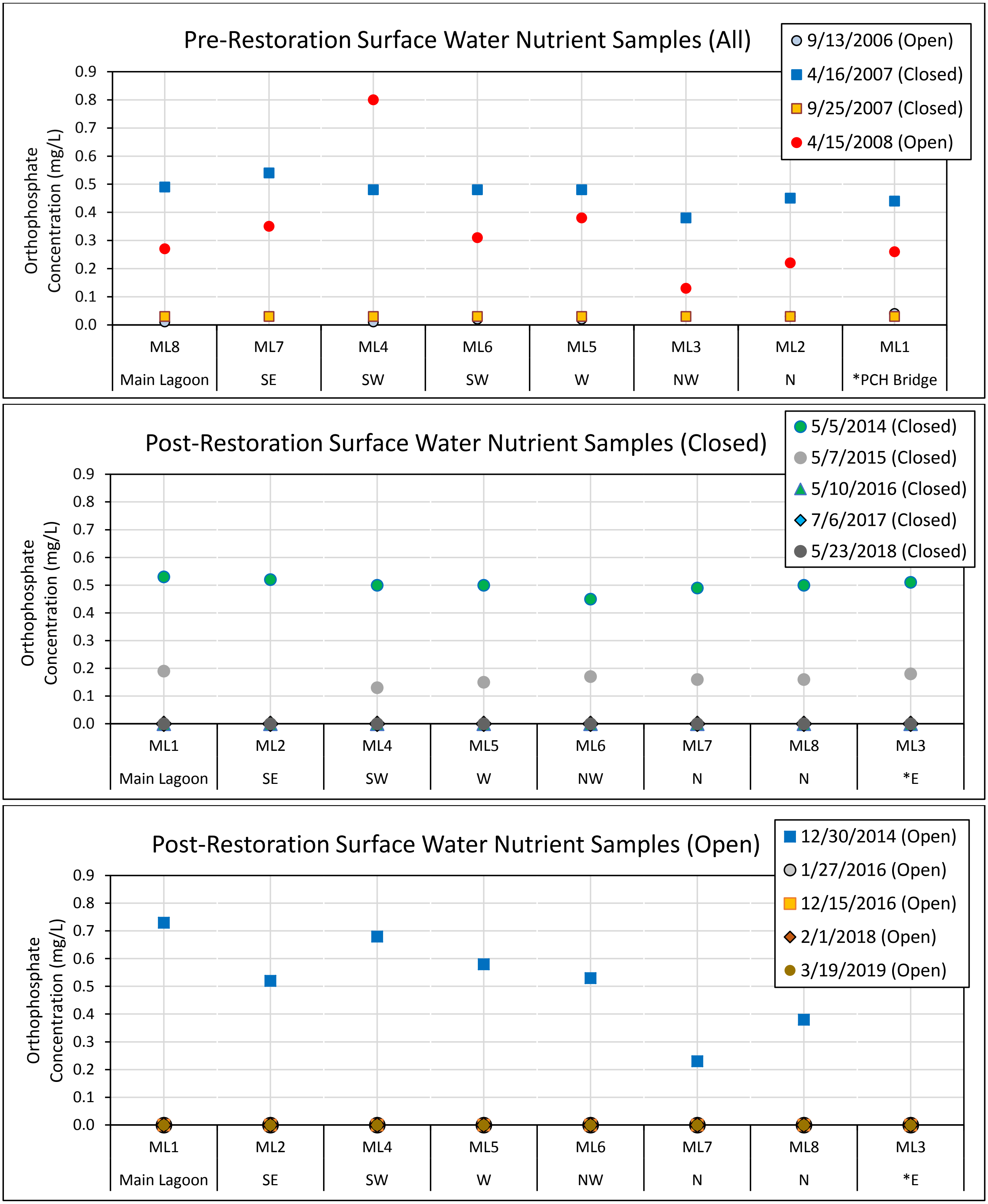
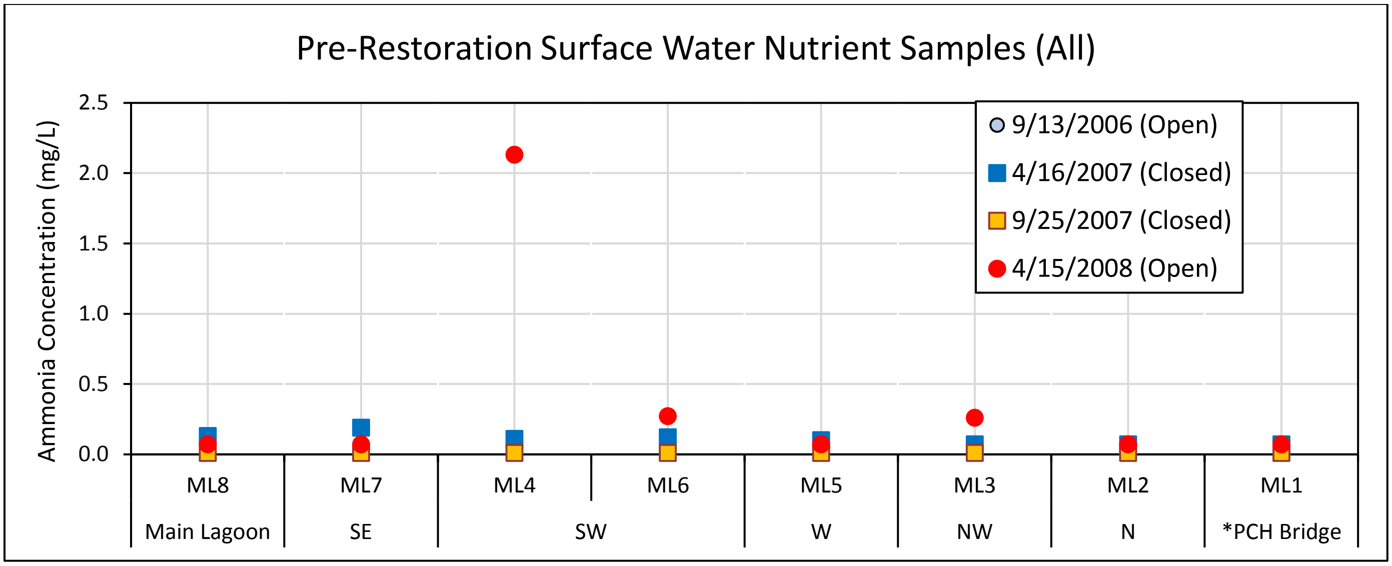
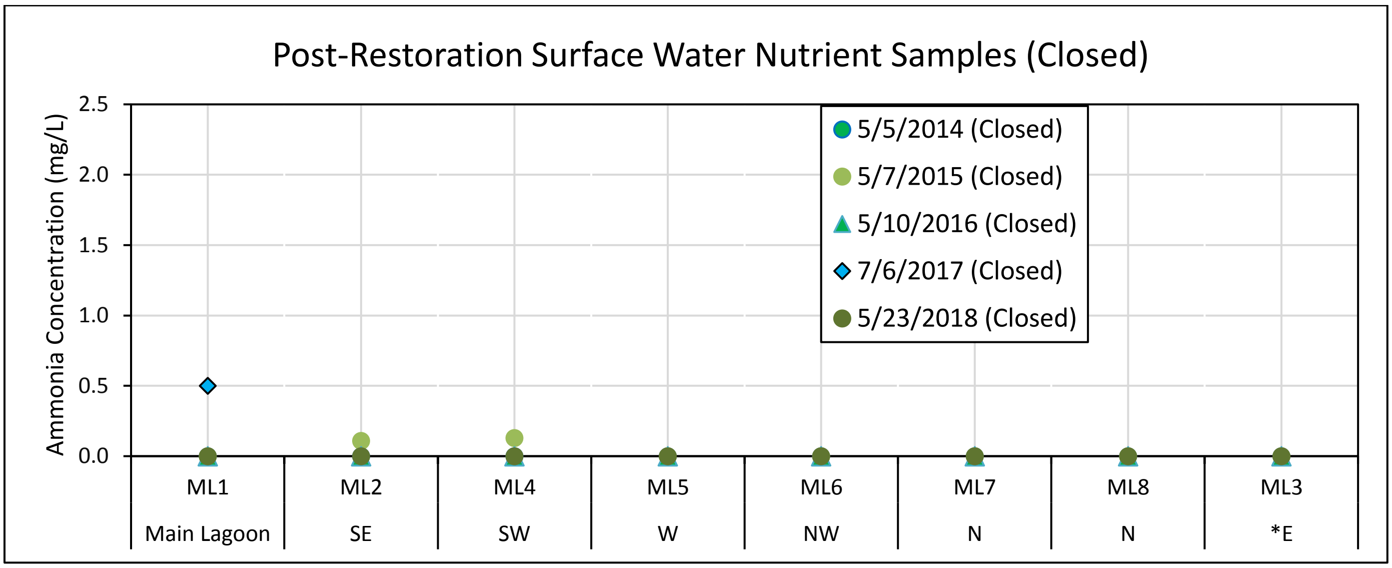


Figure 48. Pre-restoration surface water nutrient samples (top graph), post-restoration closed (middle graph), and post-restoration open condition (bottom graph) surface water nutrient samples for Orthophosphate (mg/L).





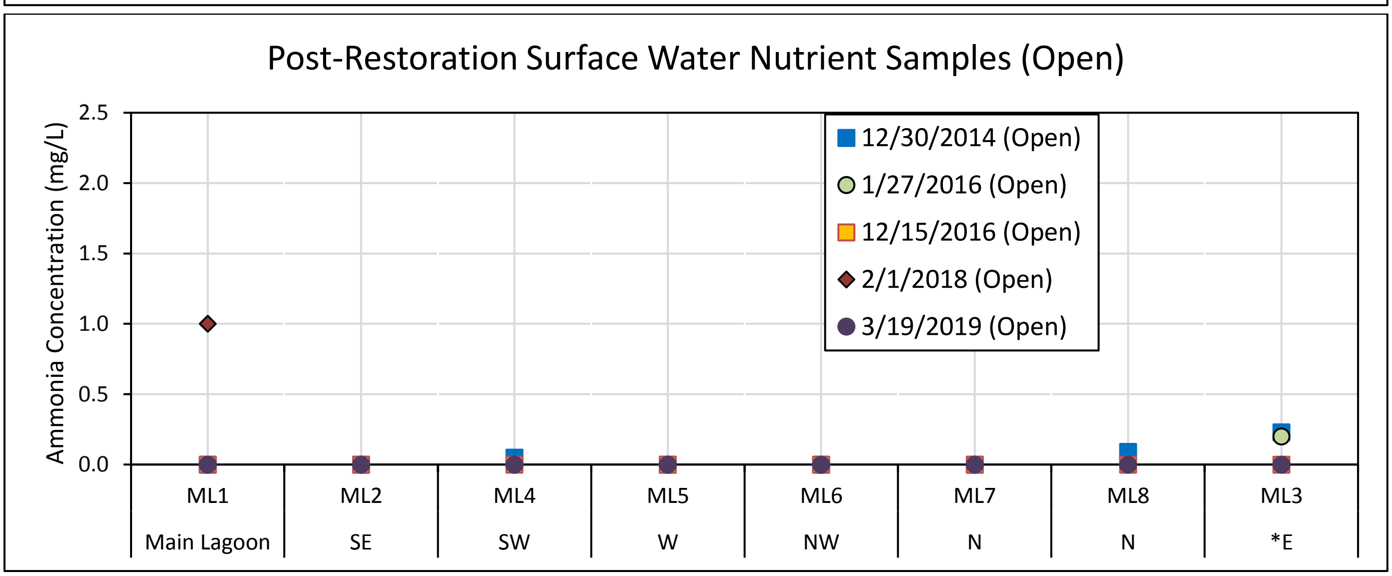
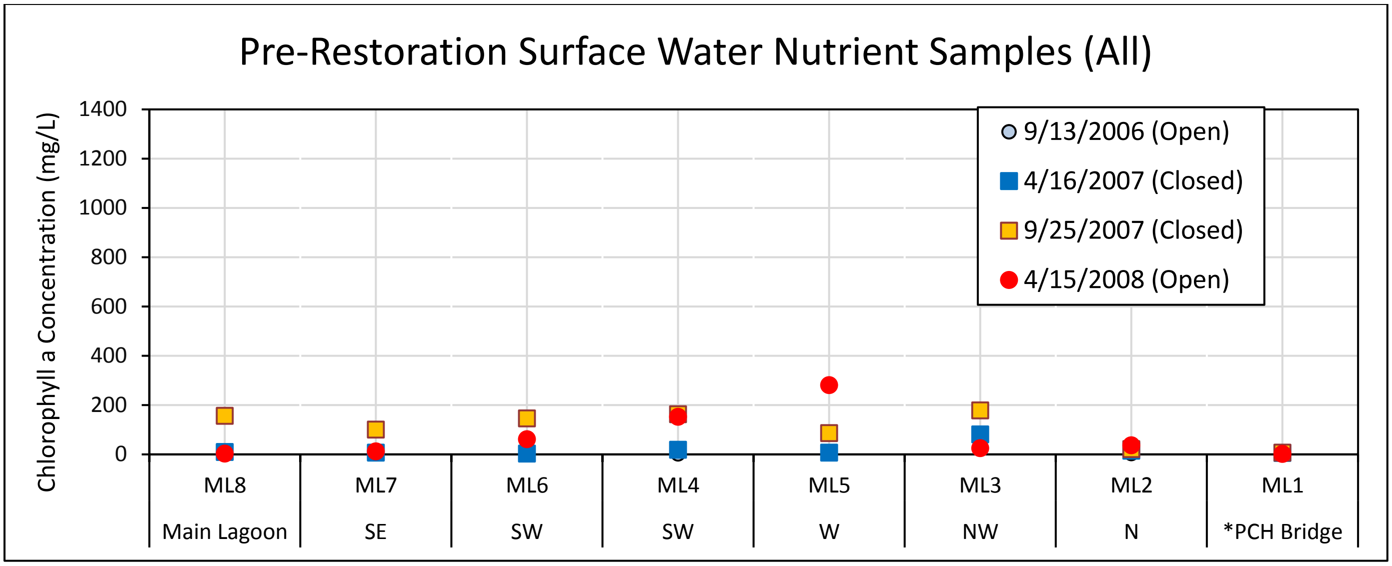
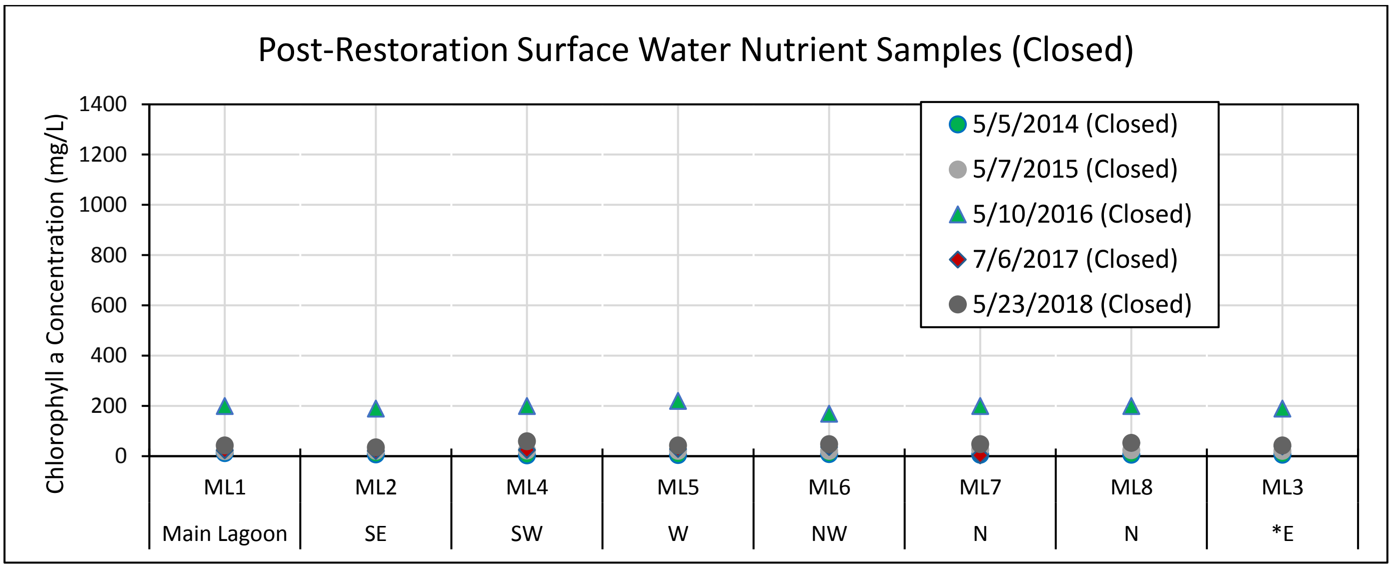


Figure 49. Pre-restoration surface water nutrient samples (top graph), post-restoration closed (middle graph), and post-restoration open condition (bottom graph) surface water nutrient samples for Ammonia (mg/L).





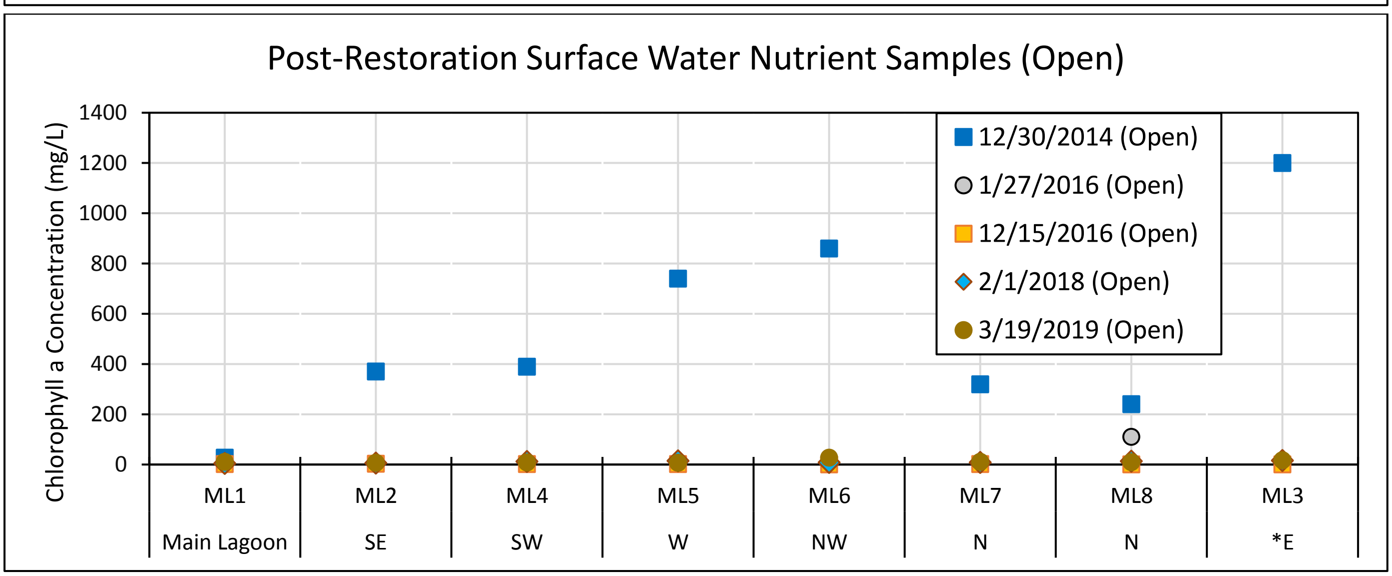


Figure 50. Pre-restoration surface water nutrient samples (top graph), post-restoration closed (middle graph), and post-restoration open condition (bottom graph) surface water nutrient samples for Chlorophyll a (mg/L).

Performance Evaluation

Although there were no specific quantitative success criteria identified for the water constituent sampling, six years of monitoring did not identify any areas of concern. Additionally, post-restoration data suggest declining numbers of TMDL bacteria exceedances and an increased "grade".

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 and trends over time. 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). Peaks in constituent data have not been seen since, even within the Tapia discharge period, and consistent low concentrations of nutrients remained present through the Year 6 surveys. Several constituents continued to register as 'non-detects' or effectively a zero reading for that constituent.

The winter of 2016 represented a wetter year than the previous four, and there were several rain events in the second half of November 2016 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. Similarly, most of the wet season of 2018-19 followed a significant event in the form of the Woolsey Fire, which could have had impacts on the water quality of the site. However, most of the readings conducted in March 2019, post-fire, were still recorded as 'non-detects' or zeroes.

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, they are no longer publicly reporting the exceedances. 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 29) on all other survey dates. Year 6 samples were collected on 12 July 2018 and 29 January 2019. 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.

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 51). 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, January 2018, July 2018, and January 2019 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.

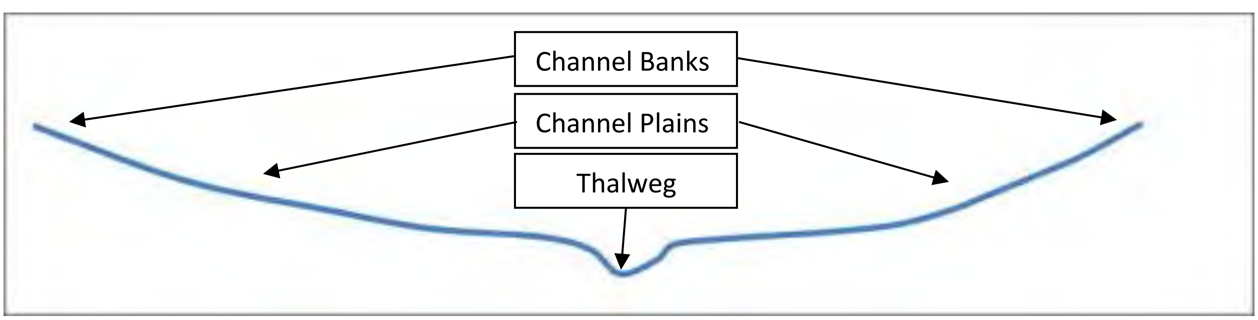


Figure 51. Representative channel cross section displaying the locations of sediment quality collection zones.

Sediment data were collected during pre-restoration conditions at four sampling locations (Figure 52) 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 52. 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). Post-restoration 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, but most samples, especially over the last several sampling events were shown to have higher proportions of sand and gravel than pre-restoration (where samples were dominated by silt). 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 11. 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 51). 'Channel' category for December 2014 is a composite of the 'Channel Banks' and 'Channel Plains' locations for both the left and right banks. Note: the laboratory alternated in providing either median grain size or 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	Coarse Sand
	3	Channel Banks	11.1	76.9	12.1	Coarse Sand
		Channel Plains	13.2	85.3	1.4	Coarse Sand
		Thalweg	4.1	81.1	14.8	Coarse 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	Coarse Sand
		Channel Plains	6.8	87.4	5.9	Very Coarse Sand
		Thalweg	0.8	79.2	20.0	Very Coarse 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	Coarse 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	Coarse 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

	Station	Location	Total Silt and Clay % (0 to 0.0625 mm)	Sand % (0.0625 mm to 2 mm)	Gravel % (>2 mm)	Mean Grain Size
July 2018	1	Channel Banks	19.30	52.16	16.65	Coarse Sand
		Channel Plains	7.07	92.93	0.00	Medium Sand
		Thalweg	42.97	57.03	0.00	Fine Sand
	2	Channel Banks	2.79	29.73	50.93	Very Coarse Sand
		Channel Plains	29.15	60.02	5.72	Medium Sand
		Thalweg	6.21	72.03	12.21	Coarse Sand
	3	Channel Banks	7.24	46.13	31.40	Very Coarse Sand
		Channel Plains	9.12	53.65	22.87	Coarse Sand
		Thalweg	29.87	70.13	0.00	Fine Sand
	4	Channel Banks	7.92	53.28	24.07	Very Coarse Sand
		Channel Plains	8.24	63.51	16.45	Coarse Sand
		Thalweg	20.61	66.99	6.61	Medium Sand
	5	Channel Banks	4.86	44.55	33.85	Very Coarse Sand
		Channel Plains	3.74	47.04	32.64	Very Coarse Sand
		Thalweg	24.52	59.20	8.86	Coarse Sand
	6	Channel Banks	12.79	73.07	7.61	Medium Sand
		Channel Plains	9.88	55.83	20.70	Very Coarse Sand
		Thalweg	42.23	45.18	6.72	Medium Sand
	7	Channel Banks	7.00	34.00	41.83	Very Coarse Sand
		Channel Plains	2.79	29.66	51.01	Very Coarse Sand
		Thalweg	6.30	35.20	41.35	Very Coarse Sand
	8	Channel Banks	2.95	46.14	34.14	Very Coarse Sand
		Channel Plains	23.07	30.19	30.50	Very Coarse Sand
		Thalweg	1.43	29.63	52.60	Very Fine Gravel

	Station	Location	Total Silt and Clay % (0 to 0.0625 mm)	Sand % (0.0625 mm to 2 mm)	Gravel % (>2 mm)	Mean Grain Size
January 2019	1	Channel Banks	1.82	96.99	1.19	Coarse Sand
		Channel Plains	29.10	70.91	0.00	Fine Sand
		Thalweg	85.33	14.68	0.00	Silt
	2	Channel Banks	6.16	87.15	6.70	Coarse Sand
		Channel Plains	1.13	84.7	14.17	Very Coarse Sand
		Thalweg	54.42	45.58	0.00	Fine Sand
	3	Channel Banks	4.86	74.67	20.48	Very Coarse Sand
		Channel Plains	40.97	59.02	0.00	Fine Sand
		Thalweg	73.52	26.48	0.00	Very Fine Sand
	4	Channel Banks	2.94	82.66	14.40	Very Coarse Sand
		Channel Plains	7.86	92.14	0.00	Medium Sand
		Thalweg	31.28	68.70	0.00	Medium Sand
	5	Channel Banks	2.40	79.31	18.29	Very Coarse Sand
		Channel Plains	51.86	48.15	0.00	Fine Sand
		Thalweg	1.31	77.83	20.85	Very Coarse Sand
	6	Channel Banks	4.77	76.53	18.70	Very Coarse Sand
		Channel Plains	46.75	53.24	0.00	Fine Sand
		Thalweg	71.21	28.79	0.00	Very Fine Sand
	7	Channel Banks	3.39	68.99	27.63	Very Coarse Sand
		Channel Plains	3.42	86.15	10.43	Coarse Sand
		Thalweg	65.03	34.97	0.00	Fine Sand
	8	Channel Banks	1.55	76.60	21.85	Very Coarse Sand
		Channel Plains	1.60	62.87	35.53	Very Coarse Sand
		Thalweg	1.09	41.89	57.00	Very Fine Gravel

Sediment Nutrients

Table 12 displays sediment nutrient values from all Stations for pre-restoration surveys; Table 13 displays post-restoration sediment nutrient values. Overall, nutrient concentrations were low in both Year 6 surveys, with only six combined detections of nitrate plus nitrite as N. Total Kjeldahl nitrogen (TKN) and total nitrogen (TN) concentrations remained relatively consistent across survey dates apart from several spikes in May 2015, which subsequently dropped, and remained low in both Year 6 surveys (Table 13). Previously in Year 5, all samples recorded as 'non-detect' for N in July 2017. 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 Year 5 and 6 surveys (Table 13), and lower, relatively, than pre-restoration data.

Table 12. Pre-restoration sediment nutrient data for all cross sections.

	Station	Location	Nitrate (mg/kg)	TN (mg/kg)	TKN (mg/kg)	TP (mg/kg)
September 2006	A	Channel Bank	2.10	61.80	59.80	325.00
		Channel Plain	1.00	107.00	107.00	327.00
		Thalweg	1.00	192.00	192.00	345.00
	B	Channel Bank	1.00	1600.00	1600.00	637.00
		Channel Plain	1.00	3450.00	3450.00	1160.00
		Thalweg	1.00	3040.00	3040.00	1020.00
	C	Channel Bank	1.00	2850.00	2850.00	839.00
		Channel Plain	1.00	2630.00	2630.00	1420.00
		Thalweg	1.00	3520.00	3520.00	965.00
	D	Channel Bank	1.76	439.00	438.00	385.00
		Channel Plain	1.00	1010.00	1010.00	640.00
		Thalweg	1.00	2233.33	2233.33	957.00
April 2007	A	Channel Bank	1.00	169.00	169.00	420.00
		Channel Plain	1.00	157.00	157.00	366.00
		Thalweg	1.00	314.00	314.00	457.00
	B	Channel Bank	1.00	1260.00	1260.00	565.00
		Channel Plain	1.00	2500.00	2500.00	776.00
		Thalweg	1.00	3300.00	3300.00	917.00
	C	Channel Bank	14.00	3260.00	3230.00	1180.00
		Channel Plain	1.00	2050.00	2050.00	651.00
		Thalweg	1.00	3500.00	3500.00	1290.00
	D	Channel Bank	1.00	592.00	592.00	296.00
		Channel Plain	1.00	1220.00	1220.00	505.00
		Thalweg	1.00	3610.00	3610.00	0.09
September 2007	A	Channel Bank	1.00	385.00	385.00	331.00
		Channel Plain	1.00	812.00	812.00	316.00
		Thalweg	1.00	3610.00	3610.00	0.09
	B	Channel Bank	1.00	612.00	612.00	402.00
		Channel Plain	1.00	1640.00	1640.00	511.00
		Thalweg	1.00	1210.00	1210.00	328.00
	C	Channel Bank	1.43	2466.00	2466.00	474.00
		Channel Plain	1.80	655.00	653.00	535.00
		Thalweg	1.00	1450.00	1450.00	253.00
	D	Channel Bank	1.00	466.00	466.00	289.00
		Channel Plain	1.00	296.00	296.00	332.00
		Thalweg	1.00	997.00	997.00	344.00

	Station	Location	Nitrate (mg/kg)	TN (mg/kg)	TKN (mg/kg)	TP (mg/kg)
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 13. Post-restoration sediment nutrient data for all cross sections.

	Station	Location	Nitrate + Nitrite, as N (mg/kg)	TN (mg/kg)	TKN (mg/kg)	TP (mg/kg)
May 2014	2	Channel Bank	2.11	630.00	628.00	704.00
		Channel Plain	2.22	754.00	752.00	588.00
		Thalweg	3.28	1921.00	1920.00	631.00
	3	Channel Bank	0.72	572.00	571.00	608.00
		Channel Plain	2.47	788.50	786.00	678.00
		Thalweg	0.66	1340.70	1340.00	575.00
	4	Channel Bank	0.51	276.00	276.00	245.00
		Channel Plain	2.47	788.50	786.00	678.00
		Thalweg	1.41	533.00	532.00	501.00
	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

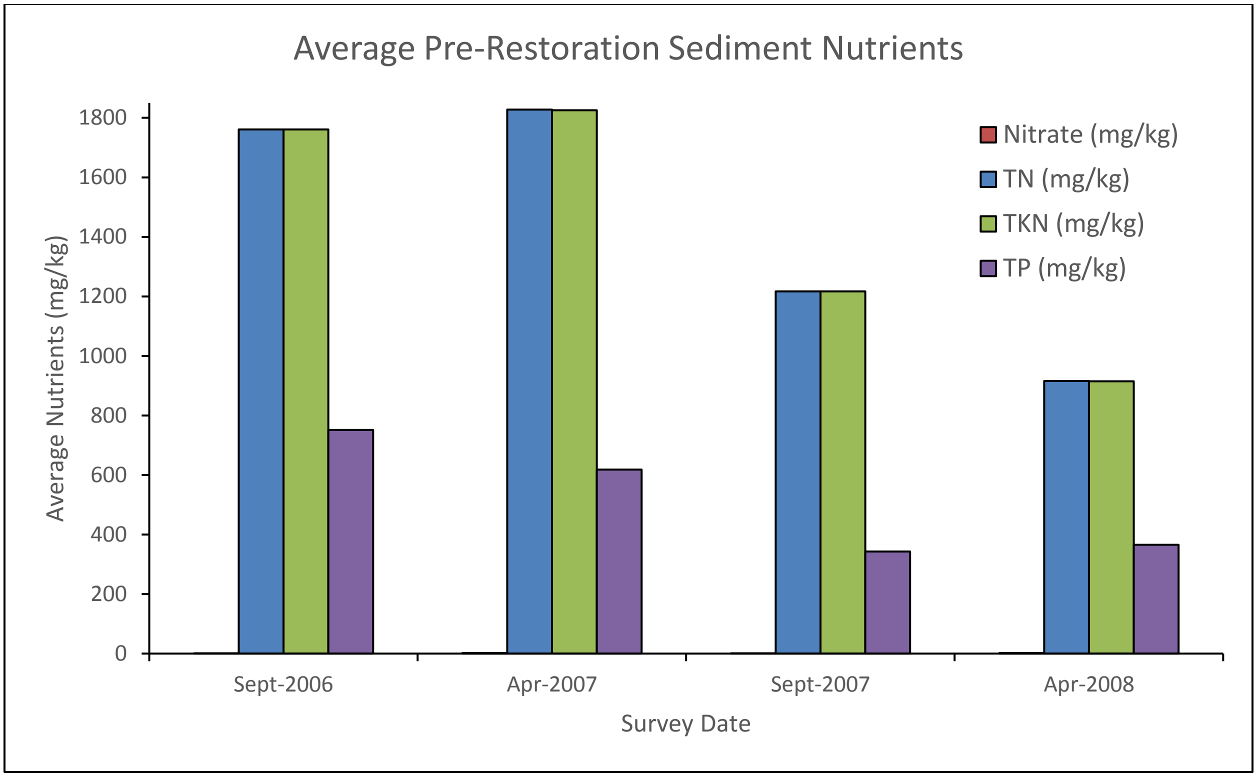
	Station	Location	Nitrate + Nitrite, as N (mg/kg)	TN (mg/kg)	TKN (mg/kg)	TP (mg/kg)
	6	Channel Bank	ND	910.00	910.00	310.00
		Channel Plain	ND	520.00	520.00	250.00
		Thalweg	ND	580.00	580.00	270.00
	7	Channel Bank	ND	690.00	690.00	390.00
		Channel Plain	ND	770.00	770.00	380.00
		Thalweg	ND	410.00	410.00	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

	Station	Location	Nitrate + Nitrite, as N (mg/kg)	TN (mg/kg)	TKN (mg/kg)	TP (mg/kg)
July 2018	1	Channel Bank	ND	54.00	54.00	230.00
		Channel Plain	ND	170.00	170.00	190.00
		Thalweg	ND	720.00	720.00	320.00
	2	Channel Bank	ND	99.00	99.00	310.00
		Channel Plain	ND	190.00	190.00	390.00
		Thalweg	ND	100.00	100.00	400.00
	3	Channel Bank	1.70	560.00	560.00	500.00
		Channel Plain	1.30	370.00	370.00	460.00
		Thalweg	ND	310.00	310.00	350.00
	4	Channel Bank	ND	390.00	390.00	570.00
		Channel Plain	ND	240.00	240.00	420.00
		Thalweg	ND	260.00	260.00	260.00
	5	Channel Bank	ND	210.00	210.00	420.00
		Channel Plain	ND	270.00	270.00	300.00
		Thalweg	ND	300.00	300.00	230.00
	6	Channel Bank	ND	320.00	320.00	450.00
		Channel Plain	ND	290.00	290.00	350.00
		Thalweg	ND	800.00	800.00	240.00
	7	Channel Bank	ND	460.00	460.00	520.00
		Channel Plain	ND	300.00	300.00	430.00
		Thalweg	ND	130.00	130.00	270.00
	8	Channel Bank	ND	670.00	670.00	340.00
		Channel Plain	ND	94.00	94.00	370.00
		Thalweg	ND	260.00	260.00	310.00
January 2019	1	Channel Bank	ND	110.00	110.00	270.00
		Channel Plain	ND	1100.00	1100.00	450.00
		Thalweg	ND	1100.00	1100.00	450.00
	2	Channel Bank	2.20	180.00	180.00	390.00
		Channel Plain	ND	340.00	340.00	690.00
		Thalweg	ND	600.00	600.00	310.00
	3	Channel Bank	ND	290.00	290.00	420.00
		Channel Plain	ND	240.00	240.00	350.00
		Thalweg	ND	570.00	570.00	340.00
	4	Channel Bank	2.10	110.00	110.00	260.00
		Channel Plain	ND	190.00	190.00	250.00
		Thalweg	ND	370.00	370.00	280.00

	Station	Location	Nitrate + Nitrite, as N (mg/kg)	TN (mg/kg)	TKN (mg/kg)	TP (mg/kg)
	5	Channel Bank	ND	140.00	140.00	410.00
		Channel Plain	ND	220.00	220.00	410.00
		Thalweg	ND	57.00	57.00	260.00
	6	Channel Bank	1.30	360.00	360.00	470.00
		Channel Plain	ND	340.00	340.00	380.00
		Thalweg	ND	280.00	280.00	230.00
	7	Channel Bank	ND	130.00	130.00	440.00
		Channel Plain	ND	280.00	280.00	410.00
		Thalweg	ND	260.00	260.00	320.00
	8	Channel Bank	1.80	160.00	160.00	380.00
		Channel Plain	ND	120.00	120.00	400.00
		Thalweg	ND	260.00	260.00	330.00

Figure 53 displays the sediment jars and labels in the field. The graphs in Figure 54 summarize the average differences in pre- (top graph) and post-restoration (bottom graph) sediment nutrients from all samples. Note the high pre-restoration sediment nutrients, especially for TKN and TN in the 2006 and 2007 samples. The y-axis for both graphs displays the same scale for ease of comparison. No increase in nutrient sequestration was seen. This trend was especially apparent in the averages displayed for the January 2018, July 2018, and January 2019 survey data, the most recent post-restoration surveys.

Figure 53. Intern from LMU's Coastal Research Institute labeling jars of sediment samples on 29 January 2019.



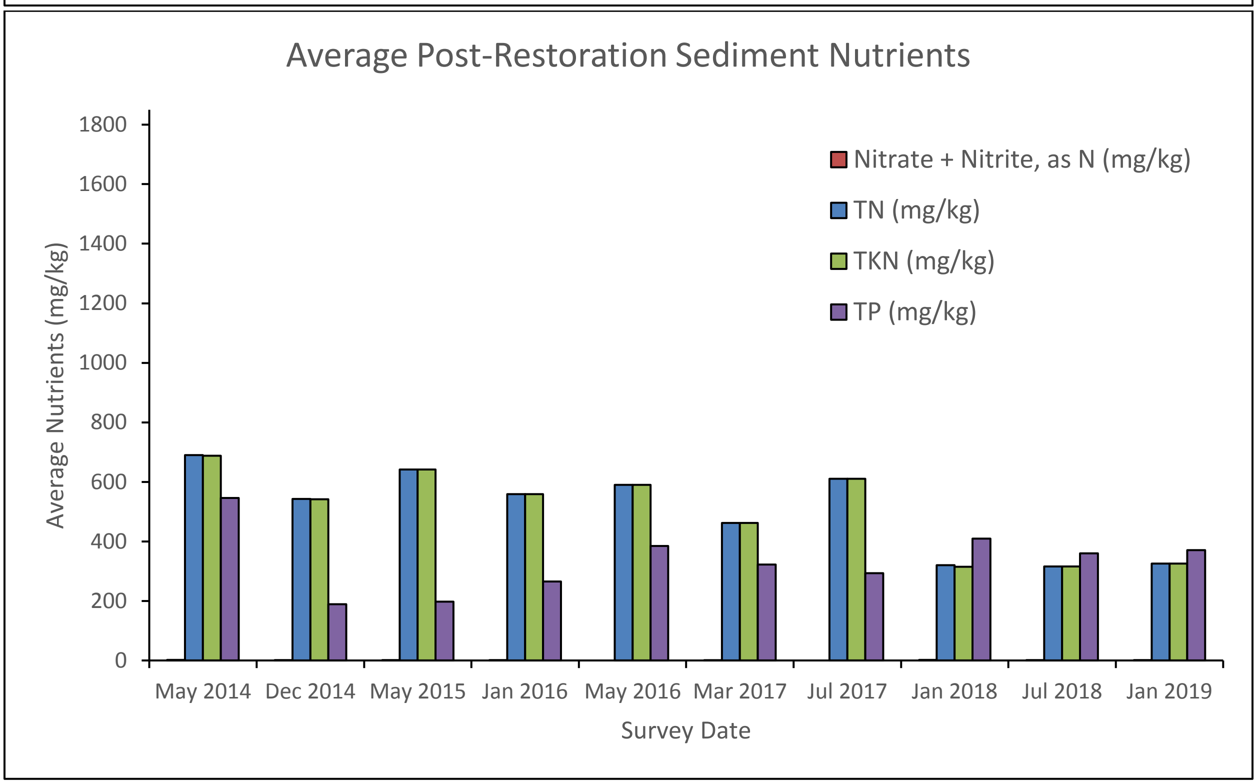


Figure 54. Sediment nutrient averages for all Stations combined for each pre- (top) and post-restoration (bottom) surveys. Note the same y-axis scale for ease of comparison.

Performance Evaluation

The trajectories of grain size distributions over the course of the six survey years were found to meet project success criteria, which specifies that grain size distribution should increase from the baseline monitoring conditions. Similarly, the restoration area was also meeting the sediment nutrient success criteria by not sequestering excess nutrients as compared to the pre-restoration conditions.

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 did not demonstrate any large-scale shifts in elevation, sediment grain size distributions are likely regularly fluctuating with variations in the hydrologic and sediment input regimes. The trajectories of grain size distributions over the course of the six survey years were found to meet project success criteria, which specifies that grain size distribution should increase from the baseline monitoring conditions. Several stations showed a long-term trend towards larger-grained sediments, especially sands and presence of small gravel. 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 nutrient averages were higher in pre-restoration surveys, especially for TKN and TN, than 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 supports the lower nutrient data results.

Sediment nutrient data have met the project success criteria, which includes reducing overall nutrient sequestering over time, based on lower nutrient maximum and average 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. Additionally, nutrients may have been sequestered into submerged aquatic vegetation (SAV), rather than being deposited in the sediments as SAV in the form of seagrasses were present throughout the last several years throughout the restoration area of the Lagoon. Lastly, nutrient values may 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 was observable improvements in the establishment and persistence of native organisms. Biological monitoring components were 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 included biological sampling across multiple seasonal parameters 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 6 of the monitoring program, though opportunistic monitoring may continue if funding is acquired.

The objectives of the biological monitoring of the Malibu Lagoon were as follows:

- Assess the habitat and vegetation changes towards restoration goals and criteria;
- Document the fish and bird communities' use of the site; and
- Provide timely identification of any challenges 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; targeted bivalve surveys; fish presence and abundance; avifauna presence and abundance; Submerged Aquatic Vegetation (SAV) and 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 29) on 5 May 2014, 30 December 2014, 21 January 2016, 8 March 2017, 24 January 2018, 13 April 2018, and 26 March 2019 using two different methods: 1) bank net sweeps, and 2) benthic cores, as described in the Monitoring Plan (Figure 55). The March 2017 and 2019 dates were later in the year due to a higher number of rain events, which delayed surveying. The April 2018 survey was added to capture multiple survey dates within a single year. Post-restoration data are compared to pre-restoration data from 13 September 2006 and 26 September 2007. Benthic invert speciation and taxonomy was conducted by scientific experts, Dancing Coyote Environmental and their subcontractors. See SMBRF 2012 for detailed benthic invertebrate collection and processing methods. Additional targeted invertebrate surveys were conducted on 12 July 2018 and 25 July 2018 using large cores and sieves to capture larger invertebrates. Both surveys were conducted specifically in closed berm conditions to assess a larger portion of the wetland habitats outside of just the targeted stations. The July 2018 surveys consisted of sampling more than 50 cores along the perimeter of the wetland areas. Once sieved *in situ*, anything removed was then returned directly to the lagoon. Additional visual assessment surveys were conducted throughout the perimeter of the lagoon multiple times over the course of the post-restoration survey years. Additional surveys recording presence and notes on invertebrates identified on other surveys such as those for SAV and algae were also conducted. Data were not quantifiably comparable to the core and net sweep surveys.

Invertebrate data were analyzed by lowest possible taxon and 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). Those more tolerant of pollution are sometimes used as indicators of more disturbed habitats.

Figure 55. Photographs of invertebrate survey team prepping for water quality sampling and benthic coring (photos taken on the 26 March 2019 survey).

Results

Cumulative data across all core and net sweep surveys included 52 taxa across 7 phyla and 14 classes represented in the post-restoration surveys. Benthic core surveys identified 42 taxa, and net sweep surveys identified 21 taxa (Tables 14a and 14b). Figures 27 and 28 display data from the 2006 and 2007 pre-restoration surveys, and all of the post-restoration surveys, including March 2019 (Year 6). Post-restoration abundances were dominated by oligochaetes, polychaetes, and ostracods. Several indicator species that have a high sensitivity to disturbance were present across multiple post-restoration surveys and multiple years. For example, *Traskorchestia sp*. a talitrid amphipod, was found across three surveys in the past several years. These species are more tolerant of a stable, less disturbed system (WoRMS, accessed June 2019).

Data were also reported using the pollution tolerance values established for freshwater invertebrate species (CAMLnet, CA Fish and Wildlife, 2003). Scores of 8-10 were 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. One example is organisms in the Tubificidae family, which have a pollution tolerance value of "5", indicating sensitivity to pollution (CAMLnet 2003). This group of organisms was identified on every benthic core survey since December 2014, and dominated one of the recent surveys in April 2018, accounting for approximately 91% of the total number of organisms.

The benthic core data suggested a long-term trend of decreasing pollution-tolerant species presence and abundances post-restoration, especially as indicated from the 8.9% sensitive species by abundance from 2007 to the 100.0% sensitive species by abundance identified in both the January and April 2018 surveys (Figure 57a). The March 2019 trend showed a high presence of disturbance species, primarily driven by pollution-tolerant ostracods (Order: Podocopida), which may have been opportunistically utilizing the restoration area nearshore environments after the Woolsey Fire, sediment input to the system, and the rain disturbances. This data pulse should not be evaluated independently from the long-term trend of decreasing abundances and numbers of pollution-tolerant taxa exhibited over the last several years of data collection. Post-restoration benthic core data were frequently dominated by oligochaetes (sensitive taxa), with additional gastropod molluscs and others.

Post-restoration net sweep abundance 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. All post-restoration years show a reduction in pollution-tolerant abundances of invertebrate taxa as compared to the average of pre-restoration survey abundances. Conversely as compared to the benthic core data, the last several years of surveys of the net sweep data suggest the percent abundances of sensitive species increasing over time, with all surveys after the January 2016 survey showing 89% or higher percent abundances of sensitive species (Figure 58a).

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 an increase in sensitive (pollution-intolerant) species use of the site as a trend on the post-restoration surveys, and a decrease in the percent of number of pollution tolerant taxa (Figures 57b and 58b). This data trend was present across all evaluation metrics for the April 2018 data (100% sensitive species in both core and net sweep data, Figures 57 and 58). The March 2019 net sweep data continued to show high abundances of pollution-sensitive taxa (88%) as compared to the pre-restoration data (6.4% and 8.3%, respectively).

In the supplemental core and visual assessment surveys, shells were identified as belonging to various species of *Chione* and partial shells that belonged to individual(s) of a larger unidentifiable bivalve. Additionally, multiple individuals across several stations were found of various species of polychaete (unidentifiable in the field), multiple species of barnacle and limpet, and shore crabs (*Pachygrapsus* and *Hemigrapsus*). Bivalve shells were commonly seen throughout the restoration area, especially in the larger channels. While all were not identified to species, blue mussels were commonly seen (*Mytilus spp.*, Figure 56) along with various species of *Chione*. Individuals of several additional species have also been identified in rockier areas of the site, including a rock crab (likely *Cancer productus*), blue mussels, and black turban snails (*Tegula funebralis*). Additionally, black sea hares (*Aplysia vaccaria*) and small anemones (*Anthopleura sp*.) were identified. For additional supplementary invertebrate data collected during the fish seining events, see the Fish Community chapter (below).

Figure 56. Photographs of blue mussels (*Mytilus spp*.) commonly found within restoration area (19 January 2019).

Table 14a. Taxa presence list for all infauna core post-restoration surveys combined. The May 2014 surveys were conducted in a closed berm condition. An orange highlighted cell indicates a new taxon for Year 6 that was not previously reported.

Phylum	Class	Order	Family	Lowest Possible Taxon	Benthic Cores						
					* May 2014	Dec 2014	Jan 2016	Mar 2017	Jan 2018	Apr 2018	Mar 2019
Annelida	Oligochaeta	Haplotaxida	Tubicidae	Tubicidae	X						
Annelida	Oligochaeta	Haplotaxida	Tubificidae	Tubificidae		X	X	X	X	X	X
Annelida	Polychaeta	Errantia	Nereididae	*Platynereis bicanaliculata*						X	
Annelida	Polychaeta	Sedentaria	Capitellidae	*Capitella capitata* complex		X	X		X	X	
Annelida	Polychaeta	Sedentaria	Capitellidae	*Mediomastus sp.*						X	
Annelida	Polychaeta	Sedentaria	Opheliidae	*Armandia brevis*		X					
Annelida	Polychaeta	Sedentaria	Spionidae	*Polydora cornuta*	X	X					
Annelida	Polychaeta	Sedentaria	Spionidae	*Polydora nuchalis*	X			X	X	X	
Arthropoda	Ichthyostraca	Harpacticoida	----	Harpacticoida						X	
Arthropoda	Collembola	----	----	Collembola						X	
Arthropoda	Insecta	Coleoptera	Caraboidea	Carabidae							X
Arthropoda	Insecta	Coleoptera	Dytiscidae	Hydroporinae	X						
Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Enochrus sp.*	X						
Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Hydrochus sp.*	X						
Arthropoda	Insecta	Coleoptera	Staphylinidae	Staphylinidae					X		
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae							X
Arthropoda	Insecta	Diptera	Chironomidae	Chronomini	X	X	X			X	
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae				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	Hemiptera	Corixidae	Corixidae	X						X
Arthropoda	Insecta	Hemiptera	Corixidae	*Trichocorixa sp.*	X						
Arthropoda	Malacostraca	----	----	Unknown larva							X

Phylum	Class	Order	Family	Lowest Possible Taxon	Benthic Cores						
					* May 2014	Dec 2014	Jan 2016	Mar 2017	Jan 2018	Apr 2018	Mar 2019
Arthropoda	Malacostraca	Amphipoda	Ampithoidae	*Ampithoe sp.*						X	
Arthropoda	Malacostraca	Amphipoda	Corophiidae	*Monocorophium insidiosum*				X			
Arthropoda	Malacostraca	Amphipoda	Gammaridae	*Gammarus sp.*		X			X		X
Arthropoda	Malacostraca	Amphipoda	Talitridae	*Traskorchestia sp.*				X	X	X	
Arthropoda	Malacostraca	Decapoda	----	Decapoda						X	
Arthropoda	Malacostraca	Isopoda	Sphaeromatidae	Sphaeromatidae							X
Arthropoda	Maxillopoda	Calanoida	----	Calanoida	X		X				
Arthropoda	Maxillopoda	Harpactacoida	----	Harpactacoida			X				
Arthropoda	Ostracoda	Podocopida	----	Podocopida	X	X	X	X			X
Arthropoda	Ostracoda	Podocopida	Cytheroidea	Cytheroidea						X	
Arthropoda	Ostracoda	Podocopida	Cypridoidea	Cypridoidea					X		X
Arthropoda	Ostracoda	Podocopida	Dawinulocopina	Dawinulocopina					X		X
Chordata	Osteichthys	----	----	Fish egg/larva	X						
Mollusca	Gastropoda	Cephalaspidea	Haminoeidae	*Haminoea vesicula*					X		
Mollusca	Gastropoda	Saccoglosa	Hermaeidae	*Alderia willowi*	X				X		
Nematoda	Adenophorea	Mermithida	Mermithidae	Mermithidae	X	X	X				
Nemertea	Anopla	Paleonemertea	----	Paleonemertea	X						
Platyhelminthes	Turbellaria	Rhabdocoela	----	Rhabdocoela	X						

Table 14b. Taxa presence list for all net sweep post-restoration surveys combined. The May 2014 surveys were conducted in a closed berm condition. An orange highlighted cell indicates a new taxon for Year 6 that was not previously reported.

Phylum	Class	Order	Family	Lowest Possible Taxon	Net Sweeps						
					* May 2014	Dec 2014	Jan 2016	Mar 2017	Jan 2018	Apr 2018	Mar 2019
Annelida	Oligochaeta	----	----	Oligochaeta	X	X	X	X	X		X
Annelida	Oligochaeta	Haplotaxida	Tubificidae	Tubificidae						X	
Annelida	Polychaeta	Sedentaria	Spionidae	*Polydora cornuta*		X					
Arthropoda	Insecta	Coleoptera	Hydrophilidae	*Enochrus sp.*	X						
Arthropoda	Insecta	Diptera	Ceratopogonidae	Ceratopogon				X			
Arthropoda	Insecta	Diptera	Ceratopogonidae	Dasyhelea	X				X		
Arthropoda	Insecta	Diptera	Chironomidae	Chronomini	X	X	X	X			
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae					X	X	X
Arthropoda	Insecta	Diptera	Chironomidae	Tanytarsini				X			
Arthropoda	Insecta	Diptera	Dolichopodidae	Dolichopodidae	X			X			
Arthropoda	Insecta	Diptera	Ephydridae	Ephydridae				X	X		X
Arthropoda	Insecta	Diptera	Psychodidae	Psychodidae				X			
Arthropoda	Insecta	Hemiptera	Corixidae	Corixidae	X		X				
Arthropoda	Insecta	Hemiptera	Corixidae	*Trichocorixa sp.*	X						
Arthropoda	Malacostraca	Amphipoda	Corophiidae	*Americorophium sp.*				X			
Arthropoda	Malacostraca	Amphipoda	Hyalellidae	Hyalella				X	X		X
Arthropoda	Ostracoda	----	----	Ostracoda		X	X	X	X		X
Arthropoda	Ostracoda	Podocopida	----	Podocopida	X						
Mollusca	Bivalvia	Veneroida	Corbiculidae	*Corbicula sp.*					X		
Mollusca	Gastropoda	----	----	Gastropoda					X		
Mollusca	Gastropoda	Saccoglosa	Hermaeidae	*Alderia willowi*					X		

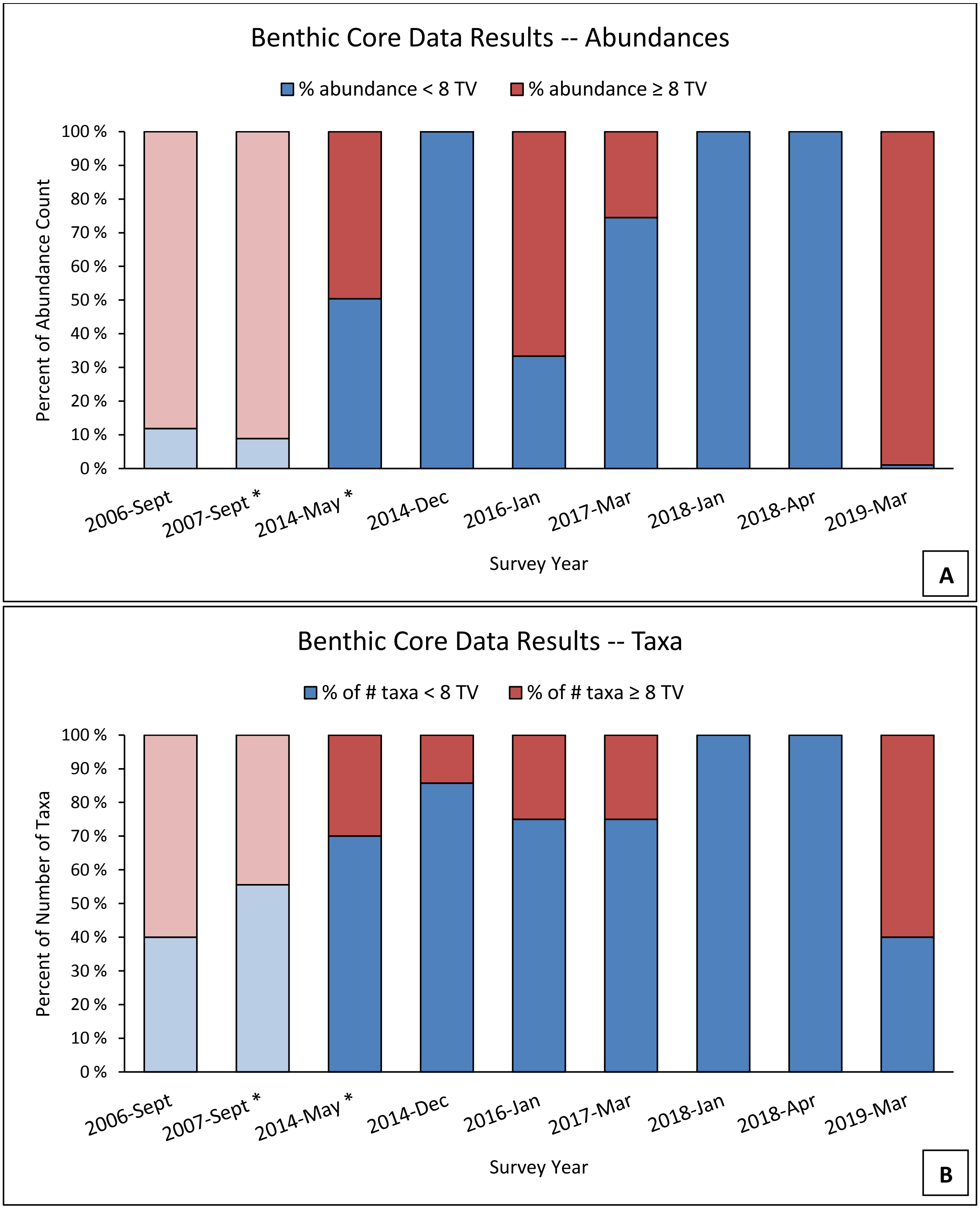


Figure 57. Benthic invertebrate core data results organized by (A) percent of abundance count data with pollution tolerance values (TV) below 8, and (B) percent of number of taxa with TV below 8. Asterisks indicate a closed berm condition. Light colors on the left represent pre-restoration survey data.

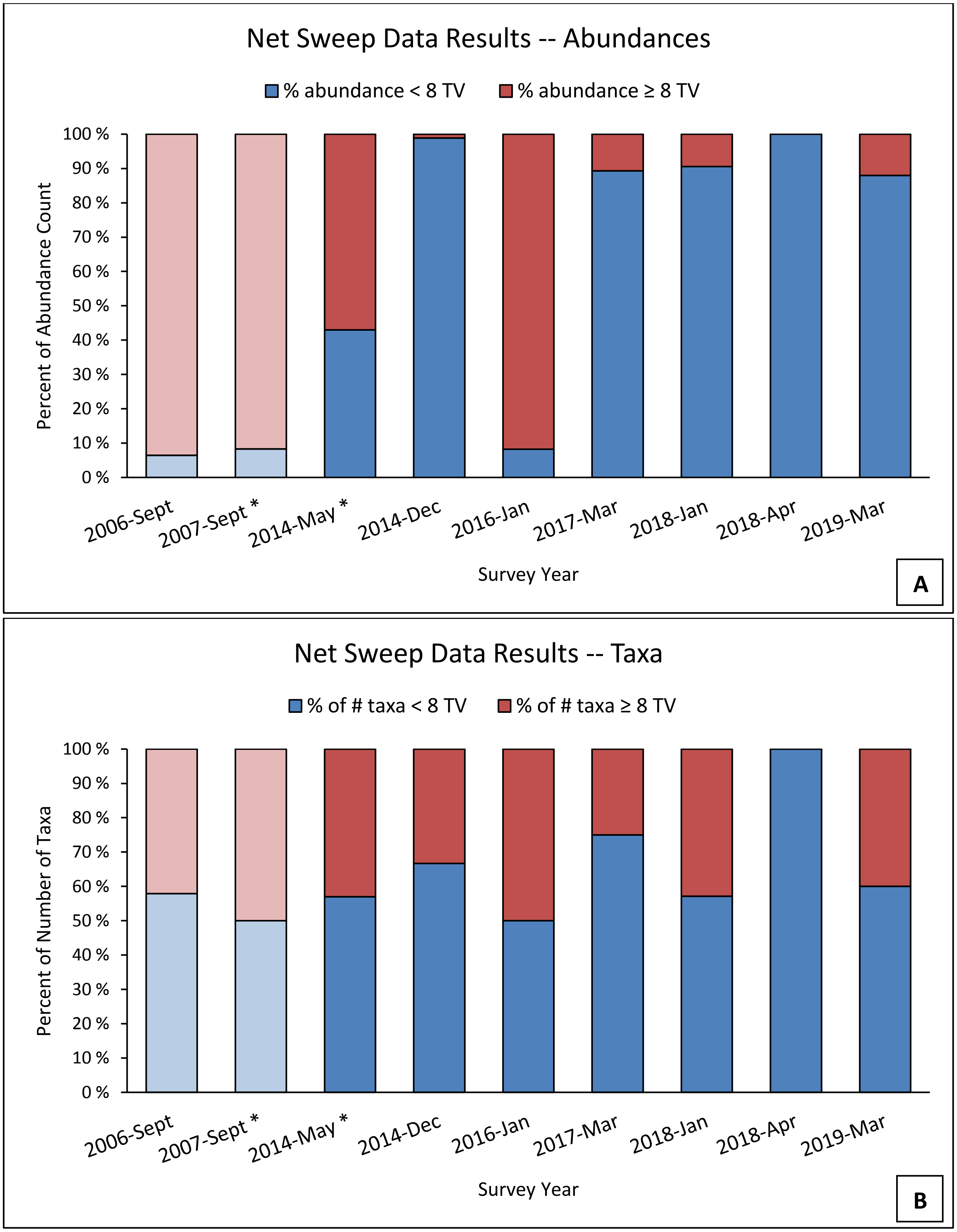


Figure 58. Net sweep invertebrate data results organized by (A) percent of abundance count data with pollution tolerance values (TV) below 8, and (B) percent of number of taxa with TV below 8. Asterisks indicate a closed berm condition. Light colors on the left represent pre-restoration survey data.

Performance Evaluation

The abundances and numbers of pollution sensitive benthic invertebrate taxa are higher than pre-restoration conditions and did not exhibit decreases across multiple years; thus, the benthic community is meeting the project goals and permitting success criteria.

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 has fluctuated slightly over the years, depending on conditions during that sampling year. However, the overall community exhibited a trend back towards pollution-sensitive taxa in the 2017 and both sets of 2018 data results, showing 100% pollution-sensitive abundances and number of taxa for both benthic core data in 2018 (i.e., January and April data).

An important consideration when reviewing the invertebrate data is the potential impacts to the wetlands from the Woolsey Fire in November 2018 and the subsequent rain events that followed, bringing significant amounts of sediment, debris, and burned materials down the watershed into the main lagoon and adjacent areas. Sedimentation is analyzed in more detail in the physical cross-section survey chapter of this report, but the invertebrate results may be a proxy indicator for fire impacts and may be reflected in some of the data from the March 2019 survey event. 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 and 2019 as well. The data are likely to continue to fluctuate slightly over time.

Taxa indicate a variety of estuarine condition preference ranging from marine to freshwater, though there are more marine (oceanic water) species as compared to pre-restoration data, which was dominated by freshwater-dependent 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 some of the evaluations 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, sea hares, and many other invertebrates that were not common or in some cases present prior to the restoration continue to support the robust nature of the invertebrate 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 was to track changes in uses by different fish species within the restored habitat areas. Summary information is included in the subsections below, with additional details and photographs included in Appendices 1 and 2 (June 2018 and February 2019, respectively).

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, 30 January 2018, 19 June 2018 (Year 6), 20 February 2019 (Year 6), and 17 July 2019 (Year 6). The lagoon (berm) was closed to the ocean for the June 2018 survey, open for the February 2019 survey, and closed for the July 2019 survey. A total of twelve surveys (six open and six closed berm surveys) have been completed since the restoration of the wetland channels were completed in 2013. Additional spot checks were conducted at a subset of sampling locations on 3 October 2018 and 6 November 2018. Surveys were led by the Resource Conservation District of the Santa Monica Mountains with assistance from State Parks, 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. Attempted spot surveys between 2005 and 2012 documented low numbers of native fish species, an abundance of invasive non-native fishes, and areas of anoxic ‘dead zones’ that grew larger over time providing less habitat for native fish species.

Six permanent sites were seined to depletion and spot surveying was conducted at three places along the banks of the Main Lagoon (Figures 59 and 60). 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. Subsequent to that survey event, 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 presumed to be higher than the final numbers included in this report.

Figure 59. Map of the six permanent fish monitoring Sites.

Figure 60. Photograph from fish survey on 20 February 2019 (Site 1).

2018 Disturbance Events

In August 2018, warming waters and an extended closed berm condition led to a low dissolved oxygen event that caused a die off of mullet (Figure 61). Additional vertical profile surveys and water quality analyses were conducted (see other chapters in this report). As part of an impact assessment, supplemental spot fishing surveys were conducted on 3 October 2018 and 6 November 2018.

Figure 61. Photographs of mullet and water quality spot sampling on 23 August 2018.

Additionally, in 2018, the Woolsey Fire burned most of the Malibu Creek Watershed, with extensive sediment and burned debris moving down the watershed and into the mouth of the estuary. The February 2019 survey was completed after the fire and several subsequent rain events, which may have impacted the results. Extensive sediment input to the system caused Site 3 and 5 to be reduced to spot seining only, rather than the full triangle pattern seine deployment. Spot seining at Site 3 was halted due to a large number of juvenile gobies captured on the first pull. The February 2019 survey results should not be evaluated alone, but instead as part of a long-term monitoring dataset.

Results

For detailed water quality parameter measurements, fish species counts, and incidental invertebrate capture counts for each survey, see Appendices 1, 2, and 3 and the previous post-restoration baseline reports (Abramson et al. 2013, 2015, 2016, 2017, and 2018). Table 15 displays presence data for each species captured or observed during each of the fishing survey dates, including the federally endangered tidewater goby (*Eucyclogobius newberryi*, Figure 62). 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, including tidewater goby. Each post-restoration survey is summarized below, with additional details in Appendices 1-3.

Figure 62. Photograph of captured and released federally endangered tidewater goby taken on 17 July 2019 (credit: R. Dagit, RCDSMM).

Table 15. 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	Jun 2018 *	Feb 2019	Jul 2019 *
Arrow goby	*Cleavlandia ios*			X										
Bay goby	*Lepidogobius lepidus*			X										
California killifish	*Fundulus parvipinnis*	X		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	X	X	X
Northern anchovy	*Engraulis mordax*		X		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	X	X	
Striped mullet	*Mugil cephalus*			X	X	X	X	X	X	X	X	X	X	X
Tidewater goby	*Eucyclogobius newberryi*	X	X	X		X		X	X	X		X	X	X
Topsmelt	*Atherinops sp.*	X	X	X	X	X	X	X	X	X	X	X		X
Topsmelt larva (< 5 cm)	*Atherinops sp.*			X		X	X	X	X	X	X	X		
Unidentified goby larva (< 5 cm)	----									X	X			X
Unidentified fish larva (< 5 cm)	----			X		X		X		X				
Unidentified smelt larva (< 5 cm)	*Atherinops sp.*			X		X	X					X		X
Non-Native Fish														
Mississippi silversides	*Menidia berylina*		X		X	X	X	X		X	X	X		X
Mosquitofish	*Gambusia affinis*	X	X	X	X	X	X	X	X	X		X		X
Carp	*Cyprinus carpio*	X		X						X				
Largemouth Bass	*Micropterus salmoides*													X

January 2013 Survey

The five native fish species documented in the first post-construction survey (January 2013, Table 15) reflect the winter, marine influenced conditions, as compared to the five native species observed in the June pre-construction survey of 2005. Tidewater gobies (*Eucyclogobius newberryi*) were observed in both the pre- and post-construction surveys. No opaleye (*Girella nigricans*) or long-jawed mudsuckers (*Gillichthys mirabilis*) were captured in January 2013, although numerous long-jawed mudsuckers were moved from the work area to the main lagoon in June 2012. Oriental shrimp and mosquitofish (*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 15). Additionally, striped mullet and carp were observed jumping throughout the lagoon, but none were captured in the nets. A single, adult steelhead trout (*Onchorhynchus mykiss*) was observed swimming near Site 3 and estimated to be approximately 20 inches long. 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. Additionally, striped mullet were observed throughout the lagoon, but only small juveniles (< 5 cm) were captured in the nets. These identifications are based on review of voucher specimens by Dr. Rick Freeney at the Natural History Museum in February 2015.

May 2015 Survey

The dominant identifiable fish species captured in seine nets was topsmelt, which was present in at least three size classes (<5cm, <15cm, >15cm). The second and third dominant species were juvenile tidewater goby and long-jawed mudsuckers. Striped mullet (*Mugil cephalus*), and non-native mosquitofish and Mississippi silversides were also present. Larval fish (<5cm) were the most abundant category sampled (n=3,235) but were not identifiable in the field due to their small size. Those species are described in Table 15 as 'unidentified fish larva' and 'unidentified smelt larva.' Voucher larval fish specimens indicate there are at least three distinct species present.

January 2016 Survey

The dominant identifiable fish species captured in seine nets during this survey was Northern anchovy (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. 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 eight 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 suggested that Malibu Lagoon was serving as a nursery site for both lagoon and ocean species at the time.

June 2018 Survey

A total of five juvenile tidewater gobies were captured during seining. Striped mullet were observed jumping throughout the lagoon and swimming away as nets were being deployed. The dominant species surveyed was topsmelt (larva n=3,128, juveniles n=15, adult n=2), followed by unidentified recently hatched smelt larva (n=2,400). A total of 10 longjawed mudsucker larvae and one adult were also observed. In addition, 12 staghorn sculpin juveniles and two adults were observed. The majority of individuals collected were extremely young larval or juvenile fish, which suggests that the Malibu Lagoon was serving as a nursery site for both lagoon and ocean species at the time.

August, October, November 2018 Targeted Surveys

In August 2018, an estimated 4,000 striped mullet and more than 100 topsmelt perished over the course of several days. Mullet die offs have occurred at the Malibu Lagoon prior to restoration and various species die offs occur periodically throughout the bar-built estuaries of southern California. No lesions were common on the carcasses. The significant biomass of mullet associated with the die off was noteworthy. Many of the individuals were over 50 cm in fork length. Expert scientists (when presented with the limited data that were available) agreed that it was likely a single event tied to extremely warm nights (27-28 °C), resulting lower dissolved oxygen levels, and potentially overcrowding in the system (Dr. Dave Jacobs, pers. comm. 2018 and Dr. Sean Anderson, pers. comm. 2018). Targeted spot surveys at several stations in October and November 2018 found longjawed mudsuckers and mosquitofish present but no other fish species (R. Dagit, pers. comm. 2018). A co-occurring die off happened at Ormond Lagoon approximately three weeks prior, with impacts also likely caused in part by higher temperatures (S. Anderson, pers. comm. August 2018).

February 2019 Survey

Five juvenile tidewater gobies were captured during the February 2019 survey. When one seine captured over 50 juvenile longjawed mudsuckers at Site 3, surveys at that station were halted so no impacts to the juvenile gobies would occur. All individuals were subsequently released after identification and size classification with no observed mortalities. The dominant species surveyed and identified was juvenile mullet (n=82), followed by larval longjawed mudsuckers (n=55+), and staghorn sculpin (juvenile n=28, adult n=5) (Figure 63). A single northern anchovy was observed. The majority of individuals collected were extremely young larval or juvenile fish, which suggests that the lagoon was serving as a nursery site. No non-native fish were captured in the February 2019 surveys.

July 2019 Survey

A total of five native fish species and three non-native species were observed in July 2019, including at least seven tidewater gobies. Striped mullet were observed jumping throughout the lagoon but not captured. The dominant species surveyed was topsmelt (juvenile n=784, adult n=228). California killifish juveniles (n=300) and adults (n=17) were also captured. One largemouth bass was captured for the first time in lagoon surveys (non-native).

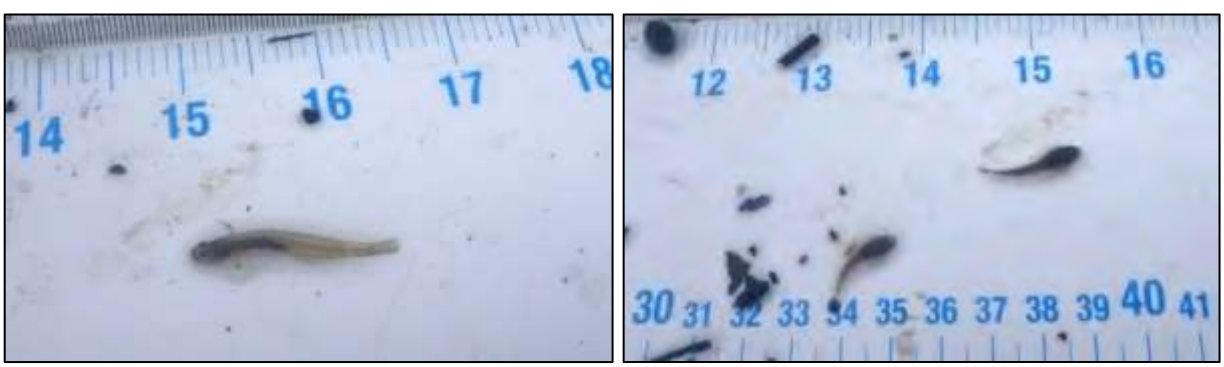


Figure 63. Photograph of a tidewater goby (left) and juvenile staghorn sculpins (right) from the February 2019 survey (credit: R. Dagit, RCDSMM).

Performance Evaluation

Both the native fish species richness' and the overall native fish abundances are higher in all six of the post-restoration summer surveys than in the pre-restoration summer survey, which indicates the site is meeting the permitting success criteria.

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, including the federally endangered tidewater goby. Both the native fish species richness' and the overall native fish abundances are higher in all six 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, which is higher compared to a pre-restoration species richness of five.

Non-native fish abundances were generally lower, post-restoration, and the non-native species richness was the same. Non-native fish species richness in the three surveys prior to July 2019 was 1, 2, and 0 species, respectively; the total count of non-native individuals across all three of those surveys combined was 25 individuals. The total count of non-native individuals in the single 2005 pre-restoration survey was 66, with over 4,000 adult mosquitofish counted in the surveys conducted immediately prior to restoration efforts. The February 2019 survey did not capture any non-native fish, even after the disturbance events. The July 2019 survey had higher numbers of non-native fish and one individual of a largemouth bass, which was the first occurrence post-restoration.

Tidewater gobies were observed in both the pre- and post-restoration surveys. Eight out of the 12 post-restoration surveys captured multiple tidewater gobies, in both open and closed berm conditions, and across many survey years. Many of those surveys also included the identification of juvenile gobies, indicating a functioning nursery habitat for the endangered gobies throughout the post-restoration timeframe which did not occur prior to restoration. The final count of tidewater gobies found after seining the *entire lagoon* prior to the wetland restoration was eight individuals in total. Six survey events post-restoration found at least eight individuals with both adults and juveniles represented, by seining only the fixed station areas which encompassed a small portion of the whole lagoon. This indicated a likely expansion of the preferred habitat by the gobies, a rise in abundances, or both.

While the temperature extremes during the summer of 2018 followed by the fire and subsequent rain events likely impacted the broader fish community, the most recent survey (February 2019) indicates a return of the fish community to previously expected standards during winter conditions, including the presence of multiple species of juvenile fish. Tidewater goby juveniles were also found in the February 2019 survey after the disturbance events, indicating a quick return to the system, if they were disturbed. Expert scientists consulted after the die off event stressed that mullet die offs have occurred prior to the restoration in Malibu Lagoon, and various species die offs occur periodically throughout bar-built estuaries of central and southern California. Dr. David Jacobs stated that lagoons can be considered 'high risk, high reward' environments for fish, and that even though they have high amounts of food and permit rapid growth, they are subject to various environmental perturbations over time (D. Jacobs, UCLA, pers. comm. 2018).

The native fish species documented in the January 2013, December 2014, January 2016, January 2018, and February 2019 post-construction surveys reflect the winter, marine influenced conditions, as compared to the native fish species observed in the summer surveys. Overall fish species richness was found to be relatively lower in the winter surveys, possibly due to the breach of the sand berm prior to the survey, as well as being exposed to tidal conditions. The Year 5 and 6 surveys followed similar previously established trends, with the addition of spotted turbot in Year 5 as a species previously unrecorded on surveys.

In summary, the post-restoration fish surveys indicate a predominantly native community of fish with relatively higher native abundances and species richness, with the added function of serving as a nursery habitat for many species. This trend is especially apparent across the summer surveys, which were identified as the period of primary assessment in the restoration permitting. Additionally, the lagoon and restoration area fish community appeared to have recovered from a year of heavy disturbances based on preliminary data. Opportunistic future surveys will confirm that trend.

Figure 64. Photograph of the fish survey team during the summer 2018 survey.

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 or shifts in bird guilds. Summary information is included in the subsections below, with additional details and data included in Appendices 4 and 5.

Methods

From late 2005 through mid-2006 pre-restoration quarterly bird surveys of the entire site were conducted, 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; 24-25 January, 20 and 23 April, 11 and 13 August, 23-24 October 2018 (Year 6 surveys). 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, quantity, habitat, and activity 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.

Surveys were subdivided into three main areas (Main Lagoon, Western Channels, and Beach). “Western Channels” represents the restoration area and results from this area are further discussed and analyzed for this report. This allows for a separate evaluation of the actual restoration area, rather than the entire lagoon system, though neither summary should be considered indicative of definitive long-term trends. Using Shannon’s Index to represent diversity, H values were calculated using the following equation: [-(Pi*lnPi), where Pi = # individuals of one species / the total # individuals of all species].

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 were considered. Aerial foragers and species that could not be reliably identified to species were omitted. Results are considered indicators rather than definitive abundances and species counts. Appendix 4 contains additional details.

Additionally, nine breeding activity surveys were conducted in 2018 on the following dates: 16 and 26 March; 9, 20, and 23 April; 4 and 23 May; and 11 and 28 August. Survey results are compared to pre-restoration surveys conducted in 2005-06 to characterize the nesting status of various species.

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. Overall numbers of individual birds detected on quarterly surveys were variable from year to year, but showed little trend following restoration (i.e., count of 8,489 in 2005-06, vs. a slight increase in average count of 8,687 between 2013-2018. Years 3 and 4 identified the highest total number of birds, post-restoration, at 11,298 and 11,736 individuals, respectively. The cumulative number of species and identifiable subspecies detected across all six years of quarterly surveys was 172 (as compared to the pre-restoration species count of 117), but approximately 85-100 species were recorded each year, illustrating the high inter-annual variability of species detected on these surveys. Annual species counts have been slightly lower since 2012, with an average of 91 species per year. It is also possible that the pre-restoration surveys overestimated species richness and abundances compared to post-restoration methods, since they may have also quantified counts of flying species (e.g., American Pipit).

In the six years since restoration, in an evaluation of the entire Malibu Lagoon area, guilds have responded differently post-restoration, with probable positive trends observed for marine and fish-eating birds, and probable negative or mixed trends noted for other groups, including urban species, waterfowl, shorebirds, and freshwater marsh species. An evaluation of the restoration area alone shows a different trend, including higher abundances, species richness, and diversity post-restoration (Shannon Index scores). Additionally, the site has similar nesting species richness as pre-restoration data, with the addition of the federally endangered California Least Tern and the federally threatened Western Snowy Plover, with both returning to the area to nest for the first time in many decades.

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. Full data sets are available in Appendix 4 (quarterly survey cumulative post-restoration avian report) and Appendix 5 (2018 breeding bird survey results).

Western Channels Analysis (restoration area only)

In the six years since restoration, birds have been documented roosting, foraging, and nesting in the western channels (Figures 65 and 66). 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 a range of post-restoration species numbers from 2014-2018 (N = 18-21 species; Table 16, Figures 67 and 68) as compared to 11 species pre-restoration. Results indicate an increase in species diversity (H value) in the 22 waterbird species since 2005, from a low of 1.83 (2005-06) to highs exceeding 2.8 in both post-restoration 2015 and 2018 years. This suggests that the restoration area is supporting a more diverse waterbird community in post-restoration years (Figure 67).

Both post-restoration total number of individuals and total species richness by year remain higher for the western channel analysis as compared to pre-restoration data (N = 174, 11, respectively, for pre-restoration data; Table 16). Post-restoration abundances vary from a low of 285 individuals in 2014 to a high of 1,802 individuals in 2015, with an average of 670 individuals across all post-restoration years. Similarly, species richness post-restoration varies in range from 16-21, with a consistent count of 21 species for 2015, 2016, and 2017. Lastly, there may be an upper limit for how many individual birds can effectively use the western channels given its limited size, which means that the site may be re-settling into an equilibrium in terms of numbers of individuals.

Figure 65. Photograph of egret foraging in the western channels (credit: H. Weyland, LMU CRI).

Figure 66. Photograph of avian use of the western restoration channels (multiple species).

Table 16. Summary of western bird data analyses including counts by species and Shannon Index (H) by year.

Species	2005-06	2013	2014	2015	2016	2017	2018
American Wigeon		30	2	1	7	8	10
Black-bellied Plover			6	60	22	49	152
Brown Pelican			3	1106	1	4	62
Caspian Tern	3	1	2	8	8	7	17
Double-cr. Cormorant		15	5	45	40	5	100
Eared Grebe		24	25	15	3	2	6
Elegant Tern				5	250		140
Gadwall	27	104	59	114	27	49	44
Great Blue Heron	9	14	5	11	9	13	7
Great Egret	5	9	2	5	4	12	7
Green-winged Teal	70	28	15	61	20	17	7
Killdeer	6	28	9	34	18	10	19
Least Sandpiper	26	6	3			11	12
Marbled Godwit			37	6	17	1	2
Northern Shoveler	5	82	13	9	26		
Pied-billed Grebe	2	16	3	4	12	8	4
Red-breasted Merganser		4	1	5	9	12	
Ruddy Duck		24	47	226	3	7	100
Snowy Egret	19	38	36	53	44	43	17
Western Grebe		3		7	8	5	
Whimbrel	2		6	17		1	1
Willet			6	10	5	8	
Number of Individuals	174	426	285	1802	533	272	707
Number of Species	11	16	20	21	21	21	18
H Value (Diversity)	1.83	2.33	1.89	2.93	2.33	1.91	2.86

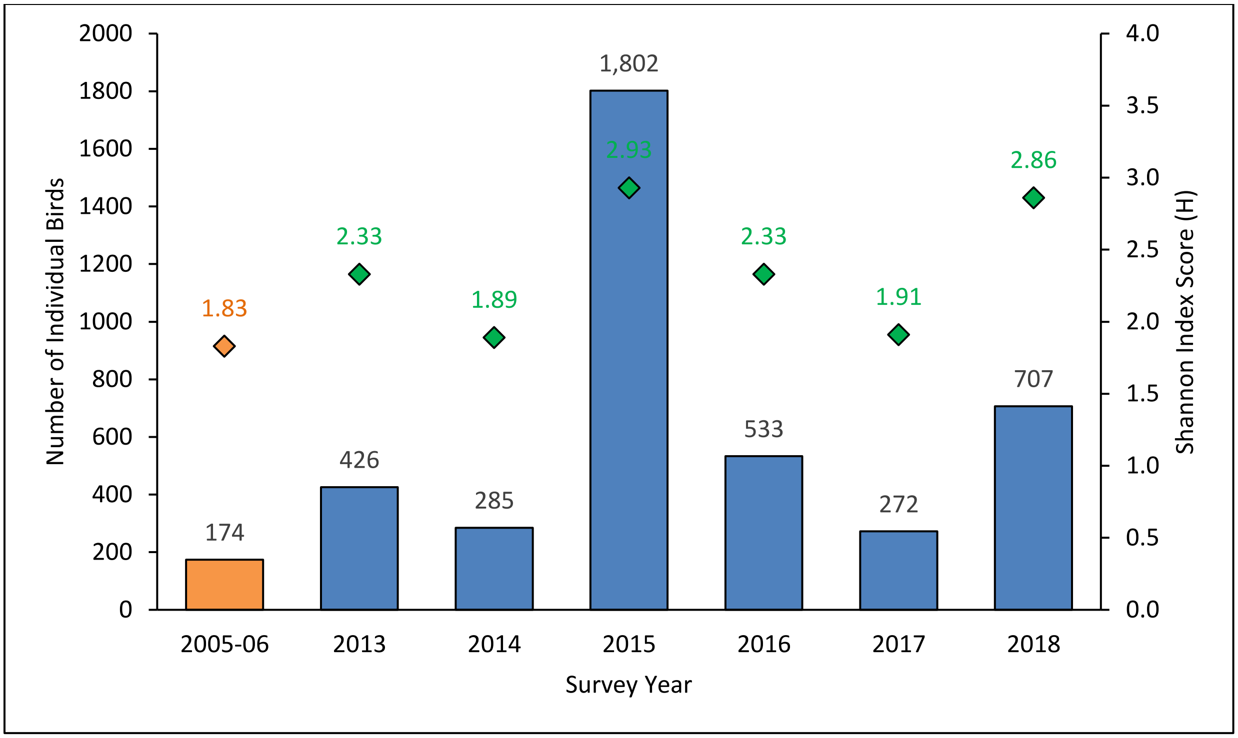


Figure 67. Summary of western channel (restoration area) bird data analyses including counts (primary y-axis) and Shannon Index (H; secondary y-axis) by year (x-axis).

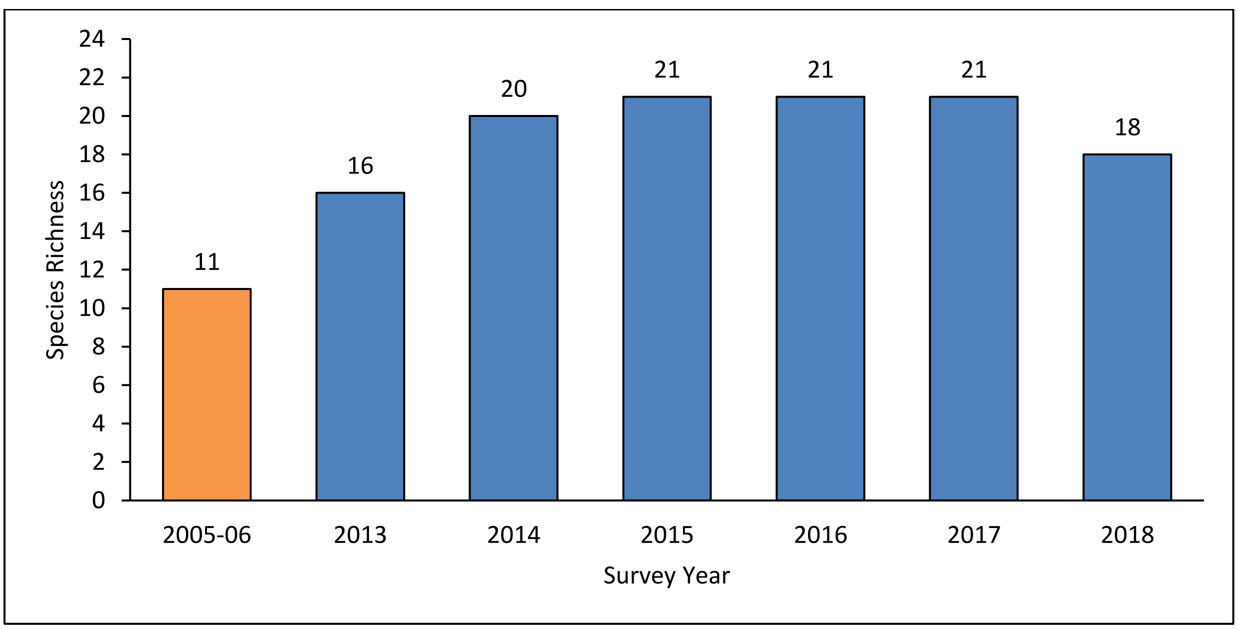


Figure 68. Summary of western channel (restoration area) bird species richness by year.

General trends

Over 50,000 individual birds were counted across all six years of post-restoration quarterly surveys. The cumulative number of species and identifiable subspecies detected across all years of quarterly surveys was 172, with 85-100 species recorded each year, illustrating the high inter-annual variability of species detected on these survey (Figure 69). Overall, total counts of individuals and species on quarterly surveys combined across all surveyed areas displayed slightly fewer total annual numbers as compared to the pre-restoration survey year, though this is likely not significant and is complicated by the fact that there was only one year of pre-restoration surveys during 2005-06. Site-wide species richness, which dropped in the first two years post-restoration (117 species, to 87 and 88, respectively), rebounded somewhat by 2015 and 2018 (100 and 99 species, respectively). 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 illustrate patterns.

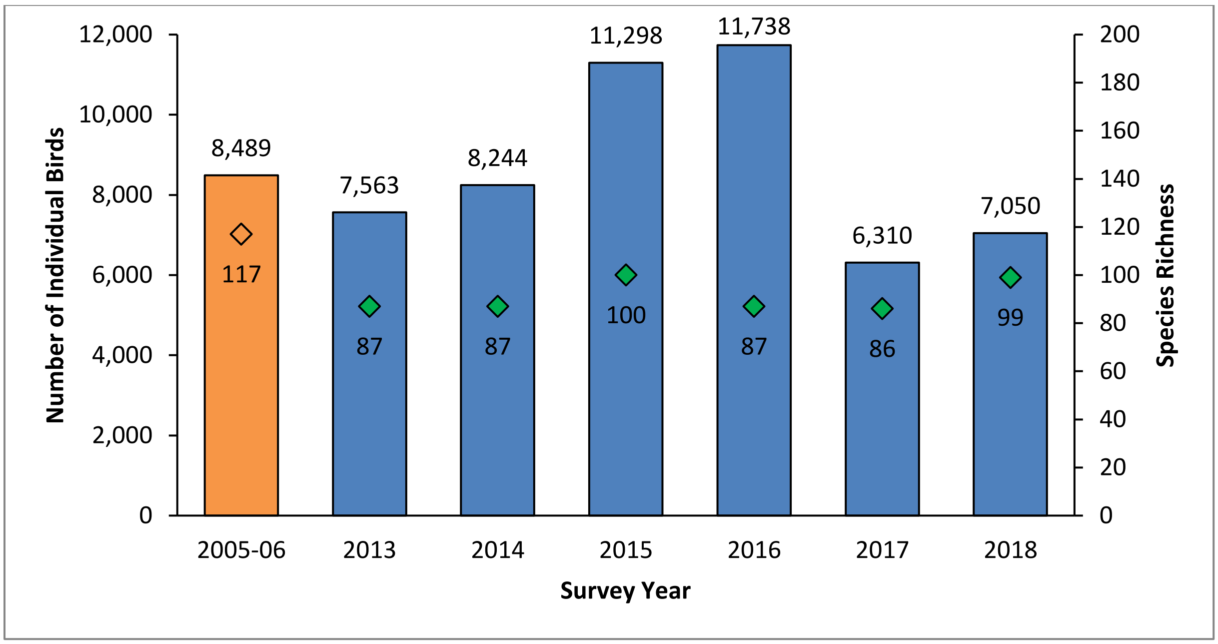


Figure 69. Summary of all quarterly survey data including counts of individual birds (primary y-axis) and species richness (secondary y-axis) by year (x-axis).

Appendix 4 contains detailed counts of selected groupings by ecological guilds of species from 2005 (pre-restoration) to 2018 (post-restoration). Counts of marine and fish-eating birds have increased at the site on quarterly surveys, with totals in recent years (e.g., 2017, 2018, etc.) higher than pre-restoration counts. Counts of most other groups have shown mixed or slight downward trends. For example, counts of urban, scrub/woodland, and open country birds were higher in the pre-restoration year, and for birds of freshwater marsh, waders, and waterfowl, higher counts were obtained in one post-restoration year.

Presumably, the upland and freshwater marsh habitat at the site 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 (citizen science) database. In one representative scrub-dwelling species, Song Sparrow, trends showed stable numbers through the spring/summer nesting season in recent years (Cooper 2017, Cooper 2019). This suggests that the species has been able to adapt well to the scrub plantings on the site year after year. Certain waterbird guilds, including shorebirds and freshwater marsh birds, show counts increasing somewhat in recent years (2015-18) versus those immediately following restoration (2013-14), suggesting that the habitat is continuing to improve for these groups (Figure 70).

Figure 70. Photograph of great egret in restored wetland habitat at Malibu Lagoon on 16 March 2019.

Nesting Results

Nesting activity is summarized here, with a focus on specific surveys conducted in 2018 during the breeding season. Additional information and data can be found in Appendix 5. In 2018, 10 species were confirmed nesting at Malibu Lagoon, which is comparable to the 11 species confirmed breeding in 2005 and 2006 (Table 17). In surveys conducted between 2013-2018, 19 species were confirmed as nesting at the Malibu Lagoon in at least one year. Three species were documented nesting in all five years evaluated (i.e., Gadwall, Mallard, and Song Sparrow), with six new species confirmed for 2018, including: Western Snowy Plover, California Least Tern, Allen's Hummingbird, Bushtit, Barn Swallow, and Northern Mockingbird. Four species nesting in 2005-06 were not detected nesting in 2018: Black Phoebe, Common Yellowthroat, California Towhee, and Red-winged Blackbird. Black Phoebe is an urban-adapted species, and Common Yellowthroat and Red-winged Blackbird prefer large reedy areas, common monocultures prior to the restoration in the lower wetland habitat areas.

Table 17. Comparison of breeding survey results from pre-restoration (2005-06) to post-restoration (2018).

Species	2005	2006	2018
Gadwall	Confirmed (2 pr., 1 brood)	Confirmed (1 brood)	Confirmed
Mallard	Confirmed (3 broods)	Confirmed (1 brood)	Confirmed
Pied-billed Grebe	Suspected nearby	Suspected	N/A
American Coot	N/A	N/A	N/A
Anna's Hummingbird	Possible	N/A	N/A
Allen's Hummingbird	Probable	Probable	Confirmed
Snowy Plover	N/A	N/A	Confirmed
Killdeer	Confirmed (1-2 pr.)	N/A	Confirmed
Least Tern	N/A	N/A	Confirmed
Barn Swallow	N/A	Suspected	Confirmed
Black Phoebe	Confirmed (1 pr; fledglings)	Confirmed (1 pr; juv.)	Suspected nearby
Bushtit	N/A	N/A	Confirmed
Northern Mockingbird	Suspected nearby	N/A	Confirmed
Common Yellowthroat	Confirmed (1-2 pr.)	Confirmed (1 pr., juv.)	N/A
Song Sparrow	Confirmed (6 pr., fledgling)	Confirmed (begging juv.)	Confirmed
California Towhee	Confirmed (2 pr., feeding juv.)	Confirmed (1 pr., juv.)	N/A

Species	2005	2006	2018
Red-winged Blackbird	Confirmed (10+ pr.; fledglings)	Confirmed (begging juvs.)	N/A
Brown-headed Cowbird	Confirmed nearby	N/A	Suspected
Hooded Oriole	Confirmed nearby	Confirmed nearby (ad. feeding young)	N/A
Great-tailed Grackle	N/A	N/A	Suspected

Figure 71. Photograph of juvenile ducks taken in western channels on 25 June 2019.

Sensitive Bird Species

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 and state endangered). Brant continued to occur in small numbers irregularly throughout the year, and the site is well outside known wintering and stopover areas for the species. A handful of sightings (N = 12 since 2014) of individual state threatened Belding's Savannah Sparrows have been made in recent years, though positive identification is difficult as they were made through a citizen science online platform (eBird).

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. California Least Tern is present between late April and early August (occasionally later). The status of nesting Snowy Plover and Least Tern at Malibu between 2013 and 2018 was summarized by Ryan et al. 2019. Least Terns established seven nests in 2013 (the first such record in over 70 years), none in 2014 and 2015, four in 2016, 22 in 2017, and six in 2018. Snowy

Plovers established two nests in 2017 (the first such modern record) with at least one chick successfully fledging and five in 2018. The 2017 chick represents the first successful nesting by this species in Los Angeles or Orange Counties in almost 70 years. Three Snowy Plover chicks fledged in 2018 out of five nests. Notably, the Least Tern has foraged heavily within the restored portion of the lagoon, often catching small fish within a few meters of the walking path around the lagoon (Figure 72).

Figure 72. Photographs of Western Snowy Plover female on nest with two eggs taken on 22 June 2018 (top), and California Least Terns foraging at Malibu Lagoon on 22 June 2018 (bottom, photo credits: Grace Murayama).

Performance Evaluation

Many species of birds utilize the site for roosting, foraging, and breeding, thus meeting the restoration success criteria. Although not part of the success criteria, post-restoration numbers of birds, species richness, and diversity (Shannon Index) remain higher on average for the restored western channels as compared to pre-restoration data.

Several patterns have emerged after six 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. Importantly, analyses of birds within the restoration area alone displayed an increase in counts, richness, and diversity. Individual species and guild patterns for the entire lagoon were variable but suggested a shift in the bird community from urban, scrub, and country guilds towards marine and fish-eating guilds, with mixed results for other communities.

Notably, special-status species in Year 6 continue to make heavy use of the site, in particular the beach and lower lagoon area (e.g., Brown Pelican and Western Snowy Plover). Seven Western Snowy Plover nests were documented across 2017 and 2018, including at least four fledglings; 39 California Least Tern nests were documented across the six post-restoration monitoring years (2013-2018), including at least 13 fledglings. Neither species had previously been identified nesting in almost 70 years in the region.

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. While the average number of birds was higher post-restoration in the quarterly surveys, it is not likely to be significant. 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 by species provides another avenue of analysis. 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. Overall, the site is clearly meeting the broadly categorized bird success criteria, and bird patterns are likely to continue to establish and vary over time and by season.

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 of the post-restoration monitoring assessment.

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, 6 February 2018, 12 July 2018 (Year 6), and 11 April 2019 (Year 6). Most surveys (N = 6) were conducted during open berm conditions, in accordance with the Monitoring Plan (SMBRF 2012). The August 2017 and July 2018 were extra surveys conducted during a closed berm condition to attempt to target warm summer months 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 visible 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. Additional visual qualitative estimate surveys were conducted on 25 July 2018 and 25 June 2019 as site checks for floating algae.

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* (Figure 73)*, Phyllospadix, Dictyota, Egregia, Eisenia*, *Cystoseira*, and woody debris*.* '*Cladophora'* is the genus for small, 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 two Year 6 surveys (12 July 2018 and 11 April 2019), the average *Ruppia* cover was 13.69% ± 4.11 and 0.22% ± 0.16, average algae cover was 7.00% ± 3.42 and 1.65% ± 0.85, and average wrack cover was 0.00% ± 0.00 and 0.99% ± 0.44 (Figures 74 and 75). Visual qualitative estimate data from the July 2018 and June 2019 surveys indicated presence of submerged live *Ruppia* across most stations, with minimal floating turf-like algae (less than 5% of the total station area, Figure 76) and very little wrack present.

Figure 73. Photograph of floating *Macrocystis* at Station 2 (14 February 2013).

Tables 18 and 19 display average cover across all eight surveys. The grand mean total algal and SAV cover (± SE) for all surveys on the Year 6 surveys (12 July 2018 and 11 April 2019) was 20.69% ± 4.50 and 2.86% ± 0.54, respectively (Table 18). *Ruppia* was found to be very high across most Stations 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; Figure 77). 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.

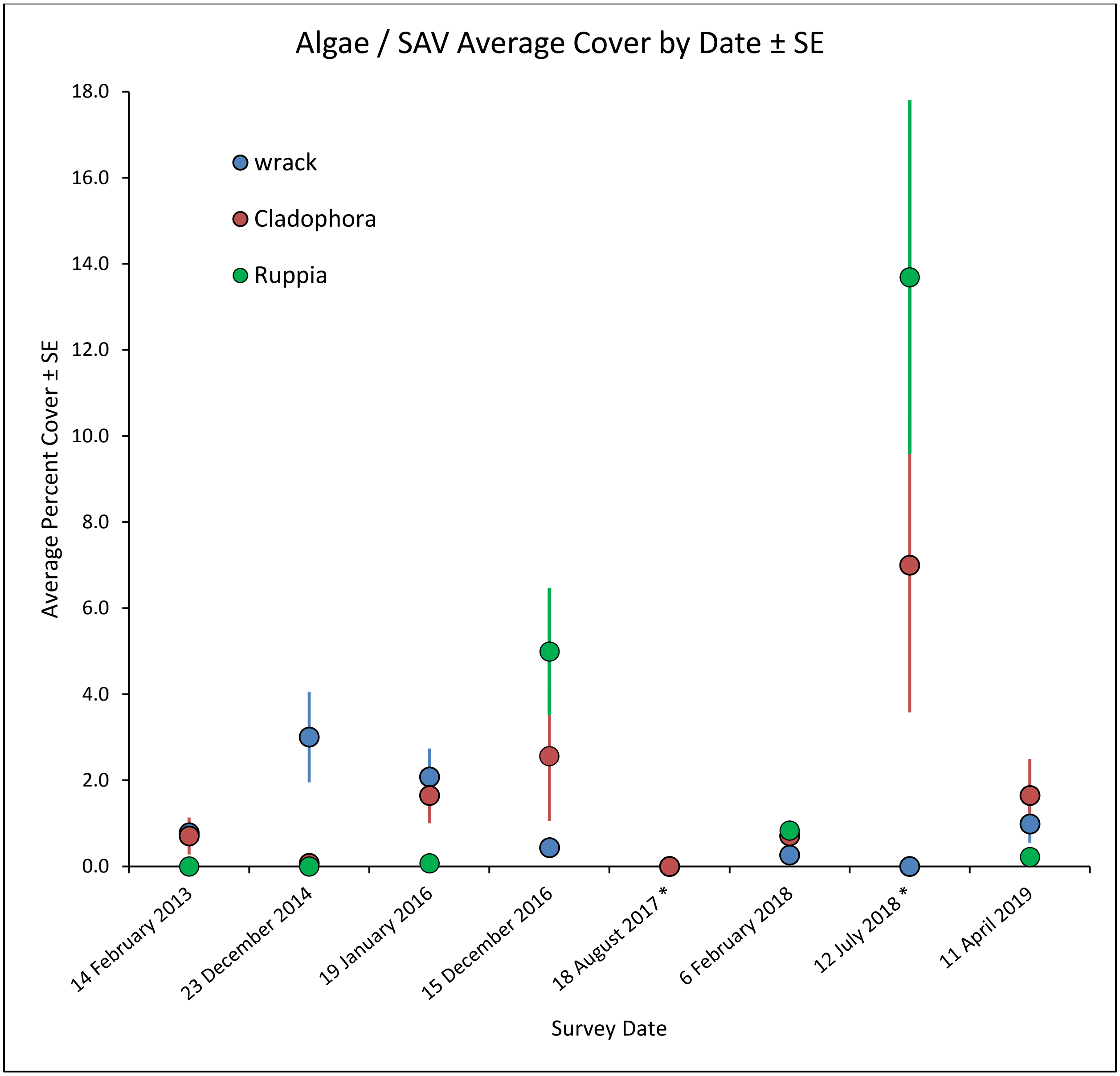


Figure 74. Graph indicating average algae and SAV cover (± SE) by survey date and category of algae/SAV. Asterisk indicates closed condition survey. Note: *Ruppia* data were excluded from the 18 August 2017 survey as an outlier from the graph; see *Ruppia* totals in Table 19.

Figure 75. Representative photograph of (top) Station 2 and (bottom) Station 5 on 12 July 2018 (closed berm).

Figure 76. Representative photograph of (top) Station 2 on 25 July 2018 and (bottom) Station 5 on 25 June 2019.

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

	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	12 Jul 2018 *	11 Apr 2019
Station 1	0.82 ± 0.82	2.33 ± 0.06	31.67 ± 5.36	1.21 ± 0.30
Station 2	87.13 ± 3.27	4.96 ± 0.12	11.39 ± 2.37	2.91 ± 0.63
Station 3	82.67 ± 2.23	6.05 ± 0.10	0.00 ± 0.00	1.29 ± 0.13
Station 4	88.25 ± 4.96	1.59 ± 0.03	1.67 ± 42.31	5.10 ± 1.32
Station 5	75.9 ± 12.46	4.21 ± 0.10	0.00 ± 0.00	2.77 ± 0.44
Station 6	84.71 ± 14.22	4.33 ± 0.10	42.31 ± 7.06	2.53 ± 0.12
Station 7	91.63 ± 3.79	11.45 ± 0.24	43.91 ± 10.28	2.50 ± 0.39
Station 8	87.08 ± 3.12	8.56 ± 0.19	34.58 ± 10.57	4.59 ± 0.99
Grand Mean	**74.77 ± 5.61**	**5.43 ± 0.12**	**20.69 ± 4.50**	**2.86 ± 0.54**

Table 19. Algae data as station average wrack, *Cladophora*, and *Ruppia* percent cover ± standard error for the eight post-restoration surveys. Note that surveys without a *Ruppia* column found no *Ruppia* present.

	14 Feb 2013		23 Dec 2014	
	wrack	*Cladophora*	wrack	*Cladophora*
Station 1	2.93 ± 0.53	0.05 ± 0.05	9.86 ± 3.70	0.31 ± 0.21
Station 2	0.44 ± 0.28	0.01 ± 0.01	7.58 ± 2.12	0.10 ± 0.10
Station 3	0.20 ± 0.20	0.67 ± 0.67	0.95 ± 0.53	0.00 ± 0.00
Station 4	1.67 ± 0.33	0.43 ± 0.30	1.12 ± 0.29	0.17 ± 0.07
Station 5	0.00 ± 0.00	0.00 ± 0.00	3.84 ± 1.50	0.00 ± 0.00
Station 6	0.00 ± 0.00	0.00 ± 0.00	0.18 ± 0.05	0.05 ± 0.05
Station 7	0.36 ± 0.06	0.11 ± 0.00	0.29 ± 0.11	0.00 ± 0.00
Station 8	0.68 ± 0.52	4.40 ± 2.42	0.25 ± 0.11	0.00 ± 0.00

	19 Jan 2016			15 Dec 16		
	wrack	*Cladophora*	*Ruppia*	wrack	*Cladophora*	*Ruppia*
Station 1	4.06 ± 1.40	2.55 ± 0.28	0.02 ± 0.02	2.59 ± 0.2	1.56 ± 0.38	4.69 ± 1.45
Station 2	7.44 ± 0.98	4.07 ± 2.04	0.00 ± 0.00	0.38 ± 0.27	6.73 ± 4.16	4.02 ± 1.25
Station 3	1.32 ± 0.53	1.21 ± 1.01	0.21 ± 0.21	0.13 ± 0.13	7.07 ± 5.72	2.49 ± 2.09
Station 4	0.72 ± 0.40	0.10 ± 0.10	0.00 ± 0.00	0.10 ± 0.10	1.22 ± 0.85	1.94 ± 0.98
Station 5	0.06 ± 0.02	3.42 ± 1.48	0.16 ± 0.16	0.02 ± 0.02	0.96 ± 0.45	5.54 ± 1.69
Station 6	0.29 ± 0.03	0.00 ± 0.00	0.11 ± 0.11	0.26 ± 0.02	0.00 ± 0.00	0.00 ± 0.00
Station 7	0.31 ± 0.12	1.88 ± 0.29	0.00 ± 0.00	0.01 ± 0.01	2.96 ± 0.51	10.17 ± 2.32
Station 8	2.44 ± 1.80	0.00 ± 0.00	0.12 ± 0.08	0.00 ± 0.00	0.00 ± 0.00	11.14 ± 2.02

	18 Aug 2017 *			6 Feb 2018		
	wrack	*Cladophora*	*Ruppia*	wrack	*Cladophora*	*Ruppia*
Station 1	0.00 ± 0.00	0.00 ± 0.00	0.82 ± 0.82	0.13 ± 0.11	0.65 ± 0.12	0.00 ± 0.00
Station 2	0.00 ± 0.00	0.00 ± 0.00	87.13 ± 3.27	0.89 ± 0.56	0.08 ± 0.02	0.68 ± 0.26
Station 3	0.00 ± 0.00	0.00 ± 0.00	82.67 ± 2.23	0.99 ± 0.12	0.70 ± 0.25	0.32 ± 0.05
Station 4	0.00 ± 0.00	0.00 ± 0.00	88.25 ± 4.96	0.07 ± 0.04	0.10 ± 0.03	0.36 ± 0.04
Station 5	0.00 ± 0.00	0.00 ± 0.00	75.90 ± 12.46	0.00 ± 0.00	0.37 ± 0.02	1.03 ± 0.27
Station 6	0.00 ± 0.00	0.00 ± 0.00	84.71 ± 14.22	0.00 ± 0.00	0.45 ± 0.14	0.99 ± 0.24
Station 7	0.00 ± 0.00	0.00 ± 0.00	91.63 ± 3.79	0.03 ± 0.03	1.27 ± 0.29	2.52 ± 0.09
Station 8	0.00 ± 0.00	0.00 ± 0.00	87.08 ± 3.12	0.03 ± 0.03	2.05 ± 0.45	0.77 ± 0.08

	12 Jul 2018 *			11 Apr 2019		
	wrack	*Cladophora*	*Ruppia*	wrack	*Cladophora*	*Ruppia*
Station 1	0.00 ± 0.00	14.17 ± 11.76	17.50 ± 5.07	0.21 ± 0.06	0.99 ± 0.39	0.00 ± 0.00
Station 2	0.00 ± 0.00	8.17 ± 2.67	3.23 ± 0.69	2.14 ± 0.75	0.77 ± 0.24	0.00 ± 0.00
Station 3	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.66 ± 0.57	0.21 ± 0.13	0.41 ± 0.40
Station 4	0.00 ± 0.00	0.42 ± 0.42	1.25 ± 0.72	0.81 ± 0.38	4.29 ± 3.12	0.00 ± 0.00
Station 5	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	1.04 ± 0.49	1.62 ± 0.55	0.12 ± 0.07
Station 6	0.00 ± 0.00	21.85 ± 7.38	20.47 ± 7.28	0.84 ± 0.10	0.64 ± 0.30	1.05 ± 0.68
Station 7	0.00 ± 0.00	9.46 ± 3.62	34.45 ± 12.51	1.19 ± 0.69	1.26 ± 0.88	0.05 ± 0.05
Station 8	0.00 ± 0.00	1.94 ± 1.55	32.64 ± 6.62	1.04 ± 0.51	3.44 ± 1.20	0.11 ± 0.11

Figure 77. Photograph of *Ruppia* underwater at Station 4 on 25 June 2019.

Performance Evaluation

Post-restoration data indicate a reduction in algae cover as compared to pre-restoration data, especially in the form of floating algal mats; thus, the site is meeting the success criteria. Algal cover shifted from pre-restoration floating mats that decomposed to create 'dead zones', to post-restoration cover dominated by wrack or submerged seagrasses.

There was significant and excessive algal growth in the Lagoon pre-restoration; algae cover was one of the key indicators of eutrophication to the system. The surveys and data were difficult to collect due to the massive amounts of organic matter and unconsolidated fine-grained sediments causing an inability to deploy transects. While no pre-restoration "baseline" was identified due to high variability in cover (2nd Nature 2010), the actual pre-restoration percent algal cover ranged from ~ 0 – 40% cover, which was dominated by floating algal mats, often becoming trapped in the back channels and decaying over time. The post-restoration cover data were dominated by 'wrack', or floating / detached marine kelp species, and after six years, the floating algal mats 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. One closed condition warm water targeted algae survey (August 2017) only identified *Ruppia* as present in high cover ratios. Similarly, while the July 2018 survey (the other closed condition warm water survey) did identify the presence of algae, cover at most stations was again dominated by *Ruppia*. 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). Attached (live) *Phyllospadix torreyi*, or surfgrass, is another species of seagrass that was identified as live at several stations and across several years of surveys, especially in the deeper channel locations.

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 detail in the data sonde section 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 of many wetland habitat functions.

Methods

Data for absolute percent cover of native/nonnative vegetation species were collected along three, 50-meter transects (Figures 78 and 79) 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, 17 April 2018, 12 July 2018 (Year 6), and 4 December 2018 (Year 6). Eleven full surveys were completed, with an extra subset of surveys to capture growth over the final growing season conducted on 25 June 2019 (Year 6). These data were combined to provide a comprehensive set of post-restoration vegetation surveys to evaluate native and non-native relative vegetation cover over time.

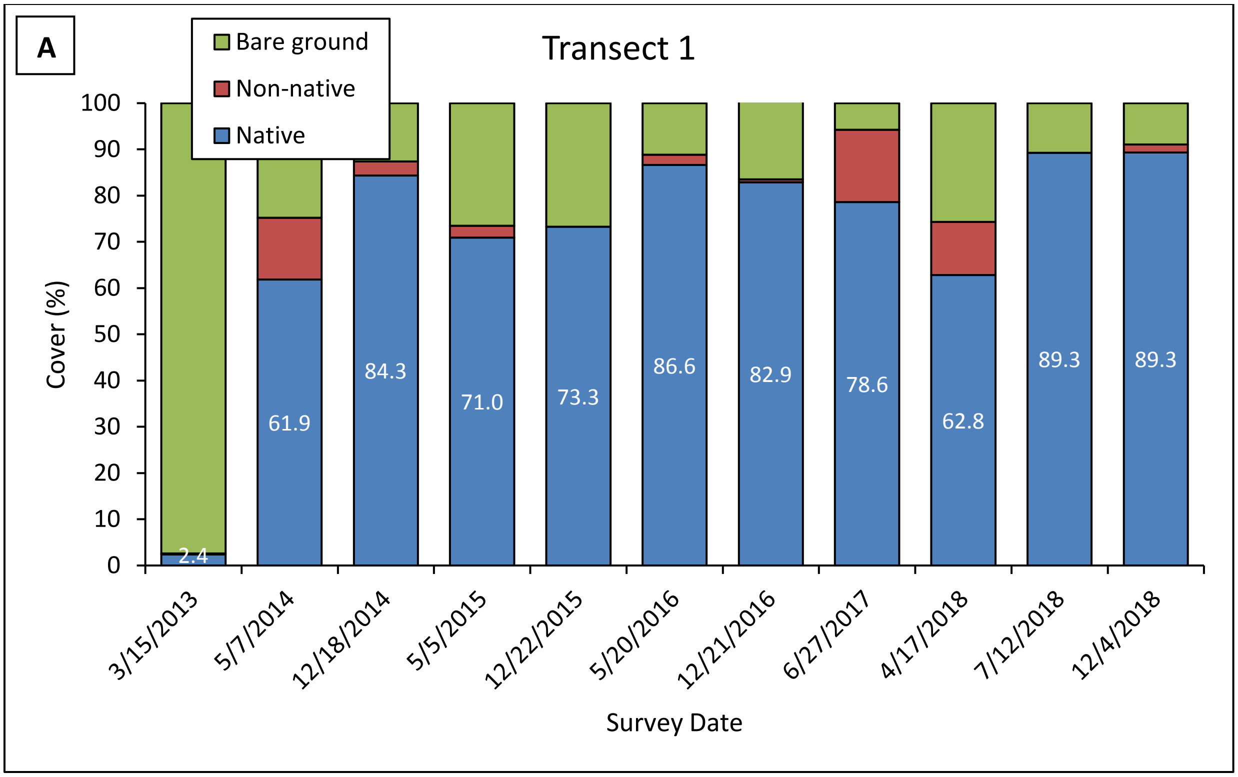
Each transect location was recorded with a submeter global positioning system (GPS) unit and photographed at each end. Absolute cover data were calculated based on the total distance for each species within each transect. Species data were collected to an accuracy of 0.01 m along each 50-meter transect.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

Figure 78. Photograph of vegetation on the southwestern island (4 December 2018).

Figure 79. Map of vegetation transect locations and start/end points.

Results

In the sixth monitoring year, the average (± standard error) native cover across all transects was 78.1 ± 12.5% and 79.2 ± 12.0%, respectively. The average non-native cover was less than 1% across both Year 6 survey dates. The relative native cover for Year 6 ranged between 96.0 – 100.0%, with a range of 98.1 – 100.0% in the most recent survey (December 2018). Cover for native vegetation species along an individual transect in the most recent survey was the highest on Transect 1, at 89.3% (with a relative native cover of 98.1%), followed by Transect 2, at 87.4% (with a relative native cover of 98.6%). Absolute cover was lowest on Transect 3 at 60.8%, but with a relative native cover of 100.0% (Figure 80). Non-native cover was very low across all transects for both Year 6 surveys, ranging from 0.0 – 2.2% absolute cover, with 0.0 – 1.8% in the most recent survey (December 2018). 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. Lastly, the species richness at a transect level is higher post-restoration, with six-year survey results indicating 8-16 native plant species representing a variety of plant types including ground cover, subshrubs, and overstory canopy. Figures 81 through 84 display representative photographs from each surveyed transect during Year 6.



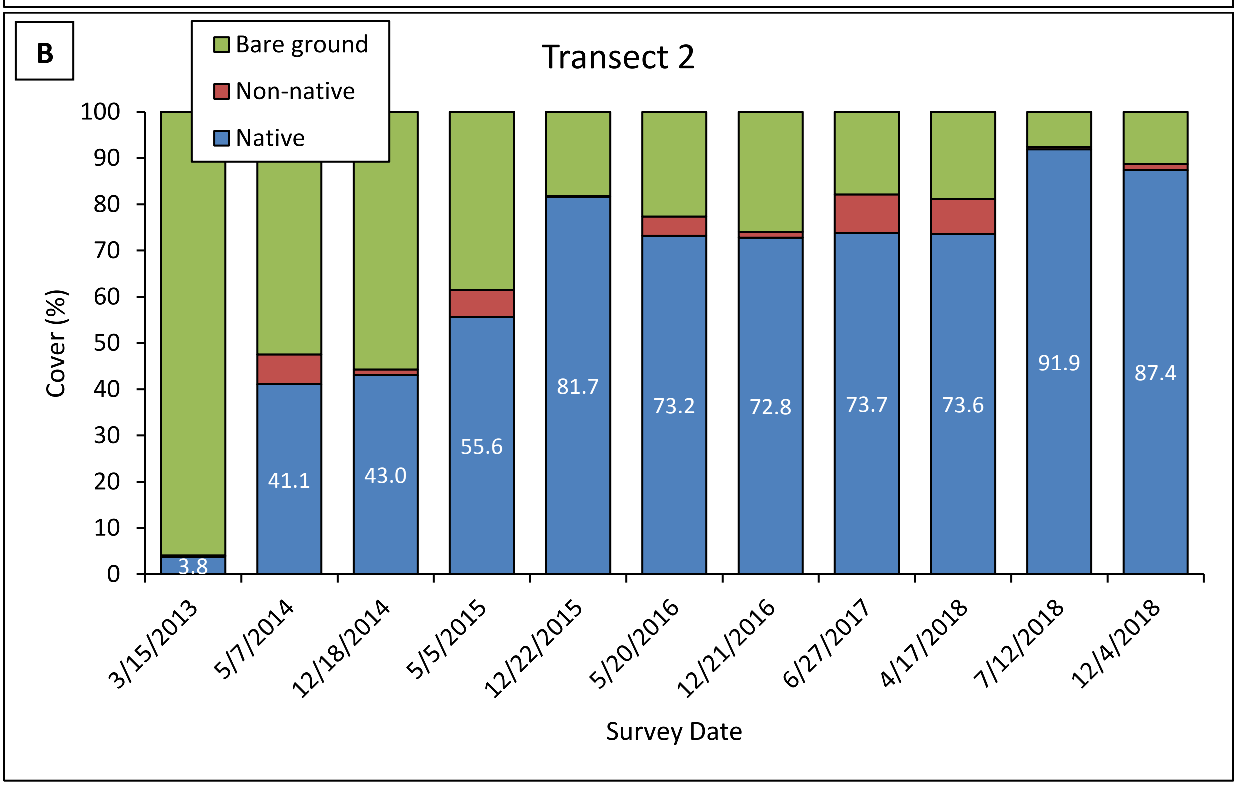


Figure 80. Graphs displaying absolute cover of vegetation across each Transect: (A) 1, (B) 2, and (C) 3.

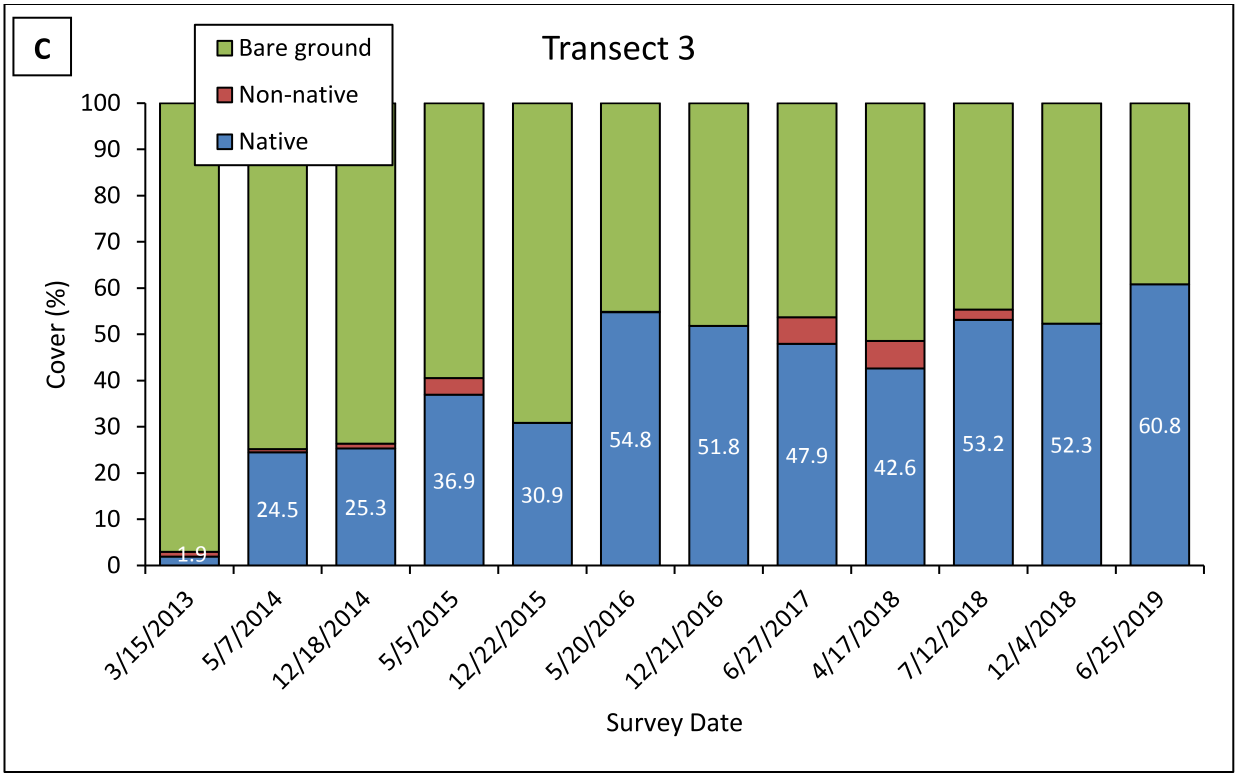


Figure 80 (continued). Graphs displaying absolute cover of vegetation across each Transect: (A) 1, (B) 2, and (C) 3.

Figure 81. Photograph of island vegetation adjacent to Transect 2 across the channels (4 December 2018).

Figure 82. Photographs of the upland habitat (top) and lower wetland habitat (bottom) portion of Transect 1 on 4 December 2018.

Figure 83. Photographs of the upland habitat adjacent to the pathway (top) and lower wetland habitat (bottom) portion of Transect 2 on 4 December 2018.

Figure 84. Photographs of the upland habitat (top) and lower wetland habitat (bottom) portion of Transect 3 on 25 June 2019.

Performance Evaluation

Vegetation cover as assessed for both native and non-native species is meeting the restoration success criteria. Relative native vegetation cover was 96-100%, with average absolute native vegetation cover across all transects between 78-80% cover for Year 6, and non-native cover less than 1%.

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 continue to grow and spread. Complexity in restoration projects can continue to develop for decades after initial plantings (Stylinski and Allen 1999, Reynier et al. 2017). Reductions or variability in non-native cover are likely the result of weeding and non-native species removal efforts during restoration events led by The Bay Foundation and State Parks. Non-native plants were removed in accordance with the Plant Communities Plan and monitoring and maintenance recommendations (ICF 2012).

The average absolute native plant cover across all transects was between 78-80% cover for Year 6. The average absolute non-native plant cover was less than 1% across both Year 6 survey dates. The relative native cover for Year 6 ranged between 96.0 – 100.0%, with a range of 98.1 – 100.0% in the most recent survey. Relative native plant cover was well above the success criteria (i.e., > 90%), by any transect assessment or an evaluation or comparison of the average. Non-native cover was also meeting the success criteria (i.e., < 10% in uplands and 5% in wetlands), as the average cover for both Year 6 surveys was less than 1% for absolute non-native plant cover, and less than 4% or 2% relative cover in the most recent surveys, respectively. Similarly, the CRAM biotic metric continued increasing across the monitoring years, and the photo-monitoring surveys visually confirmed the trend, supplementing the vegetation cover assessment that the community continues to develop and become more complex over time. While there were no CRAM or photo-monitoring point success criteria identified in the permits, these categories further illustrated the project meeting its overall goals for vegetation including a more diverse, well-established, native plant community as compared to pre-restoration conditions.

While the Plant Communities Plan (ICF 2012) did not specify whether the success criteria were specific to absolute or relative native cover, it was assumed to refer to relative native cover. This assumption is based on the document stating a 90% native plus less than 10% non-native “cover” criteria (totaling around or just less than 100% cover), which would be completely unrealistic for most habitat types in southern California, even when undisturbed. Presence of unvegetated ground in native vegetated habitats is common in undisturbed areas and vitally important to many ecosystem functions for wildlife. In any evaluation (i.e., “relative” versus “absolute”), the non-native criterion was being met. To further justify the use of relative cover for the native “cover” success criteria assessment, a literature review was performed on relevant published scientific and technical reporting documents, with an emphasis on coastal sage scrub habitats. The upper portion of Transect 3, dominated by scrub and upland habitats, was the only location within the surveyed areas that had slower growth (relative to the other habitat areas). Relevant literature suggested natural scrub habitats ranged from approximately 62-68% cover (Stylinski and Allen 1999, Beyers and Wirtz 1997), and restoration success criteria recommendations for similar projects identified a range of 65-85% cover (ESA 2018, Technology Associates 2009, Lukos 2006) after five years of monitoring, with an emphasis that scrub habitats are "naturally patchy" (CDFW 1993). Table 20 summarizes the results by literature source, with an indication that all average cover results for the most recent survey year are meeting the combined summary results.

Table 20. Summary of referenced literature for cover assessment compared to Malibu Lagoon data.

Literature Source	Literature Category	Native Cover	Non-Native Cover	Monitoring Assessment
Stylinski and Allen 1999	Natural habitat assessment	68% across 12 undisturbed sites	----	✓
Beyers and Wirtz 1997	Natural habitat assessment	62-66% cover for optimal function habitat	----	✓
Bell et al. 2016	Restoration assessment	~50% native shrub cover	----	✓
ESA 2018	Restoration Recommendations	65% absolute native cover	<10% cover	✓
Technology Associates 2009	Restoration Recommendations	80% native cover	<5% cover	✓
Lukos 2006	Restoration Recommendations	75-85% native cover	<5% cover	✓

The number and species richness of vegetation planted throughout the Lagoon was 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 8 to 16 native plant species identified immediately adjacent to the transects (within about 10 meters), compared to an average of six or fewer dominant species pre-restoration. Species richness varied by habitat and area. While there were no specific success criteria tied to number of species, it can be assumed that the variety of native species present in post-restoration surveys across the varying habitats within restoration area are preferable, based on the project goals, to the limited number of native species forming distinct monocultures in pre-restoration conditions.

Periodic non-native maintenance may still be required in future years and should be evaluated qualitatively for need in the spring of each year prior to annual non-native species going to seed. Community maintenance and restoration events may continue to be a relevant non-native vegetation control method, especially in upland habitats or those adjacent to walkways or other areas that may be more prone to invasion.

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 21 and Figure 85) 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, 27 June 2017, 23 May 2018, 4 December 2018, and 25 June 2019 (Table 21). Approximate bearing is relative to the center of the photograph; detailed bearing ranges are included on the datasheets.

Table 21. GPS coordinates, bearings, and time of photo-point surveys.

Date	Station	Approximate Bearing	Time	Number of Photos
15 March 2013	Photo Point 1	155°	8:15 AM	1
	Photo Point 2	300°, 75°	8:30 AM	2
	Photo Point 3	220°, 100°	8:46 AM	2
7 May 2014	Photo Point 1	155°	11:22 AM	1
	Photo Point 2	300°, 75°	11:13 AM	2
	Photo Point 3	220°, 100°	11:08 AM	2
18 December 2014	Photo Point 1	155°	12:47 PM	1
	Photo Point 2	300°, 75°	12:41 PM	2
	Photo Point 3	220°, 100°	12:37 PM	2
5 May 2015	Photo Point 1	155°	3:00 PM	1
	Photo Point 2	300°, 75°	2:59 AM	2
	Photo Point 3	220°, 100°	2:56 PM	2
22 December 2015	Photo Point 1	155°	3:40 PM	1
	Photo Point 2	300°, 75°	3:49 PM	2
	Photo Point 3	220°, 100°	3:49 PM	2
16 May 2016	Photo Point 1	155°	7:20 AM	1
	Photo Point 2	300°, 75°	7:34 AM	2
	Photo Point 3	220°, 100°	7:47 AM	2
27 December 2016	Photo Point 1	155°	8:37 AM	1
	Photo Point 2	300°, 75°	8:41 AM	2
	Photo Point 3	220°, 100°	8:45 AM	2

Date	Station	Approximate Bearing	Time	Number of Photos
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
23 May 2018	Photo Point 1	155°	11:32 AM	1
	Photo Point 2	300°, 75°	11:00 AM	2
	Photo Point 3	220°, 100°	10:45 AM	2
4 December 2018	Photo Point 1	155°	2:40 PM	1
	Photo Point 2	300°, 75°	2:50 PM	2
	Photo Point 3	220°, 100°	2:55 PM	2
25 June 2019	Photo Point 1	155°	2:33 PM	1
	Photo Point 2	300°, 75°	2:28 PM	2
	Photo Point 3	220°, 100°	2:19 PM	2

Figure 85. 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 87 through 91 (A - K) display the photos from the five locations post-restoration on the eleven survey dates, respectively. Photo Point 1 displays the intersection of several channels along with a tree snag for bird roosting. Photographs from this position indicate a wetland assemblage of native plants. Photo Point 2 displays two directions along the public access path to the beach in the southernmost channel. Visible plant species range from upland and transition zone species to lower wetland vegetation. Photo Point 3 (both bearings) show the most increase in plant cover in recent years, which corresponded to the vegetation cover assessments from this location.

Performance Evaluation

The vegetation community has continued to establish over time within the restoration area as demonstrated by the photo point series. Non-native, invasive vegetation was removed through community restoration events.

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 first few survey years, photographs from the latter years showed more subtle variations. Figure 86 is a representative recent photo from the Photo Point series. All 15 pages of Photo Point results can be found after the Final Restoration Assessment and Conclusions section, below.

Figure 86. Representative photograph from Photo Point 2 at bearing 300° on 25 June 2019.

Final Restoration Assessment and Conclusions

This report assessed the post-restoration conditions of Malibu Lagoon across approximately six years of monitoring by evaluating a suite of parameters as part of the long-term monitoring plan of the Malibu Lagoon Restoration and Enhancement Project. The goals of the restoration project were to: (1) increase circulation of water in the lagoon during both open mouth and closed mouth conditions to improve water quality and decrease eutrophication; (2) to restore the lagoon habitat by re-establishing suitable soil conditions and native plant species and removing non-native species; and to (3) evaluate, record, and analyze existing and changing ecological conditions of the lagoon using physical, chemical, and biological parameters to measure restoration success (CCC Staff Report, CDP No. 4-07-098). The restoration project has been determined to be wholly successful as assessed against defined project goals, performance standards, and success criteria (Table ES-1) outlined in California Coastal Commission CDP No. 4-07-098 and supporting documentation, including monitoring plans.

An evaluation of post-restoration conditions, through detailed physical, chemical, and biological monitoring components has resulted in several overarching trends. Year 6 data support the long-term trend of increasing health and recovery of Malibu Lagoon following the restoration effort in 2013. All monitoring components have met or exceeded established success criteria set by the project documents and the California Coastal Commission, and adaptive management measures are not recommended. However, it is recommended to annually qualitatively assess the growth of non-natives along the perimeter access trails in areas likely to be exposed to non-native seed dispersal through human activity. If found, non-native plants should be removed before going to seed. Educational tour groups like those frequently led by Audubon Society and RCDSMM could also provide updates to State Parks if invasive vegetation is identified during the course of the educational activities. If funding is available, additional surveys such as biennial CRAM or cross-section transects would continue to inform long-term monitoring trends to further support the six-year assessments and analyses.

The rapid wetland condition indicator score (CRAM) increased in each post-restoration year, and the site-intensive data supported those results. The vegetation community continued to become more complex over time, and as this establishment continued, 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 were significantly reduced post-restoration, and well below established criteria limits. Similarly, dissolved oxygen, vertical profiles, and other indicators showed that the improved circulation has resulted in enhanced water quality throughout the site. Overall, post-restoration monitoring surveys have identified the distinct recovery and establishment of many important chemical and biological wetland functions supporting a healthy, stable, predominantly native ecosystem that was resilient to several external stressors during the course of this assessment.

Table 22. Summary of 5-year success criteria results by survey type.

Survey Category	Survey Type	5-Year Success Criteria Summary	Meeting 5-Year Criteria?	Criteria Evaluation Details
L2 Rapid Assessment	California Rapid Assessment Method	None identified.	N/A	Although there were no specific quantitative success metrics identified for the CRAM scores, the final trend is above pre-restoration scores, with a consistent increase over time, suggesting support for a healthy and robust wetland community.
Physical	Channel Cross-Sections	Lack of a continual occurrence of sandbar formation and sedimentation in the form of a sandbar that isolates the western restoration area from the main channel three times over a six-year period during open lagoon conditions.	Yes	No isolation of the western restoration area and channels has occurred during the six-year assessment period; thus, the restoration is meeting the project success criteria. Additionally, the lack of sedimentation suggests that the restored lagoon is experiencing improved circulation as compared to pre-restoration conditions.
Water Quality	Automated Sonde Sampling	Locations within the western channel shall not have persistent dissolved oxygen levels below 1.5 mg/L for a sustained period of more than 12 hours a day over two closed lagoon periods of more than 60 days; or consistently low dissolved oxygen levels below 1.0 mg/L that occur for more than 6 hours a day over the course of 30 days during closed conditions.	Yes	Dissolved oxygen average data across all post-restoration years exceeded all project success criteria at all stations during closed conditions. No dissolved oxygen levels were below the identified thresholds for the sustained periods. Additionally, the assessments of trends across all years suggest higher dissolved oxygen post-restoration as compared to pre-restoration conditions, as well as a lack of 'dead zones' that occurred prior to restoration.
	Vertical Profiles	Water quality monitoring should not indicate persistent stratification of lagoon waters and depressed bottom water dissolved oxygen during closed conditions; restored lagoon should show improvements in water circulation and tidal flushing.	Yes	Dissolved oxygen was well above the success criteria threshold (i.e., > 1 mg/L) for all samples collected across all stations and all surveys. Data suggest the restored lagoon represents a brackish water bar-built estuary habitat, with good circulation and dissolved oxygen levels.
	Surface and Bottom Water Constituents	None identified.	N/A	Although there were no specific quantitative success criteria identified for the water constituent sampling, six years of monitoring did not identify any areas of concern. Additionally, post-restoration bacteria data show higher annual "grades".
Sediment Quality	Sediment Grain Size and Constituents	(1) Grain size distribution at each sampling station should increase from the baseline monitoring conditions; (2) Increased sediment nutrient sequestration should not occur over three consecutive years.	Yes	The trajectories of grain size distributions over the course of the six survey years were found to meet project success criteria, which specifies that grain size distribution should increase from the baseline monitoring conditions. Similarly, the restoration area was also meeting the sediment nutrient success criteria by not sequestering excess nutrients as compared to the pre-restoration conditions.

Survey Category	Survey Type	5-Year Success Criteria Summary	Meeting 5-Year Criteria?	Criteria Evaluation Details
Biological	Benthic Invertebrates	Increasing the diversity and species richness of benthic invertebrates and the number of species and individual taxa with lower pollution tolerance values in Malibu Lagoon.	Yes	The abundances and numbers of pollution sensitive benthic invertebrate taxa are higher than pre-restoration conditions and did not exhibit decreases across multiple years; thus, the benthic community is meeting the project success criteria.
	Fish Community	Abundance and species richness of native fish shall not decrease; maintain at or above pre-restoration levels.	Yes	Both the native fish species richness' and the overall native fish abundances are higher in all six of the post-restoration summer surveys than in the pre-restoration summer survey, which indicates the site is meeting the project success criteria.
	Bird Community	Utilization of restoration area for roosting and foraging.	Yes	Many species of birds utilize the site for roosting, foraging, and breeding. Although not part of the success criteria, post-restoration numbers of birds, species richness, and diversity (Shannon Index) remain higher on average for the western channels (restored areas) as compared to pre-restoration data.
	SAV and Algae Cover	Decrease in % SAV; decrease in eutrophication impacts.	Yes	Post-restoration data indicate a reduction in algae cover as compared to pre-restoration data, especially in the form of floating algal mats, thus the site is meeting the success criteria. Algal cover shifted from pre-restoration floating mats that decomposed to create 'dead zones', to post-restoration cover dominated by wrack or submerged seagrasses.
	Plant Cover	90% native plant cover in seeded or planted areas by Year 5; 10% or less non-native plant cover.	Yes	Vegetation cover as assessed for both native and non-native species is meeting the restoration success criteria. Relative native vegetation cover was 96-100%, with average absolute native vegetation cover across all transects between 78-80% cover for Year 6, and non-native cover less than 1%.
	Photo Point	Vegetation establishment.	Yes	The vegetation community has continued to establish over time within the restoration area as demonstrated by the photo point series. Non-native, invasive vegetation was removed through community restoration events.

Figure 87. Photo Point 1 at bearing 155° on (A) 15 March 2013; (B) 7 May 2014; (C) 18 December 2014; (D) 5 May 2015.

Figure 87 (continued). Photo Point 1 at bearing 155° on (E) 22 December 2015; (F) 16 May 2016; (G) 27 December 2016; (H) 27 June 2017.

Figure 87 (continued). Photo Point 1 at bearing 155° on (I) 23 May 2018; (J) 4 December 2018; (K) 25 June 2019.

Figure 88. Photo Point 2 at bearing 300° on (A) 15 March 2013; (B) 7 May 2014; (C) 18 December 2014; (D) 5 May 2015.

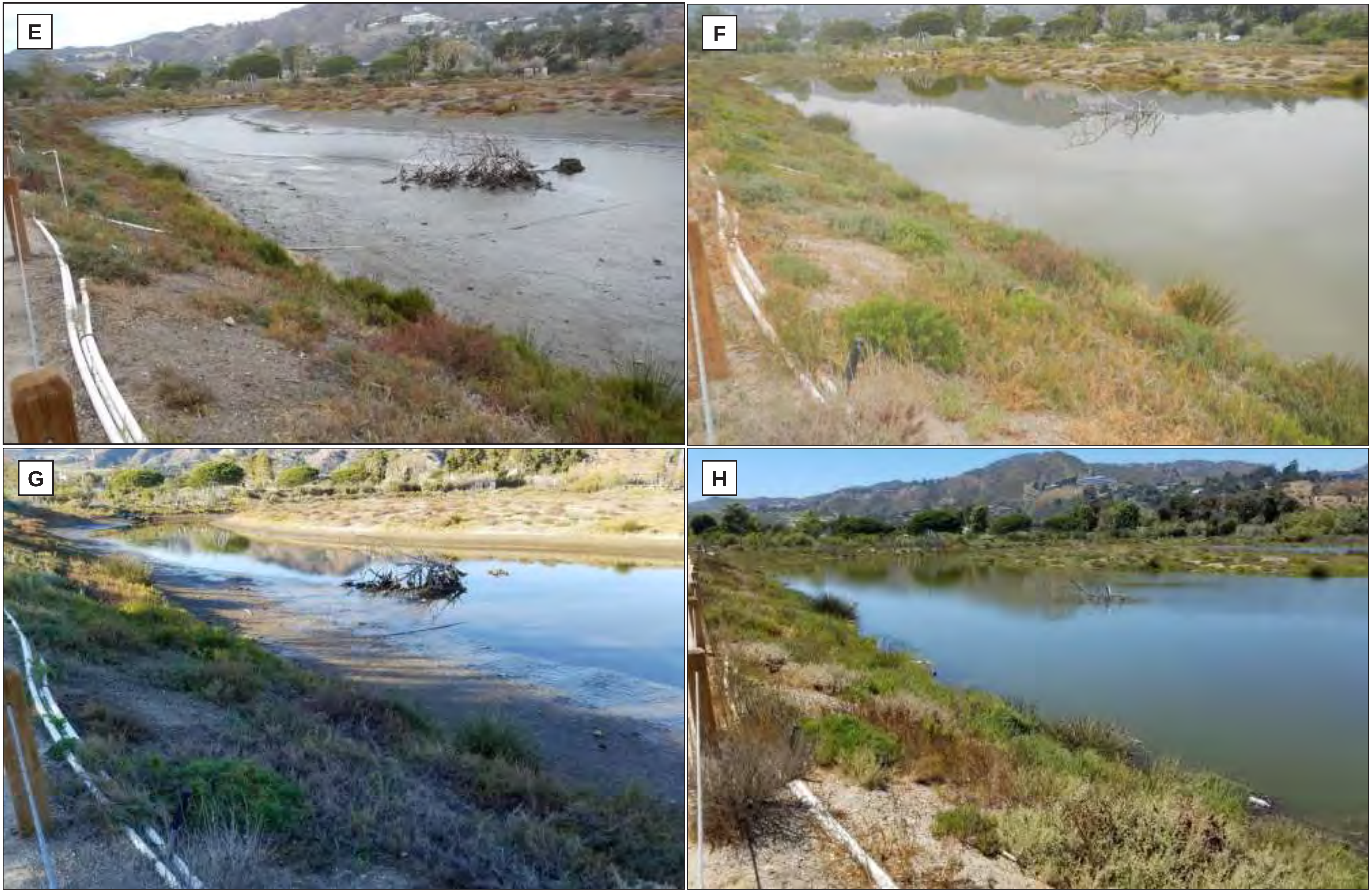


Figure 88 (continued). Photo Point 2 at bearing 300° on (E) 22 December 2015; (F) 16 May 2016; (G) 27 December 2016; (H) 27 June 2017.

Figure 88 (continued). Photo Point 2 at Bearing 300° on (I) 23 May 2018; (J) 4 December 2018; (K) 25 June 2019.

Figure 89. Photo Point 2 at bearing 75° on (A) 15 March 2013; (B) 7 May 2014; (C) 18 December 2014; (D) 5 May 2015.

Figure 89 (continued). Photo Point 2 at bearing 75° on (E) 22 December 2015; (F) 16 May 2016; (G) 27 December 2016; (H) 27 June 2017.

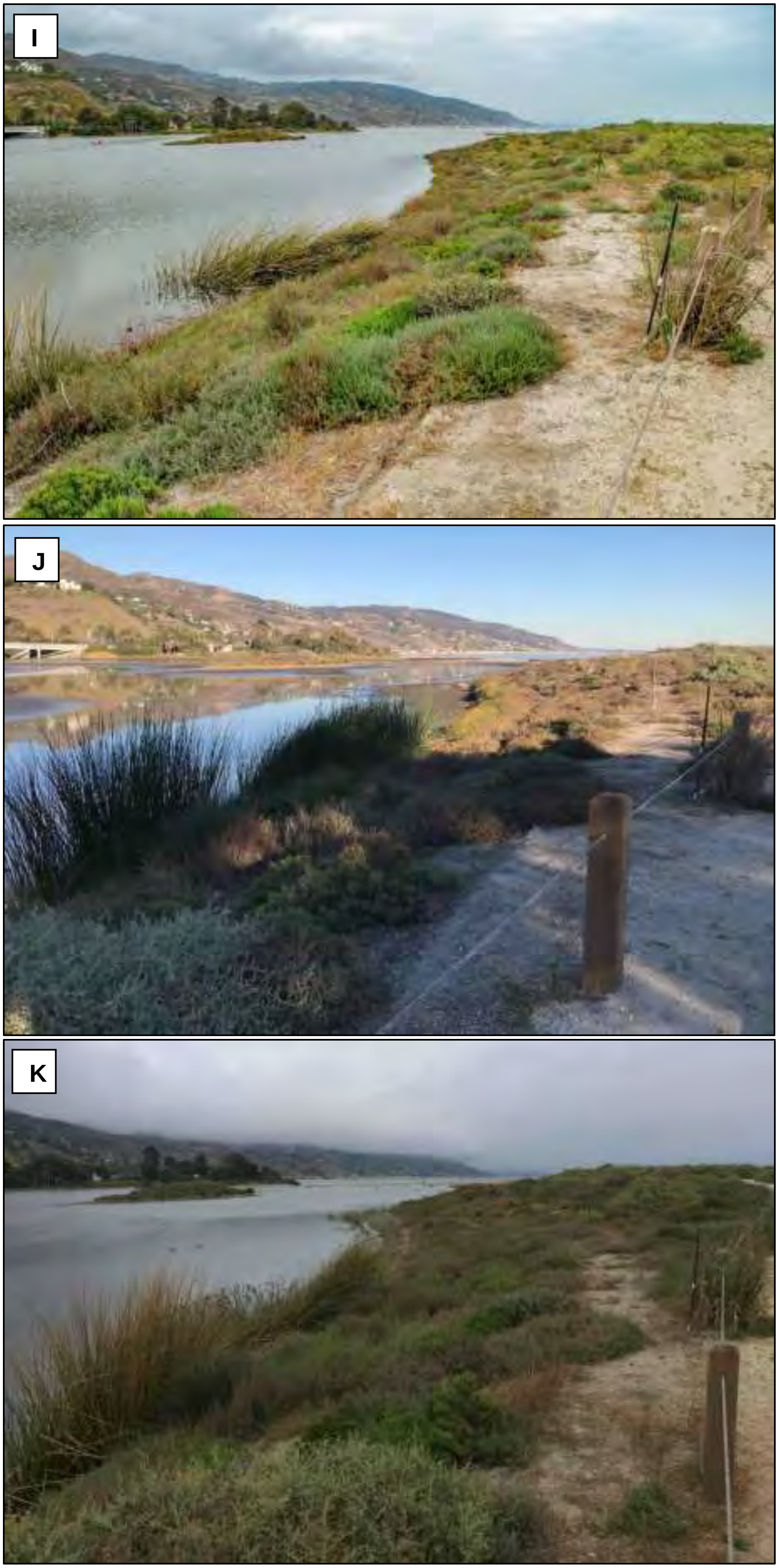


Figure 89 (continued). Photo Point 2 at Bearing 75° on (I) 23 May 2018; (J) 4 December 2018; (K) 25 June 2019.

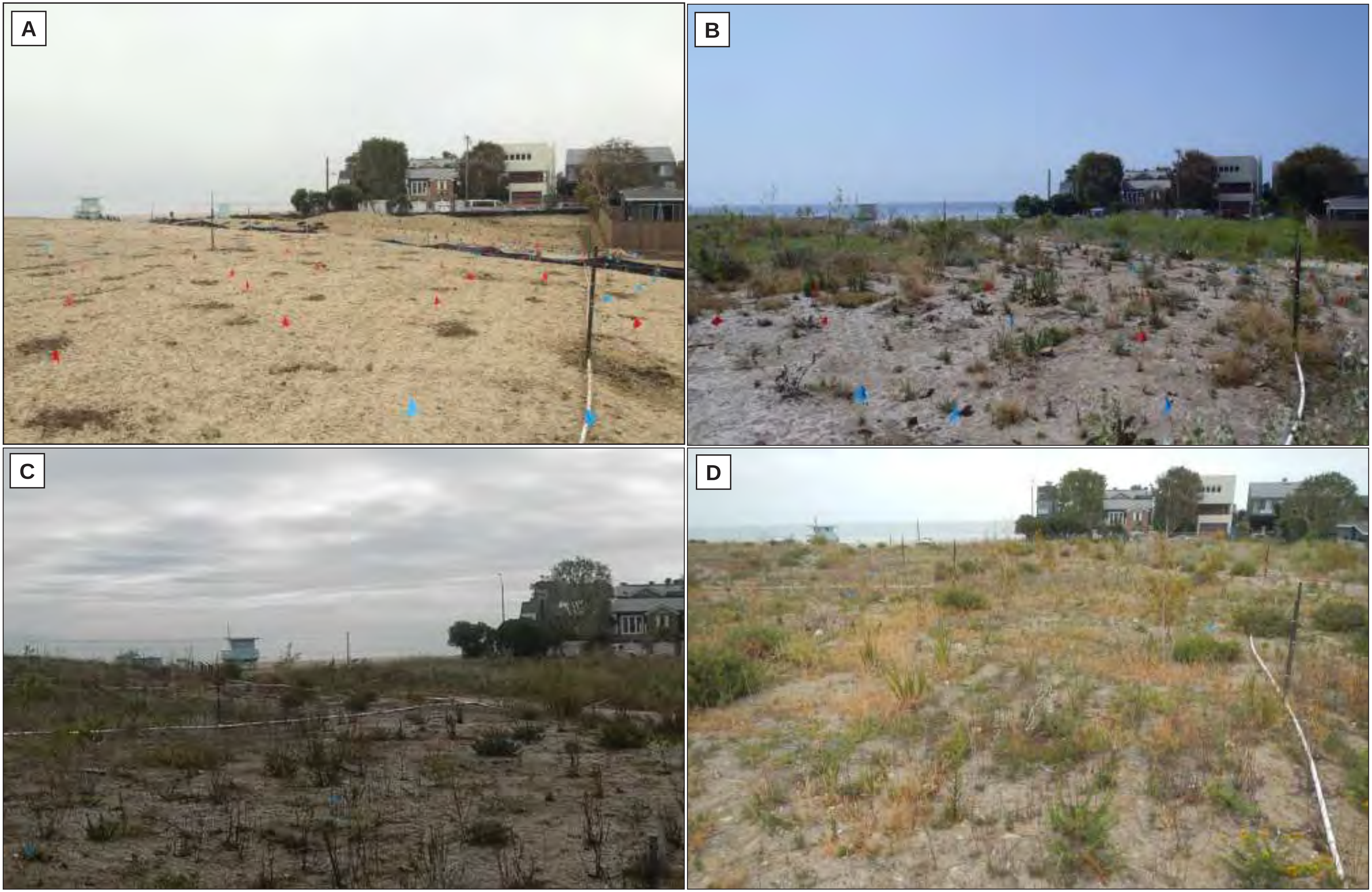


Figure 90. Photo Point 3 at bearing 220° on (A) 15 March 2013; (B) 7 May 2014; (C) 18 December 2014; (D) 5 May 2015.

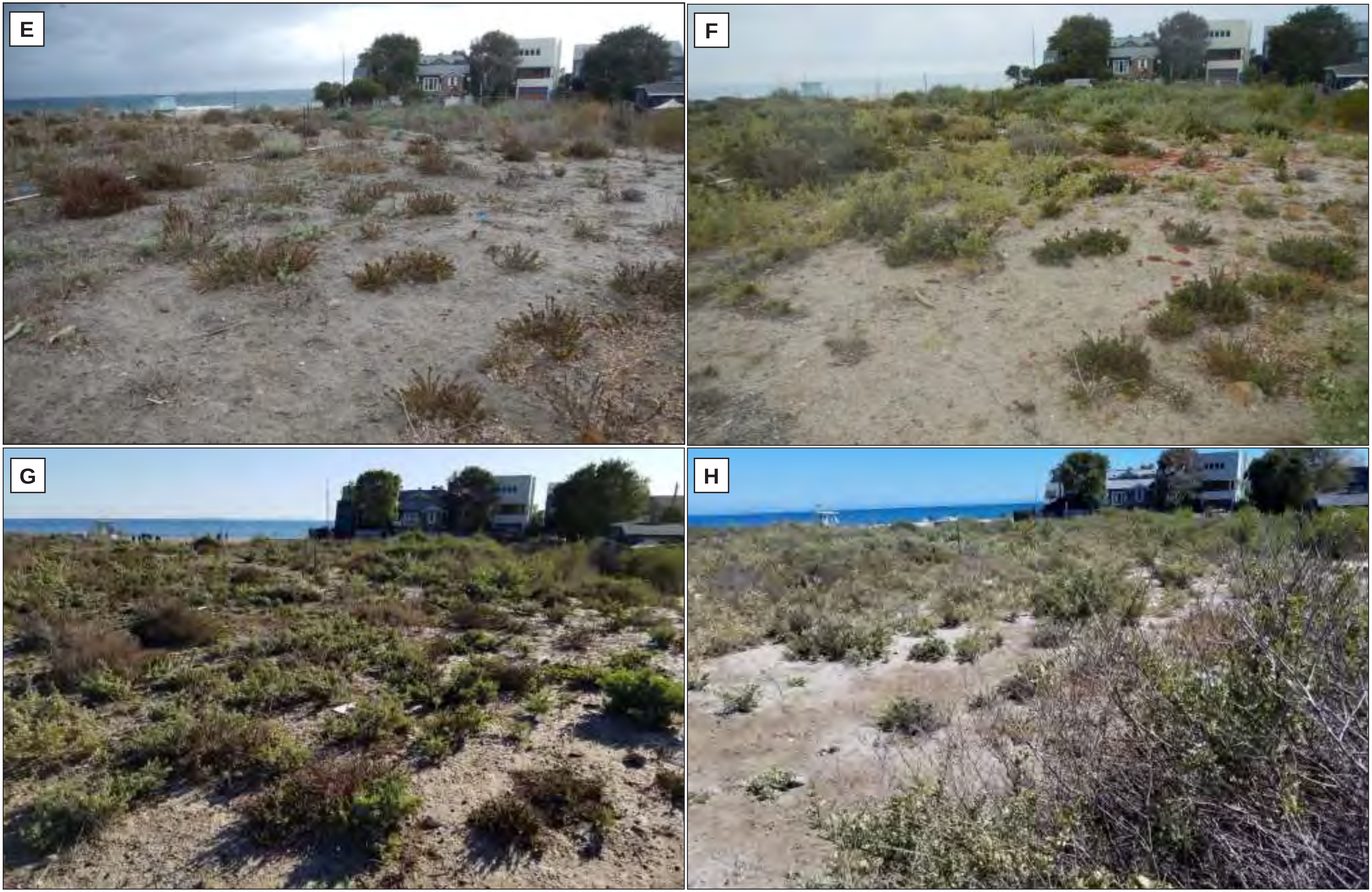


Figure 90 (continued). Photo Point 3 at bearing 220° on (E) 22 December 2015; (F) 16 May 2016; (G) 27 December 2016; (H) 27 June 2017.

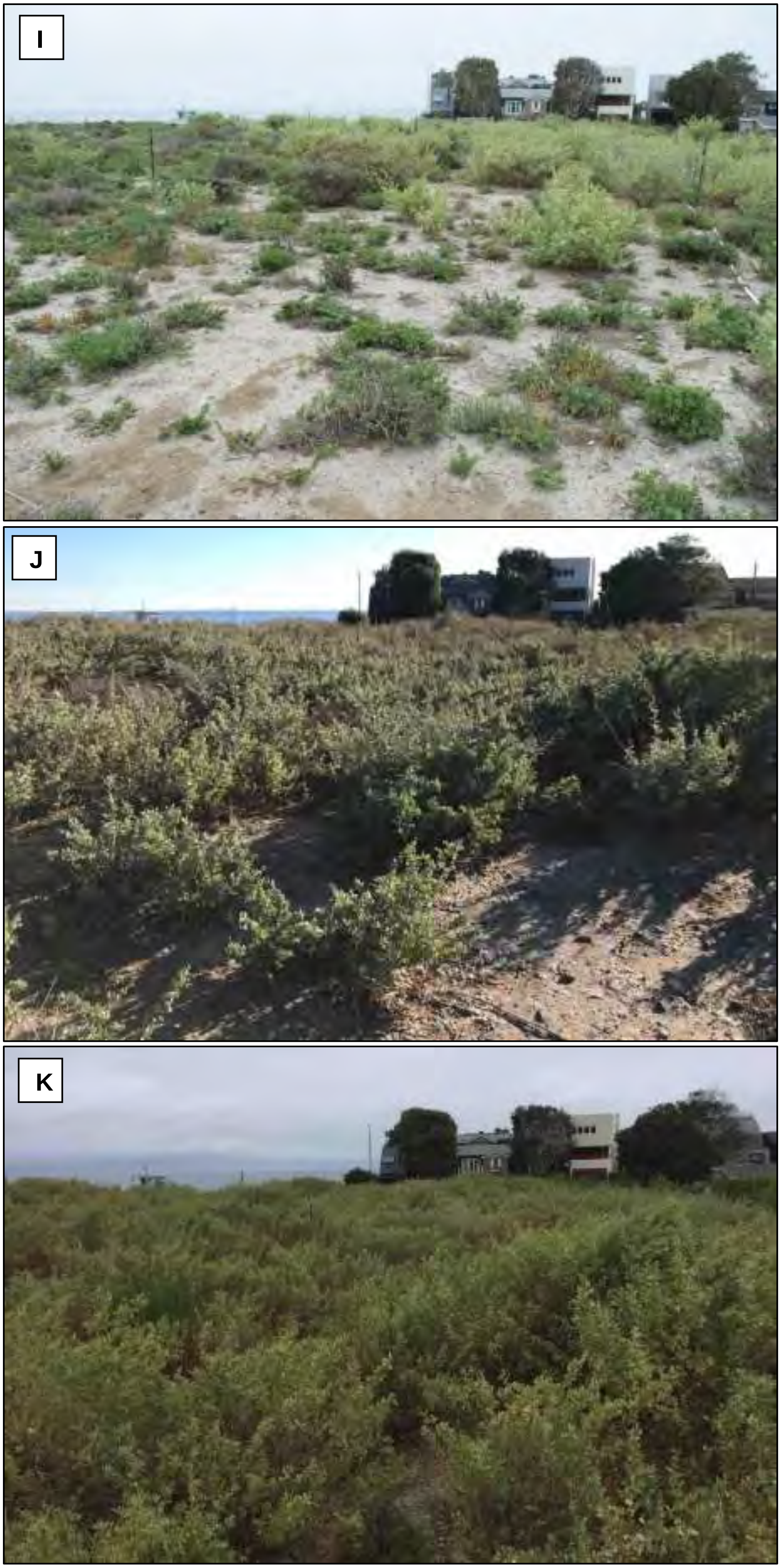


Figure 90 (continued). Photo Point 3 at Bearing 220° on (I) 23 May 2018; (J) 4 December 2018; (K) 25 June 2019.

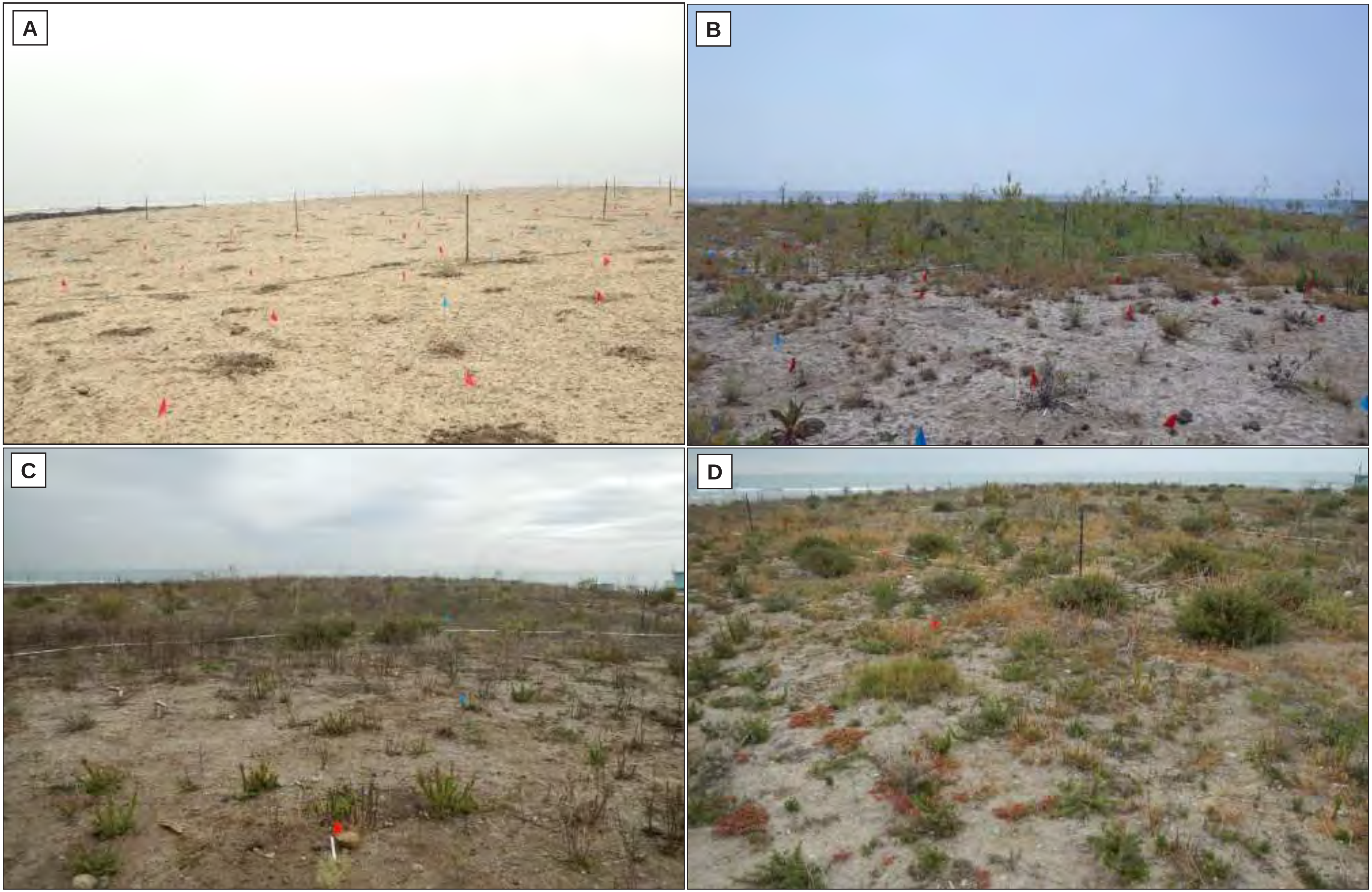


Figure 91. Photo Point 3 at bearing 100° on (A) 15 March 2013; (B) 7 May 2014; (C) 18 December 2014; (D) 5 May 2015.

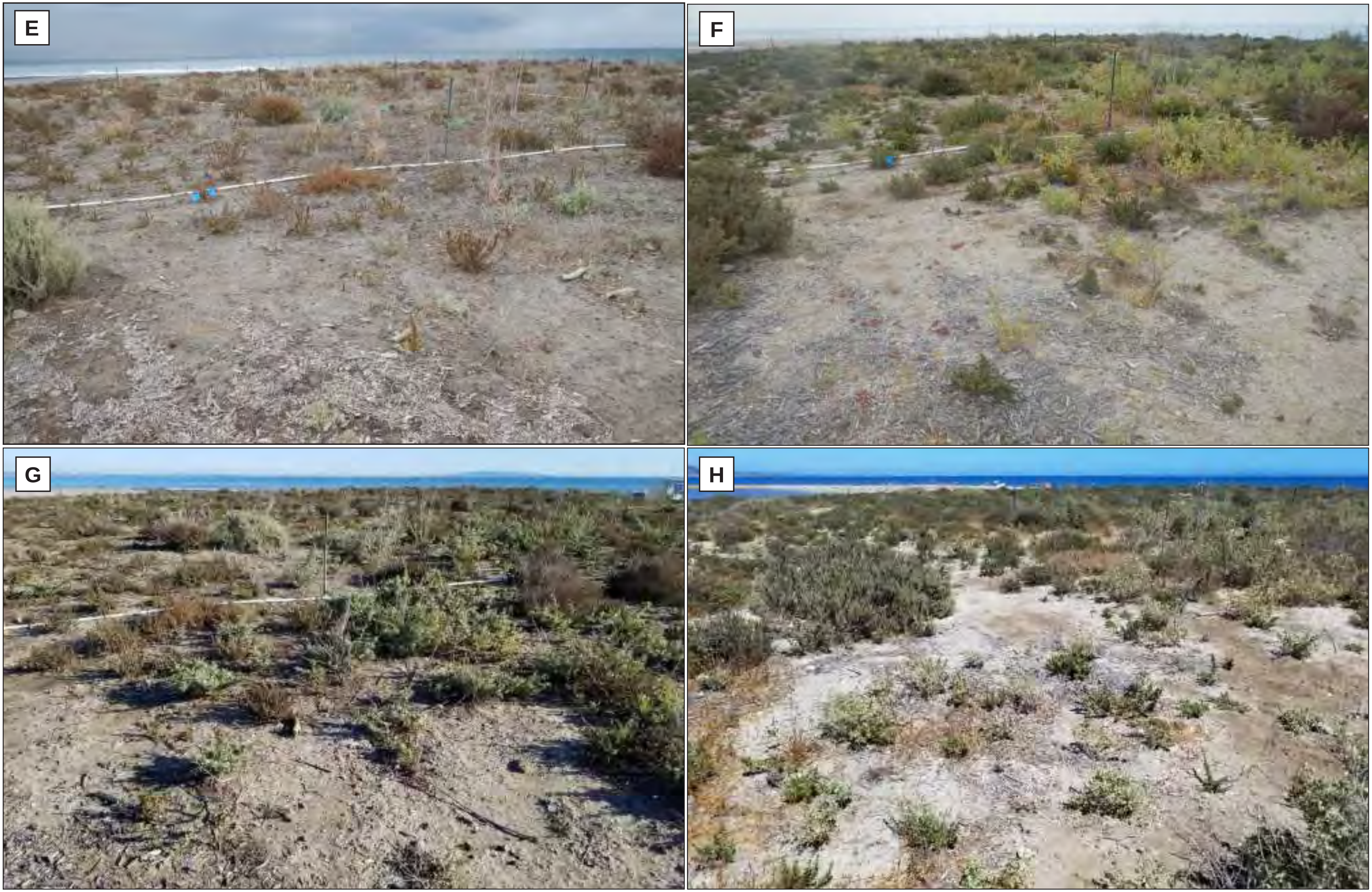


Figure 91 (continued). Photo Point 3 at bearing 100° on (E) 22 December 2015; (F) 16 May 2016; (G) 27 December 2016; (H) 27 June 2017.

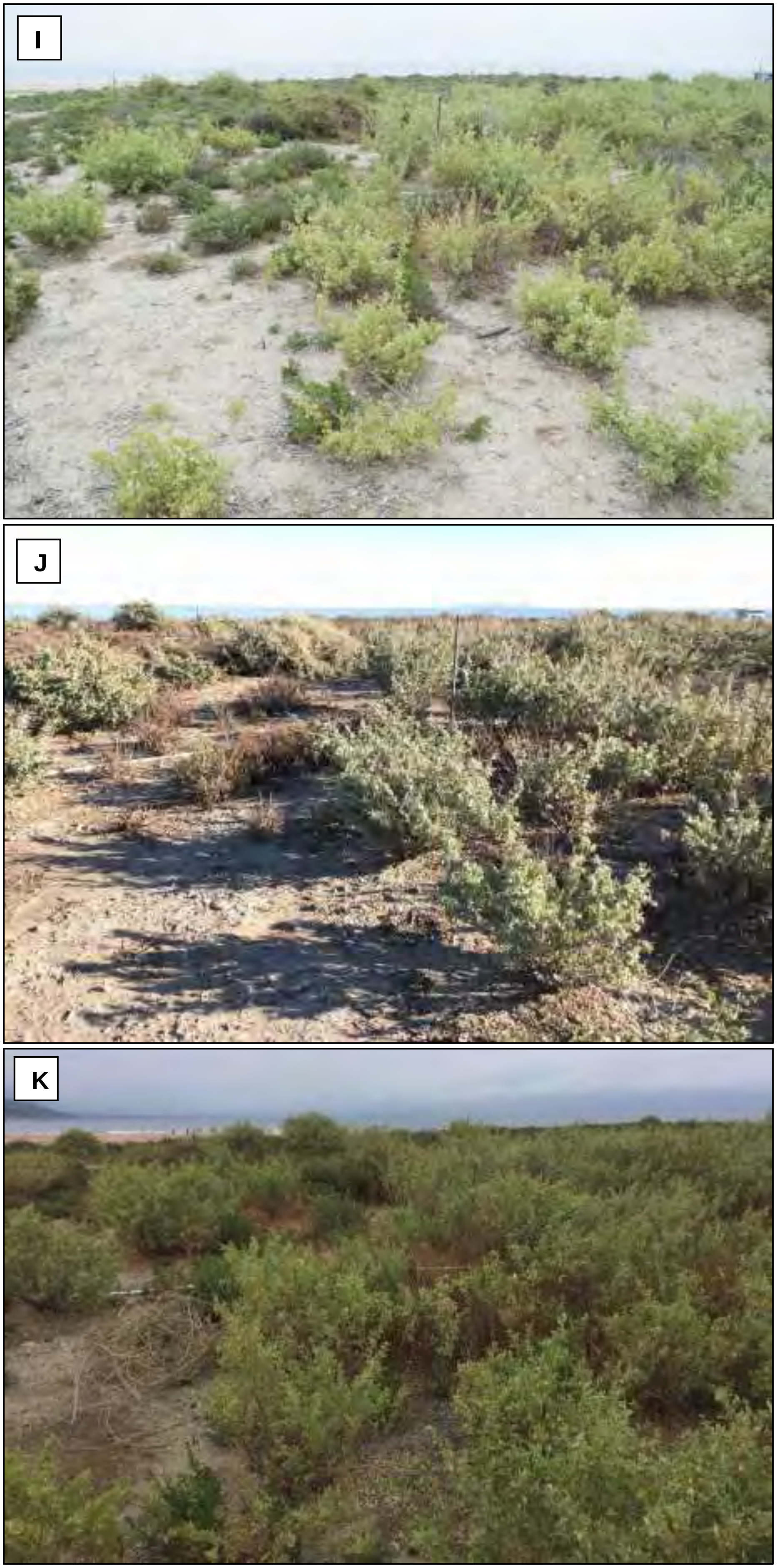


Figure 91 (continued). Photo Point 3 at Bearing 100° on (I) 23 May 2018; (J) 4 December 2018; (K) 25 June 2019.

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Appendix 1. Malibu Lagoon Post-Restoration Fish Survey Results: June 2018 (Prepared by R. Dagit, RCDSMM)

Malibu Lagoon
Post Construction Fish Survey June 2018

Prepared for:
Angeles District
California Department of Parks and Recreation

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

20 June, 2018

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EXECUTIVE SUMMARY

A post-construction fish survey of Malibu Lagoon was conducted on Tuesday 19 June 2018 by a team from the RCD of the Santa Monica Mountains with assistance from The Bay Foundation staff and volunteers.

Malibu Lagoon has been closed to the ocean since late April 2018, with lagoon levels remaining relatively constant and deep. We were able to seine to depletion at all sites. High water levels contributed to emergent vegetation at the banks of all survey sites. Low tide was at 9:12 am (1.3' elevation) and high tide was at 4:14 pm (6.2' elevation). Due to closed conditions, tide did not affect depth levels in the lagoon during this survey. 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 two spot surveys along the eastern end of the beach along the closed berm.

A total of 5 juvenile federally endangered tidewater gobies (*Eucyclogobius newberryi)* were captured during seining at Site 3 and Site 6. All individuals were subsequently released after identification and size classification. Striped mullet (*Mugil cephalus*) were observed jumping throughout the lagoon and were observed swimming away from sites as blocking nets were being positioned. The dominant species surveyed and identified was topsmelt (*Atherinops affinis, larva = 3128, juveniles =15, adult = 2*), followed by smelt larva that appeared to have recently hatched (*Atherinops sp = 2400*), and Oriental Shrimp (*Palaemonetes spp. = 442*). A total of 10 longjawed mudsucker larvae (*Gillichthys mirabilis*) and 1 adult were also observed. Additionally, 12 Staghorn sculpin (*L. armatus*) juveniles and 2 adults were 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 species.

Species captured or observed during the June 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*

Non-Native Fish Species

Mississippi Silversides	*Menidia beryllina*
Mosquitofish	*Gambusia affinis*

Invertebrates

Oriental shrimp	*Palaemonetes sp.*
Hemigraspus crab	
Water boatman juvenile	
Damselfly nymph	
Caddisfly larva	

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Field Assistants from 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:

Jayni Shuman, Stream Team
Salvador Contreras, Stream Team
Garrett Nichols, Stream Team
Brianna Demirci, Watershed Steward Program member

PURPOSE OF SURVEY

The Malibu Lagoon restoration was completed in Fall 2012. A total of six post-construction monitoring locations were identified by the Malibu Lagoon Restoration and Enhancement Hydrologic and Biological Project Monitoring Plan (Abramson 2012) and accepted by various permitting agencies. Sites were distributed throughout the restoration area to provide documentation of fish diversity, abundance, distribution, and to replicate as closely as possible the stations used previously in the 2005 pre-construction survey. Surveys are to be conducted in spring and fall annually until 2019. In 2018, the lagoon was surveyed open in January and closed in June.

SUMMARY OF POST CONSTRUCTION SURVEY EVENTS

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

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

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

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

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

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.

The tenth survey occurred on 19 June 2018. The lagoon was closed and full, with signs of regular overwash across the entire span of the berm. The weather was warm with full cloud cover in the morning that completely dissipated as the day progressed. A light NW wind persisted throughout the day with air temperatures in the mid 70's F. A protective fence was set up along the beach across most of the berm in anticipation of nesting snowy plovers – one individual was observed on the walk to do a spot seine at the normal breach point of the lagoon. Tides were not a factor.

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
- 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 19 June 2018

Variable	**Site 1**	**Site 2**	**Site 2a**	**Site 3**	**Site 5**	**Site 6**
Avg depth (cm)	102	125	40	160	120	75
Water T (ºC)	22.3	24.3	23.8	23.9	25.1	22.9
Air T (ºC)	24	25	24	25	25	23
Salinity ppt	10	10	12	10	10	10
DO mg/l	7.9	8.29	7.8	7.25	7.51	5.97
pH	8.9	9	8.96	8.93	8.89	8.87
Conductivity	16.4	17.1	17.2	17.4	17.4	17
% Floating Algae cover	0	0	0	0	0	0
% Submerged/ Attached Algae cover	0	0	0	0	10	0
% emergent vegetation bank cover	100	95	100	100	100	100
Emergent Vegetation type	Tules, Distichlis, Salicornia, Juncus	Distichlis, Salicornia	Distichlis, Salicornia	Jaumea, Distichlis, Salicornia	Distichlis, Salicornia, Juncus	Jaumea, Distichlis, Salicornia
Dominant Substrate	Sand	Sandy muck	Sand	Mud	Sandy muck	Cobble/ vegetation
Time start	10:45	13:00	11:45	13:50	14:40	09:25

Table 3. Summary of Fish and Invertebrates captured/observed 19 June 2018.

Lagoon-ocean connection conditions	**Closed, overwash**	**Site 1**	**Site 2**	**Site 2a**	**Site 3**	**Site 5**	**Site 6**	**Spot Seine**	**TOTALS**
Seine pull total to depletions		25	21	27	19	21	22	2	137
Native Fish Species									
Steelhead trout	*O.mykiss*								0
Unidentified goby larva (<5 cm)									0
Tidewater goby juveniles (<5cm)	*Eucyclogobius newberryi*				3		2		5
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*	2		2	1	2	2	1	10
Long-jawed mudsucker (5-10 cm)	*Gillichthys mirabilis*				1				1
Topsmelt larva (<5 cm)	*Atherinops sp*	213	154	275	176	226	84	2000	3128
Topsmelt juvenile (6 cm)	*Atherinops sp*	2	4		5	3	1		15
Topsmelt adult (16 cm)	*Atherinops sp*				1		1		2
Unidentified smelt larva (<5 cm)	*Atherinops sp*	287	345	1169	11	51	537		2400
Staghorn sculpin (<5 cm)	*L. armatus*	6	3		1	2			12
Staghorn sculpin (5-10 cm)	*L.armatus*					1	1		2
Staghorn sculpin (10-15cm)	*L.armatus*								0
Opaleye	*Girella nigricans*								0
Diamond turbot	*Hypsopsetta guttulata*								0
Spotted turbot	*Pleuronichthys ritteri*								0
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*								0
Unidentified fish larva									0
Non-Native Fish Species									0
Mosquitofish Juveniles (<5cm)	*Gambusia affinis*				1		6		7
Mosquitofish Adults (5-10cm)	*Gambusia affinis*								0
Carp	*Cyprinus carpio*								0
Mississippi silversides <5cm	*Menida audens*	3	2		5			2	12

Mississippi silversides (5-10cm)	*Menida audens*	2	1				2		5
Invertebrates									0
Oriental shrimp	*Palaemonetes sp.*	42	19	7	31	102	241		442
Hemigraspus crabs				1				1	2
Water boatman juveniles							1000 +		0
Amphipods									0
Isopods									0
Ctenophore sp (<2 cm)									0
Salp sp (<2 cm)									0
Sea hare (5-10 cm)	*Aplysia californica*								0
Segmented worm <2 cm)									0
Gastropoda									0
Water scavenger larva	Hydrophilidae								0
Dragonfly larvae					1				1
Caddisfly larvae							1		1
Crayfish	*Procambarus clarkii*								0

SUMMARY

The June 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 ten post-construction surveys (2013-2018).

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

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

		Survey 6/1/2005 open	**Relocation June 2012 open**	**Survey 1/8/2013 open**	**Survey 5/15/2014 closed**	**Survey 12/11/2014 open**	**Survey 5/27/2015 closed**	**Survey 1/12/2016 open**	**Survey 6/1/2016 closed**	**Survey 3/3/2017 open**	**Survey 7/26/2017 closed**	**Survey 1/30/2018 open**	**Survey 6/19/2018 closed**
Native Fish Species													
Steelhead trout	*O.mykiss*				1 observed								
Unidentified goby larva (<5 cm)	----		2		~500						8	1	
Tidewater goby larva (<5cm)	*Eucyclogobius newberryi*				13				17	12	10		5
Tidewater goby adult (6-8cm)	*Eucyclogobius newberryi*	473	8				41						
Arrow goby (<5 cm)	*Cleavlandia ios*				5								
Bay goby?	*Lepidogobius lepidus*				2								
CA Halibut	*Paralichthys californicus*								2				
CA killifish juveniles (<5cm)	*Fundulus parvipinnis*		306						1	1			
CA killifish (5-10 cm)	*Fundulus parvipinnis*	46	16		5								
Long-jawed mudsucker (<5 cm)	*Gillichthys mirabilis*	1	8		5		3		11	2	4	3	10
Long-jawed mudsucker (5-10 cm)	*Gillichthys mirabilis*		11				22	5	52		13		1
Topsmelt larva (<5 cm)	*Atherinops sp*		1	3			176	6	1289	35	2618	276	3128
Topsmelt juvenile (6 cm)	*Atherinops sp*	244			24		60		133	48	933	264	15

Malibu Lagoon Fish Survey June 2018

		Survey 6/1/2005 open	Relocation June 2012 open	Survey 1/8/2013 open	Survey 5/15/2014 closed	Survey 12/11/2014 open	Survey 5/27/2015 closed	Survey 1/12/2016 open	Survey 6/1/2016 closed	Survey 3/3/2017 open	Survey 7/26/2017 closed	Survey 1/30/2018 open	Survey 6/19/2018 closed
Topsmelt adult (16 cm)	*Atherinops sp*						6				56		2
Unidentified smelt larva (<5 cm)	*Atherinops sp*		101		15,293		2,244	64					2,400
Staghorn sculpin (<5 cm)	*L. armatus*			17	11			1		130	1	8	12
Staghorn sculpin (5-10 cm)	*L.armatus*		3						5	4	2		2
Opaleye	*Girella nigricans*										2		
Diamond turbot	*Hypsopsetta guttulata*			7	1				5				
Spotted turbot	*Pleuronichthys ritteri*											12	
Garabaldi (28 cm FL) dead dropped by birds	*Hypsypops rubicundus*												
Northern anchovy <5 cm	*Engraulis mordax*		5					180	1		423		
Northern anchovy 5-10 cm	*Engraulis mordax*										239		
Striped mullet	*Mugil cephalus*	observed	observed	observed	observed	7	1	observed	observed	observed	observed	1	observed
Unidentified fish larva							991		3		52		
Non-Native Fish Species													
Mosquitofish Juveniles (<5cm)	*Gambusia affinis*						13	6	10	1	271		7
Mosquitofish Adults (5-10cm)	*Gambusia affinis*	65	4,072			2	3				3		
Carp	*Cyprinus carpio*	1			observed						1		
Mississippi silversides	*Menida audens*			1		970	9	15	16		650	1	17
Invertebrates													
Oriental shrimp	*Palaemonetes sp.*			37	209	43	10	5	58	89	280	7	442
Hemigraspus crabs			6		8	1	20	1	1	2	2		2
Water boatman juveniles			6,000+		2,504						14		
Amphipods			2,500+										
Isopods			2,500+									3	

		Survey 6/1/2005 open	Relocation June 2012 open	Survey 1/8/2013 open	Survey 5/15/2014 closed	Survey 12/11/2014 open	Survey 5/27/2015 closed	Survey 1/12/2016 open	Survey 6/1/2016 closed	Survey 3/3/2017 open	Survey 7/26/2017 closed	Survey 1/30/2018 open	Survey 6/19/2018 closed
Ctenophore sp (<2 cm)				3									
Salp sp (<2 cm)				3									
Sea hare (5-10 cm)	*Aplysia californica*			2									
Segmented worm <2 cm)				3									
Gastropoda							4						
Water scavenger larva	Hydrophilidae						1						
Dragonfly											16		1
Caddisfly											8		1
Crayfish	*Procambarus clarkii*									1			

Appendix A. Photographs of fish species

Tidewater Goby

Mississippi silverside

Staghorn sculpin

Topsmelt

Appendix B. Site Photos 19 June 2018

Site 1

Site 3

Site 2

Site 5

Site 2a

Site 6

Spot seine near beach face close to breach location

Spot seine along berm between breach point and nesting habitat

Appendix 2. Malibu Lagoon Post-Restoration Fish Survey Results: February 2019 (Prepared by R. Dagit, RCDSMM)

Malibu Lagoon
Post Construction Fish Survey February 2019

Prepared for:
Angeles District
California Department of Parks and Recreation

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20 February 2019

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EXECUTIVE SUMMARY

A post-construction fish survey of Malibu Lagoon, Los Angeles County, was conducted on Wednesday, 20 February 2019 by a team from the RCD of the Santa Monica Mountains with assistance from The Bay Foundation, USFWS, and UCLA staff and volunteers.

Malibu Lagoon has been open to the ocean since late November 2018, with lagoon levels remaining relatively constant and shallow. Sediment plumes from the Woolsey Fire, which burned most of the upper watershed above Rindge Dam, have reshaped the alluvial area and created multiple thalwegs which expanded the ocean connectivity and reduced the beach berm.

We were able to seine to depletion at sites 1, 2, 2A and 6. We did spot seine pulls at sites 3 and 5 due to deep muck that made pulling the nets extremely difficult. At site 3, we captured more than 50 larval gobies in the first pull, and decided to stop to avoid any take. Water levels dropped extensively from the start to end of the survey due to an extreme tide associated with the full moon on 19 February. High tide was at 09:19 (6.5' elevation) and low tide was at 16:03 (-1.3' elevation). 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 to official sites, we conducted spot surveys upstream and under the PCH bridge on the west side to the old Texaco drain site. Additional spot surveys were done at several locations within the thalweg between the lagoon and ocean along the beach. We then hiked up the east bank above the PCH bridge and were able to seine in the main channel as far up as the north end of the parking lot drainage area.

Five juvenile federally endangered tidewater gobies (*Eucyclogobius newberryi)* were captured during seining at Site 2 and Site 3. When seining at Site 3, after catching more than 50 juvenile longjawed mudsuckers in one pull, the remainder of pulls were called off so as not to harm that species. All individuals were subsequently released after identification and size classification with no observed mortalities. Juvenile mullet (*Mugil sp.*) were observed at Sites 1 and 3 as well as during spot seines under the west side of PCH bridge. The dominant species surveyed and identified was juvenile mullet (*Mugil sp., juvenile=82*), followed by larval longjawed mudsuckers (*Gillithys mirabilis =55+)*, and staghorn sculpin (*L. armatus, juvenile=28, adults: 5-10cm=5*). A single Northern anchovy (*Engraulis mordax*) was also observed. Additionally, 12 oriental shrimp (*Palaemonetes sp.*) were captured. A few small water boatman were also observed. A dead salp was washed up on the east bank upstream of the PCH bridge.

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 many lagoon species.

Species captured or observed during the 20 February 2019 survey include:

Native Fish Species	
Striped mullet	*Mugil cephalus*
Tidewater goby	*Eucyclogobius newberryi*
Staghorn sculpin	*Leptocottus armatus*
Longjawed mudsucker	*Gillithys mirabilis*
Northern anchovy	*Engraulis mordax*
Invertebrates	
Oriental shrimp	*Palaemonetes sp.*
Water boatman	*Corixid sp.*

ACKNOWLEDGEMENTS

We wish to thank Suzanne Goode, Jamie King, and Danielle LeFer, CDPR for their assistance. The contract for this work was provided by CDPR. Chris Enyart from The Bay Foundation and Kendra Chan from USFWS were 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:

Allison Della Bella, Stream Team
Steve Williams, Stream Team
Tanessa Hartwig, Stream Team
Angelica Kahler, Watershed Steward Program Member
Peter Dixon, Nature Conservancy in Ventura
Oliver Miano, Biologist
Rachel Turba, UCLA Grad Student
David Jacobs, UCLA Professor

PURPOSE OF SURVEY

The Malibu Lagoon restoration was completed in Fall 2012. A total of six post-construction monitoring locations were identified by the Malibu Lagoon Restoration and Enhancement Hydrologic and Biological Project Monitoring Plan (Abramson 2012) and accepted by various permitting agencies. Sites were distributed throughout the restoration area to provide documentation of fish diversity, abundance, distribution, and to replicate as closely as possible the stations used previously in the 2005 pre-construction survey. Surveys are to be conducted in spring and fall annually until 2019. In 2018, the lagoon was surveyed open in January and closed in June.

SUMMARY OF POST CONSTRUCTION SURVEY EVENTS

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

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

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

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

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

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.

The tenth survey occurred on 19 June 2018. The lagoon was closed and full, with signs of regular overwash across the entire span of the berm. The weather was warm with full cloud cover in the morning that completely dissipated as the day progressed. A light NW wind persisted throughout the day with air temperatures in the mid 70's F. A protective fence was set up along the beach across most of the berm in anticipation of nesting snowy plovers – one individual was observed on the walk to do a spot seine at the normal breach point of the lagoon. Tides were not a factor.

The eleventh survey occurred on 20 February 2019. The lagoon was open and the tide was at its highest when the survey began at 09:19. The tide receded throughout the day, affecting seining opportunities as water levels lowered. The weather was chilly in the morning with partial cloud cover throughout the day. Air temperatures spanned from the mid to upper 60's F. A handful of snowy plovers were observed in the mudflats during transition from site to site.

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
- 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. Due to the extremely low tide, sites were adjusted into the channels to get to the remaining water as the day went on. The recent rain events and subsequent strong stream flow into the lagoon appear to have diluted any incoming ocean waters and salinity overall remained brackish. There were no algae observed.

Table 2. Water Quality and site conditions at the permanent monitoring sites 20 February 2019.

Variable	**Site 1**	**Site 2**	**Site 2a**	**Site 3**	**Site 5**	**Site 6**
Avg depth (cm)	50	30	30	35	30	30
Water T (ºC)	11.3	12.5	9.9	13.5	14.5	11
Air T (ºC)	21	20	14	17.5	18.5	16.5
Salinity ppt	6	6	6	13	8	6
DO mg/l	10.35	10.45	10.25	13.12	10.55	10.67
pH	7.5	7	7	7.5	7.5	7.5
Conductivity	N/A	N/A	N/A	N/A	N/A	N/A
% Floating Algae cover	0	0	0	0	0	0
% Submerged/ Attached Algae cover	0	0	0	0	0	0
% emergent vegetation bank cover	100	0	10	0	0	100
Emergent Vegetation type	Distichlis, Salicornia, Juncus		Distichlis			Distichlis
Dominant Substrate	Sand /Gravel	Sandy/Silt/ Muck	Sand/ Cobble	Muck over sand	Sandy muck	Gravel/ Sand
Time start	10:30	11:45	09:30	13:50	14:40	09:25

Table 3. Summary of fish and invertebrates captured/observed 20 February 2019. Note Site 3 and Site 5 were only surveyed via spot seines, not seined to depletion.

Lagoon-ocean connection conditions	**open**	**Site 1**	**Site 2**	**Site 2a**	**Site 3**	**Site 5**	**Site 6**	**Spot Seine**	**TOTALS**
Seine pull total to depletions		7	24	6	2	2	6	18	65
Native Fish Species									
Steelhead trout	*O.mykiss*								0
Unidentified goby larva (<5 cm)									0
Tidewater goby larva (<5cm)	*Eucyclogobius newberryi*		5						5
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*		1		50+				50+
Long-jawed mudsucker (5-10 cm)	*Gillichthys mirabilis*								0
Topsmelt larva (<5 cm)	*Atherinops sp*								0
Topsmelt juvenile (6 cm)	*Atherinops sp*								0
Topsmelt adult (16 cm)	*Atherinops sp*								0
Unidentified smelt larva (<5 cm)	*Atherinops sp*								0
Staghorn sculpin (<5 cm)	*L. armatus*	1	17			4		6	28
Staghorn sculpin (5-10 cm)	*L.armatus*		4					1	5
Staghorn sculpin (10-15cm)	*L.armatus*								0
Opaleye	*Girella nigricans*								0
Diamond turbot	*Hypsopsetta guttulata*								0
Spotted turbot	*Pleuronichthys ritteri*								0
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*							1	1
Striped mullet	*Mugil cephalus*								0
Mullet sp juveniles <5cm	*Mugil sp.*	66			2			14	82
Unidentified fish larva									0

Table 3. Continued.

Lagoon-ocean connection conditions	open	Site 1	Site 2	Site 2a	Site 3	Site 5	Site 6	Spot Seine	TOTALS
Seine pull total to depletions		7	24	6	2	2	6	18	65
Native Fish Species									
Steelhead trout	*O. mykiss*								0
Unidentified goby larva (<5 cm)									0
Tidewater goby larva (<5cm)	*Eucyclogobius newberryi*		5						5
Tidewater goby adult (6-8cm)	*Eucyclogobius newberryi*								0
Arrow goby (<5 cm)	*Clevelandia 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*		1		50+				50+
Long-jawed mudsucker (5-10 cm)	*Gillichthys mirabilis*								0
Topsmelt larva (<5 cm)	*Atherinops sp*								0
Topsmelt juvenile (6 cm)	*Atherinops sp*								0
Topsmelt adult (16 cm)	*Atherinops sp*								0
Unidentified smelt larva (<5 cm)	*Atherinops sp*								0
Staghorn sculpin (<5 cm)	*L. armatus*	1	17			4		6	28
Staghorn sculpin (5-10 cm)	*L. armatus*		4					1	5
Staghorn sculpin (10-15cm)	*L.armatus*								0
Opaleye	*Girella nigricans*								0
Diamond turbot	*Hypsopsetta guttulata*								0

		Site 1	Site 2	Site 2a	Site 3	Site 5	Site 6	Spot Seine	TOTALS
Mullet sp juveniles <5cm	*Mugil sp.*	66			2			14	82
Unidentified fish larva									0
Non-Native Fish Species									
Mosquitofish Juveniles (<5cm)	*Gambusia affinis*								0
Mosquitofish Adults (5-10cm)	*Gambusia affinis*								0
Carp	*Cyprinus carpio*								0
Mississippi silversides <5cm	*Menida audens*								0
Mississippi silversides (5-10cm)	*Menida audens*								0
Invertebrates									
Oriental shrimp	*Palaemonetes sp.*	2	6			2		2	12
Hemigraspus crabs									0
Water boatman juveniles			50+						50+
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
Gastropoda									0
Water scavenger larva	Hydrophilidae								0
Dragonfly									0
Caddisfly									0
Crayfish	*Procambarus clarkii*								0

SUMMARY

The February 2019 post-construction fish survey was completed in one day with a team of 10 people. Table 4 provides a summary comparing abundance of species documented in Malibu Lagoon prior to restoration (2005), species relocated during restoration (2012), and eleven post-construction surveys (2013-2019). A total of five native fish species and zero non-native fish species were observed in February 2019.

Table 4. Summary of fish and invertebrates captured/observed 2005 – 2019.

		Survey 6/1/2005 open	Relocation June 2012 open	Survey 1/8/2013 open	Survey 5/15/2014 closed	Survey 12/11/2014 open	Survey 5/27/2015 closed	Survey 1/12/2016 open	Survey 6/1/2016 closed	Survey 3/3/2017 open	Survey 7/26/2017 closed	Survey 1/30/2018 open	Survey 6/19/2018 closed	Survey 2/20/2019 open
Native Fish Species														
Steelhead trout	*O.mykiss*				1 observed					0	0	0	0	0
Unidentified goby larva (<5 cm)			2		500~				0	0	8	1	0	0
Tidewater goby larva (<5cm)	*Eucyclogobius newberryi*				13				17	12	10	0	5	5
Tidewater goby adult (6-8cm)	*Eucyclogobius newberryi*	473	8		0		41		0	0	0	0	0	0
Arrow goby (<5 cm)	*Cleavlandia ios*				5				0	0	0	0	0	0
Bay goby?	*Lepidogobius lepidus*				2				0	0	0	0	0	0
CA Halibut	*Paralichthys californicus*								2	0	0	0	0	0
CA killifish juveniles (<5cm)	*Fundulus parvipinnis*		306		0				1	1	0	0	0	0
CA killifish (5-10 cm)	*Fundulus parvipinnis*	46	16		5				0	0	0	0	0	0
Long-jawed mudsucker (<5 cm)	*Gillichthys mirabilis*	1	8		5		3		11	2	4	3	10	50+
Long-jawed mudsucker (5-10 cm)	*Gillichthys mirabilis*		11				22	5	52	0	13	0	1	0
Topsmelt larva (<5 cm)	*Atherinops sp*		1	3			176	6	1289	35	2618	276	3128	0
Topsmelt juvenile (6 cm)	*Atherinops sp*	244	0		24		60		133	48	933	264	15	0
Topsmelt adult (16 cm)	*Atherinops sp*		0				6		0	0	56	0	2	0
Unidentified smelt larva (<5 cm)	*Atherinops sp*		101		15,293		2244	64		0	0	0	2400	0
Staghorn sculpin (<5 cm)	*L. armatus*			17	11			1		130	1	8	12	28
Staghorn sculpin (5-10 cm)	*L.armatus*		3						5	4	2	0	2	5
Opaleye	*Girella nigricans*									0	2	0	0	0
Diamond turbot	*Hypsopsetta guttulata*			7	1				5	0	0	0	0	0
Spotted turbot	*Pleuronichthys ritteri*											12	0	0
Garabaldi (28 cm FL) dead dropped	*Hypsypops rubicundus*									0	0	0	0	0
Northern anchovy <5 cm	*Engraulis mordax*		5					180	1	0	423	0	0	0
Northern anchovy 5-10 cm	*Engraulis mordax*										239	0	0	1
Striped mullet	*Mugil cephalus*	observed		observed	observed	7	1		observed	observed	0	1	0	0
Mullet juveniles <5cm	*Mugil sp.*													82
Unidentified fish larva							991		3	0	52	0	0	0
Non-Native Fish Species														
Mosquitofish Juveniles (<5cm)	*Gambusia affinis*						13	6	10	1	271	0	7	0
Mosquitofish Adults (5-10cm)	*Gambusia affinis*	65	4072			2	3			0	3	0	0	0
Carp	*Cyprinus carpio*	1			observed					0	1	0	0	0
Mississippi silversides	*Menida audens*			1	0	970	9	15	16	0	650	1	17	0
Invertebrates														
Oriental shrimp	*Palaemonetes sp.*			37	209	43	10	5	58	89	280	7	442	12
Hemigraspus crabs			6		8	1	20	1	1	2	2	0	2	0
Water boatman juveniles			6,000+		2504					0	14	0	0	50+
Amphipods			2500+							0	0	0	0	0
Isopods			2500+							0	0	3	0	0
Ctenophore sp (<2 cm)				3						0	0	0	0	0
Salp sp (<2 cm)				3						0	0	0	0	0
Sea hare (5-10 cm)	*Aplysia californica*			2						0	0	0	0	0
Segmented worm <2 cm)				3						0	0	0	0	0
Gastropoda							4			0	0	0	0	0
Water scavenger larva	Hydrophilidae						1			0	0	0	0	0
Dragonfly											16	0	1	1
Caddisfly											8	0	1	1
Crayfish	*Procambarus clarkii*									1	0	0	0	0

Appendix A. Photographs of fish species.

Tidewater Goby

Stripped mullet juveniles

Staghorn sculpin

Northern anchovy

Juv. longjawed mudsuckers

Appendix B. Site Photos

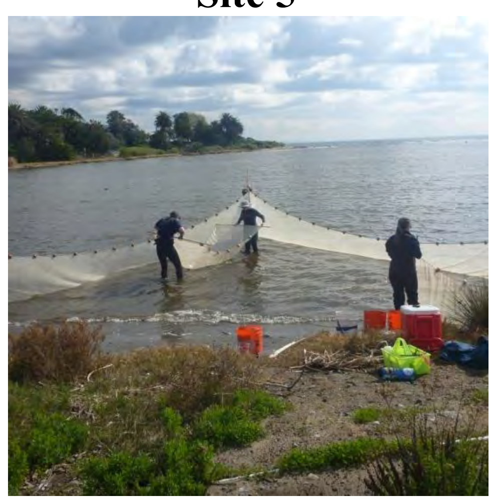
Site 1 (photo missing)

Site 2

Site 2a

Site 3

Site 5



Site 6

Spot seine near beach face close to breach location

Spot seine on eastern beach upstream of PCH Bridge

Spot seine in main channel at N end of parking lot near drainage

Appendix 3. Malibu Lagoon Post-Restoration Fish Survey Results: July 2019 (Prepared by R. Dagit, RCDSMM)

Malibu Lagoon
Post Construction Fish Survey July 2019

Prepared for:
Angeles District
California Department of Parks and Recreation

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

17 July 2019

Table of Contents

EXECUTIVE SUMMARY

A post-construction fish survey of Malibu Lagoon, Los Angeles County, was conducted on Wednesday, 17 July 2019 by a team from the RCD of the Santa Monica Mountains with assistance from The Bay Foundation, USFWS, LMU, Marymount High School, UCCE Ventura, and UCLA staff and volunteers.

Malibu Lagoon was open to the ocean beginning in late November 2018. Sediment plumes from the Woolsey Fire, which burned most of the upper watershed above Rindge Dam, reshaped the alluvial area and created multiple thalwegs in the main Malibu Lagoon channel. The lagoon remained connected until 3 July, and so the final closed condition survey was conducted on 17 July 2019.

We were able to seine to depletion at all sites. 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.

Seven juvenile federally endangered tidewater gobies (*Eucyclogobius newberryi)* were captured during seining at Site 2, Site 3, Site 5, and Site 6. All individuals were subsequently released after identification and size classification, with one observed mortality at Site 3. Six unidentified goby larvae were also observed. The dominant species surveyed and identified was juvenile topsmelt (*Atherinops sp.,* juvenile = 784), followed by Mississippi Silversides (*Menida audens* <5cm = 441*,* 5-10cm = 137*)*, unidentified smelt larvae (*Atherinops sp* = 317), CA killifish (*Fundulus parvipinnis* <5cm = 300, 5-10cm = 17), adult topsmelt (*Atherinops sp.* = 228), and lastly Long-jawed mudsucker (*Gillichthys mirabilis* <5cm = 18, 5-10cm = 4). A single juvenile Largemouth bass (*Micropterus salmoides*) was also observed at Site 3. Additionally, 66 Mosquitofish (*Gambusia affinis*), 12 Hemigraspus crabs, and five oriental shrimp (*Palaemonetes sp.*) were captured. Hundreds of water boatman were also observed at all sites. Striped mullet were observed jumping throughout the lagoon as well.

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 many lagoon species.

Species captured or observed during the 17 July 2019 survey include:

Native Fish Species	
Tidewater goby	*Eucyclogobius newberryi*
Topsmelt	*Atherinops sp*
Longjawed mudsucker	*Gillithys mirabilis*
CA killifish	*Fundulus parvipinnis*
Striped mullet	*Mugil cephalus*
Non-Native Fish	
Mississippi silversides	*Menida audens*
Mosquitofish	*Gambusia affinis*
Largemouth Bass	*Micropterus salmoides*
Invertebrates	
Oriental shrimp	*Palaemonetes sp.*
Water boatman	*Corixid sp.*
Hemigraspus crab	

ACKNOWLEDGEMENTS

We wish to thank Suzanne Goode, Jamie King, and Danielle LeFer for their assistance. The contract for this work was provided by CDPR. We would also like to thank Chris Enyart from The Bay Foundation, as well as interns with The Bay Foundation: Melinda Saadathejadi, Hanna Weyland, Karlie O'loughlin, and Joelle Willegas, as well as UCLA volunteers Dave Jacobs, Sara Roos, and Rachel Turba. Additional volunteers included Sabrina Drill with the University of California Cooperative Extension, Ventura, and finally Coleen Grant from USFWS for helping the RCDSMM accomplish this seining event.

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:

Salvador Contreras, Stream Team
Liam Hay, Stream Team
Carly Simon, Stream Team
Angelica Kahler, Watershed Steward Program Member
Sabrina Drill, UCCE in Ventura
Oliver Miano, Biologist
Rachel Turba, UCLA Grad Student
Sara Roos, UCLA
David Jacobs, UCLA Professor
Chris Enyart, The Bay Foundation
Melinda Saadathejadi, Loyola Marymount University
Hanna Weyland, Loyola Marymount University
Karlie O'Loughlin, Marymount High School
Joelle Villegas, Marymount High School

PURPOSE OF SURVEY

The Malibu Lagoon restoration was completed in March 2013. A total of six post-construction monitoring locations were identified by the Malibu Lagoon Restoration and Enhancement Hydrologic and Biological Project Monitoring Plan (SMBRF 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 were conducted in spring and fall annually through 2019. In 2019, the lagoon was surveyed open in February 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.

The tenth survey occurred on 19 June 2018. The lagoon was closed and full, with signs of regular overwash across the entire span of the berm. The weather was warm with full cloud cover in the morning that completely dissipated as the day progressed. A light NW wind persisted throughout the day with air temperatures in the mid 70's F. A protective fence was set up along the beach across most of the berm in anticipation of nesting snowy plovers – one individual was observed on the walk to do a spot seine at the normal breach point of the lagoon. Tides were not a factor.

The eleventh survey occurred on 20 February 2019. The lagoon was open and the tide was at its highest when the survey began at 09:19. The tide receded throughout the day, affecting seining opportunities as water levels lowered. The weather was chilly in the morning with partial cloud cover throughout the day. Air temperatures spanned from the mid to upper 60's F. A handful of snowy plovers were observed in the mudflats during transition from site to site.

The twelfth and final survey occurred on 17 July 2019. The lagoon was closed and full. A full moon on 16 July resulted in high spring tides, but there was no evidence of overwash. The weather was warm with full cloud cover in the morning that completely dissipated as the day progressed. By the afternoon, air temperatures wavered between the low to mid 80s^{o}F. A protective fence was set up along the beach across most of the berm to protect nesting snowy plovers. Tides were not a factor.

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 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 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
- 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 site 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. Due to lack of tidal influence, salinity overall remained brackish. Conductivity was not measured. *Ruppia* and *Ulva intestinalis* were the only seagrass and algae species observed.

Table 2. Water Quality and site conditions at the permanent monitoring sites 17 July 2019.

Variable	Site 1	Site 2	Site 2a	Site 3	Site 5	Site 6
Avg depth (cm)	100	120	100	100	120	100
Water T (ºC)	27.9	25	25.5	26.7	27.9	27.8
Air T (ºC)	28	27	27	31	34	31
Salinity (ppt)	11	8	9	10	10	10
DO (mg/l)	9.66	8.61	9.1	8.95	10.33	11.09
pH	8.38	8.6	8.62	8.38	8.53	8.62
Conductivity	N/A	N/A	N/A	N/A	N/A	N/A
% Floating Algae cover	0	0	0	0	10	0
% Submerged/ Attached Algae cover	0	0	0	70	0	0
Algae Type	N/A	N/A	N/A	*Ruppia*	*U. intestinalis*	N/A
% emergent vegetation bank cover	100	100	100	100	100	100
Emergent Vegetation type	*Distichlis, Juncus, Jaumea*	*Distichlis, Jaumea*	*Distichlis, Jaumea, Salicornia*	*Distichlis, Jaumea, Salicornia, Juncus*	*Distichlis, Jaumea, Salicornia*	*Distichlis, Jaumea, Salicornia*
Dominant Substrate	Sand	Mud/gravel	Sand	Muck	Muck	Gravel/ Sand/Cobble
Time start	15:55	09:45	10:55	13:50	12:50	15:15

Table 3. Summary of Fish and Invertebrates captured/observed 17 July 2019.

7/17/2019								
Lagoon-ocean connection condition	open	**Site 1**	**Site 2**	**Site 2a**	**Site 3**	**Site 5**	**Site 6**	**TOTALS**
Seine pull total to depletions		13	23	24	28	19	18	125
Native Fish Species								
Steelhead trout	*O.mykiss*							0
Unidentified goby larva (<5 cm)			6					6
Tidewater goby larva (<5cm)	*Eucyclogobius newberryi*		2		2	2	1	7
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*	9	32	255	1	2	1	300
CA killifish (5-10 cm)	*Fundulus parvipinnis*		6	10		1		17
Long-jawed mudsucker (<5 cm)	*Gillichthys mirabilis*	3	2		6	4	3	18
Long-jawed mudsucker (5-10 cm)	*Gillichthys mirabilis*	1	1		1		1	4
Topsmelt larva (<5 cm)	*Atherinops sp*							0
Topsmelt juvenile (6 cm)	*Atherinops sp*	77	137	158	62	154	196	784
Topsmelt adult (16 cm)	*Atherinops sp*	7	13	10	53	93	52	228
Unidentified smelt larva (<5 cm)	*Atherinops sp*	1	229	25	57	5		317
Staghorn sculpin (<5 cm)	*L. armatus*							0
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*							0
Garabaldi (28 cm FL) dead dropped by b	*Hypsypops rubicundus*							0
Northern anchovy <5 cm	*Engraulis mordax*							0
Northern anchovy (5-10 cm)	*Engraulis mordax*							0
Striped mullet	*Mugil cephalus*							0
Mullet sp juveniles <5cm	*Mugil sp.*							0
Unidentified fish larva								0
Non-Native Fish Species								
Mosquitofish Juveniles (<5cm)	*Gambusia affinis*		15	12	30	1		58
Mosquitofish Adults (5-10cm)	*Gambusia affinis*		3	5				8
Carp	*Cyprinus carpio*							0
Mississippi silversides <5cm	*Menida audens*	17	306		9	100	9	441
Mississippi silversides (5-10cm)	*Menida audens*	16	6		24	81	10	137
Largemouth Bass	*Micropterus salmoides*				1			1
Invertebrates								
Oriental shrimp	*Palaemonetes sp.*				4	1		5
Hemigraspus crabs		1	2		1	8		12
Water boatman juveniles		100	100	100	100	100	100	600
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
Gastropoda								0
Water scavenger larva	*Hydrophilidae*							0
Dragonfly								0
Caddisfly								0
Crayfish	*Procambarus clarkii*							0

SUMMARY

The 17 July 2019 post-construction fish survey was completed in one day with a team of 17 people. A total of five native fish species and three non-native species were observed in July 2019. Striped mullet were observed jumping but not captured.

Table 4 provides a summary comparing abundance of species documented in Malibu Lagoon prior to restoration (2005), species relocated during restoration (2012), and twelve post-construction surveys (2013-2019).

Table 4. Summary of Fish and Invertebrates captured/observed 2005-2019.

		Survey 6/1/2005 open	Relocation June 2012 open	Survey 1/8/2013 open	Survey 5/15/2014 closed	Survey 12/11/2014 open	Survey 5/27/2015 closed	Survey 1/12/2016 open	Survey 6/1/2016 closed	Survey 3/3/2017 open	Survey 7/26/2017 closed	Survey 1/30/2018 open	Survey 6/19/2018 closed	Survey 2/20/2019 open	Survey 7/17/2019 closed
Native Fish Species															
Steelhead trout	*O.mykiss*				1 observed										
Unidentified goby larva (<5 cm)			2		500~						8	1			6
Tidewater goby larva (<5cm)	*Eucyclogobius newberryi*				13				17	12	10		5	5	7
Tidewater goby adult (6-8cm)	*Eucyclogobius newberryi*	473	8				41								
Arrow goby (<5 cm)	*Cleavlandia ios*				5										
Bay goby?	*Lepidogobius lepidus*				2										
CA Halibut	*Paralichthys californicus*								2						
CA killifish juveniles (<5cm)	*Fundulus parvipinnis*		306						1	1					300
CA killifish (5-10 cm)	*Fundulus parvipinnis*	46	16		5										17
Long-jawed mudsucker (<5 cm)	*Gillichthys mirabilis*	1	8		5		3		11	2	4	3	10	50+	18
Long-jawed mudsucker (5-10 cm)	*Gillichthys mirabilis*		11				22	5	52		13		1		4
Topsmelt larva (<5 cm)	*Atherinops sp*		1	3			176	6	1289	35	2618	276	3128		
Topsmelt juvenile (6 cm)	*Atherinops sp*	244			24		60		133	48	933	264	15		784
Topsmelt adult (16 cm)	*Atherinops sp*						6				56		2		228
Unidentified smelt larva (<5 cm)	*Atherinops sp*		101		15,293		2244	64					2400		317
Staghorn sculpin (<5 cm)	*L. armatus*			17	11			1		130	1	8	12	28	
Staghorn sculpin (5-10 cm)	*L.armatus*		3						5	4	2		2	5	
Staghorn sculpin (10-15cm)	*L.armatus*														
Opaleye	*Girella nigricans*										2				
Diamond turbot	*Hypsopsetta guttulata*			7	1				5						
Spotted turbot	*Pleuronichthys ritteri*											12			
Garabaldi (28 cm FL) dead dropped	*Hypsypops rubicundus*														
Northern anchovy <5 cm	*Engraulis mordax*		5					180	1		423				
Northern anchovy 5-10 cm	*Engraulis mordax*										239			1	
Striped mullet	*Mugil cephalus*	observed		observed	observed	7	1		observed	observed		1			
Mullet juveniles <5cm	*Mugil sp.*													82	
Unidentified fish larva							991		3		52				
Non-Native Fish Species															
Mosquitofish Juveniles (<5cm)	*Gambusia affinis*						13	6	10	1	271		7		58
Mosquitofish Adults (5-10cm)	*Gambusia affinis*	65	4072			2	3				3				8
Carp	*Cyprinus carpio*	1			observed						1				
Mississippi silversides	*Menida audens*			1		970	9	15	16		650	1	17		578
Largemouth Bass															1
Invertebrates															
Oriental shrimp	*Palaemonetes sp.*			37	209	43	10	5	58	89	280	7	442	12	5
Hemigraspus crabs			6		8	1	20	1	1	2	2		2		12
Water boatman juveniles			6,000+		2504						14			50+	600+
Amphipods			2500+												
Isopods			2500+									3			
Ctenophore sp (<2 cm)				3											
Salp sp (<2 cm)				3											
Sea hare (5-10 cm)	*Aplysia californica*			2											
Segmented worm <2 cm)				3											
Gastropoda							4								
Water scavenger larva	*Hydrophilidae*						1								
Dragonfly											16		1	1	
Caddisfly											8		1	1	
Crayfish	*Procambarus clarkii*									1					

Appendix A. Photographs of fish species

Tidewater Goby.

Topsmelt adult.

CA Killifish adult and juvenile.

Longjawed mudsucker (right) alongisde topsmelt (left).

Mississippi silverside (middle) surrounded by topsmelt.

Female adult longjawed mudsucker.

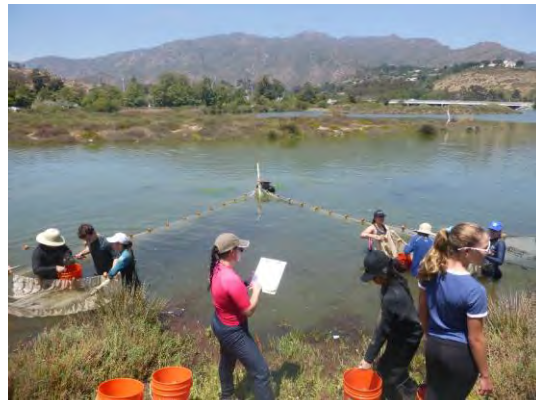
Hemigraspus crab.

Appendix B. Site Photos

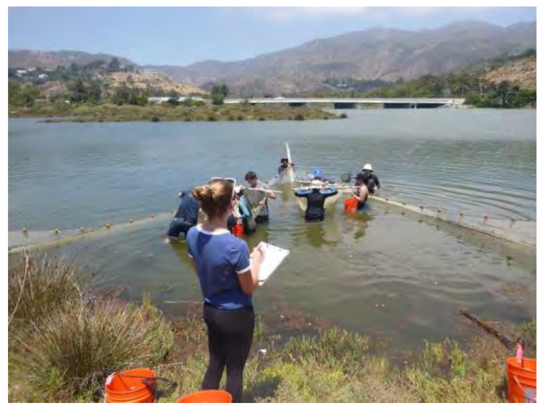
Site 1(blocking nets missing)

Site 2

Site 2a



Site 3



Site 5

Site 6

Appendix 4. Avian Usage of Post-Restoration Malibu Lagoon: Year 6 (2018) (Prepared by D. Cooper)

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Avian Usage of Post-restoration Malibu Lagoon 2013-2018

Malibu Lagoon State Beach

Malibu, California

Prepared for:
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The Bay Foundation
1 LMU Drive
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Los Angeles, CA 90045

Prepared by:
Daniel S. Cooper, President
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May 14, 2019

Summary

Here I present an analysis of quarterly survey results from 55 visits to Malibu Lagoon from 2005-2018, with references to changes in the avifauna of the "Western Channels" portion of the lagoon that were the subject of restoration in 2012-13. Overall numbers of individual birds detected on quarterly surveys were variable from year to year, but showed little trend following restoration (8,489 in 2005-06, vs. average of 8,687 between 2013-2018. Species numbers have been lower since 2012 (ave. 91 species per year, vs. 117 in 2005-06). Different guilds have responded differently post-restoration, with likely positive trends observed for marine and fish-eating birds, and likely negative (or mixed) trends noted for other groups, including waterfowl, shorebirds, and freshwater marsh species. However, looking at the restoration project area alone, individual counts, species numbers, and species diversity as measured by the Shannon Index) appears to be higher post-restoration for a group of 22 waterbird species analyzed, suggesting that the goals of the restoration have been met. And, whether related to the restoration or not, two special-status species, Western Snowy Plover and California Least Tern, initiated nesting at Malibu Lagoon for the first time in many decades in the years following restoration.

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[1]), who also compared results from two-day, site-wide surveys of Malibu Lagoon in January 2006 to similar surveys in February 2013.

No quantitative goals had been established for birds at Malibu Lagoon; however, the restoration proposal included the following language regarding goals and success criteria (PMP 2012):

> **Goals**: Increase habitat diversity for avian species. While the Lagoon restoration is not expected to increase the number of birds that frequent or nest at Malibu Lagoon, increased habitat diversity will create more roosting and foraging areas for various bird species."
>
> "**Success Criteria**: Success of the newly configured Lagoon for avian species will be achieved when birds are documented roosting or foraging in the newly created habitats. The avian monitoring survey reports will also note any changes in habitat uses attributable to the Lagoon restoration."

---

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

Here I present an analysis of quarterly survey results from the pre-restoration era (2005-06) versus six post-restoration years, 2013-2018, with references to changes in the "Western Channels" that were the subject of the restoration project effort. The following dates are treated here[2]:

Pre-restoration dates:

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

Post-restoration dates:

- 2013: 11-12 February, 18-19 April, 22-23 July, 28-29 October;
- 2014: 6-7 January, 21-22 April, 22-23 July, 28-29 October;
- 2015: 6-7 January, 21 April[3], 9-10 July, 26-27 October;
- 2016: 11-12 January, 26-27 April, 25-26 July, 25-26 October;
- 2017: 17-18 January, 24 and 26 April, 13-14 July, 30-31 October;
- 2018: 24-25 January, 20 and 23 April, 11 and 13 August[4], 23-24 October.

During each survey period, I (Cooper) would walk the entire site in the morning or afternoon on two consecutive or near-consecutive days 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, or 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

---

[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.

[3] Both surveys done same day (morning and afternoon)

[4] Funding uncertainty delayed surveys in July; however, the mid-July avifauna is essentially similar to that present in mid-August (pers. obs.), and so the August data were used as a substitute.

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 since the last restoration attempt at the site decades ago, along with the 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 in the case of resident species, or by 2 or 4 for wintering ones) to get something closer to an average daily estimate[5].

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

Results

General Trends

Overall, total counts of individuals and species on quarterly surveys show a slight negative trend from pre-restoration conditions (Figure 1), though this is likely insignificant[6] and complicated by the fact that there was just one year of pre-restoration surveys, during 2005-06. The cumulative number of species and identifiable subspecies detected across all years of quarterly surveys was 172[7], but only 85-100 species were recorded each year, illustrating the high inter-annual variability of species detected on these survey (Figure 1). Site-wide species richness, which dropped in the first two years post-restoration (117 species, to 87 and 88, respectively), rebounded somewhat by 2015 and 2018 (100 and 99 species, resp.). 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[8].

[6] Note that this number includes the cumulative total over two consecutive days, for a total of eight survey days per year.
[7] This includes species pairs not identified to one species or another, so could be corrected downward slightly.
[8] 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).

Figure 1. Total number of individuals vs. number of species on quarterly surveys at Malibu Lagoon, 2005-2018.

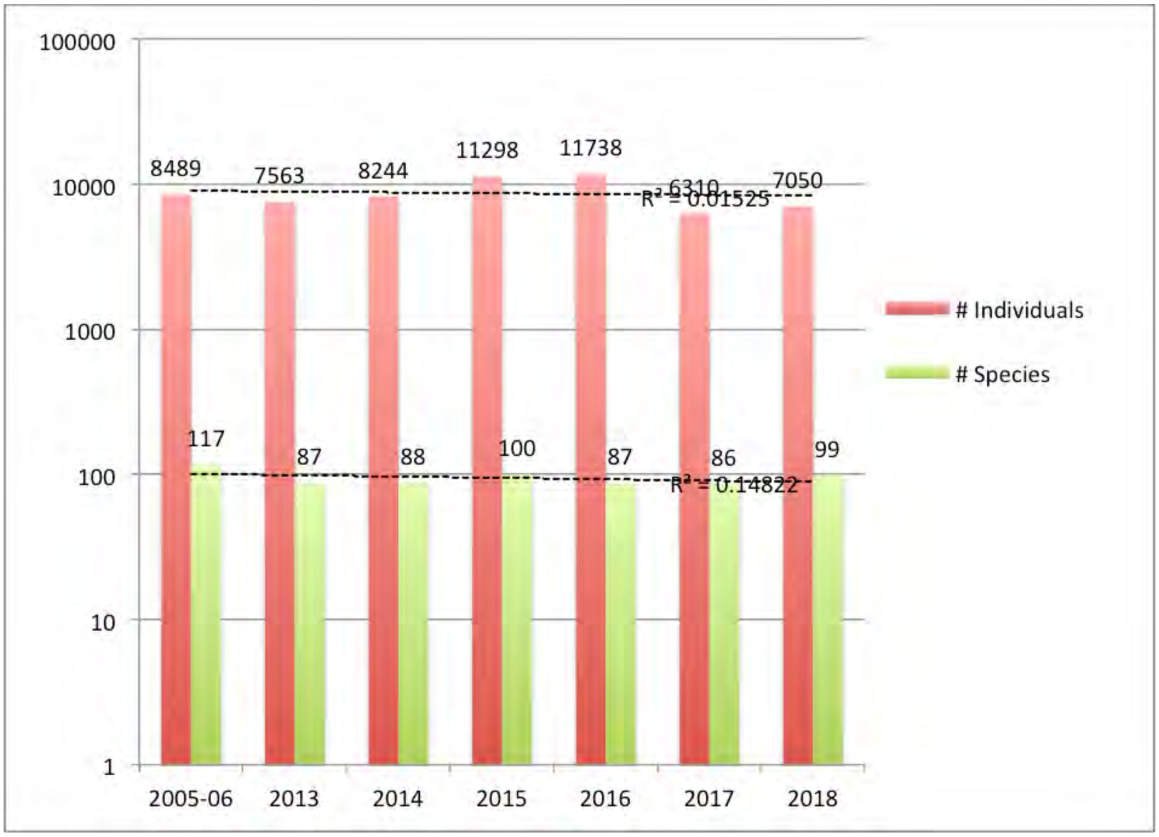

Table 1a summarizes counts of selected groupings by ecological guilds of species from 2005 (pre-restoration) to 2018 (post-restoration); more detailed counts are found in Tables A1 and A2. Counts of marine and fish-eating birds have increased at the site on quarterly surveys, with totals in recent years (e.g., 2017, 2018, etc.) higher than pre-restoration counts. Counts of most other groups have shown downward trends. For example, in no post-restoration year were counts of scrub/woodland, open country or shorebirds higher than that in the pre-restoration years, and for birds of freshwater marsh, waders and waterfowl, higher counts were obtained in just a single post-restoration year (and counts during the most recent year, 2018, were lower than that in 2005-06).

Table 1a. Summary of quarterly bird counts (total count/# species), by guild, at Malibu Lagoon, 2005-2018. Please refer to Tables A1 and A2 for species used in analysis. T = trend post-2006.

Guild	T	2005-06	2013	2014	2015	2016	2017	2018
Open country	+/-	61 (4)	48 (5)	50 (4)	105 (5)	43 (4)	37 (4)	55 (5)
Scrub/woodland	-	276 (15)	97 (8)	116 (12)	129 (16)	156 (11)	128 (12)	181 (15)
Urban	-	320 (8)	54 (7)	42 (6)	67 (6)	153 (7)	153 (7)	134 (8)
FW marsh	-	181 (6)	57 (2)	17 (2)	76 (4)	96 (5)	245[9] (4)	90 (4)
Marine/beach	+	2311 (19)	2054 (21)	5672 (18)	4404 (19)	3879 (16)	1237 (15)	3475 (16)
Shorebirds	-	917 (13)	398 (11)	282 (9)	183 (11)	334 (10)	664 (10)	615 (9)
Waders	+/-	124 (5)	121 (4)	105 (5)	97 (5)	94 (3)	160 (4)	62 (4)
Waterfowl	-	1267 (15)	1790[10] 11)	962 (12)	909 (15)	735 (13)	859 (13)	619 (11)
Fish-eaters	+	371 (12)	498 (12)	303 (12)	369 (13)	301 (10)	524 (12)	531 (12)

Presumably, the upland and freshwater marsh habitat at the site 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, in one representative scrub-dwelling species, the Song Sparrow, shows stable numbers through the spring/summer nesting season in recent years (Cooper 2017[11], Cooper 2019[12]). This suggests that the species has been able to adapt well to the scrub plantings on the site year after year.

Certain waterbird guilds, including shorebirds and freshwater marsh birds, show counts increasing somewhat in recent years (2015-18) versus those immediately following restoration (2013-14), suggesting that the habitat is continuing to improve for these groups (Table 1a). Qualitatively, there seem to be more shorebirds in general roosting on the

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[9] Includes a very large flock of Great-tailed Grackles present briefly.

[10] Includes a very large flock of American Coot present early in the restoration project

[11] Cooper, D.S. 2018. Avian usage of post-restoration Malibu Lagoon, Year 5 (2017). Prepared for Santa Monica Bay Restoration Foundation. Mar. 20, 2018.

[12] Cooper, D.S. 2019. Post-restoration Nesting Bird Survey of Malibu Lagoon, 2018. Prepared for Santa Monica Bay Restoration Foundation. Jan. 15, 2019.

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).

Waterfowl continue to show a downward trend, with counts of individuals and species 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.

Intra-site Patterns

In the years since restoration, certain bird species have been able to use more of the site, particularly notable for 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 2) shows little change in post-restoration species numbers since 2014, the first full year post-restoration, to 2018 (range = 18-21 species). Looking at species diversity, I used Shannon's Index to calculate H values [-(Pi*lnPi), where Pi = # of individuals of one species divided by the total # of individuals of all species], and found an increase in species diversity (H value) in the 22 waterbird species since 2005[13], from a low of 1.83 (2005-06) to highs exceeding 2.8 in both 2015 and 2018. This suggests that the Western Channels are in fact supporting a more diverse waterbird community today, as envisioned by the restoration effort. 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 an equilibrium in terms of numbers of individuals or diversity.

[13] In the Shannon Diversity comparison, I replaced the exceptionally high count of Brown Pelicans in 2015 with the 6-year average (400 individuals), since this outlier strongly affected the calculation of the H value that year.

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

Species	2005-06	2013	2014	2015	2016	2017	2018
American Wigeon		30	2	1	7	8	10
Black-bellied Plover			6	60	22	49	152
Brown Pelican			3	1106	1	4	62
Caspian Tern	3	1	2	8	8	7	17
Double-cr. Cormorant		15	5	45	40	5	100
Eared Grebe		24	25	15	3	2	6
Elegant Tern				5	250		140
Gadwall	27	104	59	114	27	49	44
Great Blue Heron	9	14	5	11	9	13	7
Great Egret	5	9	2	5	4	12	7
Green-winged Teal	70	28	15	61	20	17	7
Killdeer	6	28	9	34	18	10	19
Least Sandpiper	26	6	3			11	12
Marbled Godwit			37	6	17	1	2
Northern Shoveler	5	82	13	9	26		
Pied-billed Grebe	2	16	3	4	12	8	4
Red-breasted Merganser		4	1	5	9	12	
Ruddy Duck		24	47	226	3	7	100
Snowy Egret	19	38	36	53	44	43	17
Western Grebe		3		7	8	5	
Whimbrel	2		6	17		1	1
Willet			6	10	5	8	
Number of Individuals	174	426	285	1802	533	272	707
Number of Species	11	16	20	21	21	21	18
H Value (Diversity)	1.83	2.33	1.89	2.93	2.33	1.91	2.86

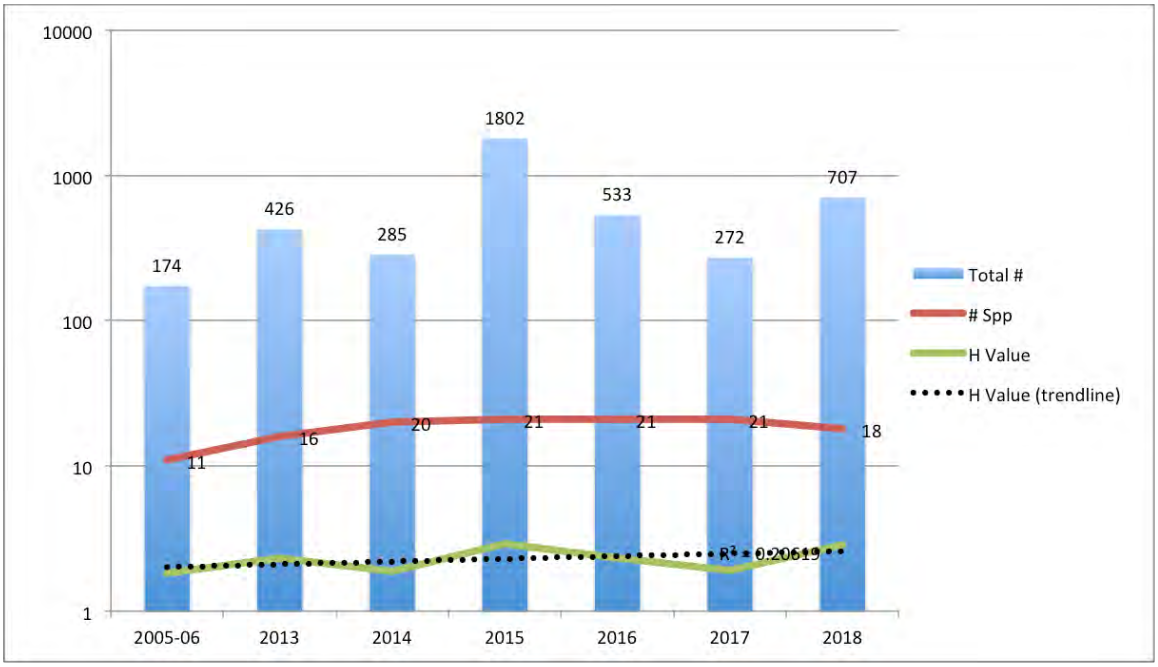

Figure 2. Comparison of total individuals ("Total #"), annual species richness (# Spp."), and Shannon's Diversity Index (H Value) in Western Channels area of Malibu Lagoon on quarterly surveys, 2005-2018.

Nesting Activity

Breeding species at Malibu Lagoon were analyzed by Cooper (2019), and summarized here. In 2018, ten species were confirmed nesting at Malibu Lagoon, which is comparable to the 11 species confirmed breeding in 2005 and 2006. From 2013-2018, 19 species were confirmed as nesting here in at least one year, but just over half this number bred each year. Three species were documented nesting in all five years evaluated (Gadwall, Mallard and Song Sparrow), and four species nesting in 2005-06 were *not* detected nesting in 2018 and thus may be considered extirpated for breeding purposes (if temporarily): Black Phoebe, Common Yellowthroat, California Towhee, and Red-winged Blackbird. Yet, species nesting in 2018 not recorded doing so in 2005-06 include Allen's Hummingbird, Snowy Plover, Least Tern, Bushtit, and Northern Mockingbird. Of these more recent nesters, each except Snowy Plover and Least Tern were either suspected of nesting in the area prior to restoration; in other words, the plover and tern were the truly "novel" breeders in the vicinity of the site. Least Tern are a federally endangered species and Western Snowy Plover are a federally threatened species.

The loss of Black Phoebe is likely due to the removal of the wooden footbridges and restroom facilities at the site during the restoration effort as it is an urban species, and the loss of nesting yellowthroat and the Red-winged Blackbird is likely due to the loss of larger patches of reeds at the site, as both breed nearby at Malibu Legacy Park (www.ebird.org).

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. A handful of sightings of individual State Threatened Belding's Savannah Sparrows have been made in recent years, though positive identification is difficult as none has been suspected of breeding locally (eBird).

Of the special-status species, the Brown Pelican and Snowy Plover make heavy usage of the site and are present most of the year. Least Tern is present between late April and early August (occasionally later). The status of nesting Snowy Plover and Least Tern at Malibu between 2013 and 2018 was summarized by Ryan et al. in 2018[14] and 2019[15]. Least Terns established seven nests in 2013 (the first such record in over 70 years), none in 2014 and 2015, four in 2016, 22 in 2017, and six in 2018. Snowy Plovers established two nests in 2017 (the first such modern record) and five in 2018.

[14] Ryan, T., J. Realegeno, C. Jauregui, and S. Vigallon, Ryan Ecological Consulting. Breeding Biology of the California Least Tern and Western Snowy Plover at Malibu Lagoon State Beach, Los Angeles, California: 2018 Breeding Season Summary. Prepared for Cooper Ecological Monitoring, Inc. Dec. 7, 2018.
[15] Ryan, T.P, S. Vigallon, D.S. Cooper, C. Dellith, K. Johnston, and L. Nguyen. 2019. Return of beach-nesting snowy plovers to Los Angeles County following a 68-year absence. Western Birds. 50:16-25.

APPENDIX. Additional Tables and Figures.

Table A1. Landbird guilds (excludes aerial foragers[16]).

Guild	Species	2005-06	2013	2014	2015	2016	2017	2018
OPEN COUNTRY[17]								
	American Pipit	10[18]	3	0	5	0	0	4
	Killdeer	48	31	14	36	30	28	36
	Savannah Sparrow	2	3	5	8	3	2	5
	Say's Phoebe	1	6	4	1	4	2	4
	Western Meadowlark	0	5	27	55	6	5	6
Total open country (# species)		61 (4)	48 (5)	50 (4)	105 (5)	43 (4)	37 (4)	55 (5)
SCRUB/WOODLAND[19]								
	Allen's Hummingbird	38	10	10	13	15	7	13
	American Robin	0	3	0	0	0	0	0
	Anna's Hummingbird	21	0	3	2	0	0	1
	Bewick's Wren	15	1	1	1	2	6	2
	Bushtit	70	22	35	24	65	50	90
	California Scrub-Jay	0	0	0	0	4	1	0
	California Towhee	18	9	7	6	7	5	7
	Cedar Waxwing	14	0	0	0	0	0	0
	Hermit Thrush	0	0	2	8	2	0	5
	House Wren	5	2	3	4	12	11	13
	Lincoln's Sparrow	5	0	2	2	0	1	1
	Oak Titmouse	1	0	0	5	5	5	3
	Orange-crowned Warbler	11	0	3	4	4	3	6
	Ruby-crowned Kinglet	5	3	8	12	3	1	5
	Song Sparrow	51	47	40	38	37	37	30
	Spotted Towhee	15	0	2	1	0	1	3
	Townsend's Warbler	0	0	0	4	0	0	1
	Wilson's Warbler	3	0	0	2	0	0	0
	Yellow Warbler	4	0	0	3	0	0	1
Total scrub/woodland (# species)		276 (15)	97 (8)	116 (12)	129 (16)	156 (11)	128 (12)	181 (15)
URBAN								
	American Crow	49	16	6	8	18	16	8
	Black Phoebe	28	17	11	7	20	11	16
	Brewer's Blackbird	27	0	0	0	0	1	0
	Brown-headed Cowbird	14	5	1	1	3	0	3
	European Starling	123	1	2	28	4	27	5
	Hooded Oriole	7	1	0	0	0	0	3
	House Finch	65	11	17	19	96	85	63
	Rock Pigeon	0	0	0	0	7	8	25
	Northern Mockingbird	7	3	5	4	6	5	11
Total urban (# species)		320 (8)	54 (7)	42 (6)	67 (6)	153 (7)	153 (7)	134 (8)

[16] 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.

[17] 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.

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

[19] 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	2018
FRESHWATER MARSH								
	Common Yellowthroat	63	16	12	22	41	46	33
	Great-tailed Grackle	20	41	5	43	25	134	34
	Marsh Wren	3	0	0	6	8	10	20
	Red-winged Blackbird	84	0	0	5	21	55	3
	Sora	5	0	0	0	1	0	0
	Virginia Rail	6	0	0	0	0	0	0
Total freshwater marsh (# species)		181 (6)	57 (2)	17 (2)	76 (4)	96 (5)	245 (4)	90 (4)
MARINE/BEACH								
	Black Oystercatcher	3	1	0	0	0	0	90
	Bonaparte's Gull	1	2	11	9	2	6	3
	Brant	4	6	0	6	6	0	0
	Brown Pelican	862	167	4142	2821	374	144	235
	Caspian Tern	83	13	26	19	20	22	50
	Double-cr. Cormorant	109	310	142	193	107	173	273
	Elegant Tern	258	219	310	781	2880	332	1684
	Forster's Tern	2	6	0	4	0	0	3
	Glaucous-winged Gull	1	2	4	10	1	0	4
	Heermann's Gull	216	30	466	176	43	34	162
	Herring Gull	1	4	2	18	2	3	3
	Horned Grebe	3	0	0	2	0	0	0
	Least Tern	30	0	0	2	0	84	0
	Mew Gull	2	0	1	0	0	0	0
	Red-breasted Merganser	7	8	4	12	9	27	1
	Red-throated Loon	0	2	1	0	0	0	0
	Royal Tern	0	7	12	26	51	26	134
	Ruddy Turnstone	10	34	21	8	24	22	21
	Sanderling	58	460	48	8	115	10	169
	Snowy Plover	52	202	137	16	76	91	188
	Surfbird	0	0	4	0	0	0	0
	Western Grebe	0	3	16	9	9	10	0
	Western Gull	608	576	325	284	160	253	455
Total marine/beach (# species)		2311 (19)	2054 (21)	5672 (18)	4404 (19)	3879 (16)	1237 (15)	3475 (16)

Table A2. (continued)

Guild	Species	2005-06	2013	2014	2015	2016	2017	2018
SHOREBIRDS[20]								
	American Avocet	9	6	0	0	0	0	0
	Black-bellied Plover	287	224	169	73	202	288	397
	Black-necked Stilt	0	0	0	4	0	0	0
	Dunlin	5	2	1	0	0	1	0
	Greater Yellowlegs	8	1	0	0	1	1	4
	Least Sandpiper	71	33	4	1	18	17	16
	Long-billed Curlew	2	0	0	0	0	0	0
	Long-b. Dowitcher	14	0	0	1	1	0	0
	Marbled Godwit	54	15	63	19	38	134	33
	Semipalmated Plover	27	16	3	10	13	9	8
	Spotted Sandpiper	11	6	7	8	2	3	2
	Western Sandpiper	197	21	11	6	26	68	28
	Whimbrel	20	27	9	21	13	22	110
	Willet	212	47	15	38	20	121	17
	Wilson's Phalarope	0	0	0	2	0	0	0
Total shorebirds (# species)		917 (13)	398 (11)	282 (9)	183 (11)	334 (10)	664 (10)	615 (9)
WADERS								
	Black-cr. Night-heron	31	5	3	5	0	2	0
	Great Blue Heron	24	26	9	17	13	30	13
	Great Egret	13	13	5	8	10	35	9
	Green Heron	1	0	1	1	0	0	1
	Snowy Egret	55	77	87	66	71	93	39
Total waders (# species)		124 (5)	121 (4)	105 (5)	97 (5)	94 (3)	160 (4)	62 (4)
WATERFOWL								
	American Coot	628	1096	562	239	461	525	291
	American Wigeon	16	49	17	10	13	22	46
	Blue-winged Teal	6	0	0	4	3	1	3
	Bufflehead	46	26	10	4	1	16	11
	Cinnamon Teal	16	0	0	3	1	0	0
	Eared Grebe	10	27	74	29	5	10	6
	Gadwall	94	164	107	143	54	102	74
	Green-winged Teal	147	48	42	66	33	32	7
	Hooded Merganser	0	0	0	2	0	16	0
	Lesser Scaup	2	1	1	0	0	2	0
	Mallard	170	98	28	99	97	88	59
	Northern Pintail	8	0	2	2	6	4	2
	Northern Shoveler	47	163	31	18	40	0	0
	Pied-billed Grebe	14	28	12	13	14	14	6
	Ruddy Duck	55	90	76	276	7	27	114
	Snow Goose	8	0	0	1	0	0	0
Total waterfowl (# species)		1267 (15)	1790 (11)	962 (12)	909 (15)	735 (13)	859 (13)	619 (11)
FISH-EATERS[21]								
	Belted Kingfisher	0	3	1	2	2	0	1
	Black-cr. Night-heron	31	5	3	5	0	2	0
	Caspian Tern	83	13	26	19	20	22	50
	Double-cr. Cormorant	109	310	142	193	107	173	273
	Forster's Tern	2	6	0	4	0	0	3

[20] Excludes marine-associated species such as Sanderling.

[21] 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).

Guild	Species	2005-06	2013	2014	2015	2016	2017	2018
	Great Blue Heron	24	26	9	17	13	30	13
	Great Egret	13	13	5	8	10	35	9
	Green Heron	1	0	1	0	0	0	1
	Hooded Merganser	0	0	0	2	0	16	0
	Least Tern	30	0	0	2	0	85	0
	Osprey	2	0	0	0	4	1	1
	Pied-billed Grebe	14	28	12	13	14	14	6
	Red-br. Merganser	7	8	4	12	9	27	1
	Red-throated Loon	0	2	1	0	0	0	0
	Royal Tern	0	7	12	26	51	26	134
	Snowy Egret	55	77	87	66	71	93	39
Total fish-eaters (# species)		371 (12)	498 (12)	303 (12)	369 (13)	301 (10)	524 (12)	531 (12)

Appendix 5. Post-restoration Nesting Bird Survey of Malibu Lagoon (2018) (Prepared by D. Cooper)

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Post-restoration Nesting Bird Survey of Malibu Lagoon 2018

Malibu Lagoon State Beach

Malibu, California

Prepared for:
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Prepared by:
Daniel S. Cooper, President
Cooper Ecological Monitoring, Inc.

January 15, 2019

Summary

The nesting season of 2018 marks the sixth year of post-restoration monitoring (since the restoration project was completed in species 2013), and our first comprehensive post-restoration assessment of the nesting avifauna of the lagoon. We confirmed 10 species nesting within the restoration area and adjacent habitat of Malibu Lagoon State Beach, one less than documented in 2005-06. However, two special-status species, Western Snowy Plover and California Least Tern, successfully bred (i.e., established nests and fledged young) at Malibu Lagoon in 2017 and both species attempted to breed at Malibu Lagoon the following year (2018).

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 in the first post-restoration monitoring report[1]. I conducted nesting bird surveys here during the pre-restoration era in 2005[2] and 2006[3], and continued these during the restoration process in 2011[4] and 2012[5]. In addition to these nesting bird surveys, I have conducted quarterly reports at the lagoon since 2013, which include visits in April and July (i.e., during the nesting season). Here I focus on avian breeding activity at the Lagoon during 2018, as compared to that of the pre-restoration era (2005-06), in an effort to better characterize the potential effects of the restoration on the local avifauna and the current nesting status of the bird species here.

In spring/summer 2018, I conducted nesting bird surveys on the following dates:

- Mar. 16 and 26
- Apr. 9
- Apr. 20 (part of the quarterly survey)
- Apr. 23 (part of the quarterly survey)
- May 4 and 23
- August 11 and 28 (follow-up for late nesters)

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1 Cooper, D.S. 2013. Avian usage of post-restoration Malibu Lagoon. Report to Santa Monica Bay Restoration Foundation. February 13, 2013.
2 Cooper, D.S. 2005. 2005 Breeding bird survey, Malibu Lagoon State Park, Malibu, California. Prepared for Resource Conservation District of the Santa Monica Mountains. August 24, 2005.
3 Cooper, D.S. 2006. Birds of Malibu Lagoon: Final report, 2006. Prepared for Resource Conservation District of the Santa Monica Mountains. August 8, 2006.
4 Cooper, D.S. 2011. Memo to Mark Abramson, Santa Monica Bay Restoration Foundation. May 19, 2011.
5 Cooper, D.S. 2013. Malibu Lagoon avian monitoring report (Final), Summer 2012. Prepared for Santa Monica Bay Restoration Foundation, Feb. 28. 2013.

During the same period (April-September), biologists and volunteers visited the lagoon as part of ongoing regional nest monitoring for two special-status species, the Western Snowy Plover and California Least Tern, both of which established nests during 2018 (Ryan Ecological Consulting 2018). I incorporate their findings here, and include the full report as an Appendix below. In addition to these surveys, I reviewed submissions to eBird (www.ebird.org) for relevant sightings, and incorporated them where appropriate.

During each nesting bird survey (March-August), I would walk the entire site, generally starting between 06:15 and 09:30, depending on weather conditions. Each visit lasted between one and two hours, depending on how many birds were present, and how long they took to count. I recorded the locations of each bird exhibiting breeding behavior (e.g., paired adults, singing males, etc.) in a field notebook, using standard breeding bird notations where multiple individuals of the same species were encountered.

Unlike in the quarterly surveys, I did not record habitat usage, but assumed breeding birds to be moving freely through the site, taking advantage of the habitat diversity present.

Results

Ten bird species were confirmed as nesting at Malibu Lagoon during 2018 (Table 1).

Table 1. 2018 nesting summary.

Species	Breeding Status	Evidence	Source/Visit
Gadwall	CONFIRMED	Up to 4 pr. during May; female w/ 2 young	CEM, Inc., 11 Aug.
Mallard	CONFIRMED	Adult w/ 3 young	CEM, Inc., 11 Aug.
Allen's Hummingbird	CONFIRMED	Female w/ nesting material	CEM, Inc., 16 Mar.
Snowy Plover	CONFIRMED	5 nests, 1 fledged successfully	Ryan Ecol. Monitoring 2018
Killdeer	CONFIRMED	Adult with 3 chicks	CEM, Inc., 20 Apr.
Least Tern	CONFIRMED	6 nests, all failed	Ryan Ecol. Monitoring 2018
Barn Swallow	CONFIRMED	Adults flying under PCH bridge, then family group	CEM, Inc.; 4 May, 11 Aug.
Black Phoebe	SUSPECTED	Adult delivering flight song along Malibu Creek	CEM, Inc., 16 Mar.
Bushtit	CONFIRMED	Pr. with nesting material; up to two family groups	CEM, Inc., 9 Apr+
Northern Mockingbird	CONFIRMED	Est. two territories; adult carrying nesting material into large saltbush shrub; 2nd pr. flying (with food?) under PCH bridge	CEM, Inc., 16 Mar.+
Song Sparrow	CONFIRMED	6-10 territories; 4 family groups on 4 May	CEM, Inc., 16 Mar.+
Brown-headed Cowbird	SUSPECTED	Displaying males	CEM, Inc.; 20 Apr and 4 May
Great-tailed Grackle	SUSPECTED	Two females appeared to fly into reeds, and at least 1 singing male	CEM, Inc.; 20 Apr.+

In addition to these sightings, a pair of Oak Titmouse was observed on 9 April, with singles thereafter, and no indication of local nesting (this species nests commonly in woodland and residential habitats in the Malibu area). Singles of Bewick's and House wrens were detected singing into March, but were not recorded thereafter in spring, so likely did not breed onsite or very close. Multiple Marsh Wren were singing on 16 Mar., with singles singing on 20 and and 23 Apr., yet no further indication of breeding. Both Spotted and California towhees were noted as singing in April and early May, but no further evidence of nesting was obtained. House Finch and (paired) Lesser Goldfinch were noted as singing in May, but no further breeding evidence was obtained. At least four Red-winged Blackbirds were singing on 16 Mar., but little activity noted subsequently; a flock of 90 individuals on 28 Aug. was apparently an early fall aggregation rather than a nesting group.

Juveniles of various species were noted using the site during the summer/fall (e.g., a juvenile Green Heron on 11 Aug., family group of Northern Rough-winged Swallows on 4 May) but unless there was some indication that breeding adults were present (e.g., observations on multiple visits in spring), these were not included as part of the nesting avifauna of the site. Likewise, individuals from the colonial waterbird rookery at Malibu Country Mart (various species of waders) were observed using the habitat at Malibu Lagoon during 2018, but were not counted as nesting at the lagoon itself.

Changes in Avian Usage, 2005-present

This count of breeding birds (10) may be compared with prior years, including pre-restoration years when nesting bird surveys were conducted (Table 2). In 2005 and 2006, 11 species were confirmed as nesting here in at least one year, roughly the same as in 2018, and 13 species were confirmed in 2011-12, the years during and immediately following the restoration project.

The identity of these species has changed substantially since 2005, and three species were documented nesting in all five years evaluated (Gadwall, Mallard, and Song Sparrow) (Table 2). Four species nesting in 2005-06 were *not* detected nesting in 2018: Black Phoebe, Common Yellowthroat, California Towhee, and Red-winged Blackbird (in addition Brown-headed Cowbird and Hooded Oriole were confirmed likely nesting in a palm tree in Malibu Colony, along the southern fenceline of the site.) Species nesting in 2018 not recorded doing so in 2005-06 include Allen's Hummingbird, Snowy Plover, Least Tern, Bushtit, and Northern Mockingbird. Of these more recent nesters, each except Snowy Plover and Least Tern were either suspected of nesting in 2005-06, or were confirmed nearby; in other words, the plover and tern were truly "novel" breeders in the vicinity of the site.

The loss of Black Phoebe is likely due to the removal of the wooden footbridges and restroom facilities at the site, which provide the substrate for this urban-adapted species in the area. It is almost certainly nesting nearby (e.g., the PCH bridge), based on continued sightings through the spring/summer of 2018.

The loss of nesting yellowthroat and the Red-winged Blackbird is likely due to the loss of larger patches of reeds at the site; both breed to the north at Malibu Legacy Park (www.ebird.org). Reed patches are still growing at Malibu Lagoon, and thus may support both species in the future here. The loss of California Towhee is harder to understand, since it is a fairly urban-tolerant species, nesting in lush yards throughout the Los Angeles area. It is possible that the 1-2 pairs that were present in 2005-06 simply shifted their territories off the site (e.g., Malibu Colony), and therefore were not detected as nesting during surveys (individuals were noted in 2018, just without breeding activity).

Table 2. Comparison of nesting birds, 2005-present, with estimates of number of nesting pairs that year.

Species	2005	2006	2011	2012	2018
Gadwall	Confirmed (2 pr., 1 brood)	Confirmed (1 brood)	Confirmed (1 brood)	Confirmed (1 brood)	Confirmed
Mallard	Confirmed (3 broods)	Confirmed (1 brood)	Confirmed (3 broods)	Confirmed (2 broods)	Confirmed
Pied-billed Grebe	Suspected nearby	Suspected	N/A	Confirmed (2 broods)	N/A
American Coot	N/A	N/A	N/A	Confirmed (1 brood)	N/A
Anna's Hummingbird	Possible	N/A	N/A	N/A	N/A
Allen's Hummingbird	Probable	Probable (multiple birds)	Probable (6-10 birds)	N/A	Confirmed
Snowy Plover	N/A	N/A	N/A	N/A	Confirmed
Killdeer	Confirmed (1-2 pr.)	N/A	Suspected (2 pr.)	N/A	Confirmed
Least Tern	N/A	N/A	N/A	N/A	Confirmed
Barn Swallow	N/A	Suspected; multiple singing birds on footbridges in April	N/A	N/A	Confirmed
Black Phoebe	Confirmed (1 pr; fledglings)	Confirmed (1 pr; juv.)	N/A	Confirmed (2 broods)	Suspected nearby
Bushtit	N/A	N/A	Confirmed nearby (2-3 broods)	N/A	Confirmed
Northern Mockingbird	Suspected nearby	N/A	Confirmed (1 nest)	Confirmed (1 nest)	Confirmed
Common Yellowthroat	Confirmed (1-2 pr.)	Confirmed (1 pr., juv.)	Confirmed (1-2 pr.)	N/A	N/A

Species	2005	2006	2011	2012	2018
Song Sparrow	Confirmed (6 pr., fledgling)	Confirmed (begging juv.)	Confirmed (5-10 pr.)	Confirmed (1 brood)	Confirmed
California Towhee	Confirmed (2 pr., feeding juv.)	Confirmed (1 pr., juv.)	Confirmed (family group)	N/A	N/A
Red-winged Blackbird	Confirmed (10+ pr.; fledglings)	Confirmed (begging juvs.)	Confirmed (2+ pr, juv.)	N/A	N/A
Brown-headed Cowbird	Confirmed nearby	N/A	N/A	N/A	Suspected
Hooded Oriole	Confirmed nearby	Confirmed nearby (ad. feeding young)	N/A	N/A	N/A
Great-tailed Grackle	N/A	N/A	N/A	Confirmed (1 brood)	Suspected

Western Snowy Plover and California Least Tern

These two special-status species attempted to nest in Malibu for the first time in modern years in 2013, with activity concentrated on the sandbar separating the lagoon from the ocean (i.e., just southeast of the main restoration area). Additional potential nesting activity was noted each subsequent year, with successful breeding (fledged young) noted in both species in 2017. Symbolic fencing has been installed in several years since 2013, and wire mesh box exclosures were placed over plover nests in 2017 and 2018 (terns cannot use nests within exclosures).

The results of these attempts have been summarized by Ryan Ecological Consulting (2017), presented in Table 3.

While the Snowy Plover has restricted its use to the beach and lagoon edge nearest the ocean, the Least Tern has foraged heavily within the restored portion of the lagoon, often catching small fish within a few meters of the walking path around the lagoon.

Table 3. Breeding results for Least Terns and Snowy Plovers at Malibu Lagoon, 2013-2018.

LEAST TERN						
Year	Number of Adults Reported	Number of Pairs	Number of Nests	Number of Eggs	Number of Fledglings	Fledglings Per Pair
2013	58	7	7	7	0	0
2014	0	0	0	0	0	0
2015	18	0	0	0	0	0
2016	10	4	4	4	0	0
2017	50	22	22	35	13	0.6
2018	41	6	6	9	0	0
SNOWY PLOVER						
2017	4	1	2	4	1	1.0
2018	4-7	2-3	5	12	3	1.0-1.3