South San Diego Bay
Coastal Wetland Restoration
and Enhancement Project

Year 4 (2015) Postconstruction Monitoring Report

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EXECUTIVE SUMMARY

Western Salt Ponds

The fourth year of the five-year monitoring program for the South San Diego Bay Restoration Project ("Project") has been completed. The western salt ponds site (ponds 10A, 10 and 11) has met the Project goals and objectives for most physical and biological monitoring parameters.

Tidal amplitude and water quality within the western salt ponds mirrors that in south San Diego Bay. The topography and bathymetry of the site continues to evolve with changes to both the excavated channels and marsh plain but is within 10% of the planned elevations

Despite initial low survival of planted salt marsh vascular plants, and a dramatic die back of cordgrass in 2015, cordgrass is once again expanding vegetatively in Pond 10 and, to a lesser extent, in Pond 11. In addition, natural recruitment of Pacific pickleweed and Bigelow's pickleweed has occurred in the western salt ponds and is expected to continue in the future.

The fish assemblage continues to evolve as the channels and marsh plain in the ponds change in relation to sediment movement and consolidation. The predominant biomass contributed in previous years by round stingray and California halibut in the restored ponds, as well as the numerically dominant slough anchovy, demonstrates a trend toward a fish assemblage that is similar to that in south San Diego Bay. In 2015, no round stingrays were collected during trawls and biomass was dominated by bat rays. Although it was hypothesized that the number of species and abundance of fish would increase as the sediment in the ponds consolidates and is colonized by invertebrates, this has not proven to be the case during the first four years of monitoring. The trawl catch in 2015 was the lowest of all four years postconstruction. While species diversity has remained stable, overall numbers have dropped through 2012- 2015. Causal factors could include the timing of spawning by slough anchovy. High numbers of young-of-the year of this species were collected in 2013 with far fewer in 2014 and fewer still in 2015. A delay in the peak spawning period for this species could explain the short-term decline in numbers collected.

Macrobenthic invertebrate assemblages continue to develop and provide food for migratory shorebirds and fish. Results from small cores during Year 4 (2015) demonstrated shifts in the benthic community to one primarily dominated by polychaetes and crustaceans, although there was seasonal and annual variability. Larger cores were dominated by California horn snail, California jackknife clam and the non-native Asian mussel. Sampling for smaller benthic invertebrates revealed substantial seasonal and interannual variability in invertebrate community composition, although there is a trend for increasing densities and species richness in the ponds over time. The benthic invertebrate communities are meeting the objectives of providing an available food source for shorebirds and fish.

Bird usage in the western ponds was among the highest of all sampling stations monitored in south San Diego Bay in 2015. The number of individual birds observed was consistently higher in Pond 11 compared to Ponds 10 and 10A. The patterns in number of individuals were heavily influenced by the numbers of western sandpiper and the timing of their migration, which was similar to the pattern observed in previous years. When compared to 2014, numbers of western sandpipers in wetland habitats in the western salt ponds were down by approximately 46%, although there were more individuals in the overall study area which includes the eastern salt ponds and parts of south San Diego Bay. These results suggest that western sandpipers are using areas other than the western salt ponds to a greater extent. We postulated that this reduced activity in the western salt ponds is directly related to development of vegetated salt marsh habitats, thereby reducing the area of mudflat favored by western sandpipers as foraging habitat. Difficulty in detecting western sandpipers due to increasing vegetative cover may also be a contributing factor.

Chula Vista Wildlife Reserve

The Chula Vista Wildlife Reserve has met some of the Project goals and objectives, but continues to fall short in terms of expectations of tidal amplitude. Monitoring data collected in 2015 using the new data loggers installed in 2013 confirmed the moderate to fairly severe truncation of the low tides within the channels of the Chula Vista Wildlife Reserve.

Water quality was within expected parameters based on a one-time sampling event in 2015. The increase in tidal influence provided by channel excavation is expected to continue to improve water quality relative to south San Diego Bay.

Cover by vascular plants planted from salvaged and nursery grown stock is expected to further increase in 2016. However, the project metric of achieving salt marsh cover similar to Tijuana Estuary by 2016 will not be met. Monitoring in 2015 revealed that California cordgrass cover was approximately 1.2% which is well below cover at Tijuana Estuary. Vegetation was dominated by Bigelow’s pickleweed which recruited naturally to the site. California horn snail, California jackknife clam and *Macoma* spp. dominated the benthic invertebrates. Fish samples were dominated by California killifish, arrow goby and topsmelt. Fish and invertebrate assemblages are similar to other southern California bays and lagoons and provide food for foraging shorebirds and ground-nesting birds.

1.0 INTRODUCTION

The U.S. Fish and Wildlife Service (USFWS) San Diego National Wildlife Refuge (NWR) Complex and the Port of San Diego (Port) completed construction of the South San Diego Bay Coastal Wetland Restoration and Enhancement Project ("Project") in December 2011. Funding support was provided by the California Coastal Conservancy (Conservancy) and National Oceanic and Atmospheric Administration (NOAA)/National Marine Fisheries Service (NMFS) through the American Recovery and Reinvestment Act of 2009; the USFWS Wildlife and Sport Fish Restoration Program through the National Coastal Wetland Conservation (NCWC) Program, and the Coastal Program; and the U.S. Environmental Protection Agency (EPA). The Project included the restoration and enhancement of approximately 261 acres of coastal wetland habitat within the south end of San Diego Bay, San Diego County, California. The project consisted of restoration activities at two locations: 1) restoration of 230 acres (including 12 acres of upland) of solar salt evaporation ponds 10, 10A and 11 (western salt ponds) located at the southwestern edge of San Diego Bay within the South San Diego Bay Unit of the San Diego Bay NWR; and 2) the approximately 50-acre Chula Vista Wildlife Reserve (CVWR) located to the west of the former South Bay Power Plant (Figure 1).

Approximately one year prior to construction of the Project, monitoring of physical and biological parameters was conducted to compile baseline conditions for comparison with those parameters following construction. Postconstruction monitoring was based on a detailed Postconstruction Monitoring Plan. Postconstruction site conditions, e.g., unconsolidated muddy substrate, required modification of some of the proposed monitoring methods. These modifications are described by parameter. This report serves as the fourth annual postconstruction monitoring report of the Project covering the period of January to December 2015.

1.1 Western Salt Ponds Restoration

The western salt ponds component of the Project restored approximately 218 acres of wetlands by converting former solar salt evaporation ponds into subtidal and intertidal habitats. The conceptual restoration plan, including the proposed distribution of habitats, is presented in Figure 2. Restoration activities included dredging shallow subtidal channels (-2 ft NAVD 88) in Ponds 10 and 11 and slurrying the dredged material to Pond 11 to raise its elevation from primarily subtidal to intertidal elevations. The dredged material was deposited into Pond 11 instead of Pond 10 because the pre-project elevation of Pond 10 was within the range of intertidal salt marsh at approximately +4 ft NAVD 88. Overall, a total of approximately 140,000 cubic yards of material was dredged with about 120,000 cubic yards excavated in Pond 10 and an additional 20,000 cubic yards in Pond 11. Approximately 102 acres of low marsh was restored in Ponds 10 and 11 within the elevation range suitable for supporting California cordgrass (*Spartina foliosa*). Approximately 39 acres of subtidal habitat were dredged in Ponds 10 and 11. Dredging created major tidal creeks with the intention that second and third-order creeks would develop naturally through tidal action.

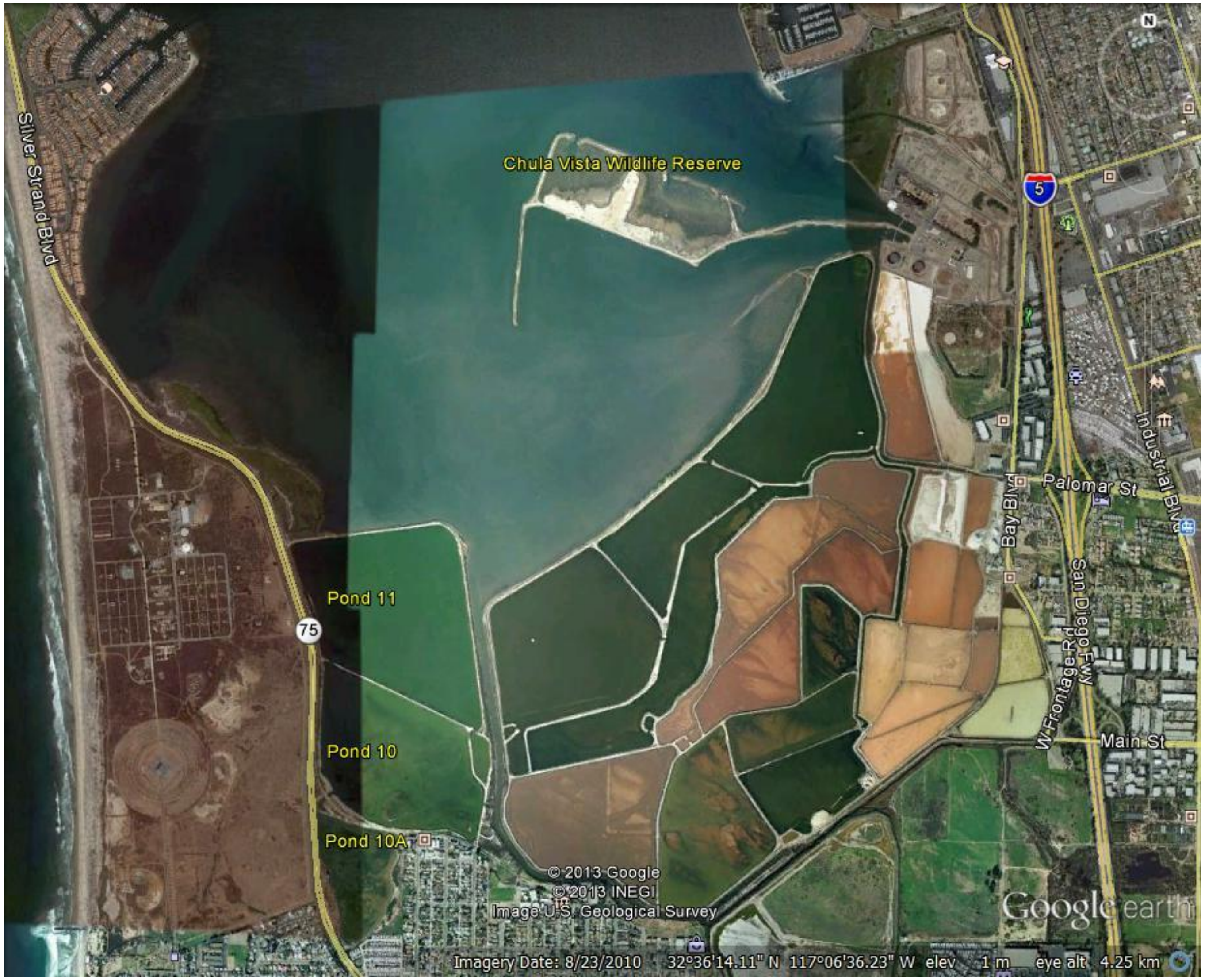

Figure 1. South San Diego Bay Coastal Wetland Restoration and Enhancement Project Locations

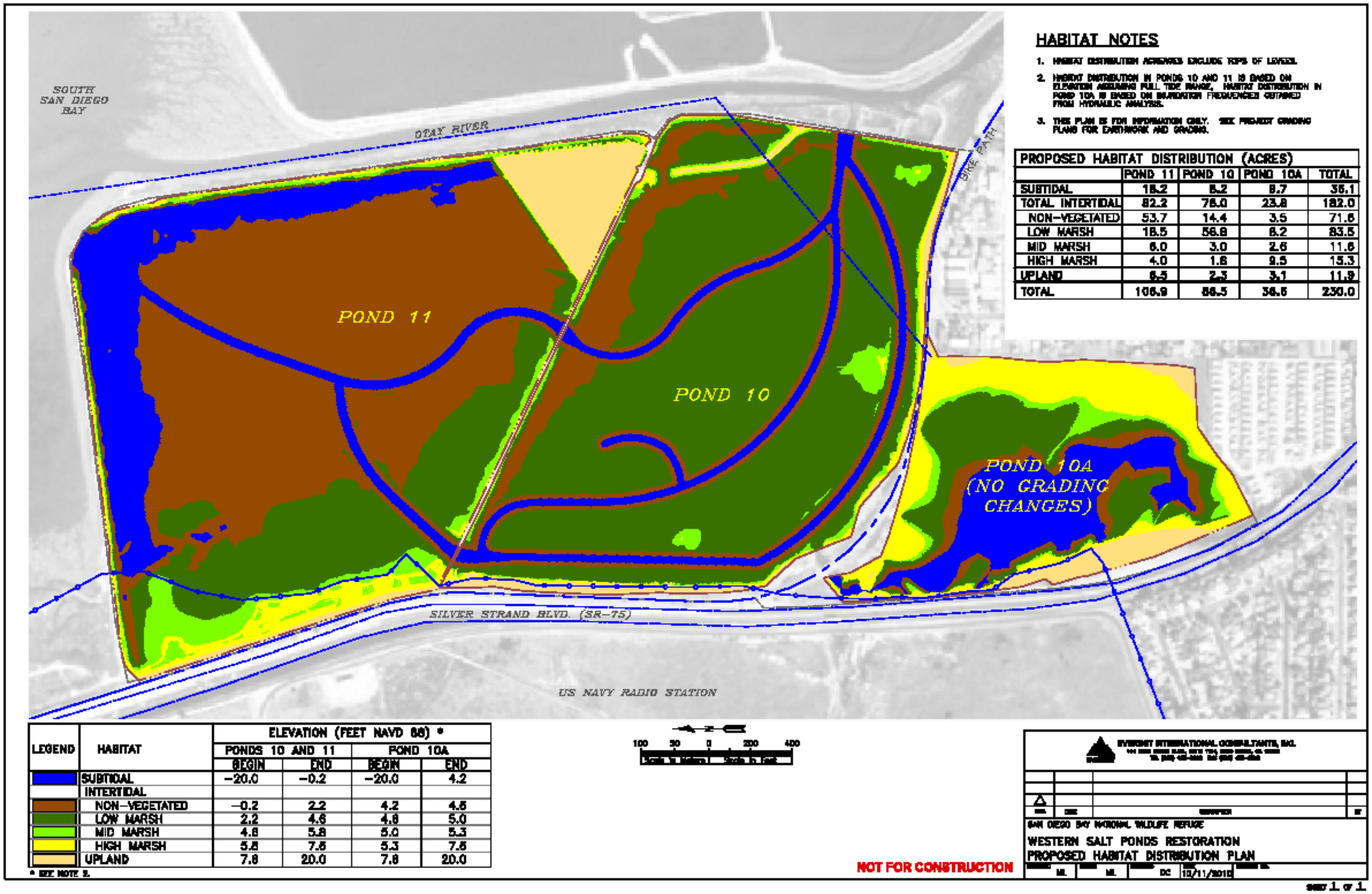

Figure 2. Habitat Restoration Plan for the Western Salt Ponds.

The remaining 77 acres of restoration was comprised of unvegetated flats and mid- and high-marsh habitat. No dredging or deposition occurred in Pond 10A, although restoration of tidal influence enhanced the existing 33 acres of former salt evaporation pond. Following the completion of the dredging operation within the salt ponds, the outer levees were breached to allow for tidal circulation and approximately 40 acres of low marsh habitat were planted with cordgrass and 4.8 acres of mid-high salt marsh were planted with a mosaic of species. The portions of the levees not affected by breaching were retained to provide roosting habitat for various avian species. An additional 67,000 cubic yards of material from the CVWR was slurried across San Diego Bay and deposited in the southeast corner of Pond 11 to create a nesting area with high-quality sandy material. A detailed account of the design of the western salt ponds is provided in the Basis of Design Report (Everest International Consultants, 2011).

Prior to beginning construction, a preconstruction monitoring program was implemented from January 2010 to September 2010. Monitoring of fish during the period revealed low diversity and abundance within the salt ponds. Low diversity of benthic invertebrates was also observed. Bird surveys were dominated by shorebirds (dowitcher sp., western sandpiper, willet and marbled godwit) in spring and early summer and by elegant tern and western sandpiper in late summer. Brown pelican and scaup sp. were also occasionally abundant. Preconstruction water quality data confirmed that the ponds were highly saline with static water temperature.

Postconstruction monitoring of the western salt ponds was initiated in January 2012 and will continue through 2016. Postconstruction monitoring includes both physical and biological components. Physical parameters monitored include tidal amplitude, bathymetry, topography, water quality and soils. Biological parameters include vascular plants, fish, benthic invertebrates and birds. Methodologies employed are presented by parameter below.

1.1.1 Goals and Objectives of the Western Salt Ponds Restoration

Two funding sources for the Project, the NCWC and NOAA grants, identified several objectives and metrics that will be assessed through the long-term monitoring program.

The overarching objectives for the NCWC grant were:

- Complete the permitting, final design, and site preparation, including all excavation, clean-up, and grading, necessary to restore and enhance 160 acres of coastal wetland and upland habitat in south San Diego Bay by March 1, 2011.

- By the end of 2016 achieve approximately 89 acres of functional estuarine intertidal emergent wetlands, approximately 41 acres of estuarine intertidal non-vegetated wetlands, approximately 28 acres of estuarine subtidal wetlands, and 10 acres of palustrine scrub-shrub vegetation.

However, these objectives also included acreage for the Emory Cove restoration site, which was not part of the NOAA grant and was not part of this monitoring program. The Emory Cove monitoring will be completed by the Port of San Diego and will be reported separately.

For the western salt ponds, the NCWC objectives were:

- By March 2013, achieve successful recruitment of benthic invertebrates and fish within Pond 11 to support migratory shorebirds and foraging ground-nesting seabirds.

- By March 1, 2011 complete the dredging and filling activities required to achieve elevations within Pond 11 that will support a mix of shallow subtidal, intertidal mudflat, cordgrass-dominated salt marsh, and pickleweed-dominated salt marsh habitats (estuarine intertidal emergent, non-vegetated, and subtidal wetlands) and breach the pond levee to restore tidal influence to the 106-acre pond.

- By the end of 2016, achieve 50 percent coverage of cordgrass (*Spartina foliosa*), with at least 25 percent of the plants in excess of 60 centimeters (cm) in height, over approximately 30 acres within the tidally restored pond.

- Between March 2011 and February 2012, monitor and record through monthly visual surveys, the recruitment of vegetation and benthic invertebrates, bird use, and any changes in bathymetry within the pond. Based on these observations, develop recommendations for how the design of future phases of salt pond restoration in San Diego Bay could be adjusted to more effectively achieve restoration objectives.

In addition, the following metrics were determined in conjunction with NOAA based on the draft Postconstruction Monitoring Plan for the western salt ponds:

- Restore wetland elevations and channel bathymetry in Ponds 10 and 11 to within plus or minus 10% of the design plan by June 2011;
- Restore tidal amplitude in Ponds 10 and 11 to approximately equal the tidal amplitude in the Otay River; restore tidal amplitude in Pond 10A to a slightly muted amplitude relative to the Otay River by 2012;
- Achieve 50% vegetation cover by wetland vascular plants in at least 30 acres of Pond 10 by June 2016;
- Demonstrate presence of one or more of the target species (flatfish and elasmobranchs) by 2013.

Postconstruction monitoring was conducted in order to demonstrate progress made toward achievement of these goals. Although postconstruction monitoring is planned through 2016, monitoring will extend far beyond the grant period(s) in order to understand the benefits of the project to the entire San Diego Bay ecosystem and to the South San Diego Bay Unit of the San Diego Bay National Wildlife Refuge.

1.2 Chula Vista Wildlife Reserve Restoration and Enhancement

Prior to restoration, the CVWR consisted of two shallow basins divided by a higher fill area managed for seabird nesting. The site suffered from poor tidal circulation, which impeded overall habitat quality within the basins. In addition, the high salinity levels occurring at higher tidal elevations impacted vegetation growth, resulting in the lack of vegetation in some areas and poor habitat quality in other areas.

Restoration of the CVWR was initiated on September 20, 2010 and completed on February 15, 2011, according to specifications. Approximately 11 acres of intertidal habitat were restored in the basins by excavating approximately 67,000 cubic yards of material and approximately 32 acres of wetland were enhanced by improving tidal circulation. The sediment that was dredged from the CVWR was pumped to the salt ponds to create a bird nesting area. The 11 acres of salt marsh habitat restored by the Project were planted by volunteer workers from the San Diego Audubon Society.

No site-specific preconstruction monitoring was conducted for the CVWR component of the Project. Postconstruction monitoring was initiated in April 2011 and includes monitoring of vegetation, water quality, fish and benthic invertebrates.

1.2.1 Goals and Objectives of the Chula Vista Wildlife Reserve

For the CVWR, the NCWC objectives were:

- By March 2013, achieve successful recruitment of benthic invertebrates and fish within the western basin of the Chula Vista Wildlife Reserve to support migratory shorebirds and foraging ground-nesting seabirds.

- By March 1, 2011, lower approximately 3 acres within the western basin of the Chula Vista Wildlife Reserve to achieve a typical marsh plain elevation of +4.5 feet Mean Lower Low Water (MLLW) (an elevation appropriate for supporting estuarine intertidal emergent wetlands) and expand the existing tidal channel by removing 3,000 cubic yards of sediment to create deeper, more well defined tidal creeks within the western basin, thus enhancing the remaining wetland habitat.

- By the end of 2016, achieve 50 percent coverage of cordgrass and pickleweed over the 3-acre excavation area and improve vigor and plant diversity throughout the remaining 16 acres of estuarine intertidal emergent wetlands within the basin.

At CVWR, the NOAA metrics were:

- Restore wetland elevations and channel bathymetry in the restored basin to within plus or minus 10% of the design plan by June 2011;
- Restore tidal amplitude to approximately equal the tidal amplitude in San Diego Bay by 2011;
- By 2016, restore typical marsh vegetation coverage, using marsh coverage at Tijuana Estuary as a target;
- Demonstrate presence of one or more of the target taxa (gobiidae and topsmelt) by 2013.

2.0 PHYSICAL PROCESSES

2.1 Topography/Bathymetry of Western Salt Ponds

Monitoring of the topography/bathymetry of the western salt ponds was a critical element in project design, during construction and during postconstruction. Elevations of the levees that separate the western salt ponds from San Diego Bay and from each other and the bathymetry of the ponds were assessed prior to construction to determine postconstruction habitat distributions and cut-and-fill volumes. During construction, the bathymetry of the ponds was measured frequently to determine achievement of target elevations and as a method of payment for the contractor. Postconstruction monitoring focused on the topography of the marsh plain and the bathymetry of the constructed channels.

2.1.1 Methods – Monitoring of Topography/Bathymetry of Western Salt Ponds

The preconstruction topography of the western salt ponds was assessed using existing topographic data generated by Ducks Unlimited, Inc. for the USFWS in 2000 as spot-checked by Psomas Engineering using conventional stadia rod and level methods tied to existing benchmarks in 2010. It was determined that the existing topographic data was accurate for project planning and those data were incorporated into the project plans. Preconstruction, the levees around the perimeter of ponds 10 and 11 and the internal levee between ponds 10 and 11 ranged from approximately +8 ft to +10 ft NAVD88 (Everest International Consultants 2011). During project planning, it was determined that both the internal and perimeter levees would be allowed to erode after tidal influence was restored to the ponds**.** Thus, postconstruction monitoring was focused on the elevations of the marsh plain and channels and not specifically focused on the levees that were breached during construction.

Year 1 (2012) postconstruction monitoring plan methodology for topography and bathymetry relied largely on determining elevations across a number of transects. The monitoring plan called for transects to be walked with elevations recorded using conventional surveying equipment, e.g., stadia rod and level. The muddy site conditions required modification of this plan and Real Time Kinematic (RTK) GPS were used to acquire elevations, latitude and longitude from a kayak or canoe. These data were supplemented by interpreting elevations from aerial photographs performed by San-Lo Aerial Surveys using photographs taken in October 2011

Surface elevations of all areas exposed at low tide in Pond 10 and approximately 50% of Pond 11 were determined by using stereoscopic aerial photographs taken immediately at the end of construction on October 26, 2011. Three separate photographic frames were taken at that time and it was determined that enough overlap between frames existed to use photogrammetric methods to extract elevation data for much of the restoration site. No ground control points were used as vertical and horizontal controls for this analysis.

During Year 2 (2013) monitoring, aerial imagery was again employed to determine site topography. False color aerial imagery of all three ponds was taken using a Red (R), Green (G), Blue (B) and Near Infrared (NIR) model UltraCam-X by Vexcel digital camera. This imagery was then converted to open water, vegetated areas and bare ground using Normalized Difference

Vegetation Index (NDVI). Vegetated areas include both salt marsh vascular plants and algae. Work continues on refining the vegetation category to differentiate between algae and vascular plants.

An orthophotograph of the western ponds was generated from the R, G, B, NIR digital image and elevation contours were generated in digital computer aided design (CAD) format and mosaicked georeferenced digital imagery within the extents of the overlapping aerial photographs. The resulting CAD file containing elevation contour data was converted to ArcGIS format for further processing and analysis.

Topography of the western salt ponds was not monitored in 2014 as monitoring efforts were directed towards contracting for LiDAR to be flown for the project in December 2014 and processed in 2015. Topography of the ponds based on the LiDAR flight and bathymetry based on a hydrographic survey system are presented below.

On 20 and 27 August 2015 a bathymetric survey was conducted at the ponds 10 and 11. A Sontek River Surveyor model S5, a high accuracy hydrographic survey system, was towed by kayak to measure water depths along transects across the channels. The system included a single beam depth sounder, mult-beam sonar and RTK GPS system which measured water depth relative to the system platform and x, y location data. The system also included software and hardware that corrected for variations in angles of the beam caused by pitching and rolling of the survey platform.

During each survey a HOBO water level data logger was set up to record water level and was surveyed to NAVD 88 vertical datum using the GPS RTK receiver. The resulting data from the water level recorder was used to post-process the relative water depths measured by the Sontek River Survey to the NAVD 88 datum.

Raw data was exported from SonTek River Surveyor software into native Matlab arrays. Raw data arrays were imported into Matlab and raw depth values were corrected for tidal variation while sampling using tide data collected during sampling.

Across channel transects were then identified and digitized from the tidally corrected output (Figures 3 -6). An interpolation routine was used to fill in elevations along channel flow directions in a more uniform grid sample pattern. This interpolation method helps account for the high resolution of the sampled elevation across channels compared with the lower resolution of samples along channels and between transects. Interpolation of samples into a surface model without first interpolating onto a regular grid produces good results very near the sampled points but with poor representation of the between channel surfaces and do not follow hydrographic convention.

In order to obtain a more complete elevation model, the tidally corrected sample points and interpolated transect points outputs derived from Matlab were imported into Arc GIS and combined with the DEM (digital elevation model). This model was generated from a Quality Level 1 (QL1 – 8pts/sq.m.) LiDAR dataset, which was obtained in October 2014 through a partnership led by USGS National Geospatial Technical Operations Center (NGTOC).

In ArcGIS, both bathymetric channel data and terrain data were interpolated and mosaicked to display a better elevation model (Figures 7 and 8). Depicting accurate elevations at the channel junctions is proving somewhat problematic using the current methodology, but different methods to fill those small gaps are currently being tested to provide a more accurate elevation model in such areas. Another issue is that the LiDAR data for Pond 10A has been classified by the contractor as all water, and there will be an attempt to reclassify the data to separate the channels from the ground, so that Pond 10A can be accurately included in the final elevation model product.

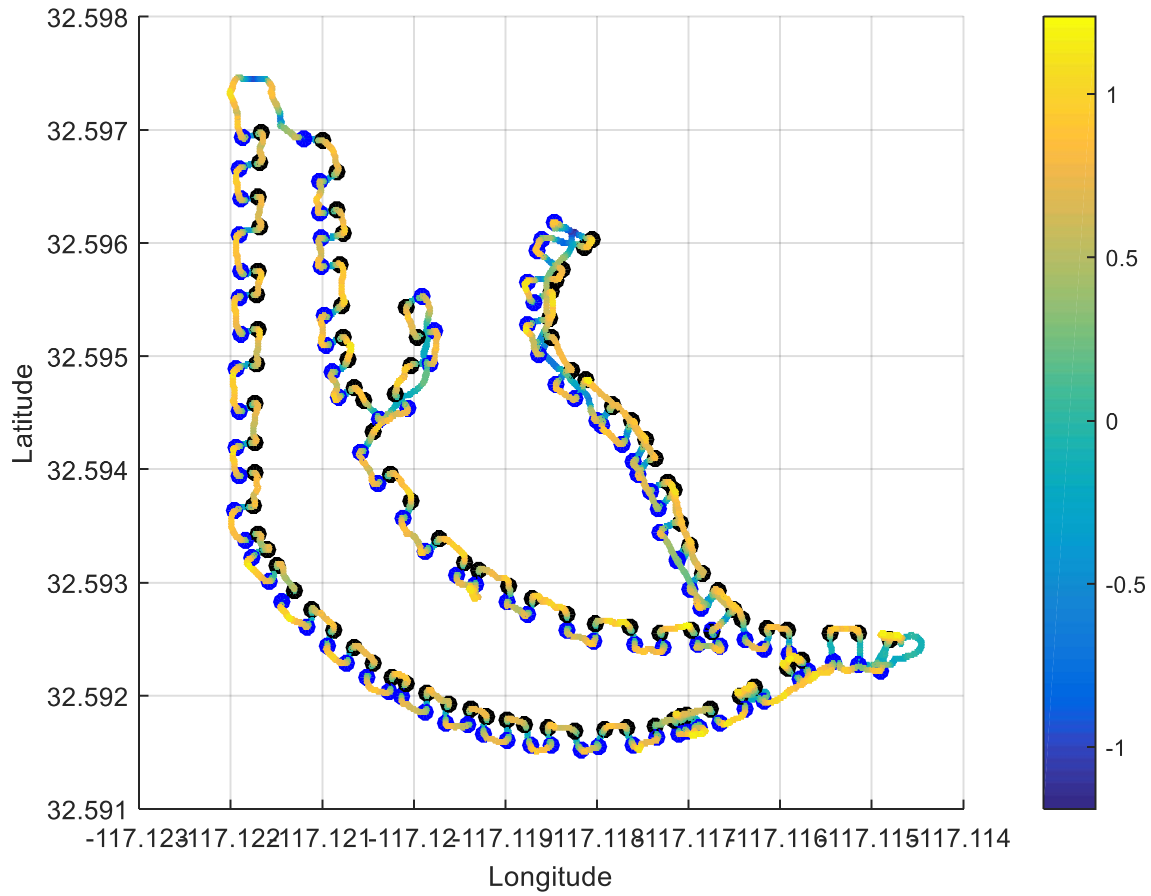

Figure 3. Pond 10 tidally corrected bathymetric data. Collected on August 20, 2015 using the River Surveyor Platform. Elevation (color bar) is shown in NAVD 88 meters. Blue and black dots are the beginning and ends of transects used in interpolation routines.

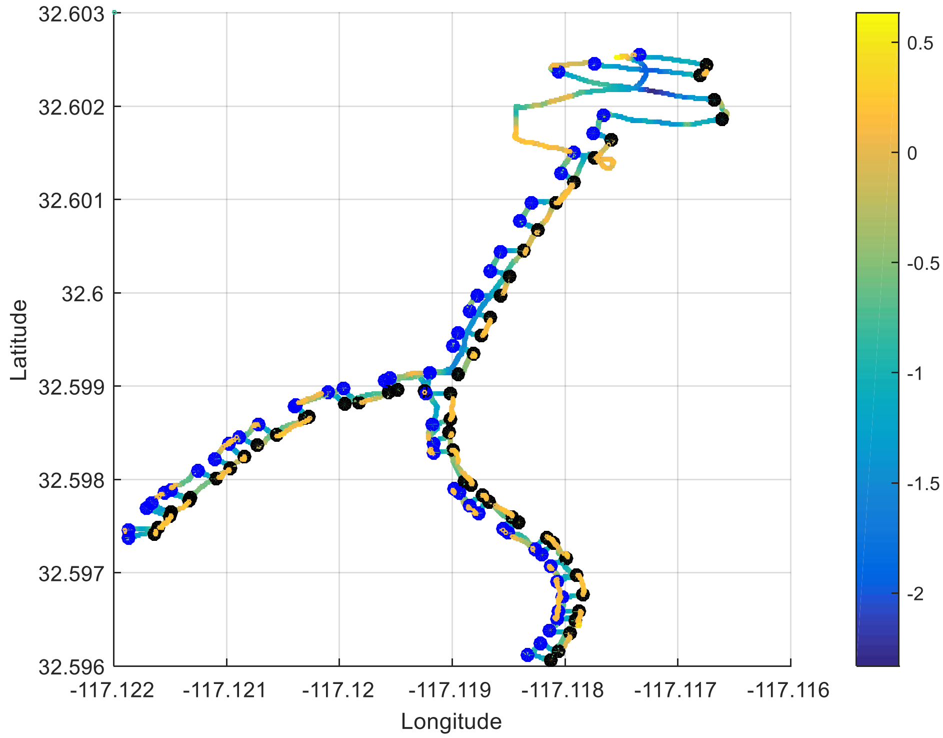

Figure 4. Pond 11 tidally corrected bathymetric data. Collected on August 20, 2015 using the River Surveyor Platform. Elevation (color bar) is shown in NAVD 88 meters. Blue and black dots are the beginning and ends of transects used in interpolation routines.

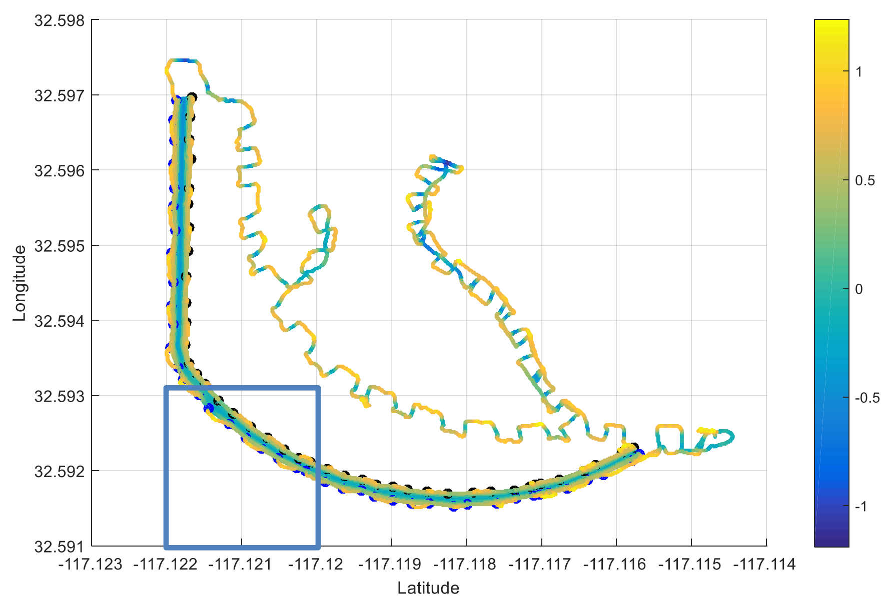

Figure 5. Pond 10 sample of transect interpolation results.

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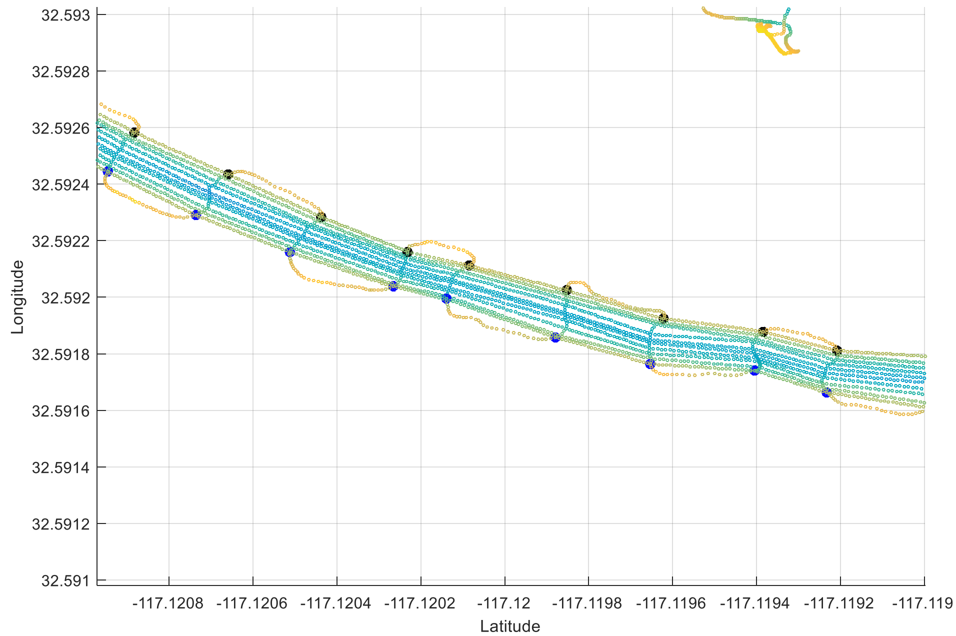


Figure 6. Pond 10 Sample transect interpolation results. Detail of above showing area in box.

2.1.2 Results - Monitoring of Topography/Bathymetry of Western Salt Ponds

As is evident from the digital terrain model (Figure 7), target elevations for Pond 10 remain within the elevation of low marsh which was targeted for +2.2 - + 4.6 NAVD 88. Pipeline scars have become *defacto* tidal creeks, and marsh plain elevations generally decrease from south to north.

Shoaling within subtidal channels appears to have occurred at the connection between Pond 10 and the Otay River and at junctions of the channels although further analysis of these areas is needed, as noted in Figure 7.

According to the model, much of the marsh elevations within Pond 11 are within the range of low marsh. Cordgrass (*Spartina foliosa*) has been observed growing on the mudflat/marsh plain within Pond 11, thereby supporting the results of the model. Deeper subtidal channels have persisted in Pond 11 compared to Pond 10.

The Project metric that the restored wetland elevations and channel bathymetry in Ponds 10 and 11 be within plus or minus 10% of the design plan by 2011 was met and the marsh plain elevations appear to be stable. Channels in Pond 10 appear to have partially filled with sediment, although these are still functional habitat for fish and invertebrates.

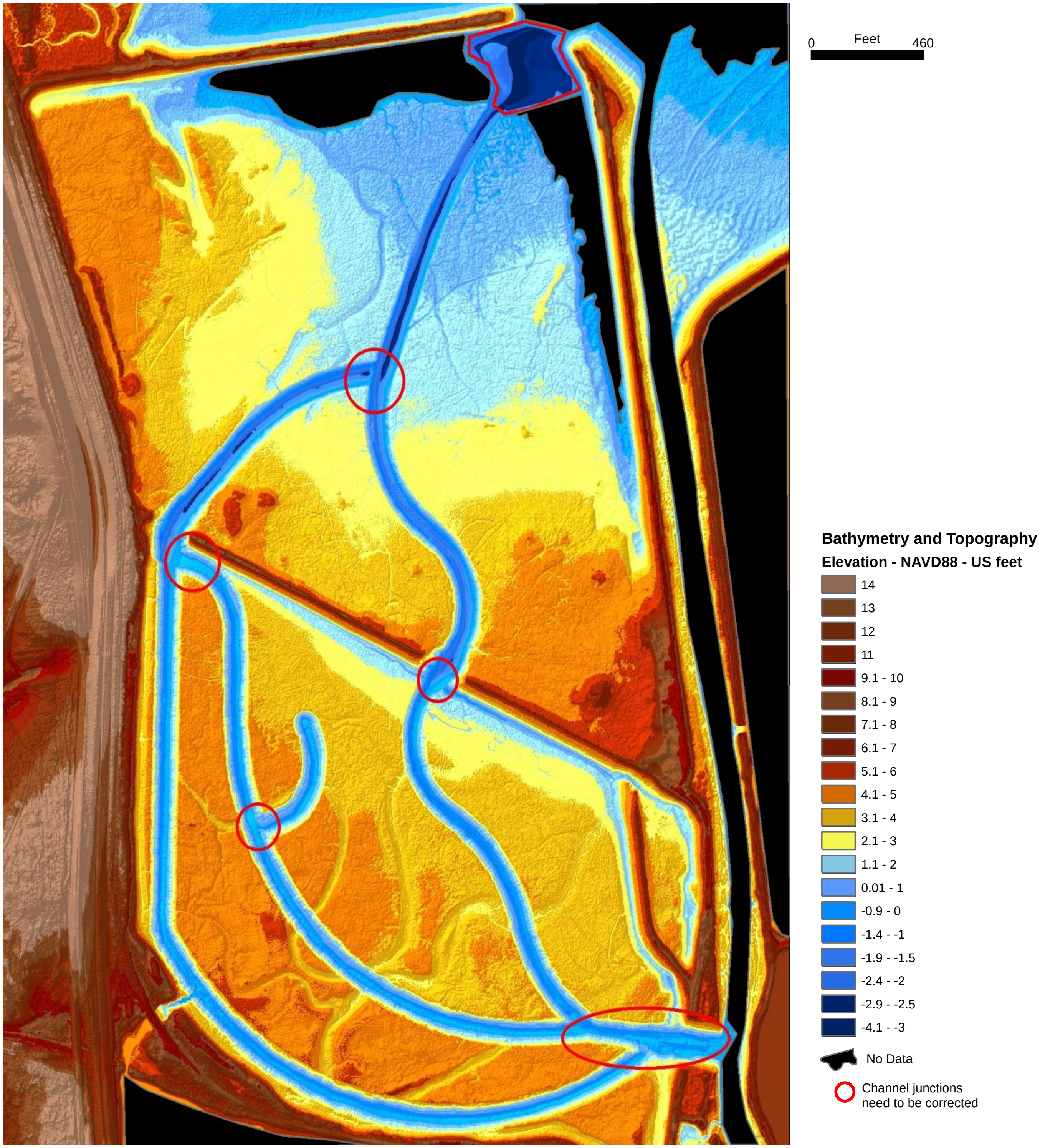


Figure 7. Bathymetry and LiDAR Data Combined. Elevation values are referenced to the NAVD88 datum and units are in US Survey feet. Areas with a red circle (creek junctions are being re-processed.

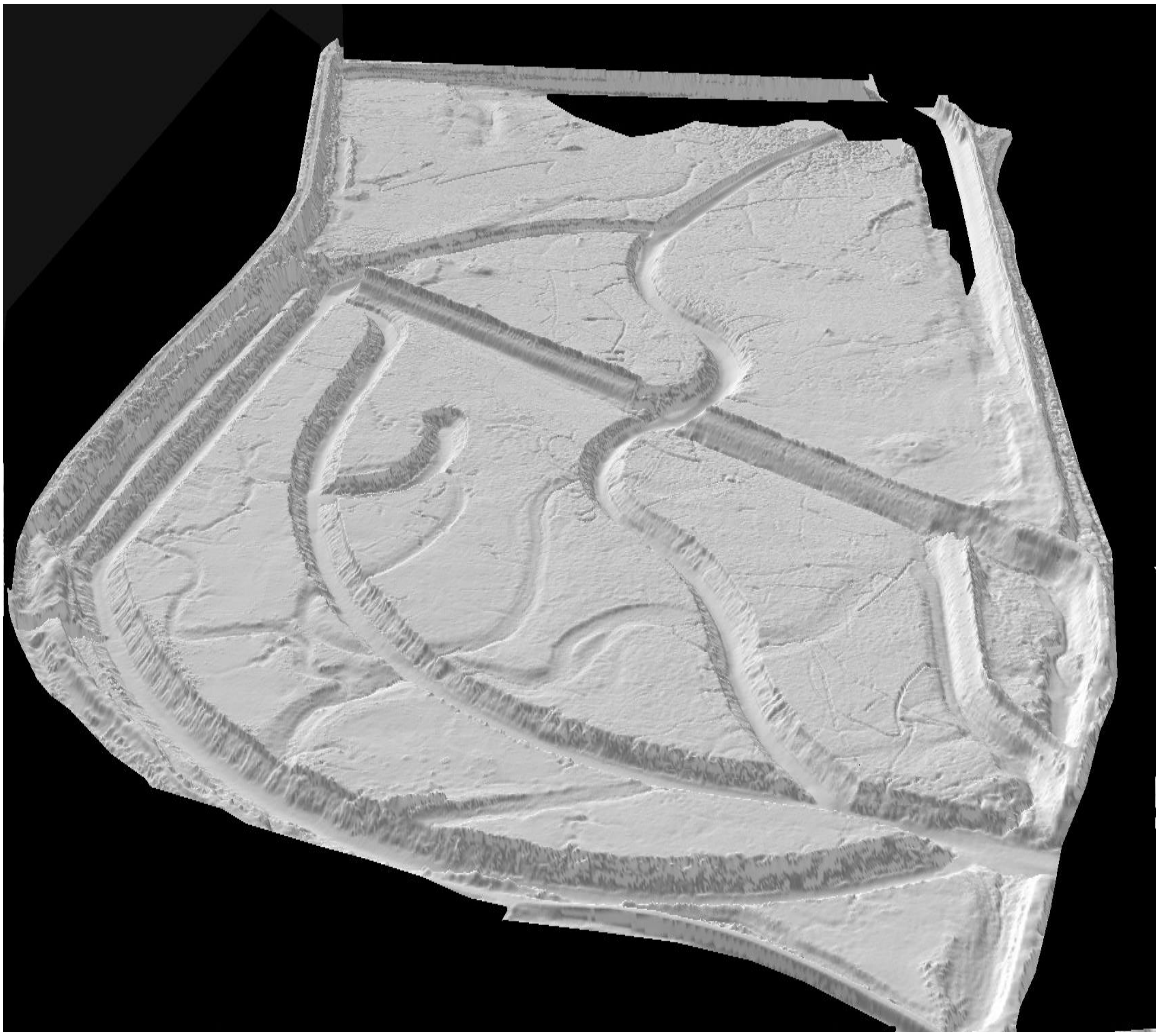


Figure 8. Topography/bathymetry model displayed in 3D.

2.2 Topography/Bathymetry of the Chula Vista Wildlife Reserve

Like the western salt ponds, monitoring of the topography/bathymetry of the CVWR was conducted during project design, during construction and postconstruction. Preconstruction elevations of the marsh plain and constructed channels were assessed to determine postconstruction habitat distributions and dredge volumes. During construction, the elevations of the marsh plain and constructed channels were measured frequently to determine achievement of target elevations and as a method of payment for the contractor. Postconstruction monitoring focused on the topography of the marsh plain and the bathymetry of the constructed channels.

2.2.1 Methods – Monitoring of Topography/Bathymetry of the Chula Vista Wildlife Reserve

Following completion of construction in mid-February 2011, a survey was conducted of the topography of the CVWR using aerial photogrammetry.

2.2.2 Results – Monitoring of Topography/Bathymetry of the Chula Vista Wildlife Reserve

The photogrammetry survey confirmed that the elevations were within the project specifications of ± 10% of design. Restoration activities at the CVWR lowered elevations in the 11-acre restoration area to between +3 and +6 ft MLLW.

2.3 Tidal Amplitude

Project objectives regarding tidal amplitude for both the western salt ponds and CVWR components of the Project included matching tidal amplitude at existing reference sites. For the western salt ponds, that reference was tidal amplitude at the mouth of the Otay River immediately adjacent to Pond 11. For the CVWR, that reference was the tidal amplitude of south San Diego Bay as measured at the NOAA tide gauge located on the Broadway Pier in San Diego.

Prior to construction, the western ponds were used as water storage ponds for solar salt evaporation and, thus, were not tidal. Water level and depth in the western salt ponds varied with water import and export associated with the solar evaporation activities. Water depth within Pond 11 between 2008 and 2010 varied from approximately +3 ft to +0.5 ft relative to the bottom of the pond. Prior to construction of the CVWR component, tidal amplitude was limited by existing elevations, however, there were no preconstruction data on tidal amplitude at the CVWR site.

2.3.1. Methods – Monitoring of Tidal Amplitude of the Western Salt Ponds

Tidal amplitude of the western salt ponds was measured using YSI model 6600 EDS Sonde dataloggers deployed at the eastern breach of the internal levee between Ponds 10 and 11 and at the mouth of the Otay River (Figure 7). The datalogger at the Pond 11 station was deployed using a 4-inch diameter PVC pipe that was strapped vertically to two "rail" style fence posts driven into the sediment. Multiple 1.5 inch holes were drilled around the bottom of the tube to permit unrestricted water flow to the sensors. During deployment the datalogger unit was placed into the PVC pipe and rested on a bolt fixed across the bottom of the tube. The datalogger at the mouth of the Otay River was deployed in a similar manner.

The deployment time varied from approximately two to four weeks. Measurements for water level (converted to tidal amplitude) were taken at 15 minute time intervals along with water quality data (specific conductivity, salinity, dissolved oxygen (percent saturation), dissolved oxygen (mg/l), temperature, turbidity, pH, and chlorophyll). At the end of each sampling period, the YSI dataloggers were retrieved and taken to the laboratory for data downloading, cleaning and recalibration. There are two designated dataloggers for both Pond 11 and the Otay River mouth. While one logger is in the field the other is in the laboratory.

In September 2013, a Solinst® level logger was deployed near Pond 10A sampling site 1 (see Figure 9). This depth logger measures only pressure and temperature. Pressure readings were converted to depth after being compensated for atmospheric pressure, which was recorded by the barometer at the CVWR (see Section 2.3.3). The Solinst® level logger failed during deployment and was replaced by a more reliable HOBO® level logger. The data from the HOBO® level logger is presented in this report.

2.3.2 Results - Monitoring of Tidal Amplitude of Western Salt Ponds

Tidal amplitude comparisons of the South Bay (Otay River) logger site, NOAA's San Diego Bay site, the Pond 10A and 11 logger sites, and the CVWR 3L logger site are shown in Figure 10. Figure 11 shows comparisons of the three CVWR logger sites with NOAA's San Diego Bay site. Comparisons included a typical 2-week spring tide series representing the higher tide scenario and a typical 2-week neap tide series representing the lower tidal cycle. During both the neap and spring tide series, tidal amplitude within the western salt ponds closely mirrors tides at both reference sites. On February 25, 2015, the South Bay (Otay River) and Pond 11 dataloggers were tied into the NAVD88 using RTK GPS. Note that, because the HOBO® depth loggers (sites Pond 10A, CVWR 1, CVWR2, and CVWR 3L) are not tied to any vertical datum, the values have been shifted manually along the y-axis so that comparisons can be made.

Figure 9. Monitoring Stations - Western Salt Ponds. Locations of water quality data-loggers are shown in black. Green dots = corners of experimental vegetation plots. Blue circles = enclosure traps and invertebrates. White circles = invertebrates only, both channel-bottom and tidal flat. Brown circles = sediment.

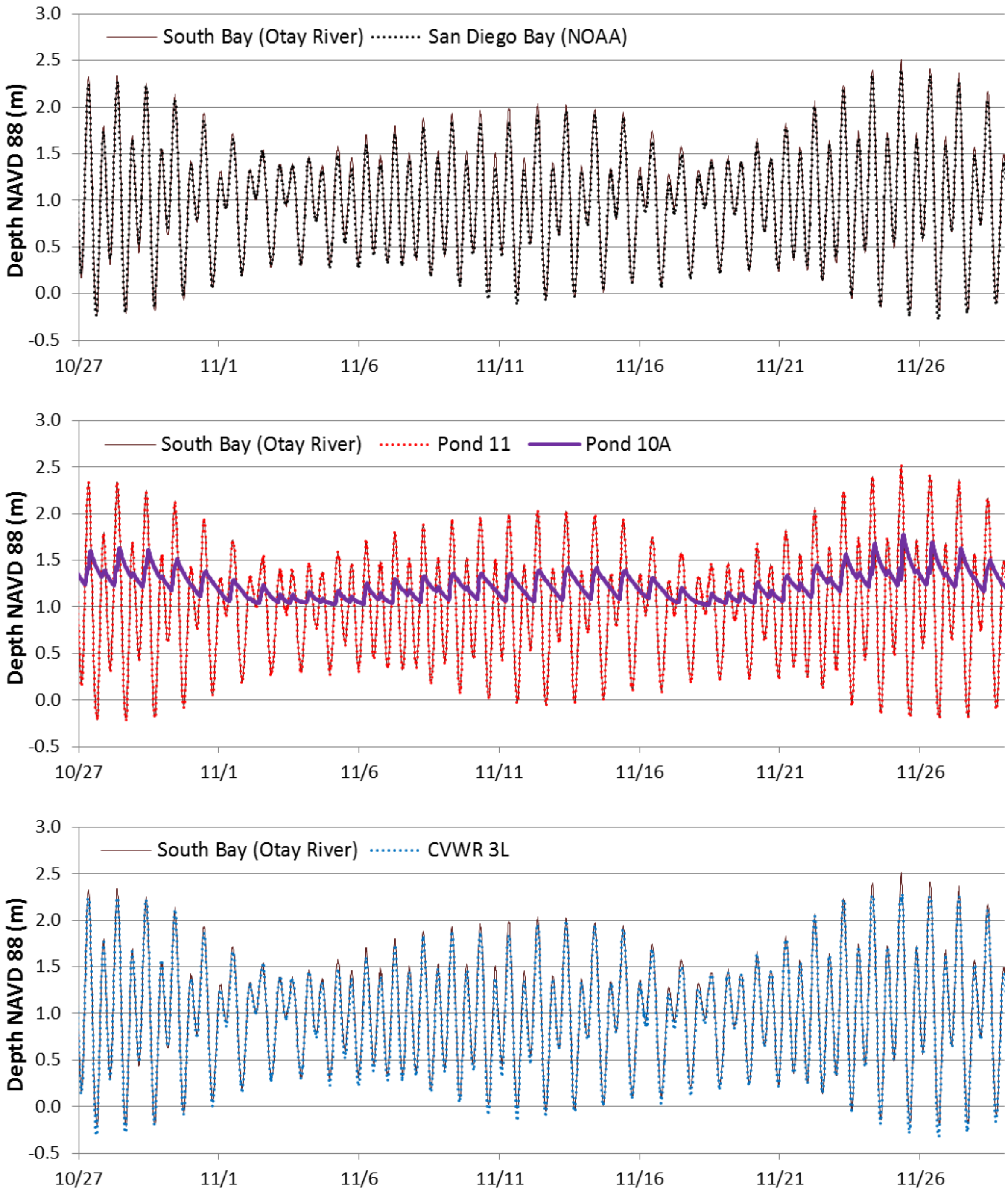


Figure 10. Comparison of the tidal amplitudes of the South Bay (Otay River) logger site to the NOAA's San Diego Bay site, the Pond 10A and Pond 11 logger sites, and the CVWR 3L Logger site.

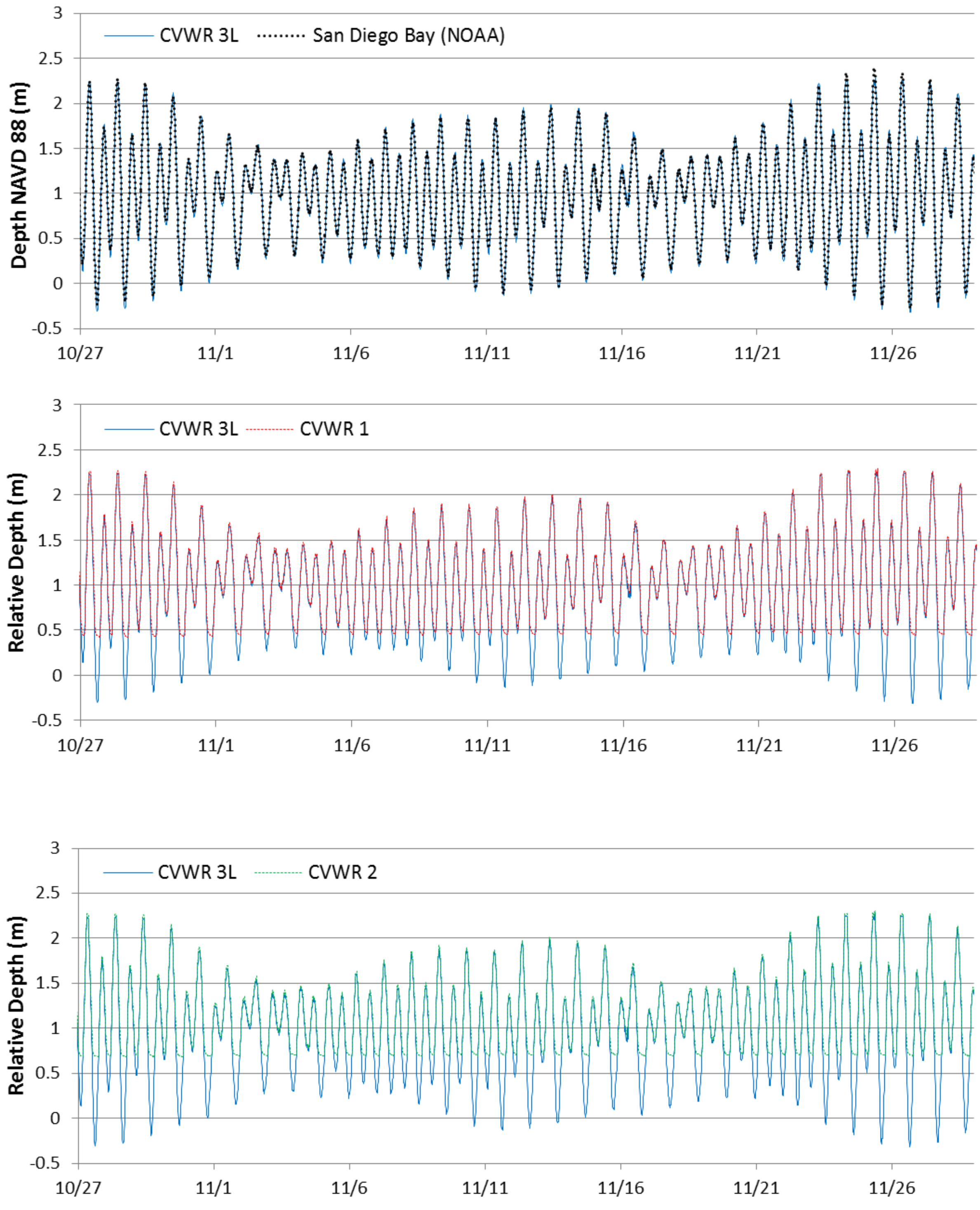


Figure 11. Comparison the tidal amplitudes of NOAA's San Diego Bay site with the three CVWR logger sites.

2.3.3 Methods - Monitoring of Tidal Amplitude of Chula Vista Wildlife Reserve

From 2012 through 2013, tidal amplitude at the CVWR was assessed using Solinst® level loggers deployed at Stations 1, 2, and 3, as depicted in Figure 9. In February 2013, the level logger at Station 3 was moved outside of the wildlife refuge (labeled 3L in Figure 12) in order to compare the tidal amplitudes inside the marsh to that of the adjacent bay. Level loggers detect pressure changes associated with water depth that can be converted to tidal amplitude after barometric compensation. As happened in 2012, failures with the loggers occurred that resulted in missing data, however, enough data was obtained to show spring and neap tidal series at each site. Due to the high failure rate experienced with the Solinst® level loggers, Onset® HOBO® data loggers were deployed in late January 2014 and have continued to function without failure.

2.3.4 Results - Monitoring of Tidal Amplitude of Chula Vista Wildlife Reserve

A comparison of the tidal amplitude at site 3L just outside of the CVWR with that in mid-San Diego Bay is presented in Figures 10 and 11**.** Two of the sensors (1 and 2) are located on the south end of the Reserve while sensor 3L is located just outside of the tidal inlet to the bay. The sensor at site 3L experiences almost an identical inundation pattern as NOAA's mid-bay sensor; however, it experiences a slightly greater range. The other two sensors still show substantial truncation of low tides. Thus, while tidal influence may have been increased through excavation of channels at the CVWR, tides are somewhat muted relative to the open bay.

In summary, the western salt ponds met the Project objectives for tidal amplitude while the CVWR did not. Low tides at the CVWR were truncated relative to tides at reference sites within San Diego Bay. Monitoring in subsequent years may determine a need for remedial measures.

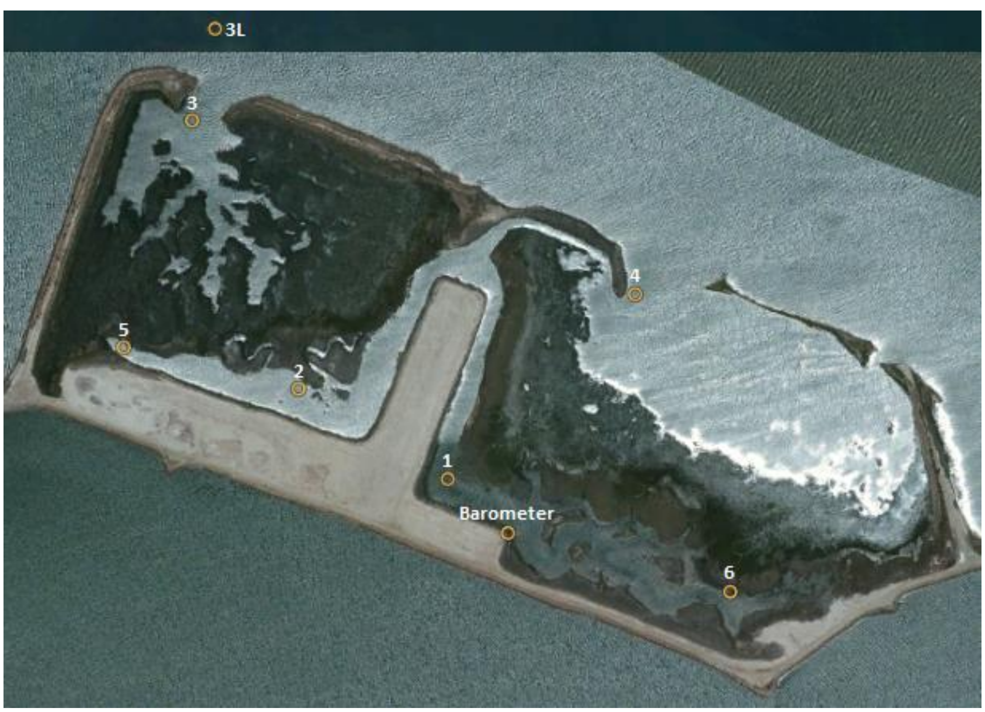


Figure 12. Monitoring Stations at the Chula Vista Wildlife Reserve.

2.4 Water Quality

Water quality objectives for the western salt ponds included developing water quality within Ponds 10 and 11 (referred to as Salt Ponds in this section) that is similar to that at the mouth of the Otay River and developing a more variable water quality in Pond 10A which has a muted tidal condition. There were no specific water quality objectives for the CVWR.

Preconstruction water quality monitoring within Pond 11, conducted from 2008 to 2010, showed variations in salinity, dissolved oxygen and temperature associated with water import and export and seasonality. Water salinities in Pond 11 varied from a high of approximately 51 ppt to a low of about 41 ppt. Dissolved oxygen varied inversely with salinity, dropping when salinities were higher and rising when salinities were lower. Water temperature varied seasonally with temperatures as high a 40 °C in summer and as low as 12 ° C in winter. Nutrients in the water also varied widely and were affected by rainfall, turbidity, temperature, dissolved oxygen and other physical factors.

2.4.1 Methods – Monitoring of Water Quality of Western Salt Ponds

As presented above, water quality monitoring of the western salt ponds and mouth of the Otay River was conducted using YSI model 6600 EDS Sonde dataloggers. The dataloggers measure depth, specific conductivity, salinity, dissolved oxygen (percent saturation), dissolved oxygen (mg/l), temperature, turbidity, pH, and chlorophyll at 15 minute intervals for a sampling period of 2-4 weeks before retrieval, downloading, cleaning, recalibration and redeployment.

2.4.2 Results – Monitoring of Water Quality Monitoring of Western Salt Ponds.

Water Quality monitoring results as measured by the datalogger in the eastern breach between Ponds 10 and 11 (Pond 11) and the Otay River Mouth (South Bay – [Otay River]) during Year 4 (2015) are presented in Figures 13 through 19. Missing data at the South Bay logger between the end of November and mid-December is due to a power failure.

Water depths were similar at both sites with similar maximum and minimum readings (Figure 13). The loggers were leveled and tied to the NAVD88 datum. The Salt Ponds logger’s depth port resides at -0.310m NAVD88 and that of the South Bay (Otay River) at -0.379m NAVD88.

Salinity was similar at both monitoring stations (Figure 14). Salinity readings near zero were recorded in response to rain events.

Water temperature varied seasonally with the highest temperatures occurring in July, August, and September and lowest in December and January (Figure 15). Trends in water temperature at both monitoring stations were very similar over the 12-month monitoring period.

Maximum chlorophyll levels as measured by the data logger were generally higher within Pond 11 compared to the Otay River (Figure 16) and maximum turbidity levels in Pond 11 were similar, although highly variable and exhibiting higher readings when an event occurred, compared to those in the Otay (Figure 17).

Dissolved oxygen levels varied seasonally and inversely with water temperature (Figure 18). Dissolved oxygen was highest during the cool winter months and lowest during summer. This parameter was similar for Pond 11 and the Otay River Mouth.

Recorded pH levels were similar at both dataloggers with greater variability at the South Bay logger (Figure 19). Minimum, average and maximum pH at both dataloggers were generally around 8.0. Periods of very low pH at the South Bay logger coincided decreases in salinity following influx of freshwater during rain events.

Orthophosphate levels varied considerably but were generally similar in Pond 11 and the Otay River (Figure 20). Ammonia and nitrate levels in Pond 11 were similar to those in the Otay River than Pond 11, although there were numerous data gaps (Figures 20 and 21).

In summary, the Project objective that water quality within Ponds 10 and 11 be similar to water quality at the mouth of the Otay River has been met. Variations in certain parameters, e.g., chlorophyll (Figure 22), may be attributed to the physical differences in the two monitoring stations. Higher chlorophyll levels in Pond 11 may be associated with higher turbidity at that monitoring station.

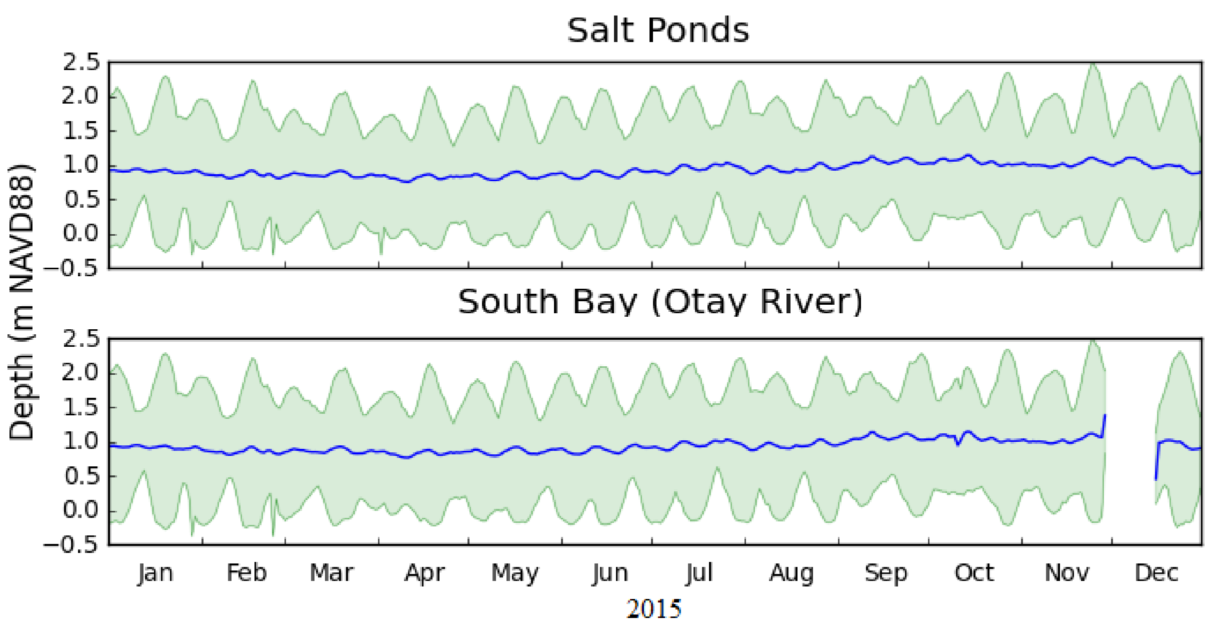


Figure 13. Daily averages, minimums and maximums of water depth in Pond 11 (above) and at the Otay River Mouth (below).

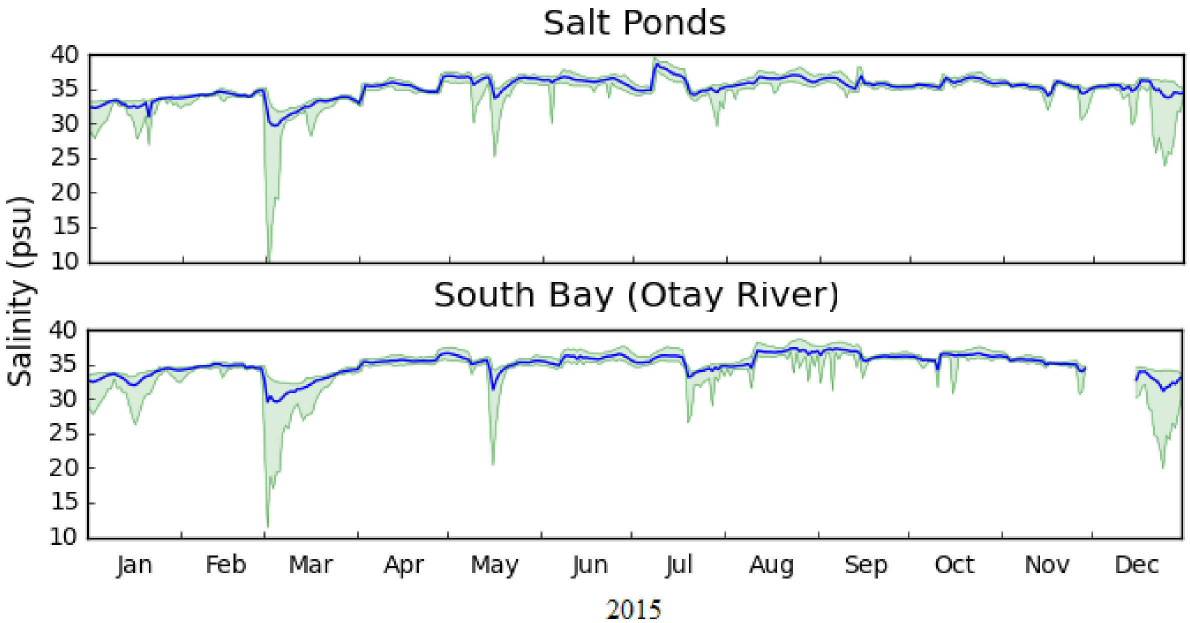


Figure 14. Daily averages, minimums and maximums of salinity in Pond 11 (above) and at the Otay River Mouth (below).

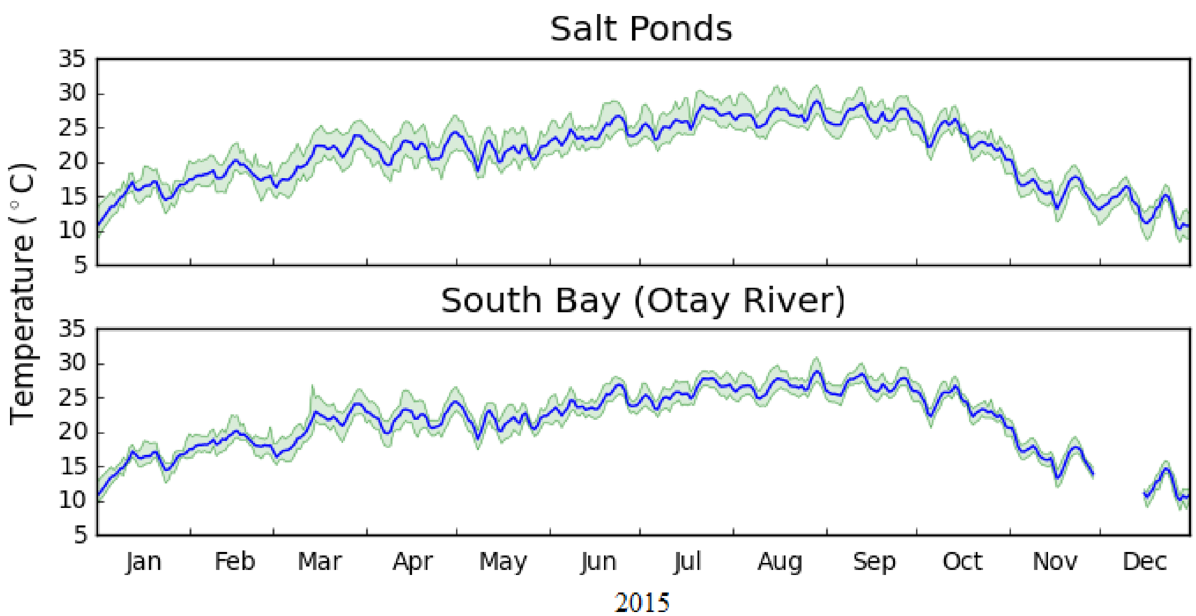


Figure 15. Daily averages, minimums and maximums of water temperature in Pond 11 (above) and the Otay River Mouth (below).

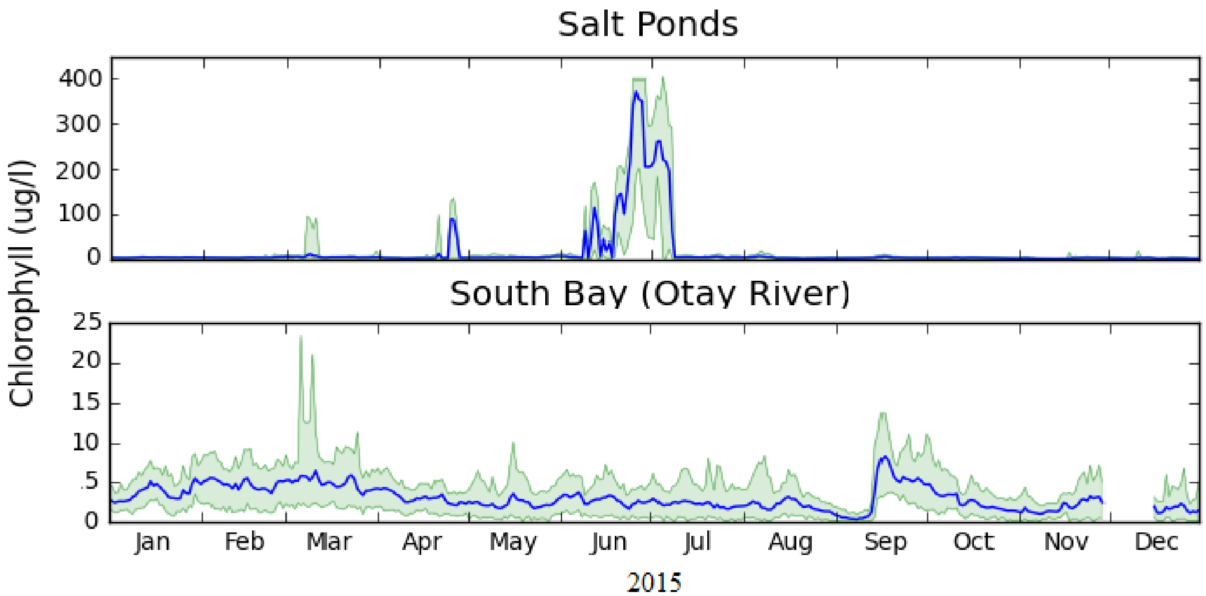


Figure 16. Daily averages, minimums and maximums of chlorophyll in Pond 11 (above) and the Otay River Mouth (below).

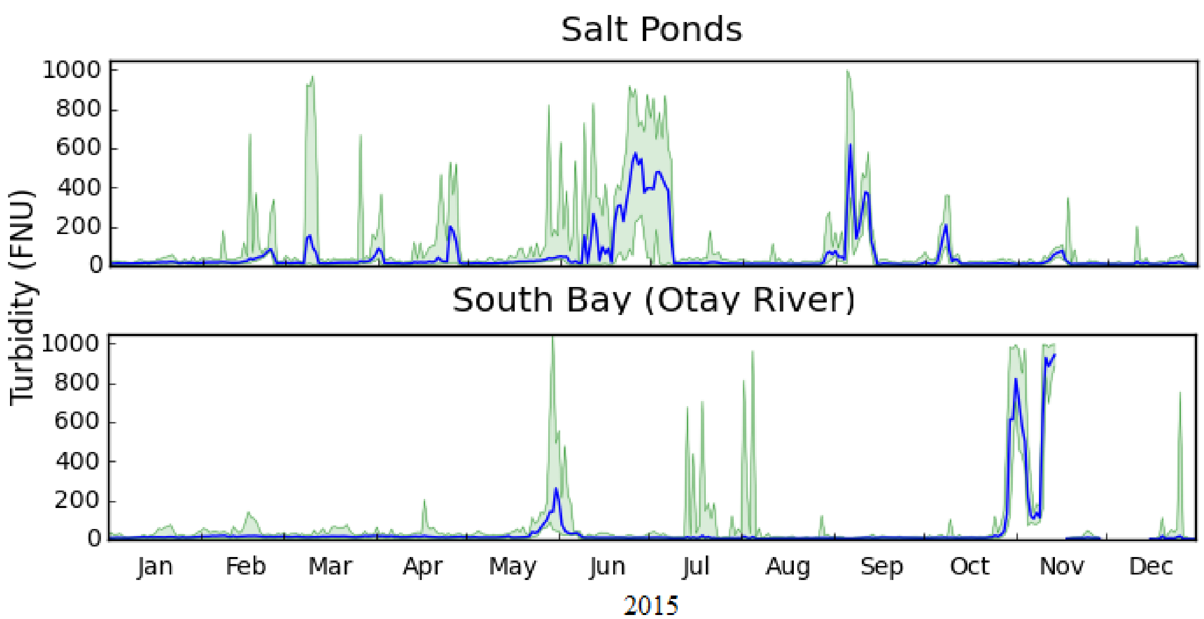


Figure 17. Daily averages, minimums and maximums of water turbidity in Pond 11 (above) and the Otay River Mouth (below).

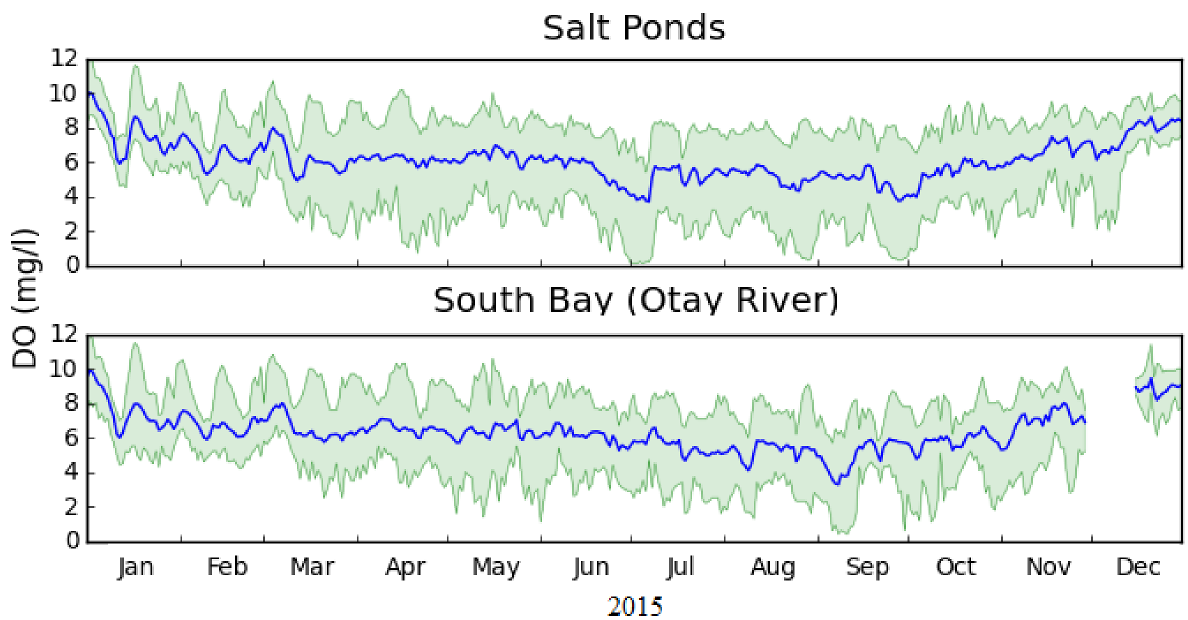


Figure 18. Daily averages, minimums and maximums of dissolved oxygen in Pond 11 (above) and the Otay River Mouth (below).

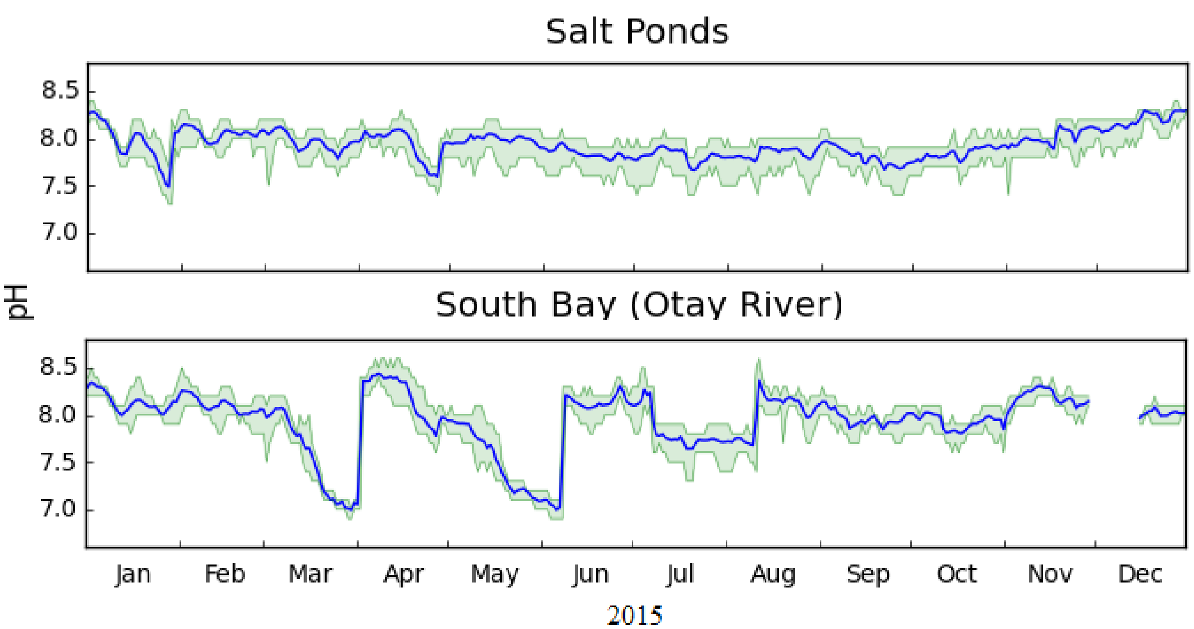
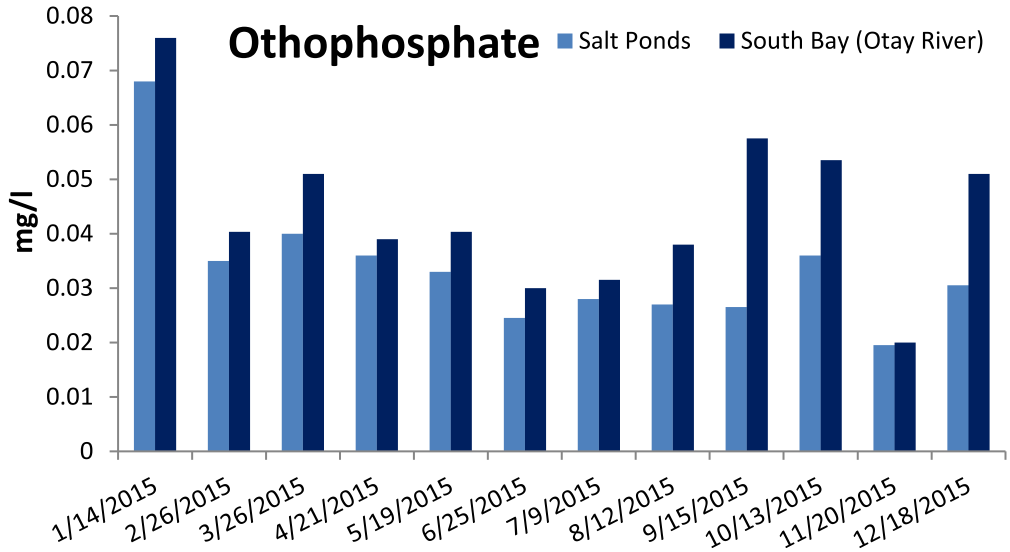


Figure 19. Daily averages, minimums and maximums of water pH in Pond 11 (above) and the Otay River Mouth (below).



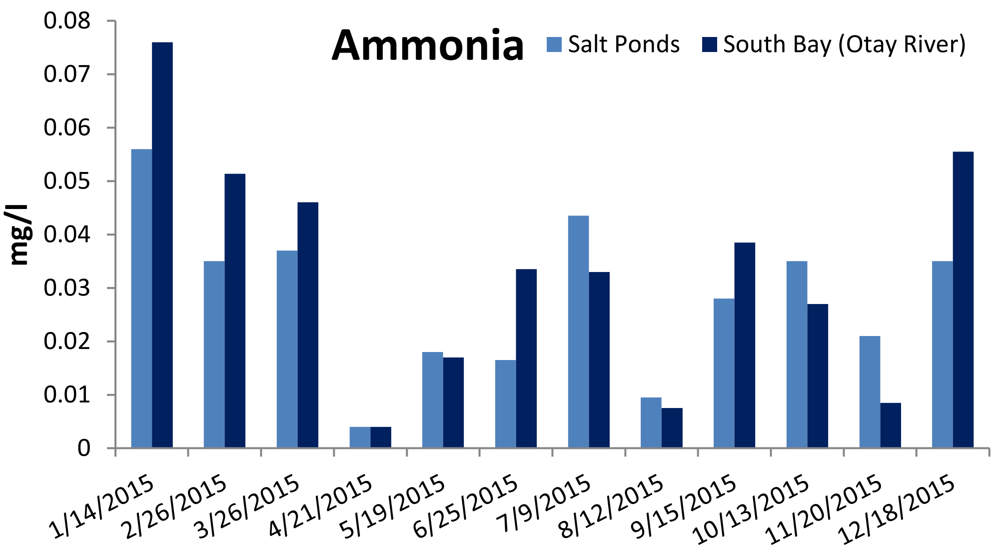
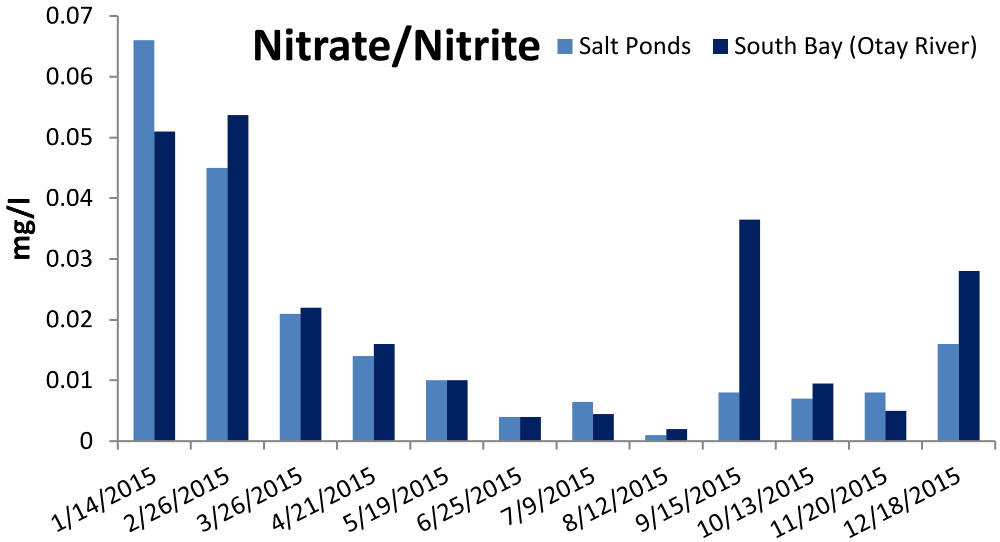


Figure 20. Orthophosphate and Ammonia in Pond 11 and the Otay River Mouth.



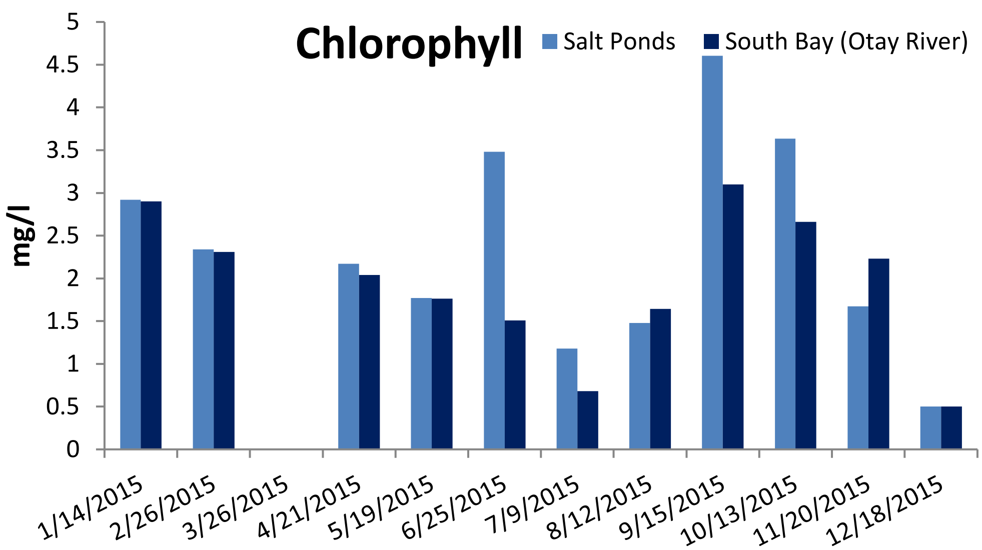


Figure 21. Nitrate/Nitrite and Chlorophyll in Pond 11 and the Otay River Mouth.

2.4.3 Methods – Monitoring of Water Quality Monitoring of Chula Vista Wildlife Reserve

Water quality data at the CVWR were collected by Merkel & Associates under contract to the San Diego Unified Port District. Data on dissolved oxygen, temperature, turbidity, pH were collected from five tidal channel stations (Figure 22) just prior to low tide on April 27, 2015 using a Hydrolab Quanta multiprobe water quality meter. Water samples were collected from tidal channels at five sampling sites (Figure 9) for laboratory analysis of nitrogen (as total Kjeidahl Nitrogen), total phosphorus and ammonia.

2.4.4 Results – Monitoring of Water Quality Monitoring Results of Chula Vista Wildlife Reserve

The results of water quality monitoring at the CVWR are summarized in Table 1. All parameters were within the expected ranges. It was concluded that there was no evidence of ponding or poor tidal circulation that could result in extremes in temperature or dissolved oxygen.

Table 1. Water Quality Data Collected from the Chula Vista Wildlife Reserve 2015

Station	Time	Nitrogen TKN (mg/l)	Total Phosphorous (mg/l)	Amonia (mg/l)
1	9:50	ND	0.055	0.061
2	10:05	0.37	0.060	0.072
3	10:20	0.36	0.067	0.066
4	10:45	ND	0.062	0.100
5	11:15	0.ND	0.220	0.120

2.5 Soils Monitoring

There were no specific Project goals and objectives for either the western salt ponds or CVWR regarding soils and their development over the life of the monitoring program.

2.5.1. Methods – Monitoring of Soils of Western Salt Ponds

Soils of Ponds 10A, 10, and 11 were collected at the stations shown in Figure 9 in September 2015. Soil sampling locations were designed to correlate with monitoring of the experimental planting blocks in Pond 10 and fish enclosure traps/invertebrate sampling stations. Soils were collected using a 6 cm long PVC pipe with an interior diameter of 4.8 cm and were analyzed in the laboratory for grain size, salinity, and organic matter content.

Figure 22. Monitoring Stations Chula Vista Wildlife Reserve.

Two samples were taken at each site and dried in an oven at 105°C. One sample was wet-sieved through 2-mm and 63-µm mesh screens to obtain weight percentages of silt/clay, sand, and pebbles/shell hash

The second sample was homogenized using a coffee grinder, and, from this sample, soil salinity and loss-on-ignition organic matter content were measured. Soil salinity was measured by rehydrating a portion of the homogenized sediment with deionized water to form soil pastes, and then expressing interstitial water onto a handheld, temperature-compensated optical salinity refractometer that measures salinity (primarily sodium chloride) in parts per thousand (ppt).

Percent weight of organic matter was estimated by heating a portion of the homogenized sediment at 550°C for 4 hours in a muffle furnace, and weighing the remainder of the sediment that did not combust after it was allowed to cool to room temperature in a desiccator. It is important to note that the method of loss-on-ignition tends to overestimate the organic carbon content in sediments due to various occurrences and losses of volatile salts, organic compounds, structural water, sulfide oxidation and/or inorganic carbon. Generally, studies have shown that the organic carbon content is approximately half the amount of organic matter determined by loss-on-ignition. It has been shown, however, that geochemical properties and grain size of the sediment strongly affects this method's reliability. More specifically, a rise in clay content leads to a larger discrepancy (Veres, 2002). For a more thorough explanation on the method of loss-on-ignition and its accuracy in determining organic carbon content, see Veres 2002 and references therein.

Lastly, *in-situ* measurements of sediment stability were conducted using a Torvane shear strength gauge that measures soil stability in units of kg/cm.

2.5.2. Results - Monitoring of Soils of Western Salt Ponds

The results of the sediment analyses are presented in Table 2. Soils of all three ponds were dominated by silts and clays. Percent silts and clays by weight were highest in Ponds 10 and 11, with means of 88% and 89%, respectively, and lower in Pond 10A, with a mean of 77%. Average weight percentages of sand within Ponds 10A, 10, and 11 were 21%, 10%, and 11%, respectively. Average weight percentages of organic matter were fairly consistent among the three ponds: 10.2%, 11.1%, and 8.8% in Ponds 10A, 10, and 11, respectively. Soil salinity ranged from 54 to >160 ppt in Pond 10A, 158 to 124 ppt in Pond 10, and 60 to 125 ppt in Pond 11. It should be noted that the method used here to measure salinity often results in salinity values that are elevated relative to the method of extracting interstitial pore water in the field and expressing it directly onto the refractometer. Thus, salinities measured using the latter method during the September 25, 2015 survey of experimental planting blocks of California cordgrass (*Spartina foliosa*) in Pond 10 (see section 3.1.3) had a mean value of 46 ppt. The homogenizing and rehydrating method was adopted in order to compare upland soils with little or no pore water to wetland soils that in some cases are saturated. It provides a basis for comparison but results in elevated readings.

Table 2. Sediment Grain Size, Organics and Salinity Results 2015– Western Salt Ponds

South San Diego Bay Salt Ponds Soil Analyses - September 2015						
		weight percentages				
		pebbles/ shell hash (> 2mm)	sand (2mm>x>63µm)	silt and clay (< 63µm)	Loss-on-Ignition Organics	Salinity (‰)
Pond 10A	1 - 1	3.0	68.4	31.6	5.3	72
	1 - 2	30.7	49.0	20.3	5.5	81
	1 - 3	3.8	72.4	23.8	2.5	54
	2 - 1	6.3	42.9	50.8	11.3	116
	2 - 2	0.0	0.7	99.3	9.9	62
	2 - 3	3.4	16.8	79.8	14.1	118
	3 - 1	1.7	10.8	87.5	14.9	>160
	3 - 2	1.1	1.9	97.0	10.3	78
	3 - 3	4.3	15.4	80.3	11.0	89
	4 - 1	0.2	8.1	91.7	4.5	>160
	4 - 2	7.6	30.0	62.4	16.1	72
	4 - 3	1.9	40.9	57.2	7.7	96
	4 - 4	1.3	25.3	73.4	10.8	86
	4 - 5	2.2	24.2	73.7	8.2	118
	5 - 1	0.0	16.9	83.1	14.9	139
	5 - 2	4.3	2.9	92.9	9.5	88
	5 - 3	3.4	20.0	76.6	8.0	62
	1	3.7	19.4	76.9	11.8	80
	2	1.6	10.5	87.9	10.3	85
	3	2.8	14.8	82.4	12.7	101
	4	1.2	39.5	59.3	15.7	116
Pond 10	1 - 1	0.0	3.7	96.3	11.4	124
	1 - 2	0.0	3.0	97.0	12.2	118
	1 - 3	8.7	31.2	60.1	9.6	95
	5 - 1	0.0	27.6	72.4	11.8	120
	5 - 2	0.4	14.7	84.8	10.8	58
	5 - 3	0.6	14.4	85.0	10.1	115
	7 - 1	0.1	5.1	94.8	11.4	110
	7 - 2	1.9	8.4	89.7	10.6	92
	7 - 3	2.1	8.2	89.7	11.8	93
	8 - 1	1.5	6.0	92.5	9.3	86
	8 - 2	0.1	1.3	98.6	12.1	95
	8 - 3	0.0	0.9	99.1	12.0	100
Pond 11	1 - 1	0.0	11.7	88.3	8.3	85
	1 - 2	2.4	26.6	70.9	4.6	63
	1 - 3	0.0	12.9	87.1	7.4	99
	3 - 1	0.0	1.7	98.3	10.2	89
	3 - 2	0.5	2.7	97.3	14.3	125
	3 - 3	0.0	0.9	99.1	11.0	103
	3 - 4	0.0	0.5	99.5	10.6	114
	3 - 5	0.0	0.3	99.7	8.3	112
	6 - 1	0.0	3.0	96.9	8.8	88
	6 - 2	0.1	29.0	71.0	6.6	87
	6 - 3	2.4	51.3	48.7	3.2	60
	6 - 4	0.1	0.9	99.1	10.2	81
	6 - 5	0.0	0.8	99.2	11.3	124

The results of the Torvane shear strength gauge (Table 3) provide a general comparison of the stability of the soils in each pond. Shear strengths were again highest in Pond 10A (0.18 kg/cm^2 average), intermediate in Pond 10 (0.12 kg/cm^2 average) and lowest in Pond 11 (0.05 kg/cm^2 average). These values can be compared to observations in the field over the sampling period. Soils in 10A can support foot traffic in almost all areas except for remnant channels. Soils in Pond 10 are softer than those in 10A and researchers often sunk knee or thigh deep when conducting field work. The soils in Pond 11, the recipient of dredge slurry from Pond 10, are unconsolidated and may remain unconsolidated for up to 5 years following deposition.

Table 3. Soil Torvane Shear Strength 2015 – Western Salt Ponds

Site Number	Average Shear Strength of Soil kg/cm^2	Standard Error of Mean	**Percent Change**
Pond 10A			
1	0.107	0.007	0.07
2	0.267	0.014	-0.30
3	0.063	0.005	-0.69
4	0.117	0.014	-0.46
5	0.127	0.003	-0.67
6	0.383	0.014	0.04
Pond 10			
1	0.117	0.014	-0.02
2	0.077	0.007	-0.42
3	0.040	0.005	-0.30
4	0.122	0.018	0.40
5	0.105	0.004	0.57
6	0.233	0.014	2.33
7	0.217	0.036	0.52
8	0.100	0.024	-0.19
9	0.050	0.000	-0.56
10	0.150	0.000	3.55
Pond 11			
1	0.030	0.000	2.00
2	0.030	0.000	9.00
3	0.027	0.003	1.70
4	0.043	0.003	5.14
5	0.090	0.000	-0.23
6	0.070	0.000	-0.42

3.0 BIOLOGICAL PROCESSES

3.1 Vascular Plants

Project goals for the western salt ponds included achieving 50% cover by wetland vascular plants in at least 30 acres of Pond 10 by June 2016 and achieving a height of California cordgrass (*Spartina foliosa*) of 60 cm or more for 25% of the cordgrass population within the minimum 30 acres of such habitat in Pond 10 by June 2016. Project goals for the CVWR included: by the end of 2016, achieve 50 percent coverage of cordgrass and pickleweed over the 3-acre excavation area and improve vigor and plant diversity throughout the remaining 16 acres of estuarine intertidal emergent wetlands within the basin; and, by 2016, restore typical marsh vegetation coverage, using marsh coverage at Tijuana Estuary as a target.

In an effort to achieve these goals, salt marsh vascular plants were planted in low, mid- and high marsh elevation zones in Pond 10 and similar habitats at the CVWR as described below.

3.1.1 Mid-Salt Marsh, High Salt Marsh and Transition Zone Plantings in Pond 10

The perimeter of Pond 10, consisting primarily of the slopes and tops of the levees, was planted with 12 species of mid- and high salt marsh and transition zone species (Table 4). Plants were grown in 2.25 by 3-inch rosepot containers by Tree of Life nursery in San Juan Capistrano, California. Pond 11 was not planted as the sediment disposed there during channel dredging was unconsolidated and therefore was subject to change in elevation over time. In addition, the unconsolidated sediments could not support foot traffic nor were they solid enough to retain plants. Pond 10A was not planted due to the high salinity of the soil. In both Pond 10A and Pond 11, natural recruitment by Pacific pickleweed (*Salicornia pacifica*) and Bigelow's pickleweed (*S. bigelovii*) has established relatively large areas of the low and mid-marsh. California cordgrass (*Spartina foliosa*) has become established on mudflat areas of appropriate elevation in Pond 11. It is assumed that cordgrass was established from bare root ramets that were planted in Pond 10 and not from seed. All three ponds are expected to recruit salt marsh species as the physical conditions in each pond change over time.

Planting of mid- and high salt marsh species and transition zone was conducted by Merkel & Associates under contract to SWIA. These plantings were completed on October 17, 2011. The areas planted are depicted in Figure 21 (Figure 2 of the as-built report Merkel & Associates, December 2011). Mid-marsh species were planted between +4.6 and +5.8 ft NAVD88. High marsh species were planted between +5.8 and + 7.6 ft NAVD88. Transition zone plantings were installed above +7.6 ft NAVD88. All transition zone plants were installed with two quart size DriWater© time release gel packs to provide moisture for approximately 90 days. All plants were installed on approximately 6-foot centers.

3.1.2 Monitoring of Mid-Salt Marsh, High Salt Marsh and Transition Zone Plantings in Pond 10

Mid-salt marsh, high salt marsh and transition zone plantings were not monitored in 2013 due to low initial survival in 2012 and the inability to access the mid-marsh plain. Casual observations in 2012 suggested a survival rate in mid-high marsh of less than 50% and less than 25% in the transition zone. Mid- and high salt marsh plantings were not surveyed in 2013 (Year 2), 2014 (Year 3) or 2015 (Year 4).

Table 4. Mid- and High Salt Marsh and Transition Zone Plant Species Planted in Pond 10

Common Name	Scientific name	Quantity	Planting Zone
Saltwort	*Batis maritima*	885	Mid-marsh
Jaumea	*Jaumea carnosa*	885	Mid-marsh
Bigelow's Pickleweed	*Salicornia bigelovii*	885	Mid-marsh
Sea-Blite	*Suaeda esteroa*	885	Mid-marsh
Saltgrass	*Distichlis spicata*	405	High marsh
Alkali Heath	*Frankenia salina*	405	High marsh
Watson's saltbush	*Atriplex watsonii*	425	High marsh
Sea Lavender	*Limonium californicum*	405	High marsh
Shoregrass	*Distichlise littoralis*	830	High marsh/Transition
Parish's Pickleweed	*Arthrocnemum subterminale*	830	High marsh/Transition
Boxthorn	*Lycium californicum*	425	Transition zone
Palmer's Frankenia	*Frankenia palmeri*	425	Transition zone
	Total	**7,690**	

3.1.3. Monitoring of Cover by Wetland Vascular Plants and Maximum Height of Cordgrass in 2016

Although data on canopy cover of salt marsh vascular plants and cordgrass height were collected in early 2016 (Year 5), the results are presented in this Year 4 report as these data have been lacking in previous reports and were specifically requested for inclusion herein. Furthermore, the methodology proposed for determining cover, remote censusing using aerial photography, was not employed. Instead, cover within vegetation releves (polygons of various shapes) was estimated visually.

3.1.4. Methods - Monitoring of Cover by Wetland Vascular Plants and Maximum Height of Cordgrass in 2016

Field surveys were conducted in February 2016. The study area was divided into homogeneous survey units (polygons) prior to field work using aerial imagery from December 2014 (Figure 23) Each initial survey unit was approximately 1 - 5 acres, although some units were later subdivided based on field conditions. Several units were not surveyed due to extremely muddy conditions that made access nearly impossible. Field crews walked the length of each survey unit and estimated the percent cover of all species present, as well as the total vascular plant cover. The height class (<60 cm or >60 cm) for the maximum height of *Spartina foliosa* was also noted, as was the height class for 25% of the *Spartina foliosa*. Height class measurements of live and dead plants were noted separately.

Figure 23. Polygons monitored for vascular plant cover and cordgrass height February 2016.

3.15. Results - Monitoring of Cover by Wetland Vascular Plants and Maximum Height of Cordgrass in 2016

Total cover of all vascular plant species combined is illustrated in Figure 24. Estimated percent cover of all species combined in Pond 10 generally exceeded 30% and frequently was greater than 50%. Thus the Project metric that there be approximately 50% vegetation cover by wetland vascular plants in at least 30 acres of Pond 10 by June 2016 appears to have been met. Furthermore, the objective that by the end of 2016 the project achieve approximately 89 acres of functional estuarine intertidal emergent wetlands, approximately 41 acres of estuarine intertidal non-vegetated wetlands, approximately 28 acres of estuarine subtidal wetlands appears to have been met. Development of salt marsh within Pond 11 strengthens this conclusion.

Estimated percent cover by cordgrass is illustrated in Figure 25. Cordgrass cover, where it occurred, ranged from < 1% to a maximum of 20% in Pond 10 and from < 1% to 5% in Pond 11. Thus, the Project objective that by the end of 2016, there be approximately 50 percent coverage of cordgrass in the restored ponds has not been met. In 2015, cordgrass decreased dramatically in density and percent cover in the randomized block experiment designed to compare survival and growth of cordgrass planted from nursery grown stock, transplanted as plugs and transplanted as bare roots. Declines in cordgrass were noted in other regional wetlands during this time period. This phenomenon is discussed in greater detail in section 3.1.6 below.

Maximum height of live cordgrass as measured in the monitoring polygons is presented in Figure 26. Cordgrass height exceeded 60 cm in height around the western, southern and eastern perimeter of Pond 10, albeit in low densities. There are no recorded cordgrass heights in excess of 60 cm in Pond 11. Thus, the objective that by the end of 2016, the project achieve 50 percent coverage of cordgrass, with at least 25 percent of the plants in excess of 60 centimeters (cm) in height, over approximately 30 acres within the tidally restored pond, has not been met. The objective that cordgrass achieve 50 percent coverage has not been met. The objective that at least 25 percent of all cordgrass exceed 60 cm in height over 30 acres has not been met.

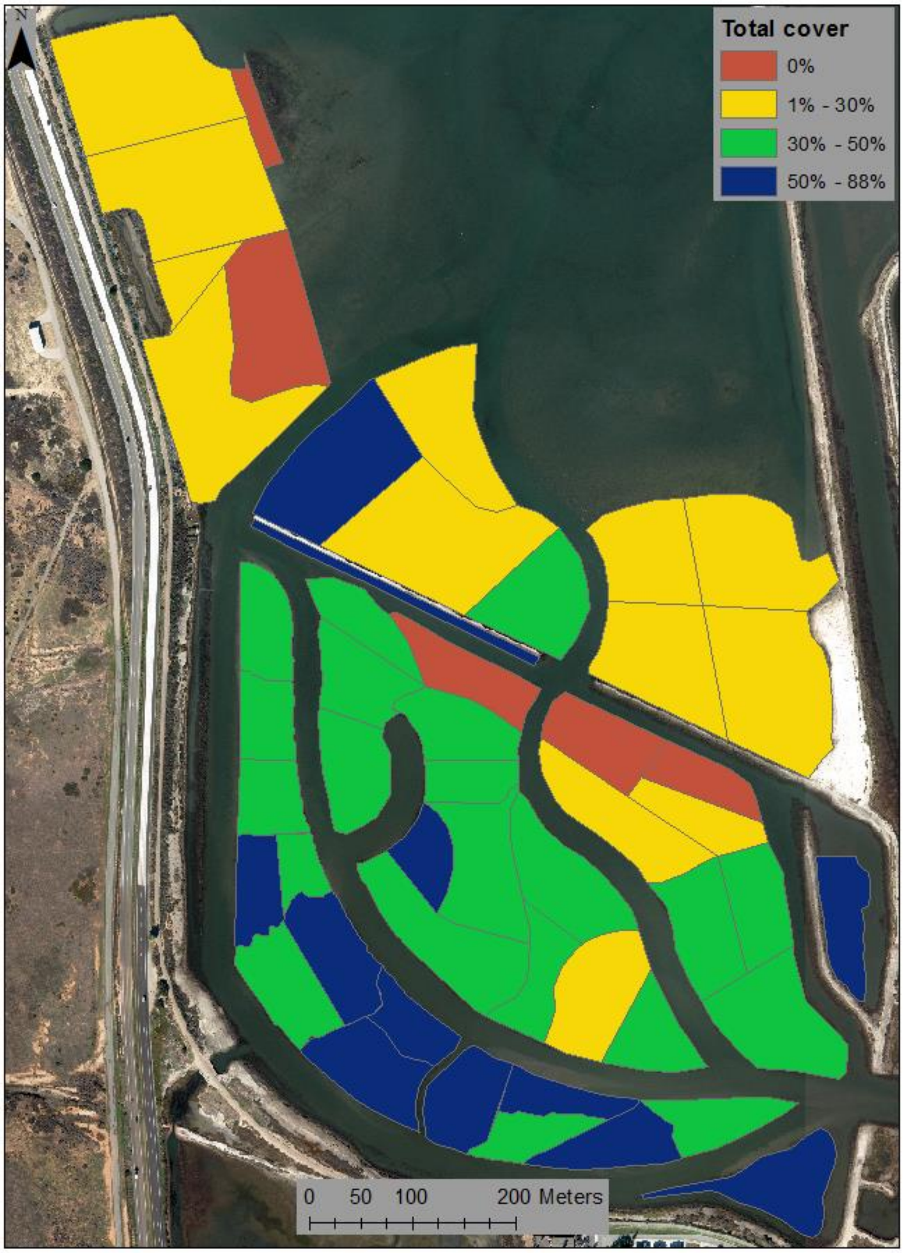


Figure 24. Estimated percent cover for all vascular plant species by polygon February 2016

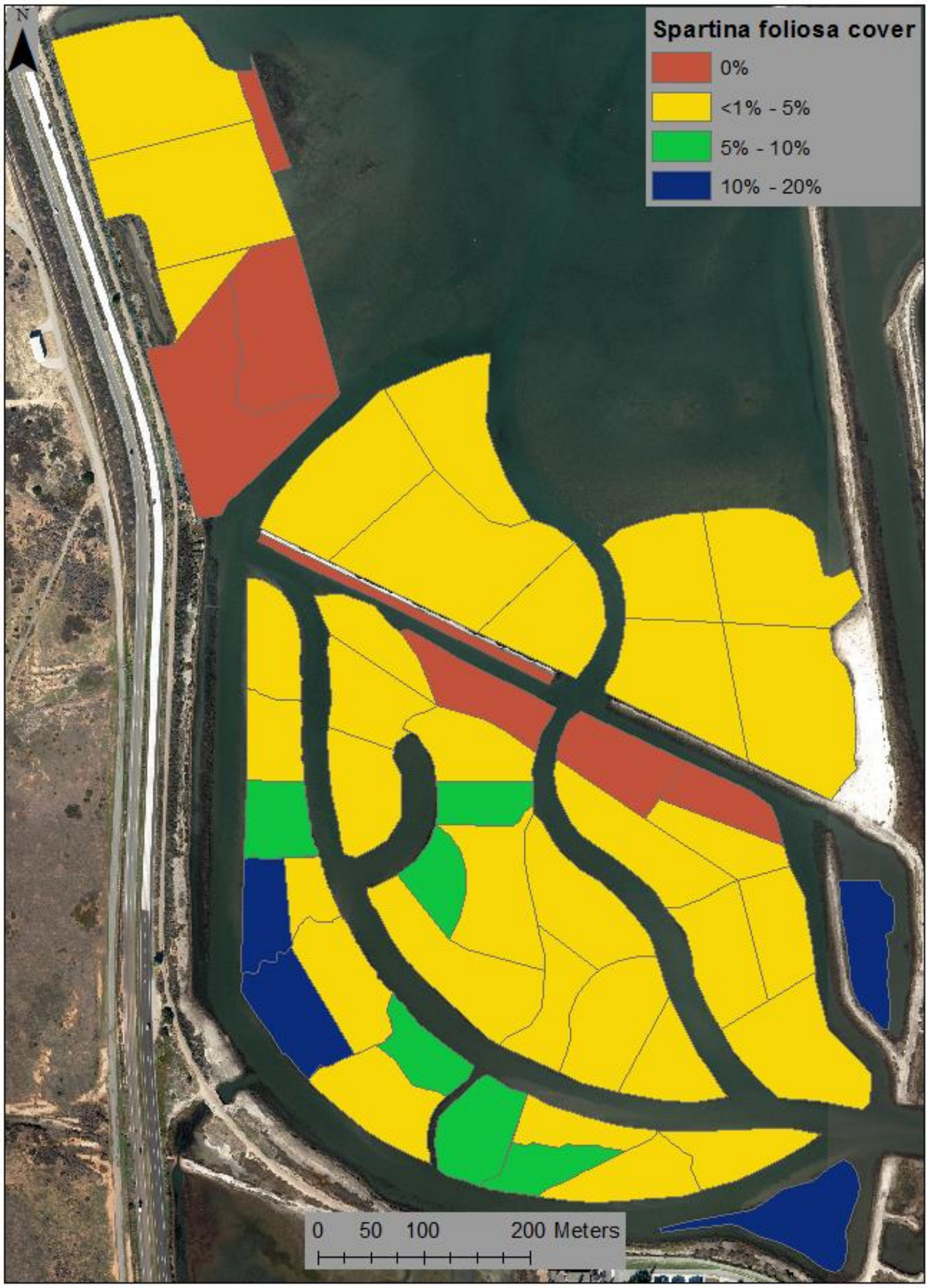


Figure 25. Estimated percent cover of cordgrass by polygon February 2016.

Figure 26. Maximum height of live cordgrass in all polygons February 2016.

3.1.6. Monitoring of Low Marsh Plantings in Pond 10

Low salt marsh elevations dominated by California cordgrass (*Spartina foliosa*) were planted in two phases. Phase I occurred between October 17 and October 21, 2011 during which 4,000 nursery grown cordgrass plants (2.25 x 3-inch rose pots) were planted on approximately 6-foot centers and arrays as illustrated in Figure 21 (Figure 2 of the as-built report; Merkel & Associates 2011). Each array was comprised of approximately 30 individual cordgrass plants and were planted at the appropriate elevations along the constructed channels and extended onto the marsh plain for a distance of approximately 20 feet.

Arrays were staggered along the channels approximately every 100 feet. In addition to the arrays, ten 60 ft by 60 ft randomized block study plots were planted with 100 cordgrass plants each on 6-ft centers (Figure 27). These study plots were expanded in Phase II as discussed below.

During Phase II, conducted between November 17 and December 3 2011, 35,700 individual cordgrass were planted. These consisted of additional nursery grown plants as well as plants harvested from a donor site immediately adjacent to Ponds 10 and 11 in the salt marsh of the Otay River. Of these 35,700 individuals 2,800 were nursery grown; 1,000 were harvested "plugs" of cordgrass and sediment defined as a small sod-like block about 6 inches deep and 4 – 6 inches in diameter containing substantial amounts of rhizomes and native soil that serves to buffer the plants during transplanting; and 31,900 plants were planted as "bare root planting units" defined as a ramet of 2 - 3 aerial stems of cordgrass with 2 – 6 inches of rhizome with a minimal amount of native soil attached to the rhizomes.

Phase II planting included expansion of the study blocks to include ten 60 by 60 ft randomized study plots with cordgrass plugs each planted with 100 cordgrass plants on 6-ft centers for a total of 1,000 plugs; ten 60 by 60 ft study plots planted with bare root cordgrass on 6-ft centers for a total of 1,000 bare root plants; ten 60 by 60 ft study plots planted with cordgrass grown from seed in the nursery on 6-ft centers for a total of 1,000 bare root plants; and ten unplanted control plots. Thus, each of the 10 study plots included equal size randomized blocks of the three propagation methods (nursery, plugs and bare roots) plus a control plot. The remaining 30,900 bare root plants were planted as shown in Figure 27. Those nursery plants not planted in study plots were planted in area K.

The project originally called for planting approximately 52 acres of low marsh habitat in Pond 10 with 56,874 nursery-grown cordgrass propagated from seed. This decision was based on the restoration team's desire to minimize impacts to existing cordgrass populations associated with the more standard practice of harvesting plugs of cordgrass and transplanting them to the restoration site. The low yield of plants propagated from seed required a change in the planting and also suggested the experimental planting blocks designed to test the effectiveness of each planting and transplantation method. The survival of planted individuals through Year 4 (2015) of the Project was monitored as described below. Future monitoring of cordgrass expansion and, potentially, recruitment into control plots, will be conducted using aerial photography.

3.1.7 Methods - Monitoring of Randomized Block Cordgrass Study Plots in Pond 10

Cordgrass canopy development within each treatment block was assessed on September 25, 2015 and consisted of estimating percent cover of live individuals within each block. Treatment blocks were accessed by kayak. The soil salinity of each block was measured by expressing a sample of soil at approximately 5 – 10 cm below surface through a syringe with filter paper onto a salinity refractometer.

3.1.8 Results – Monitoring of Randomized Cordgrass Study Plots in Pond 10

The results of the Year 4 (2015) survey are summarized in Table 5. Cordgrass total cover decreased dramatically in 2015. Mean percent cover of nursery-grown plants and transplanted plugs was 5.1% and 8.9%, respectively, compared to 25.1% and 25.8%, respectively in Year 3 (2014). Mean percent cover in Year 2 (2013) for nursery-grown plants and transplanted plugs was 13% and 12%, respectively in 2013. Mean percent cover of bare root plantings in Year 4 (2015) was 1.5% compared to an estimated mean percent cover of 5.3% in Year 3 (2014).

Table 5. Estimated Percent Cover of *Spartina foliosa* in Pond 10 September 25, 2015. Cover of *S. foliosa* and *Salicornia bigelovii* combined in parentheses.

Plot	Bare Root	Nursery Grown	Plugs	Control	Salinity
1	1% (20%)	3% (30%)	15% (40%)	<1% (20%)	40
2	1% (40%)	2% (35%)	5% (35%)	1% (30%)	46
3	1% (25%)	10% (35%)	20% (40%)	<1% (30%)	42
4	4% (25%)	5% (25%)	3% (25%)	1% (25%)	40
5	<1% (30%)	4% (25%)	5% (30%)	<1% (30%)	40
6	1% (45%)	5% (45%)	8% (40%)	1% (45%)	46
7	4% (40%)	5% (45%)	5% (30%)	1% (40%)	45
8	<1% (20%)	4% (20%)	15% (35%)	<1% (30%)	50
9	1% (10%)	12% (20%)	12% (30%)	2% (25%)	40
10	1% (25%)	1% (30%)	1% (12%)	2% (25%)	44
Mean	1.5% (28%)	5.1% (31%)	8.9% (31.7%)	<1% (29.5%)	43.3

* Estimated coverage values of <1% were assigned a value of 0.5% for determination of mean

Figure 27. As-built Salt Marsh Planting in Pond 10 (Figure 2 from As-built Report).

A decline in cordgrass populations was noted in other Southern California coastal wetlands in 2015. Notably, the distribution and abundance of cordgrass in Upper Newport Bay declined significantly during that time period raising concern over availability of nesting habitat for the light-footed Ridgway's rail (D. Zembal, Orange County Water District, pers. comm.). It has been postulated that this decline is the result of above normal high tides associated with warm water temperatures brought about by the El Niño conditions which persisted throughout 2015 and much of 2016. High tides in south San Diego Bay the during winter 2015-2016 were observed to be as much as 1 foot higher than predicted (C. Nordby, unpublished data from D Street Wetland Restoration Project). As the elevational range of cordgrass at the western salt ponds was determined to be between +2.2 and +4.6 ft NAVD 88, a considerable portion of its range would have been subjected to prolonged inundation, potentially resulting mortality between + 2.2 and +3.2 ft NAVD 88. Decline of cordgrass cover in the Western Salt Ponds could be attributed to this phenomenon.

Estimated cover of Bigelow's pickleweed also declined in Year 4 (2015) as demonstrated in Figure 28, although not as dramatically as cordgrass. Total estimated cover (cordgrass and pickleweed combined) peaked in 2014 and declined in 2015. While much of the difference in combined mean cover was attributable to cordgrass decline, not all of the decrease was the result of cordgrass decline. It is possible that this annual species also responded negatively to increased tide levels.

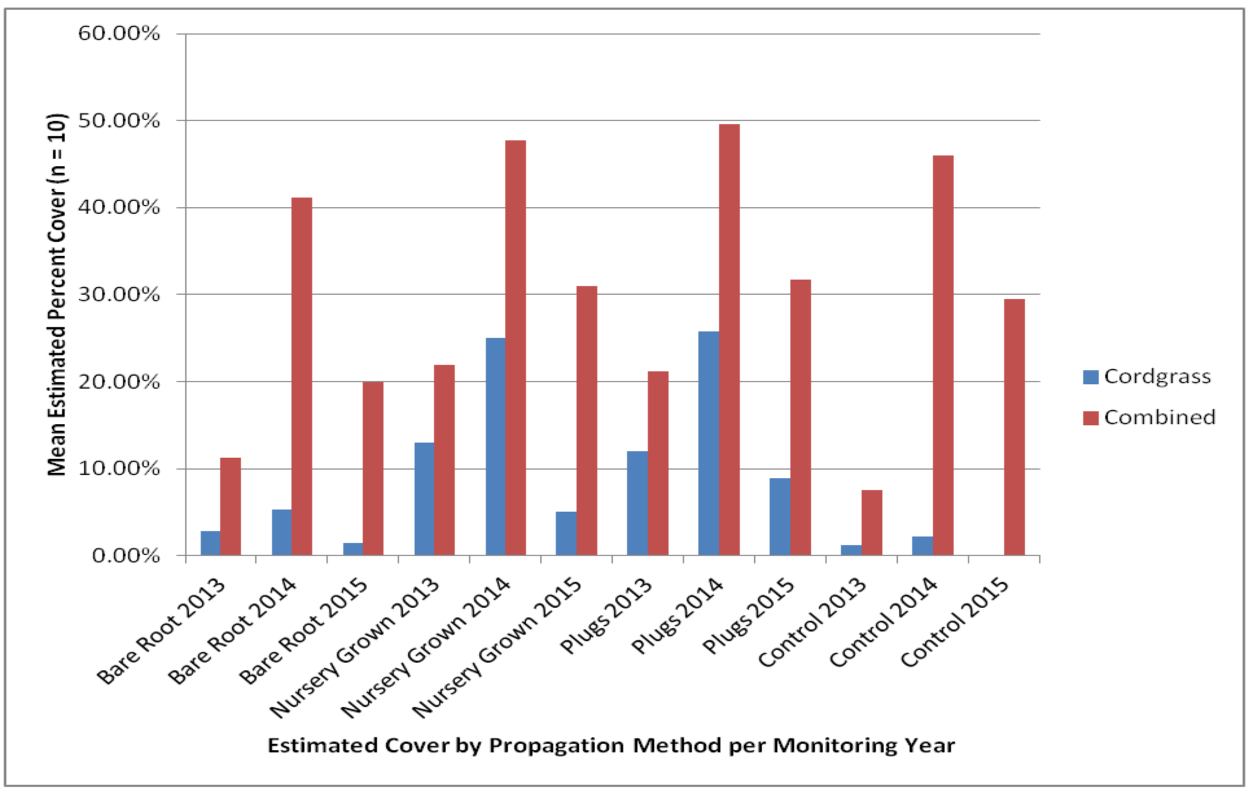


Figure 28. Mean Estimated Percent Cover of Cordgrass and Cordgrass and Bigelow's Pickleweed Combined at 10 Randomized Block Study Plots Year 2 (2103), Year 3 (2014) and Year 4 (205).

3.1.9 Monitoring of Vascular Plants in the Chula Vista Wildlife Reserve

The CVWR component of the Project restored 11 acres of salt marsh habitat and enhanced 32 acres of salt marsh through improved tidal influence at the site. The restored habitats included low, mid- and high salt marsh planted from existing marsh that was salvaged prior to construction impacts and supplemented with nursery grown plants. The enhanced habitats were expected to benefit from increased tidal circulation associated with a series of new tidal channels excavated in the existing marsh plain.

Nine species of salt marsh vascular plants were planted at the CVWR. These were salvaged from existing salt marsh on-site and supplemented with nursery stock as presented in Table 6. All species were replanted following completion of construction.

3.1.10 Methods – Monitoring of Vascular Plants in the Chula Vista Wildlife Reserve

The success of the salt marsh plantings at the CVWR was assessed at four monitoring stations: three restoration stations and one reference station (see Figure 22). At each station a baseline was established perpendicular to the tidal channel, extending from the low marsh up to the mid-marsh. Four 50-m transects were established perpendicular to the baseline. Two transects extended across low marsh plain and two across the mid-marsh plain. Point intercept data were recorded along each transect at 1-m intervals and data was presented as percent cover.

Table 6. Salt Marsh Plant Species Planted in the Chula Vista Wildlife Reserve

Habitat Zone	Species	Planting Unit	Count
Low Salt Marsh	*Batis maritima*	Plugs	181 Salvaged Plugs
	Salicornia pacifica	72” X 36” X 10” sods	129 Salvaged Sods
	Spartina foliosa	Bare Root Plugs	1,432 Bare Root Plugs
Mid Salt Marsh	*Batis maritima*	Plugs	96 Salvaged Plugs
	Frankenia salina	1-Gallon	214 Containers
	Spartina foliosa	Bare Root Plugs	190 Bare Roots Plugs
	Salicornia pacifica	72” X 36” X 10” sods	137 Salvaged Sods
	Suaeda taxifolia	1-Gallon	69 Containers
High Salt Marsh	*Distichlis spicata*	Plugs	74 Nursery Plugs
	Frankenia salina	1-Gallon	74 Containers
	Distichlise littoralis	Plugs	132 Salvaged Plugs
	Suaeda taxifolia	1-Gallon	47 Containers
	Salicornia subterminalis = Arthrocnemum subterminale	1-Gallon	81 Salvaged Containers
Total			2,856 Units

3.1.11 Results – Monitoring of Vascular in the Chula Vista Wildlife Reserve

Monitoring of planted salt marsh habitats in Year 1 using the point intercept method revealed that the planted area was largely bare, with an average of 4% cover (Merkel & Associates, May10, 2012). The dominant species was naturally recruited Bigelow’s pickleweed (2.3%) followed by

Pacific pickleweed (0.7%), naturally recruited sea-blight (0.3%) and shoregrass (0.2%). Additional species present included California cordgrass, saltwort and alkali heath – all of which were planted. Low percent cover is common following planting of wetland restoration sites and is not necessarily indicative of poor survival.

In Year 2 (2013), mean percent cover in the planted marsh was 25.5%. By comparison, mean percent cover in the reference marsh was 96.0% (SD = 3.2%) in Year 1 and 99.5 % (SD = 1) during Year 2. Like Pond 10 salt marsh habitat, planted species at the CVWR are expected to expand in cover in subsequent years.

During Year 2, the dominant species observed was Bigelow's pickleweed. Mean cover of this species at the three monitoring stations ranged from 5.5% to 34.0%. Pacific pickleweed mean cover ranged from 0.5% to 3.5%.

During Year 3 (2014), the dominant species observed continued to be Bigelow's pickleweed with mean cover of this species of approximately 34% and 32% in low and mid-marsh transects, respectively. Mean cover by Pacific pickleweed was 4.5% along all transects combined. Cordgrass comprised 2% cover along all transects combined. Algerian sea lavender (*Limonium ramosissimum*), which was first observed on the CVWR in 2009, has spread and may invade the restoration area. Currently, this invasive species occurs adjacent to the restoration site at CVWR.

In Year 4 (2015) the dominant species continued to be Bigelow's pickleweed with a mean cover of approximately 48% and 44% in low and mid-marsh, respectively. Mean cover by saltwort was approximately 9.7% along all transects combined and mean cover by Pacific pickleweed was approximately 8% along all transects combined. The authors noted that cordgrass was not as abundant as in the previous year, with a mean percent cover of 1.2%.

In summary, the objectives for salt marsh establishment at the CVWR by the end of 2016, including the achievement 50 percent coverage of cordgrass and pickleweed over the 3-acre excavation area and improvement of vigor and plant diversity throughout the remaining 16 acres of estuarine intertidal emergent wetlands within the basin appears to have been met. Although mean cordgrass cover remains quite low, the overall objective of 50% combined cover by cordgrass and pickleweed will likely be achieved. However, the metric that the salt marsh on the CVWR develop similarly to that at Tijuana Estuary has not been met and will not likely be met by 2016.

3.2 Fish Monitoring

The NOAA metric for fish at the western salt ponds was to demonstrate presence of one or more of the target taxa (flatfish and elasmobranchs) by 2013. At CVWR, the NOAA metric for fish was to demonstrate presence of one or more of the target taxa (gobiidae and topsmelt) by 2013. At both sites, NCWC objectives were to achieve successful recruitment of benthic invertebrates and fish within Pond 11 to support migratory shorebirds and foraging ground-nesting seabirds by 2013.

In Year 4 (2015), fish were monitored using a variety of sampling gear, including minnow traps, enclosure traps and otter trawls in the western salt ponds and minnow traps, enclosure traps and seines with blocking nets at the CVWR. The Project monitoring plan had specified the use of beach seines and blocking nets in the western salt ponds; however, the soft substrate in Ponds 10 and 11 precluded this method and the trawls, traps and enclosures were used exclusively in western salt ponds during Years 1 – 4 (2012 – 2015).

3.2.1 Methods - Fish and Invertebrates Collected Using Otter Trawls in the Western Salt Ponds

Otter trawls were conducted in Ponds 10 and 11 on August 10, 2015. The otter trawl was a 12-foot semi-balloon otter trawl with 1-inch mesh netting lined with 0.25-inch knotless mesh netting.

The trawls were towed behind a small, shallow-draft vessel at approximately 2.5 – 3.5 knots. All trawls were towed for approximately 100 meters once the net was on the bottom. All collected trawls were towed within a tide range of approximately +3.0 to +4.5-ft MLLW (+2.82 to +4.32-ft NAVD88). This tidal range allowed most trawls to be performed with mudflats visible to aid navigation. Weather conditions were good for the survey with clear skies, light winds and calm water.

A total of 9 otter trawls were collected (Figure 27). The otter trawls were designated as stations 15-23. Stations 1 – 12 were sampled with a beam trawl in 2012. That methodology was dropped for the current effort. All stations were performed as planned except for station 18 which was moved slightly relative to the 2012 sampling.

All captured fish were identified to species, weighed, and measured. Fish lengths were measured as total length. For stingrays, length measurements consisted of disc length. When more than 30 individuals of a given species were captured, the remaining individuals were counted and weighed. In the event that there were very high numbers of a species captured, 100 individuals were counted and weighed; the data allowed the remaining number of individuals to be estimated by weighing the remaining fish as a batch.

Figure 29	MTS Marine Taxonomic Services, Ltd.	**Otter Trawl Sampling Locations – Western Salt Ponds.**

In addition to the captured fish, data were collected for invertebrates and marine debris captured within each trawl. Marine debris was simply noted as present in the trawls. Marine debris generally consisted of pieces of drift or unattached algae and were not part of the investigation. Invertebrates were noted for presence.

3.2.2 Results – Monitoring of Fish and Invertebrates Using Otter Trawls in the Western Salt Ponds

Fish

A total of 232 individuals representing 8 species and 6 families were collected using otter trawls in 2015 (Table 7). In terms of relative abundance, otter trawls were dominated by juvenile slough anchovy (*Anchoa delicatissima*; 216) which combined comprised 93.1% of the catch. The majority of the slough anchovies measured approximately 3-7 cm and weighed approximately 0.1 to 2.0 gm. California bat rays (*Myliobatis californica*) dominated the otter trawls in terms of biomass. Surprisingly, no round stingrays (*Urobatis halleris*) were collected. This species dominated the catch in terms of biomass in all previous years. Photographs of representative fish species collected during the trawling effort are presented in Figure 30.

By comparison, otter trawls conducted in Year 3 (2014) captured a total of 888 individuals representing 11 species and 8 families. The trawls were dominated by juvenile slough anchovies (216; 93.1% of total catch). Otter trawls in Year 2 (2013) captured total of 1,915 individuals representing 11 species and 9 families. Trawls were dominated by juvenile slough anchovy (1,388) and juvenile deepbody anchovy (*Anchoa. compressa;* 454) which combined comprised 96.2% of the catch. In Year 1 (2012), trawls captured a total of 501 individuals representing 7 species and 7 families. The trawls were dominated by juvenile slough anchovy (267; 53.3%) and juvenile topsmelt (*Atherinops affinis*; 40; 42.3%). Round stingrays dominated the otter trawls in terms of biomass on all previous monitoring years.

The presence of round stingray, California halibut (*Paralichthys californicus*) and diamond turbot (*Hypsopsetta guttulata*) in the 2014 and 2015 surveys, as well as bat ray and gray smoothound in Year 2 (2013) meets the NOAA metric for fish (elasmobranchs and flatfishes). Recruitment of fish species that provide forage for ground nesting seabirds meets the NCWC Project objectives. Thus, the Project goals for fish in Ponds 10 and 11 are considered met.

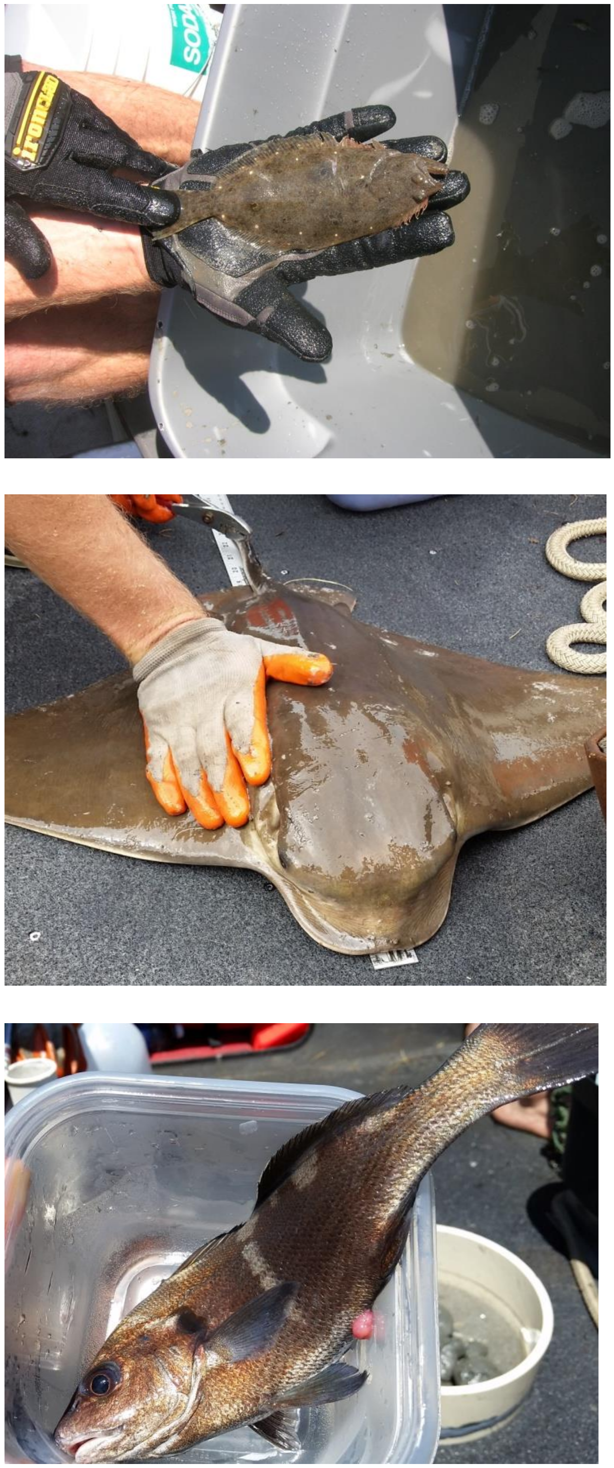


Figure 30. Photograph of Trawl Results 2014 [California halibut (top), bat ray (middle) and black croaker (bottom)]

Invertebrates and Marine Algae

Seven taxa of invertebrates were collected in the trawls, including brittle star, the invasive Asian mussel (*Musculista senhousia*) and the (tunicate *Styela plicata*; Table 8). One species of marine algae was also collected. The sessile invertebrate *Zoobotryon verticillatum* and marine algae gracillaria (*Gracilaria* sp.) were the most common.

Table 7. Fish Collected Using Otter Trawls Western Salt Ponds 2015.

Family	Species	Common Name	Total Collected	% of Total
Engraulidae	*Anchoa delicatissima*	slough anchovy	216	93.1%
	Anchoa compressa	deepbody anchovy	2	0.9%
Dasyatidae	*Myliobatis californica*	California bat ray	3	1.3%
Bothidae	*Paralichthys californicus*	California halibut	1	0.4%
Pleuronectidae	*Hypsopsetta guttulata*	diamond turbot	1	0.4%
Sciaenidae	*Cynoscion xanthulus*	orangemouth corvina	4	1.7%
	Cheilotrema saturnum	black croaker	2	0.9%
Atherinidae	*Atherinops affinis*	topsmelt	1	0.1%

Table 8. Invertebrates and Algae Collected Using Otter Trawls Western Salt Ponds 2015.

Taxonomic Name	Common Name	Type of Organisms
Zoobotryon verticillatum.	zoobotryon	Bryozoa
Gracillaria sp.	gracillaria	Algae
Musculista senhousia	Asian mussel	Bivalve mollusc
Styela plicata	rough tunicate	tunicate
Halichondria bowerbaanki)	yellow sponge	Porifera
Ophiuroidae	Brittle star	Echindoderm
Actiniaria sp.	Sea anemone	Actniidae

3.2.3 Methods - Fish and Invertebrates Collected Using Minnow Traps in the Western Salt Ponds

In order to provide a general characterization of fish populations in the salt ponds, minnow traps were deployed in Ponds 10A, 10, and 11 (Figure 31). The traps were deployed just offshore at low tide to a depth of complete submersion and left for 24 hours. Due to the traps resting on the substrate, the fish sampled were primarily limited to those that reside or feed in the benthic zone. The locations of trap deployment were based on the availability to safely walk without disturbing bird nesting areas along the levees and ease of accessing the site without significantly sinking in the mud. Due to the transport of fine sediment, resulting in local shoaling in the northwest corner of Pond 11 it was impossible, on foot, to deploy a minnow trap at site 9 and have it submerged during low tides. Site 9 was abandoned and moved to a location between sites 10 and 11.

Minnow traps were deployed on 6 occasions – once each in January, March, May, July, September and November, 2015. Sampling consisted of retrieving the traps at low tide, emptying the trap in a bucket of site water, measuring to the nearest millimeter the lengths of the first 20 fish of each species, and counting the remaining fish, grouped by species. Most of the species were identified in the field and the majority was released alive. Those species not identified in the field were brought back to the lab, identified, and released.

3.2.4 Results – Monitoring of Fish and Invertebrates Using Minnow Traps in the Western Salt Ponds

Throughout 2015, a total of 705 individual fish representing 3 species and 3 families were collected at the 11 sampling sites within the western salt ponds using minnow traps (Table 9). This is up significantly from last year's total of 130 individuals. Totals for 2013 and 2012 were 262 and 642 individuals, respectively. The dominant species collected in 2015 was California killifish (*Fundulus parvipinnis*) with 389 individuals representing 55% of the catch (50% last year). Longjaw mudsucker (*Gillichthys mirabilis*) was the second most abundant species with 137 individuals collected over the 6 monitoring dates (19%; 28% last year). Striped mullet (*Mugil cephalus*) was also abundant in minnow traps in Pond 10A in May, accounting for 25% of the total catch (178 individuals). One arrow goby (*Clevelandia ios*) was also caught.

The majority of all individuals, 99.7%, were collected from Pond 10A. Only 2 individuals were caught in Pond 11. No individuals were caught in Pond 10. This bias was likely caused by the location of the traps. The traps in Pond 10A were restricted to the narrow inlet in the northwest corner through which fish must traverse to enter the pond. Three of the 4 traps in Pond 10 were located in the farthest southeast corner of the pond and all of the Pond 11 traps were located along the northern most shore of the pond. Fish populations, particularly benthic fishes, are likely still adjusting to the sediment movement in both ponds. Populations are expected to increase as the sediment consolidates. Future monitoring will determine whether this hypothesis is valid.

Invertebrates collected using minnow traps in the western salt ponds included 4 species of decapod crustaceans (Table 9). Decapod crustaceans were dominated by yellow shore crab (*Hemigrapsus oregonenisis*) and striped shore crab (*Pachygrapsus crassipes*). Of the 35 individuals collected, approximately 63% were yellow shore crab and 29% were striped shore crab. The remainder consisted of 2 California green shrimp (*Hippolyte californiensis*) and 1 California pistol shrimp (*Alpheus californiensis*). The majority (97%) of invertebrates were collected in Ponds 10A and 10.

Figure 31. Minnow Trap Sampling Stations Western Salt Ponds.

3.2.5 Methods – Monitoring of Fish and Invertebrates Using Minnow Traps in the Chula Vista Wildlife Reserve

Minnow traps were deployed within the CVWR at sampling sites 2, 3, 4 and 6 (see Figure 10) on September 25, 2015. Like the traps set at the western salt ponds, traps were deployed in the channels at low tide to a depth of complete submersion and left for 24 hours.

3.2.6 Results – Monitoring of Fish and Invertebrates Using Minnow Traps in the Chula Vista Wildlife Reserve

A single individual was caught in the minnow traps at the CVWR in 2015, a barred pipefish (*Syngnathus auliscus*), compared to no fish being caught in 2014. In 2013, a total of 17 fish were captured with the California killifish representing 94% of the total catch.

3.2.7 Methods - Monitoring of Fish Using Enclosure Traps in the Western Salt Ponds and Chula Vista Wildlife Reserve

Following the sampling protocol of the San Onofre Nuclear Generating Station (S.O.N.G.S.) Wetland Mitigation Program, an enclosure trap (Figure 32) was employed to sample primarily gobies (family *Gobiidae*), small, burrowing fishes that are often poorly sampled by other methods. The enclosure trap is composed of a polypropylene sheet fixed as a 1m-tall cylinder with a $0.4m^2$ sampling area. The trap is thrown away from the sampler in an attempt to minimize the startling of any fish nearby. A BINCKE net is then swept inside the trap and fish were identified by species, counted, measured for length, and released. This was repeated until no fish were caught a total of 3 times. The trap was deployed at 6 sites in each of ponds 10A and 10 (see Figure 7) and at the 6 sampling sites at the CVWR (see Figure 9).

3.2.8 Results – Monitoring of Fish Using Enclosure Traps in the Western Salt Ponds and Chula Vista Wildlife Reserve

The results of enclosure trap sampling at the western salt ponds and the CVWR are presented in Table 10. Pond 10A had a total of 6 individual fish, with the California killifish and arrow goby representing 50%. Five invertebrate species were captured in the enclosure traps in Pond 10A, where California horn snail (*Cerithidea californica*) represented 87% of the 127 individuals. The California pistol shrimp, bent-nose clam (*Macoma nasuta*), California jackknife clam (*Tagelus californianus*) and Asian mussel (*Musculista senhousia)* were also present.

Only 2 arrow gobies were caught throughout Pond 10 and the Asian mussel was the only invertebrate sampled.

A total of 8 individual fish were collected from the 6 sampling sites located at the CVWR (5 arrow gobies, 1 shadow goby (*Quietula y-cauda*), and 2 California killifish). Nine invertebrate species, for a total of 35 individuals, were also captured (Table 10). The dominant species were the Asian mussel (40%) and the bent-nose clam (37%). A species of brittle star was captured in great numbers, but were not counted. The presence of brittle stars and polychaetes are noted in the table with an asterisk.

Table 9. Fish and Invertebrates Collected Using Minnow Traps Western Salt Ponds 2015.

Species		Minnow Traps																							
		Pond 10A																							
Scientific Name	Common Name	January				March				May				July				September				November			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Fundulus parvipinnis	California Killifish	2				3	4	1	1	42	93	61	11		2		14	9		6	3	3		2	131
Gillichthys mirabilis	Longjaw Mudsucker			3				1	1	18	12	11	24	2	7	3	6	10	1	13	7	9		4	5
Clevelandia ios	Arrow Goby																								
Mugil cephalus	Striped mullet									20	39	44	72				3								
Syngnathus auliscus	Barred Pipefish																								
Alpheus Californiensis	Californial Pistol Shrimp																								
Palaemon macrodactylos	Oriental Shrimp						2																		
Portunus xantusii	Xantus' Swimming Crab																								
Pachygrapsus crassipes	Striped Shore Crab	2		1		2																			
Hemigrapsus oregonensis	Yellow Shore Crab	1	2	1			3	2	6			1													
Total ***Fish*** Abundance per Site		2	0	3	0	3	4	2	2	80	144	116	107	2	9	3	23	19	1	19	10	12	0	6	136
Mean ***Fish*** Abundance per Site		1.3				2.8				111.8				9.3				12.3				38.5			
Mean ***Fish*** Abundance per Site per Pond, All Surveys		29.3																							
Fish Species Richness per Pond, All Surveys		3																							
Total ***Invertebrate*** Abundance per Site		3	2	2	0	2	5	2	6	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Mean ***Invertebrate*** Abundance per Site		1.8				3.8				0.3				0.0				0.0				0.0			
Mean ***Invertebrate*** Abundance per Site per Pond, All Surveys		1.0																							
Invertebrate Species Richness per Site per Pond, All Surveys		3																							

Species		Minnow Traps																							
		Pond 10																							
Scientific Name	Common Name	January				March				May				July				September				November			
		5	6	7	8	5	6	7	8	5	6	7	8	5	6	7	8	5	6	7	8	5	6	7	8
Fundulus parvipinnis	California Killifish																								
Gillichthys mirabilis	Longjaw Mudsucker																								
Clevelandia ios	Arrow Goby																								
Mugil cephalus	Striped mullet																								
Syngnathus auliscus	Barred Pipefish																								
Alpheus Californiensis	Californial Pistol Shrimp												1												
Palaemon macrodactylos	Oriental Shrimp																								
Portunus xantusii	Xantus' Swimming Crab																						1		
Pachygrapsus crassipes	Striped Shore Crab																								
Hemigrapsus oregonensis	Yellow Shore Crab																								
Total ***Fish*** Abundance per Site		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mean ***Fish*** Abundance per Site		0.0				0.0				0.0				0.0				0.0				0.0			
Mean ***Fish*** Abundance per Site per Pond, All Surveys		0.0																							
Fish Species Richness per Pond, All Surveys		0																							
Total ***Invertebrate*** Abundance per Site		0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0
Mean ***Invertebrate*** Abundance per Site		0.0				0.0				0.3				0.0				0.0				0.3			
Mean ***Invertebrate*** Abundance per Site per Pond, All Surveys		0.1																							
Invertebrate Species Richness per Site per Pond, All Surveys		2																							

Species		Minnow Traps																					
		Pond 11																		CVWR			
Scientific Name	Common Name	January			March			May			July			September			November			September			
		9	10	11	9	10	11	9	10	11	9	10	11	9	10	11	9	10	11	2	3	4	6
Fundulus parvipinnis	California Killifish																	1					
Gillichthys mirabilis	Longjaw Mudsucker																						
Clevelandia ios	Arrow Goby				1																		
Mugil cephalus	Striped mullet																						
Syngnathus auliscus	Barred Pipefish																			1			
Alpheus Californiensis	Californial Pistol Shrimp																						
Palaemon macrodactylos	Oriental Shrimp		1																				
Portunus xantusii	Xantus' Swimming Crab						1																
Pachygrapsus crassipes	Striped Shore Crab																						
Hemigrapsus oregonensis	Yellow Shore Crab																						
Total ***Fish*** Abundance per Site		0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
Mean ***Fish*** Abundance per Site		0.0			0.3			0.0			0.0			0.0			0.3			0.3			
Mean ***Fish*** Abundance per Site per Pond, All Surveys		0.1																					
Fish Species Richness per Pond, All Surveys		2																		1			
Total ***Invertebrate*** Abundance per Site		0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mean ***Invertebrate*** Abundance per Site		1			1			0			0			0			0			0			
Mean ***Invertebrate*** Abundance per Site per Pond, All Surveys		0.1																					
Invertebrate Species Richness per Site per Pond, All Surveys		2																		0			

Figure 32. Enclosure Trap

Table 10. Fish and Invertebrates Collected Using Enclosure Traps Western Salt Ponds and Chula Vista Wildlife Reserve 2015

Species		Enclosure Traps																	
Scientific Name	Common Name	Pond 10A						Pond 10						Chula Vista Wildlife Reserve					
		1	2	3	4	5	6	1	4	5	7	8	9	1	2	3	4	5	6
Clevelandia ios	Arrow Goby		1	2						1		1				1		4	
Quietula y-cauda	Shadow Goby															1			
Fundulus parvipinnis	California Killifish					1	2								2				
Alpheus californiensis	Pistol Shrimp	2																1	
Hippolyte californensis	California Green Shrimp																	1	
Cerithidea californica	California Horn Snail				1	28	81												
Chione californiensis	California Venus														4				
Macoma nasuta	Bent-nosed Clam	7	2											3	2			8	
Macoma secta	Sand Clam																	1	
Protothaca staminea	Pacific Littleneck Clam														1				
Tagelus californianus	California Jackknife Clam	1	4																
Musculista senhousia	Asian Mussel	1						1	2	2		3		12	1	1			
Ophiuroidea	Brittle Star													*					
Polychaete		*	*															*	
	Total ***Fish*** Abundance per Site	0	1	2	0	1	2	0	0	1	0	1	0	0	2	2	0	4	0
	Mean ***Fish*** Abundance per Site	1.0						0.3						1.3					
	Fish Density per Pond (#/m^2)	2.5						0.8						3.3					
	Fish Species Richness per Pond	2						1						3					
	Total ***Invertebrate*** Abundance per Site	11	6	0	1	28	81	1	2	2	0	3	0	15	8	1	0	11	0
	Mean ***Invertebrate*** Abundance per Site	21.2						1.3						5.8					
	Invertebrate Density per Pond (#/m^2)	52.9						3.3						14.6					
	Invertebrate Species Richness per Pond	6						1						9					

A total of 25 individual fish were collected from the 6 sampling sites located at the CVWR in 2014, down from 79 the previous year. The arrow goby was the dominant species collected at 23 individuals, comprising 92% of the catch. Thus, the number of fish collected at the CVWR using minnow traps has decreased over the last three years of sampling.

3.2.9 Methods - Monitoring of Fish Using Seines in the Chula Vista Wildlife Reserve

Due to the lack of great success catching fish with either minnow traps or enclosure traps, it was deemed suitable to seine at two locations at the CVWR. Following the protocols of the monitoring plan of the S.O.N.G.S. Wetland Mitigation Program, a small purse seine (6 m wide) and blocking nets were used to help better characterize the fish populations there. Blocking nets were spaced approximately 5 meters apart. The seine was hauled 5 times before closing and retrieving the blocking nets, for a total of 7 hauls. After each haul, organisms were retrieved from the nets, placed in buckets, identified, measured (first 30 of each species), counted, and released.

3.2.10 Results - Monitoring of Fish Using Seines in the Chula Vista Wildlife Reserve

Two sites were sampled at the CVWR using seines with blocking nets. At site 1, an approximately $35m^2$ area was sampled while at site 2 an approximately $22.5m^2$ area was sampled. The results are presented in Table 11. A total of 292 individuals were collected, averaging 5.1 individuals/m^2. California killifish were the most abundant comprising 57% of the catch, followed by arrow goby (26%) and topsmelt (*Atherinops affinis*; 9%). Three species of benthic invertebrates were collected including 2 species of shrimp and 1 species of crab.

In 2014, a total of 253 individuals were collected, averaging approximately 4 individuals/m^2. Arrow goby were the most abundant comprising 63% of the catch, followed by topsmelt (17%) and California killifish (12.6%). Four species of benthic invertebrates were collected including 3 species of shrimp and 1 species of crab.

The presence of gobies and topsmelt found in enclosure traps and purse seines at the CVWR meets the NOAA metric for target taxa (gobies and topsmelt). In addition, the recruitment of fish in the restored site demonstrates the NCWC objective for support of foraging shorebirds and ground-nesting birds.

3.3 Benthic Macroinvertebrates

NCWC grant objectives for both the CVWR and western ponds included: by March 2013, achieve successful recruitment of benthic invertebrates and fish to support migratory shorebirds and foraging ground-nesting seabirds. In order to demonstrate such a trend, benthic macroinvertebrate infauna and epifauna were monitored using the methods described below.

3.3.1 Methods – Monitoring of Benthic Macroinvertebrates in the Western Salt Ponds

Two sets of cores were collected to characterize the infaunal invertebrate assemblage at the western salt ponds. These included large cores for taxa such as bivalves and large crustaceans, and small cores for smaller macrofuana. The large cores were 10 cm in diameter and were expressed into the sediment to a depth of 50 cm. The cores were then sieved through a 3-mm

Table 11.Fish and Invertebrates Collected Using a Purse Seine and Blocking Nets at the Chula Vista Wildlife Reserve 2015

Species		Seines	
		CVWR	
Scientific Name	Common Name	1	2
Atherinops affinis	Topsmelt	16	10
Clevelandia ios	Arrow Goby	71	6
Quietula y-cauda	Shadow Goby	9	
Fundulus parvipinnis	California Killifish	104	63
Anchoa compressa	Deepbody Anchovy		
Gillichthys mirabilis	Longjaw Mudsucker	2	5
Hypsopsetta guttulata	Diamond Turbot	1	
Mugil cephalus	Striped Mullet		1
Syngnathus auliscus	Barred Pipefish	3	1
Syngnathus leptorhynchus	Bay Pipefish		
Urobatis halleris	Round Stingray		
Gymnura marmorata	California Butterfly Ray		
Alpheus californiensis	Pistol Shrimp	2	
Hippolyte californensis	California Green Shrimp		
Palaemon macrodactylus	Oriental Shrimp		1
Hemigrapsus oregonensis	Yellow Shore Crab		1
Lophopanopeus bellus	Black-clawed Crab		
	Total ***Fish*** Abundance per Site	206	86
	Fish Species Richness	7	6
	Fish Density per Site (#/m^2)	9.2	4.3
	Overall ***Fish*** Abundance	292	
	Overall ***Fish*** Species Richness	8	
	Overall ***Fish*** Density (#/m^2)	6.9	
	Total ***Invertebrate*** Abundance per Site	2	2
	Invertebrate Species Richness	1	2
	Invertebrate Density per Site (#/m^2)	0.1	0.1
	Overall ***Invertebrate*** Abundance	4	
	Overall ***Invertebrate*** Species Richness	3	
	Overall ***Invertebrate*** Density (#/m^2)	0.1	

screen in the field with organisms identified, counted and released. Six channel-bottom sites were sampled in each pond using the large cores, and an additional 6 tidal flat sites (i.e. on the flat adjacent to the channel site) were sampled in Pond 11 (see Figure 9).

For the large infauna, two large cores were taken at each sampling site in 2012. Because very few invertebrates were sampled that year, it was decided to increase the number of cores taken per site. In 2013 - 2015, a total of 9 cores were taken at each site, 3 in the middle of the channel and 3 near the edges on either side of the channel.

The cores for the smaller infaunal invertebrates were collected at each site using a small push core (6 cm long, 4.8 cm diameter). The cores were preserved in the field in 8% buffered formalin and Rose Bengal and processed in that laboratory at California State University, Long Beach (CSULB). In the laboratory, the cores were sieved through a 300 micron mesh, identified, counted and preserved in 70% ethanol. All individuals in each replicate sample were sorted to the lowest practical taxonomic level. Sampling methodologies are the same used in the Huntington Beach

Wetlands Restoration Project Monitoring Program, allowing for comparison across these two restoration efforts.

Sampling station locations for collection of smaller cores are illustrated in Figure 33. In fall 2011 (preconstruction), sampling was not completely replicated with six total samples collected, two each in Pond 10 subtidal, Pond 10 intertidal and Pond 11 panne (marsh plain). Cores were only 2 cm in depth. These were used as baseline comparisons with future years.

In fall 2012 (Year 1), 6 samples were collected at each of four sampling stations: Pond 10A subtidal; Pond 10 subtidal; Pond 11 subtidal and Pond 11 intertidal (mudflat). Cores included 0-6 cm depths, but only 0-2 cm depths were reported for comparison with preconstruction results. In spring 2013, fall 2014 and spring and fall 2015 the 2012 methodology was replicated, with the exception that the entire 0-6 cm depths were reported in 2015.

3.3.2 Results – Monitoring of Benthic Macroinvertebrates in the Western Salt Ponds

Large Cores. The results of infaunal monitoring at the western salt ponds are presented in Table 12. Pond 10A had a total of 75 individual invertebrates, with the majority (87%) of them being the California horn snail (*Cerithidea californica*). A total of 17 individuals were sampled in Pond 10, with the majority being the California horn snail (59%) and the California jackknife clam (*Tagelus californianus*, 35%). Pond 11 had a total of 14 individuals with the majority being the Asian mussel (*Musculista senhousia*; 82%). Mean densities were calculated excluding the California horn snail, as they are not an infaunal species. Mean densities per site for Ponds 10A, 10, and 11 were 23.6, 18.9, and 75.5 individuals/m^2, respectively. The presence of polychaetes and anemones were documented and are noted in the table with an asterisk.

3.3.3 Methods – Monitoring of Benthic Macroinvertebrates in the Chula Vista Wildlife Reserve

At the CVWR, 9 large cores (50 cm long, 10 cm diameter) were taken at the 6 sampling stations (see Figure 9) with the same protocol as the Western Salt Ponds. Smaller cores were not collected at the CVWR.

3.3.4 Results – Monitoring of Benthic Macroinvertebrates in the Chula Vista Wildlife Reserve

The results of infaunal monitoring at the CVWR are presented in Table 13. A total of 105 (75 in 2014) individuals, representing 5 species of invertebrates (8 in 2014), were sampled in the cores. California horn snail was the numerical dominant at 81% (67% in 2014), with the California jackknife clam the second most abundant at 7% (12% in 2014). Mean density per site was approximately 63.7 individuals/m^2 (177 individuals/m^2 in 2014). Note, mean densities were calculated excluding the California horn snail, as they are not an infaunal species.

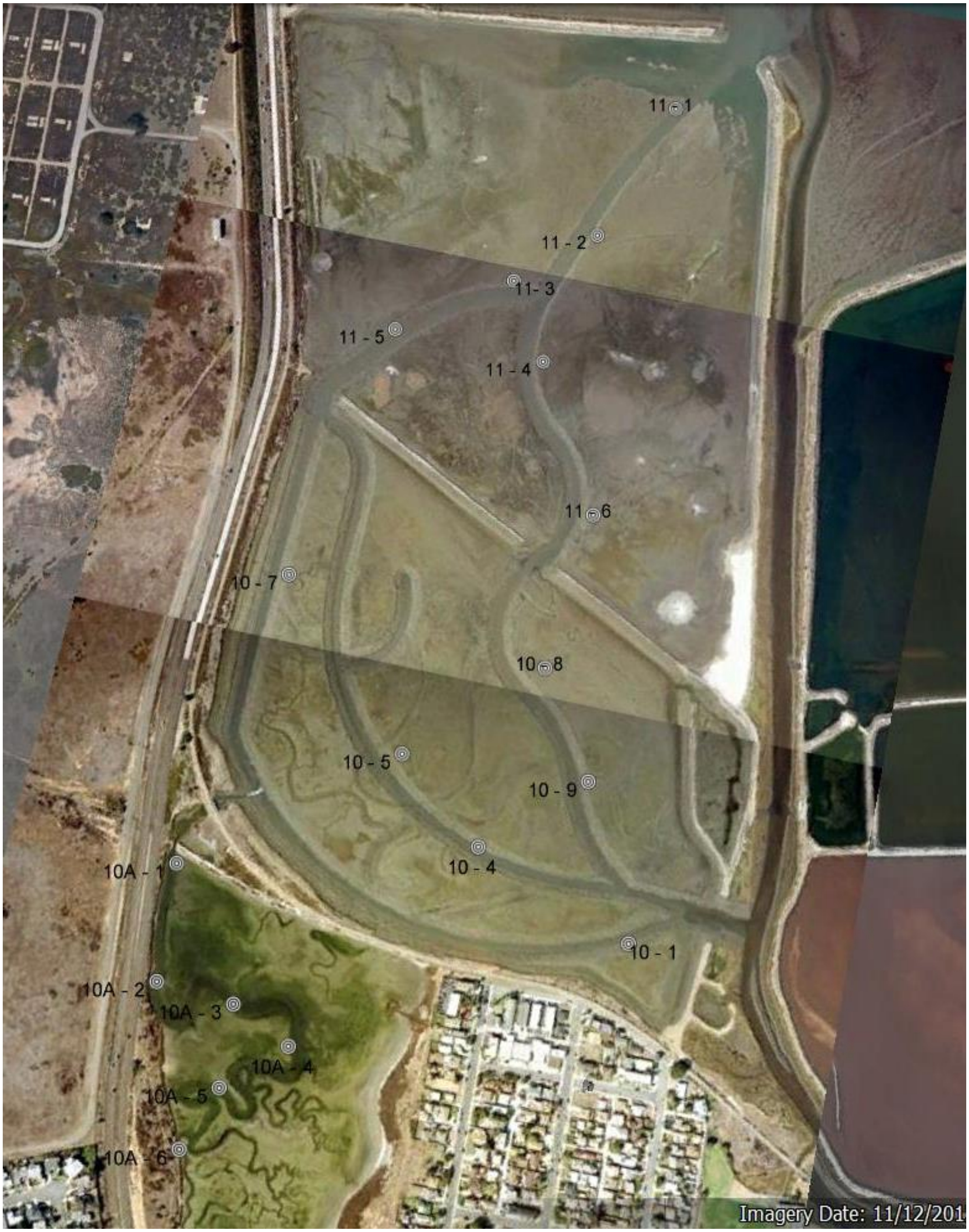


Figure 33. Locations of Sampling Stations – Small Cores.

Table 12. Infauna and Epifauna Collected at the Western Salt Ponds 2015.

Species		Pond 10A						Pond 10						Pond 11					
Scientific Name	Common Name	1	2	3	4	5	6	1	4	5	7	8	9	1	2	3	4	5	6
		Macroscopic Infauna - 10 cm Core* (# in all 9 cores)																	
Cerithidea californica	California Horn Snail		4	4	18	17	22		1	9									
Protothaca staminea	Pacific littleneck clam																		
Tagelus californianus	California jackknife clam	1	1					2					4				2		1
Bulla bouldiana	California Bubble snail																		
Macoma nasuta	Bent-nose macoma																		
Macoma secta																			
Mytilus galloprovincialis	Mediterranean mussel																		
Musculista senhousia	Asian Mussel	1	7											4	6	8			
Alpheus californianus	Pistol Shrimp																	1	
Neotrypaea californiensis	Bay Ghost Shrimp							1											
Hemigrapsus oregonensis	Yellow Shore Crab																		
Anemone			*																
Polychaete sp.			*										1	4	4	2			
Density per Site (#/m^2)		28	113	0	0	0	0	42	0	0	0	0	71	113	141	141	28	14	14
Mean Density per Site (#/m^2)		23.6						18.9						75.5					
Species Richness per Pond		5						4						4					
		Epifauna - Two .25m x .25m Quadrats† (# in both quadrats)																	
Cerithidea californica	California Horn Snail	53	58	63	70	48	139	127	60	79	155	10	90	0	0	0	0	111	5
Density per Site (#/m^2)		424	464	504	560	384	1112	1016	480	632	1240	80	720	0	0	0	0	888	40
Mean Density per Site (#/m^2)		574.7						694.7						154.7					
*core volume = 3.927dm^3	†quadrat area = .0625m^2	*core area = 0.00785m^2																	

Small Cores. In 2015, invertebrates collected using small cores were dominated by polychaetes with crustaceans, oligochaetes and insects also common (Figures 34 and 35). Although the invertebrate community in the western salt ponds has demonstrated substantial variability, these taxa were important components in previous years. Density, expressed as number or organisms per unit area, has gradually increased through time with the highest densities occurring in fall 2014and fall 2015 (Figure 36). Species richness has also increased through time with the highest species richness in fall 2015, especially in Pond 15 (Figure 37). Community composition has evolved relative to pre-construction and the current community is significantly different than that in 2011.

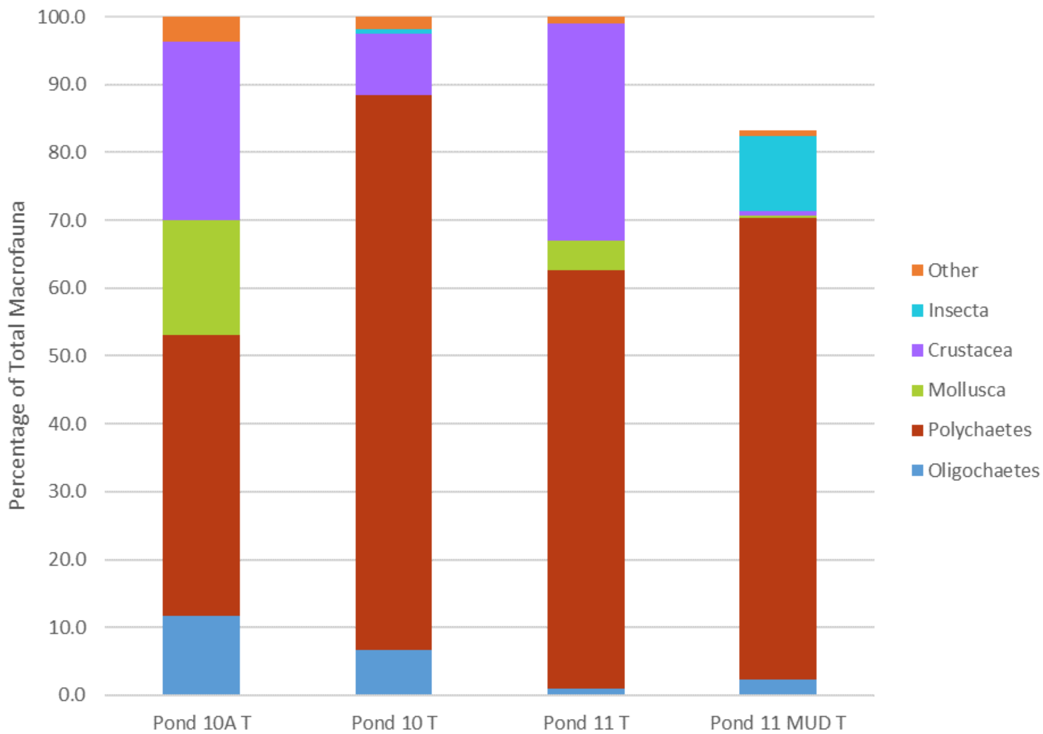


Figure 34. Relative Abundance of Macrofaunal Taxa Collected Using Small Cores – Spring 2015 Postconstruction

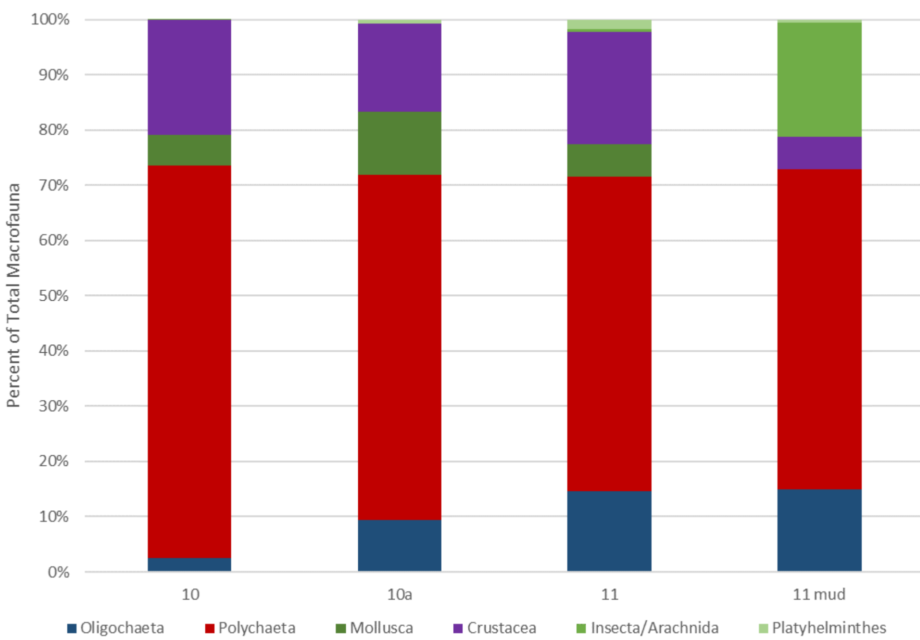


Figure 35. Relative Abundance of Macrofaunal Taxa Collected Using Small Cores – Fall 2015 Postconstruction

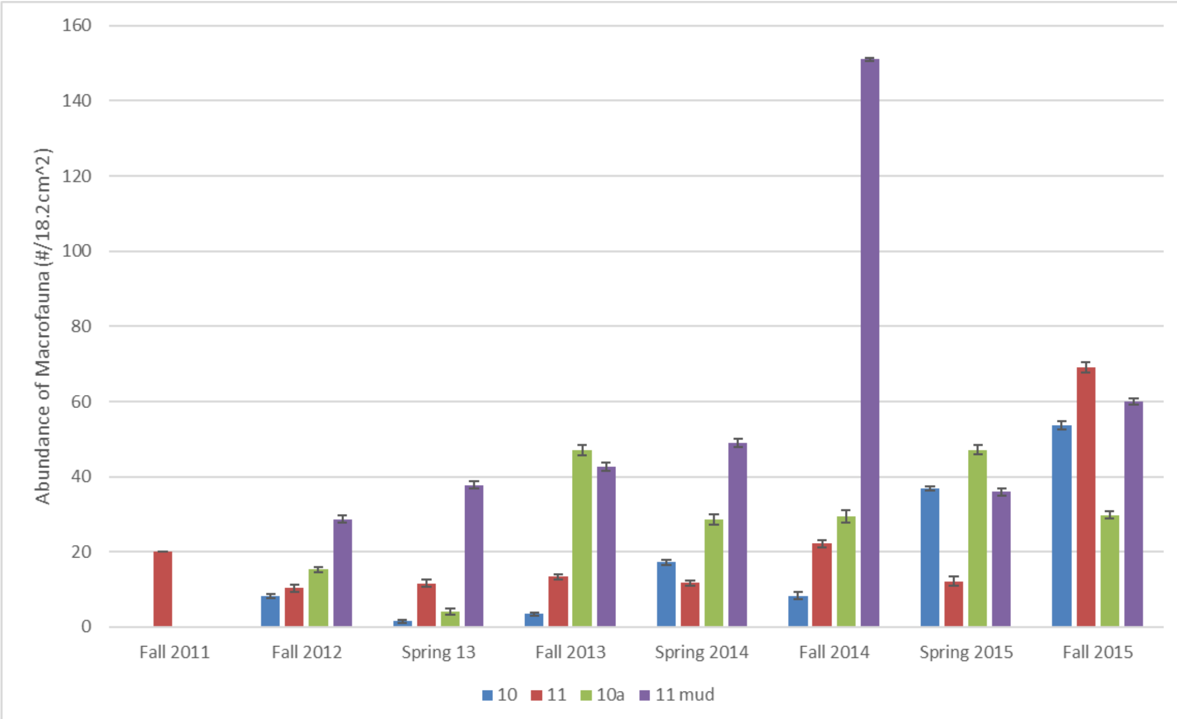


Figure 36. Density of Macrofaunal Taxa Collected Using Small Cores. Fall 2011 (Preconstruction) Through Fall 2015.

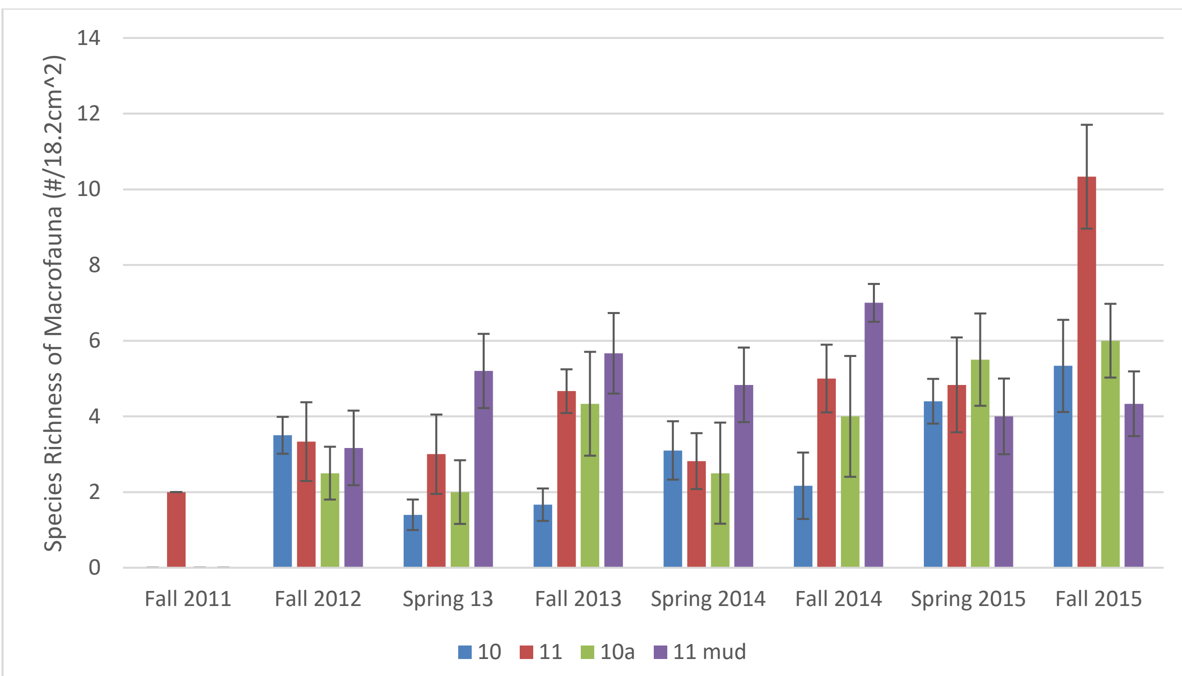


Figure 37. Species Richness of Macrofaunal Taxa Collected Using Small Cores. Fall 2011(Preconstruction) Through Fall 2015

3.3.5 Methods – Monitoring of Epifauna in the Western Salt Ponds and Chula Vista Wildlife Reserve

At each sampling site (6 sites in each salt pond and 6 sites at the CVWR), a .25 m x .25 m quadrat was used to sample epifauna assemblages. The quadrat was thrown near the channel's edge and those species found alive were counted. The quadrat was then flipped along one of its edges and the sampling was repeated.

3.3.6 Results – Monitoring of Epifauna in the Western Salt Ponds and Chula Vista Wildlife Reserve

California horn snails were the only epifaunal species encountered at both the western salt ponds and CVWR (Tables 12 and 13). At the western salt ponds, mean densities per site were again highest in Pond 10 at 695 individuals/m^2, up from 111 individuals/m^2 in 2012. Densities in Pond 10A and Pond 11 were 575 and 155 individuals/m^2, respectively. Mean horn snail density per site at the CVWR was 441 individuals/m^2, up from 72 individuals/m^2 in 2012 (Table 13).

Table 13. Infauna and Epifauna Collected at the Chula Vista Wildlife Reserve 2015.

Species		Chula Vista Wildlife Reserve					
Scientific Name	Common Name	1	2	3	4	5	6
		Macroscopic Infauna					
Cerithidea californica	California Horn Snail	2	1				82
Protothaca staminea	Pacific littleneck clam						
Tagelus californianus	California jackknife clam	2		1	3		1
Bulla bouldiana	California Bubble snail						
Macoma nasuta	Bent-nose macoma	1		2	1		
Macoma secta					5		
Mytilus galloprovincialis	Mediterranean mussel						
Musculista senhousia	Asian Mussel		3		1		
Alpheus californianus	Pistol Shrimp						
Neotrypaea californiensis	Bay Ghost Shrimp						
Hemigrapsus oregonensis	Yellow Shore Crab						
Anemone			2				
Polychaete sp.		1	1		3		
	Density per Site (#/m^2)	57	85	42	184	0	14
	Mean Density per Site (#/m^2)	63.7					
	Species Richness at CVWR	7					
		Epifauna					
Cerithidea californica	California Horn Snail	45	55	46	6	112	67
	Density per Site (#/m^2)	360	440	368	48	896	536
	Mean Density per Site (#/m^2)	441.3					
*core volume = 3.927dm^3	†quadrat area = .0625m^2	*core area = 0.00785m^2					

3.4 Food Web Analyses Through the Use of Stable Isotopes

Although not a specific restoration goal of the grants supporting the restoration of the western salt ponds, the analysis of food web development of the ponds was included as a means of measuring the evolution of this aspect of the project. Analysis of stable isotopes of elements such as Carbon and Nitrogen in plant and animal tissues allow for assessment of food web patterns, under the principle "you are what you eat." Primary producers have differing isotopic signatures based on their respective photosynthetic pathways, and consumers will have isotopic signatures that relate in a predictable way to their food sources. Stable isotopic analyses were used to assess (a) whether signatures of the primary producers and consumers change with time and restoration state, and (b) whether consumer species rely on different food sources in different restoration states.

3.4.1. Methods – Stable Isotope Analysis – Western Salt Ponds

Sampling methodologies are the same used in the Huntington Beach Wetlands Restoration Project Monitoring Program (Whitcraft et al. 2013), allowing for comparison across these two restoration efforts. Samples of sediment organic matter, microalgae, macroalgae, and macrofauna were collected at each sampling time point in each pond (with the exception of pond 10a in Fall 2011) using collection methods described above and were analyzed for d13C and d15N signatures. Microalgae were collected using density centrifugation with ludox (colloidal silica), providing a pure algal sample (devoid of sediment). Macrofaunal invertebrates were sieved on a 0.3 mm mesh, sorted live, and identified to species. All animals were kept alive in seawater and allowed to evacuate guts for up to 24 hrs. Animal material was washed in Milli-Q water (Millipore, Billerica, Massachusetts, USA) and frozen in combusted vials (500°C for 4 h) or tin boats until analysis. Larger organisms were removed from the shell or carapace, dried at 658C, and then ground with a mortar and pestle. Isotopic composition of animal and algal samples was analyzed using a PDZ Europa 20-20 mass spectrometer connected to an elemental analyzer (PDZ Europa ANCA-GS, Northwich, UK) at UC Davis Stable Isotope Facility. Stable isotope abundance is expressed in parts per thousand in a ratio of heavy to light isotope content (15N:14N or 13C:12C). Working standards, sucrose and ammonium sulfate, were d13C¼23.83ø vs. Vienna Pee Dee Belemnite Standard or d 15N ¼þ1.33ø vs. air N2.

Data for the Stable Isotope Analysis (SIA) are still being gathered and processed, but initial patterns are discussed below. Samples of fish tissue and gut contents, benthic invertebrates, sediment, microalgae, macroalgae, and plants from throughout the wetland system continue to be collected for further analysis. These are being processed at California State University, Long Beach and sent to UC Davis for analyses.

3.4.2 Results -Stable Isotope Analysis – Western Salt Ponds

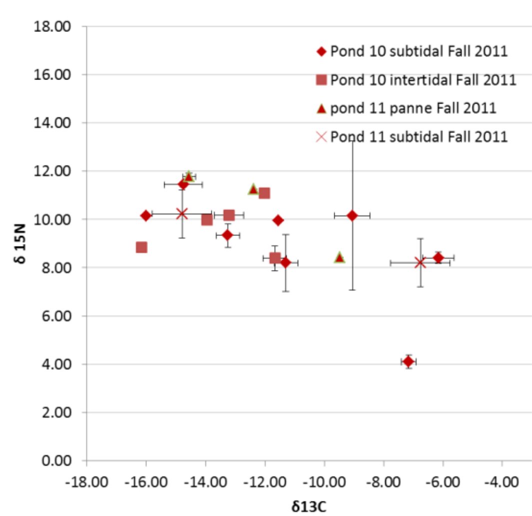
There were no stable isotope analyses data available for this report. The following discussion is repeated verbatim from the Year 3 (2014) monitoring report.

Stable isotope analysis was utilized to characterize the functional restoration metric of trophic structure. Potential food sources and thus consumers can be differentiated from one another using stable isotope ratios among the ponds. To date, monitoring of the western salt ponds demonstrates that initial fish signatures (and aggregated food source signatures) were different among marshes both pre-restoration (2011) and three years post-restoration (2014). Two important factors drive this pattern; first, actual abundances of invertebrates and community composition differ between the ponds and two the actual isotopic signatures of invertebrate species differ between ponds due to different physical and biological conditions. These conditions will be explored in future analyses through correlations with plant cover and water quality parameters. It is hypothesized that as invertebrate and plant communities continue to develop within the restored ponds, there will be a convergence of the stable isotope signatures of both consumers (fish) and food sources.

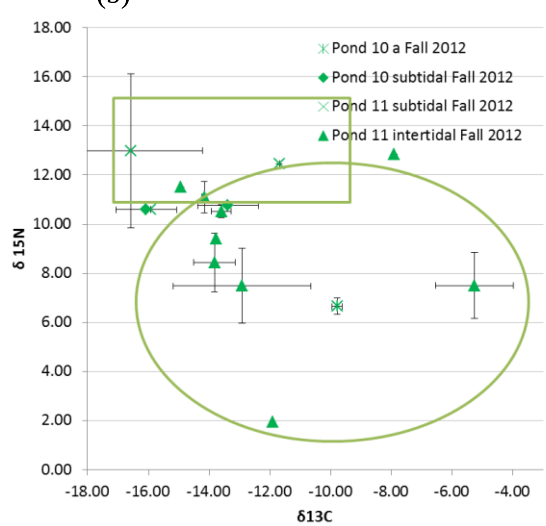
At each sampling period (fall 2011 – present), samples of fish tissue, benthic invertebrates, sediment, microalgae, macroalgae, and plants were collected from each pond (10a, 10, 11). Currently, all samples have been processed isotopic analysis run for fall 2011, fall 2012, fall 2013 and spring 2014. Samples from fall 2014 and spring 2015 are currently being processed at UC Davis Stable Isotope Facility.

Initially, in fall 2011 (pre-restoration), there were no differences between Ponds 10 and 11 Pond 10a was not sampled in fall 2011. In fall 2012, isotope signatures were distinct between Ponds 10 and 11 and Pond 10a (Figure 34). Again, in fall 2013, isotope signatures were distinct between Ponds 10 and 11 and Pond 10a (Figure 38). In spring 2014, the overall isotopic signature, representative of trophic structure, of the restored ponds (10, 11) differs from the reference pond, 10a. Through all sampling time points, Ponds 10 and 11 have significantly more variability in signatures than in Pond 10a. Across all seasons, Pond 10a had lower δC13 than Pond 11 (with Pond 10 intermediate) and lower δ N15 than Ponds 10 & 11. Temporally, all ponds differ with time as spring 2014 is significantly different than fall 2012. The overall food web structure (Figure 34) is significantly different among all 3 ponds due to altered community composition among ponds and due to differences in actual signatures of the same organisms. However, as the ponds are now experiencing more similar physical conditions, the trajectories appear to be following similar shapes and directions (Figure 39). A more detailed analysis, including a mixing model, with species-level groupings needs to be conducted.

(a)



(b)



(c)

(d)

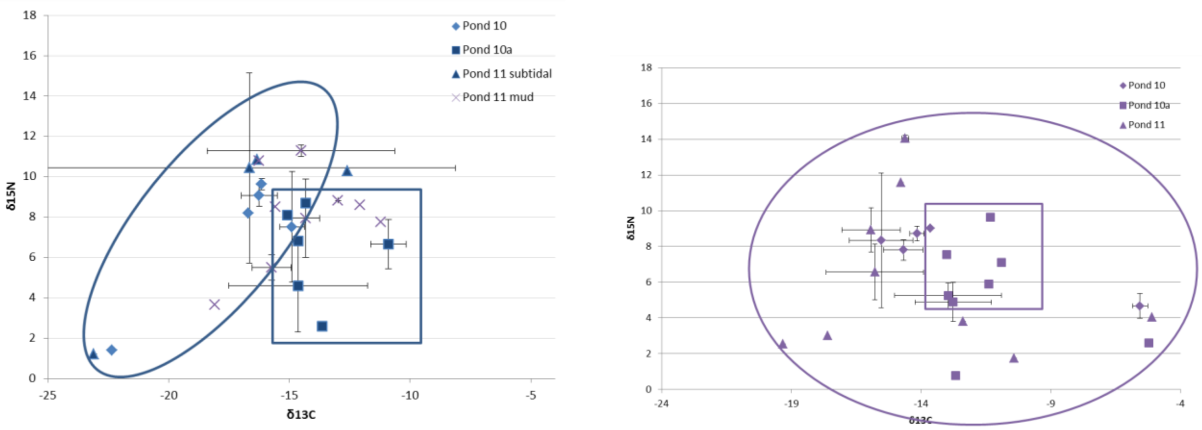


Figure 38. Dual Isotope Plots for Invertebrates Collected from the Western Salt Ponds. [(a) Fall 2011, (b) Fall 2012, (c) Fall 2013, and (d) Spring 2014. Note: Pond 10a not sampled in Fall 2011. Error bars indicated standard error around the mean. Shapes indicate significant differences among sites (ANOSIM)].

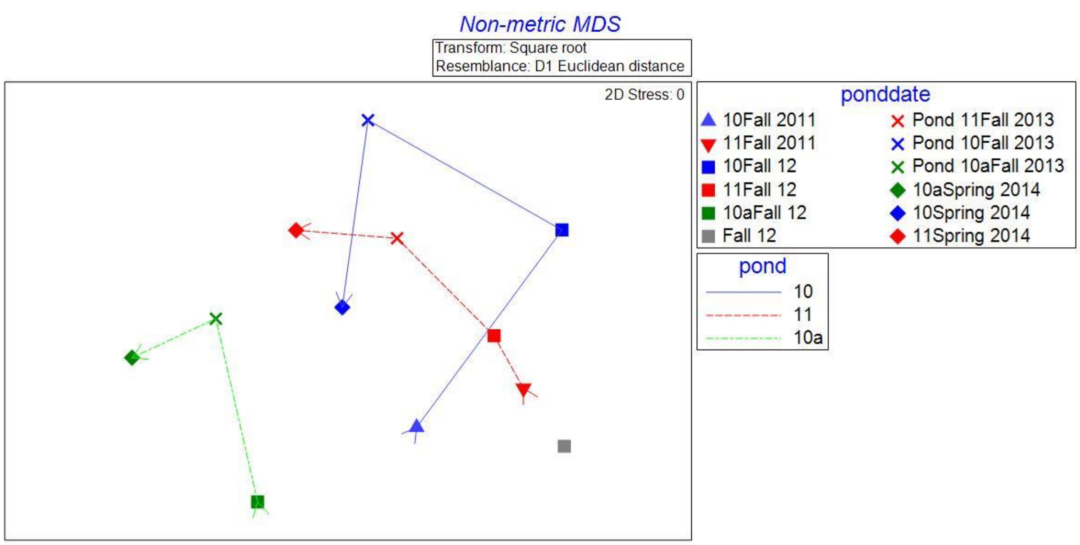


Figure 39. Averaged Non-metric MDS Plot with Individual Invertebrate Species in Western Salt Ponds by Season. (Fish from Fall 2012 are shown as grey square)

In summary, the NCWC Project goal of demonstrating recruitment of infauna and epifauana for support of foraging shorebirds and ground-nesting seabirds by March 2013 has been met. Relatively high densities of infauna and epifauna were collected using a variety of sampling techniques. Small cores revealed high densities of polychaetes, crustaceans, molluscs and insects available as food sources for foraging birds. Benthic invertebrates collected in fish enclosure traps and fish trawls included motile organisms, such as shrimp and crabs, demonstrating a greater diversity of benthic invertebrates than those collected in the large cores. Stable isotope analyses indicate that invertebrate and plant communities continue to develop within the restored ponds with a convergence of the stable isotope signatures of both consumers (fish) and food sources.

3.5 Monitoring of Avian Use of the Western Salt Ponds

There were no specific objectives or metrics for avian use at the western salt ponds. However, it was postulated that the avian assemblage would shift from one dominated by species that prefer open water habitat to one that included shorebirds and wading birds during low tide combined with species that utilize open water during high tides. In order to assess this predicted trend, avian use of the western salt ponds was monitored by the San Diego Natural History Museum (SDNHM) and Avian Research Associates (ARA) prior to and following construction of the Project.

3.5.1 Methods – Monitoring of Avian Use of Western Salt Ponds

SDNHM and ARA conducted surveys of the general use of the western ponds by water-dependent birds, including shorebirds, waterfowl, gulls, terns and others, and their behaviors. Surveys were conducted monthly from January 2015 to December 2015 and included the shallow water habitat and berms of the ponds as well as the shallow tidal habitats of the adjacent bay as far north as Emory Cove. Monthly monitoring will continue through 2016. Surveys were conducted using the methods employed in the multi-year bay-wide survey of avian species (Tierra Data Incorporated 2009). Those methods included:

- Surveys were conducted in the four hours before low tide to capture bird use of foraging habitats, such as mudflats and other habitats, that become exposed by receding water;
- Surveys conducted using a system of grids (= cells) previously established for the bay-wide survey (Tierra Data Incorporated 2009);
- Data collected included species abundance and diversity; general location/habitat categories, including wetland, upland, and aerial; and noted general behavior categories, including foraging, resting/rafting, courting/breeding.

Avian surveys of the entire South San Diego Bay Unit of the San Diego Bay National Wildlife Refuge were conducted as part of the monitoring project. These included surveys of the general use of the interior salt ponds by water-dependent birds, including shorebirds, waterfowl, gulls, terns and others, and their behaviors. Surveys were conducted monthly as described above and included the shallow water habitat and berms of the ponds, and adjacent upland habitats. Surveys also included the Otay River channel, tidal mudflats adjacent to the outer salt pond levees, and the grids of the bay within practical viewing range of those levees. Surveys were conducted using the methods described above for the western ponds, including use of the grid system, species abundance and diversity, location/habitat, and behavior (Figure 40). In addition, data from surveys of the same protocol conducted at adjacent Pond 20A were included in the data set for analysis since birds regularly shift between Pond 20A, the western ponds, and interior ponds.

3.5.2 Results – Monitoring of Avian Use of Western Salt Ponds

In order to assess shifts in bird usage following restoration of the salt ponds, a subset of the data collected during pre- and postconstruction monitoring was analyzed. Specifically, all birds observed using wetland habitats, defined as occurring below the high tide line, were summarized and compared. In addition, birds using the levee between Ponds 10 and 11 were summarized and compared across the four years of monitoring to assess changes in their use associated with restoration.Birds observed flying overhead (aerial) were excluded as it was assumed that many were in transit to other habitats, such

Figure 40. Avian Monitoring Grid – South San Diego Bay and Salt Works

as the open bay and ocean. In general, the majority of the birds observed during the monthly surveys were wetland species.

The number of avian species observed in wetland habitat during the 2015 surveys peaked in January with 37 species observed in Pond 11 (Figure 41). In 2014, the peak for number of avian species observed in wetland habitats peaked in November with more than 40 species observed in all three ponds (Figure 42). In 2015, Pond 11 had the greatest number of species during all monitoring surveys except March and August and more species were observed in Pond 10 than 10A. In the past, Pond 11 generally had the highest number of species and Pond 10A generally had more species than Pond 10. The mean number of species over the 2015 monitoring period was 17.8 species in Pond 10A (17.8 in 2014), 24.25 species in Pond 10 (15.2 in 2014), and 26.6 in Pond 11 (25.6 in 2014). The trend in the number of avian species observed in wetland habitat is illustrated in Figures 41 through 45.

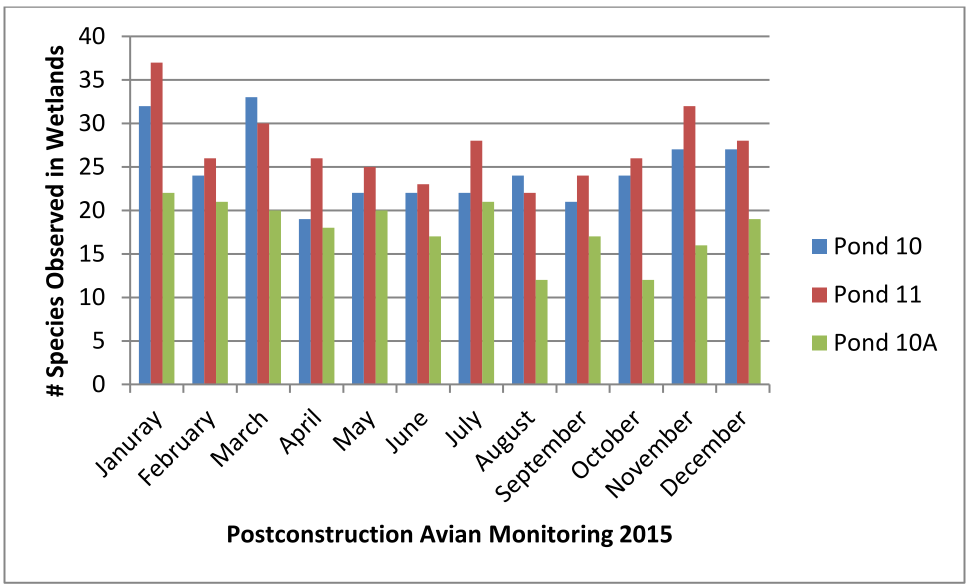


Figure 41. Number of Avian Species Observed in Wetland Habitats – 2015.

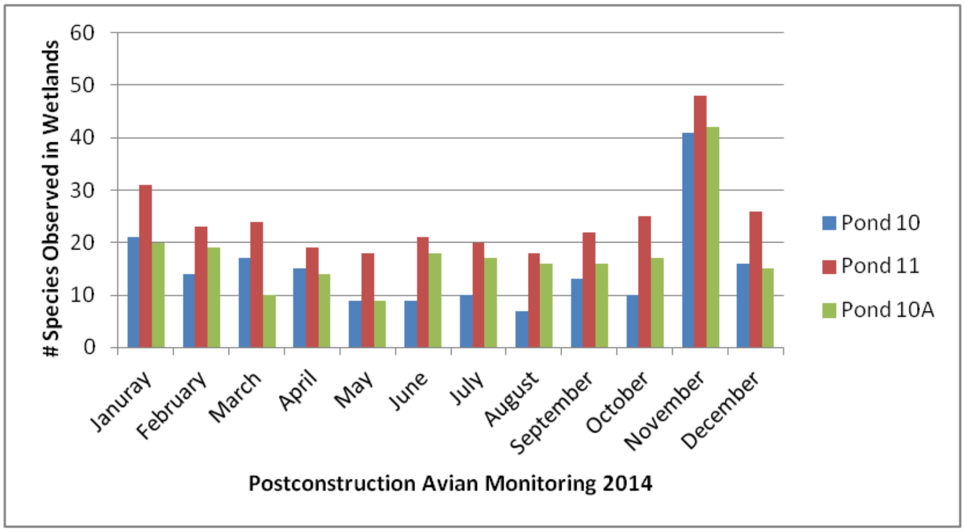


Figure 42. Number of Avian Species Observed in Wetland Habitats – 2014

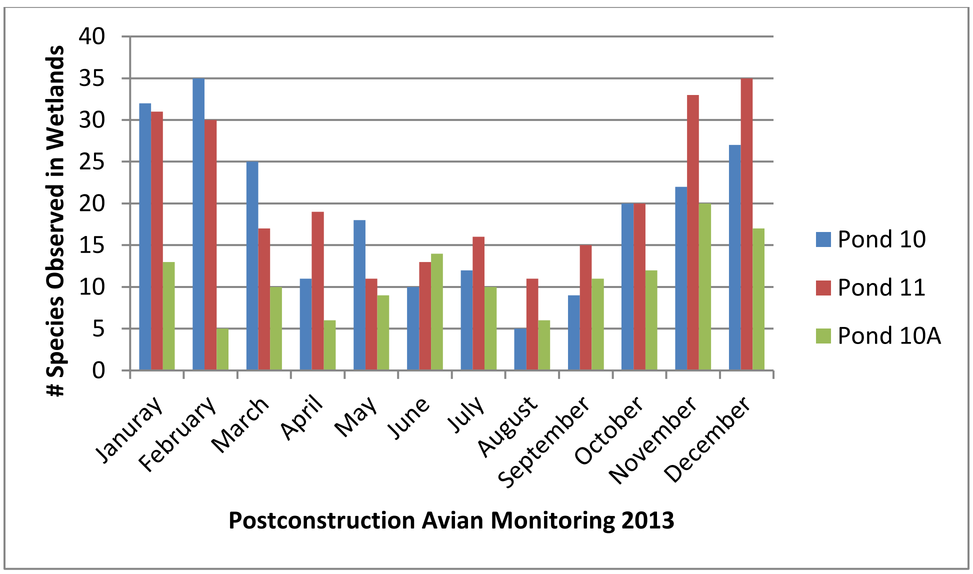


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Figure 43. Number of Avian Species Observed in Wetland Habitats – 2013

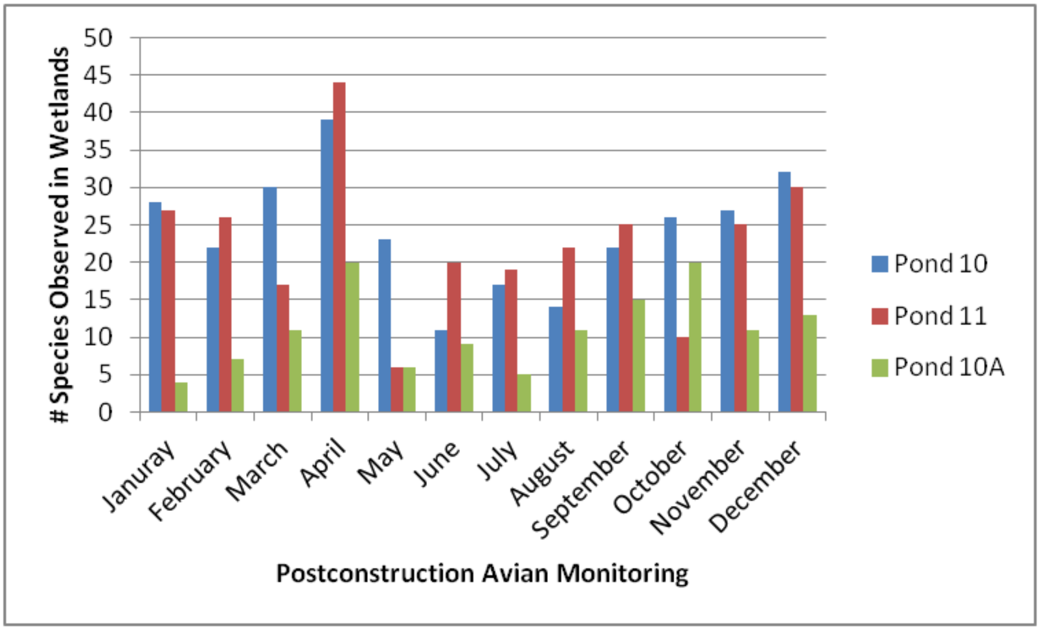

Figure 44. **Number of Avian Species Observed in Wetland Habitats – 2012**

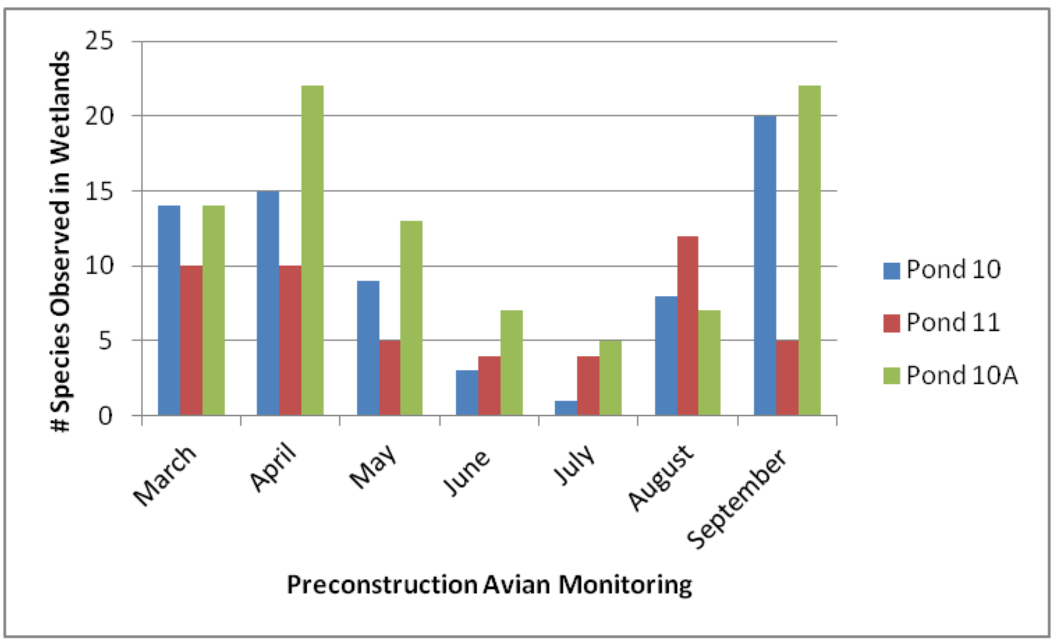

Figure 45. Number of Avian Species Observed in Wetland Habitats – 2011

The number of individuals observed in wetland habitat during 2015 monitoring also varied seasonally with the greatest numbers occurring in fall and winter and the fewest in spring and early summer (Figure 46). Peaks exceeding 4,400 individuals were recorded in Pond 11 in January and November 2015 and a low of 87 individuals were observed in June in Pond 10A. The highest number of individuals occurred in Pond 11 with one exception while ponds 10 and 10A were more variable.

Both the number of species and number of individuals observed in 2015 continue to support a trend of increased use of Pond 11 and decreased use of Pond 10, presumably in response to the developing salt marsh vegetation in Pond 10. In 2012, the number of individuals observed was typically highest in Ponds 10 and 11 and lower in Pond 10A. By 2013, the number of individuals was nearly always highest in Pond 11. By 2014, the numbers of individuals was clearly highest in Pond 11. By 2015 the majority of individuals observed were observed in Pond 11. Despite the seasonal and annual variability, bird usage of the ponds increased in all three years postconstruction relative to preconstruction surveys in 2011, demonstrating that restoration of intertidal habitats was beneficial to resident and migratory species. The trend in the number of individuals observedin wetland habitats is illustrated in Figures 46 through 50.

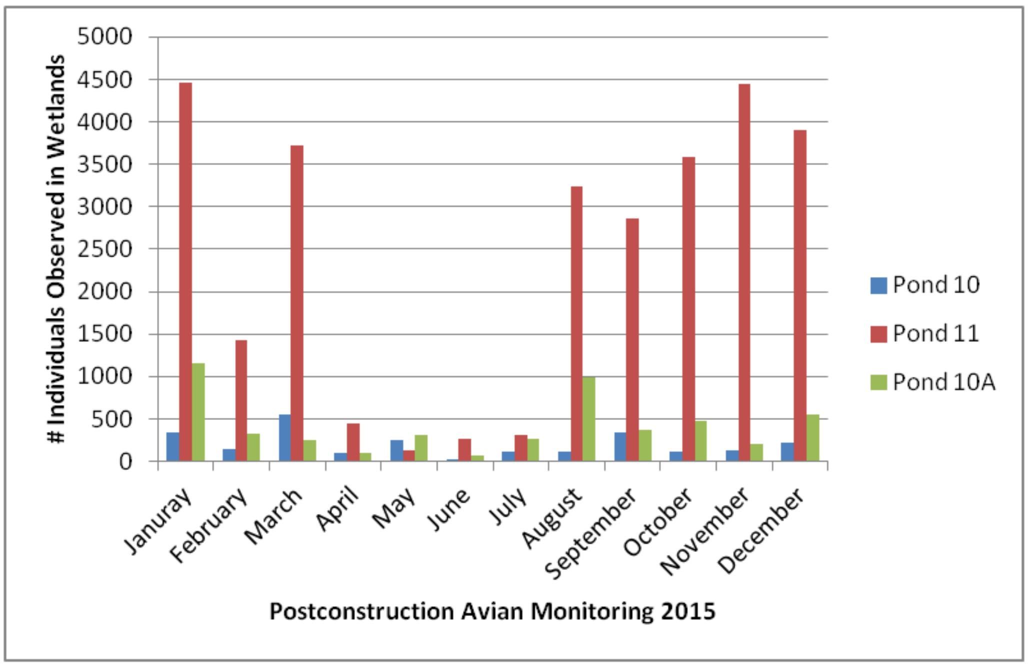

Figure 46. Number of Individual Birds Observed in Wetland Habitats – 2015

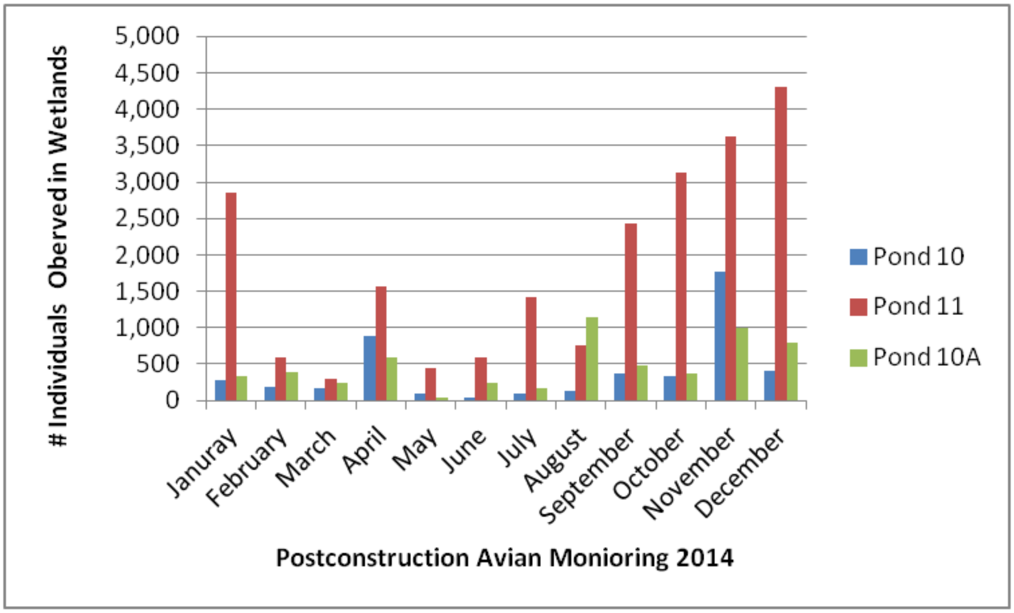

Figure 47. Number of Individual Birds Observed in Wetland Habitats – 2014

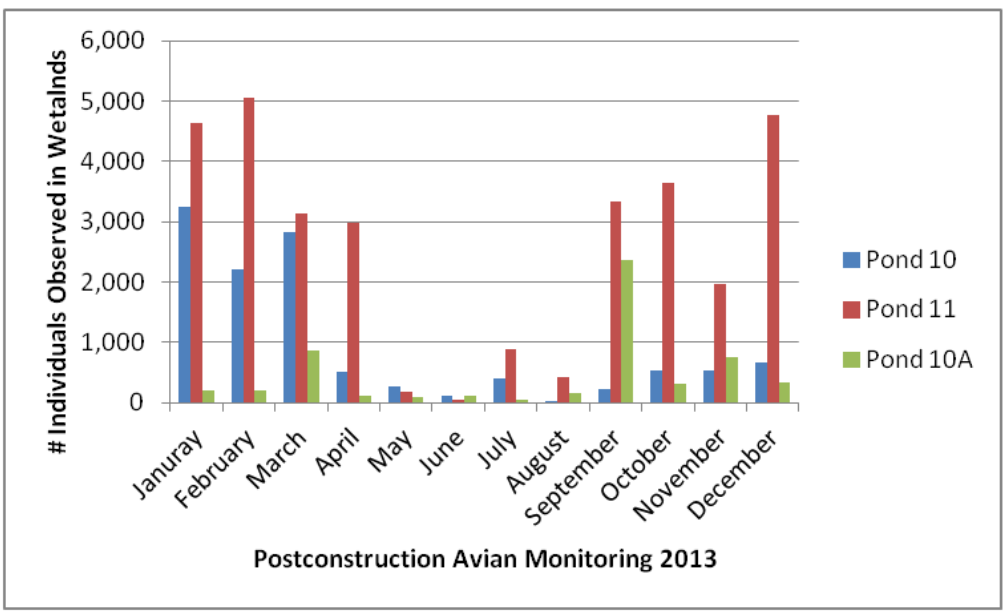

Figure 48. Number of Individual Birds Observed in Wetland Habitats – 2013

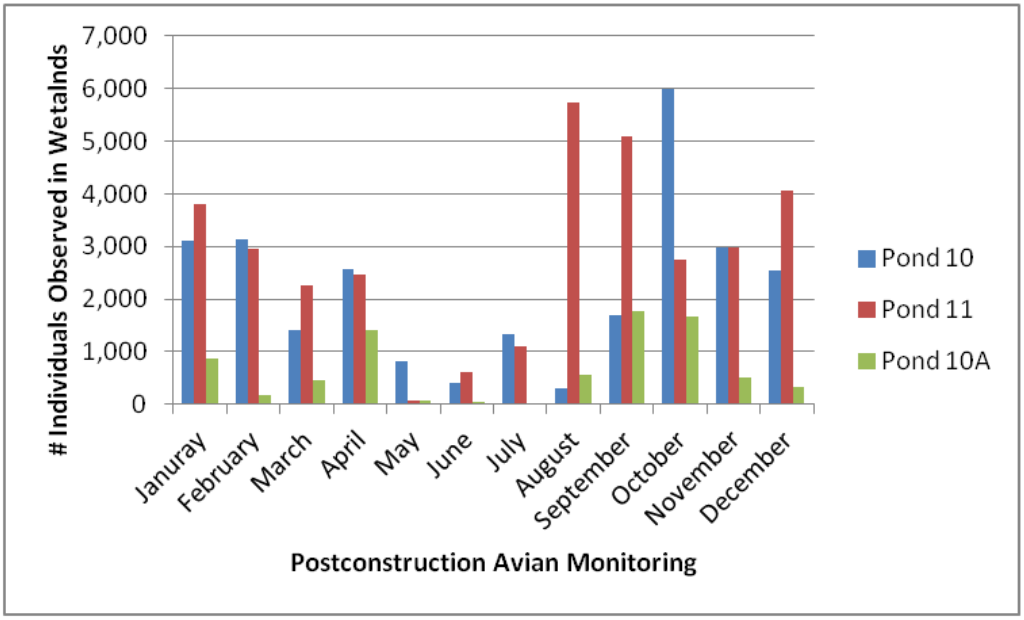

Figure 49. Number of Individual Birds Observed in Wetland Habitats – 2012

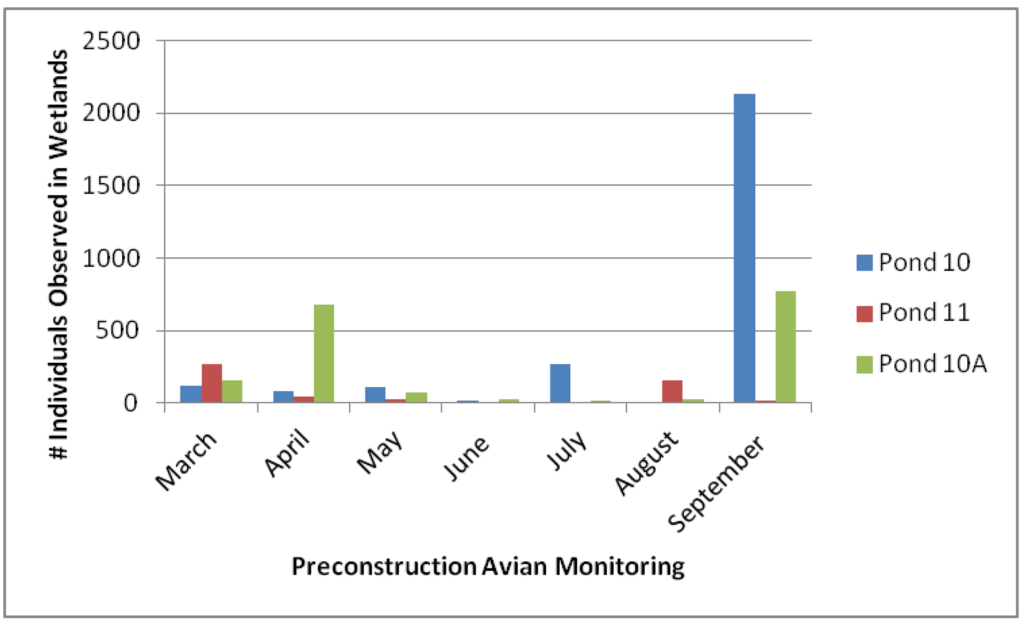

Figure 50. Number of Individual Birds Observed in Wetland Habitats – 2011

The numerically dominant species observed in wetland habitats of the western salt ponds during 2015 monitoring are summarized in Table 14. The numerically dominant species were shorebirds, including western sandpiper, least sandpiper, semipalmated plover, dowitcher species, willet and marbled godwit. Notable exceptions were American widgeon, northern pintail and northern shoveler in Ponds 10 and 11 in winter. It should be noted that elegant tern numbers were substantially down compared to previous years and that the state-listed endangered Belding's savannah sparrow was among the top three species numerically in Pond 10 on 7 survey dates and 2 surveys in Pond 11, albeit during periods of low absolute abundance. Nonetheless, the developing mid-elevation salt marsh in Pond 10 appears to be providing breeding habitat for this species. Belding's savannah sparrow did not rank among the top 3 species numerically in any pond at any time prior to 2014.

As in past years, the numbers of western sandpiper observed in 2015 in Pond 11 closely mirrored the overall numbers of individuals observed. This species was by far the numerically dominant species during all years (Table 14). However, use of Pond 10 by western sandpipers has declined relative 2013 as the planted salt marsh develops displacing mudflat habitat favored by this species as foraging habitat (Figures 50 through 52). When compared to 2013, numbers of western sandpipers in wetland habitats Ponds 10, 11 and 10A were down by approximately 47% (49,164 in 2013; 17,514 in 2014, and 22,967 in 2015), although there were more individuals in the overall study area which includes the eastern salt ponds and parts of south San Diego Bay (152,397 observations in 2015; 129,590 observations in 2014; 123,931 observations in 2013). This suggests that western sandpipers are using areas other than the western ponds to a greater extent. It is postulated that this reduced activity is directly related to development of salt marsh habitats in all three ponds, thereby reducing the area of mudflat favored by western sandpipers as foraging habitat.

Table 14. Total Numbers and Numerically Dominant Species of Birds Observed in Wetland Habitats of the Western Salt Ponds During Postconstruction Surveys 2015.

	Month Surveyed					
	January	**February**	**March**	**April**	**May**	**June**
Pond 10A	Total = 1,160 least sandpiper 400 dowitcher sp. 350 semipalm plover 110	Total = 324 dowitcher sp. 104 northern shoveler 26 least sandpiper 37	Total = 248 dowitcher sp. 109 willet 43 least sandpiper 35	Total = 92 dowitcher sp. 45 greater yellowlegs 15 willet 12	Total = 308 dowitcher sp. 147 semipalm. Plover 69 west. sandpiper 68	Total = 64 semipalm plover 20 west sandpiper 12 Belding's savannah sparrow 7
Pond 10	Total = 343 least sandpiper 49 Am. widgeon 41 northern pintail 53 northern shoveler 35	Total = 137 northern pintail 36 Am. widgeon 27 Belding's savannah sparrow 22	Total = 556 Am. wigeon 307 least sandpiper 120 green-winged teal 26	Total = 103 cliff swallow 30 Belding's savannah sparrow 20 least sandpiper 19	Total = 246 marbled godwit 71 dowitcher sp. 32 black-necked stilt 21	Total = 23 Belding's savannah sparrow 16
Pond 11	Total = 4,456 west. sandpiper 3,180 northern pintail 167 northern shoveler 131 least sandpiper 87	Total = 1,420 west. sandpiper 964 least sandpiper 90 marbled godwit 81 brant 53	Total = 3.727 west. sandpiper 3,204 marbled godwit 102 dunlin 81 brant 64	Total = 445 west sandpiper 285 marbled godtwit 64 willet 26 brant 17	Total = 136 west sandpiper 57 western gull 24 Belding's savannah sparrow 20	Total = 271 elegant tern 232 willet 12 Belding's savannah sparrow 8

	Month Surveyed					
	July	**August**	**September**	**October**	**November**	**December**
Pond 10A	Total = 272 west. sandpiper 98 dowitcher sp 60 black-necked stilt 22	Total = 983 west sandpiper 845 semipalm. plover 78 least sandpiper 20	Total = 376 short-billed dowitcher 112 west sandpiper 72 semipalm. plover 24	Total = 476 dowitcher sp 227 willet 121 marbled godwit 81 killdeer 20	Total = 209 willet 77 least sandpiper 41 marbled godwit 32	Total = 552 dowitcher sp 280 marbled godwit 163 willet 194 least sandpiper 30
Pond 10	Total = 117 west. sandpiper 70 Belding's savannah sparrow 24 dowitcher sp. 10	Total = 117 west. sandpiper 60 Belding's savannah sparrow 16 least sandpiper 12	Total = 343 least. sandpiper 175 west.sandpiper100 Belding's savannah sparrow 42	Total = 115 west sandpiper 19 least sandpiper 47 Belding's savannah sparrow 28	Total = 135 least sandpiper 56 west. sandpiper 25 Belding's savannah sparrow 14	Total = 219 least sandpiper 80 west. sandpiper 40 northern pintail 30
Pond 11	Total = 317 western sandpiper 143 dowitcher sp. 70 willet 30	Total = 3,243 west sandpiper 2,590 black-bellied plover 164 least sandpiper 150 dowitcher sp. 119	Total = 2,861 west sandpiper 2,460 least sandpiper 100 black-bellied plover 83	Total = 3,588 west sandpiper 2,810 least sandpiper 212 dowitcher sp. 148	Total = 4,452 west sandpiper3,750 least sandpiper 125 marbled godwit 81 willet 76	Total = 3,903 west sandpiper 3,450 dowitcher sp. 81 dunlin 45

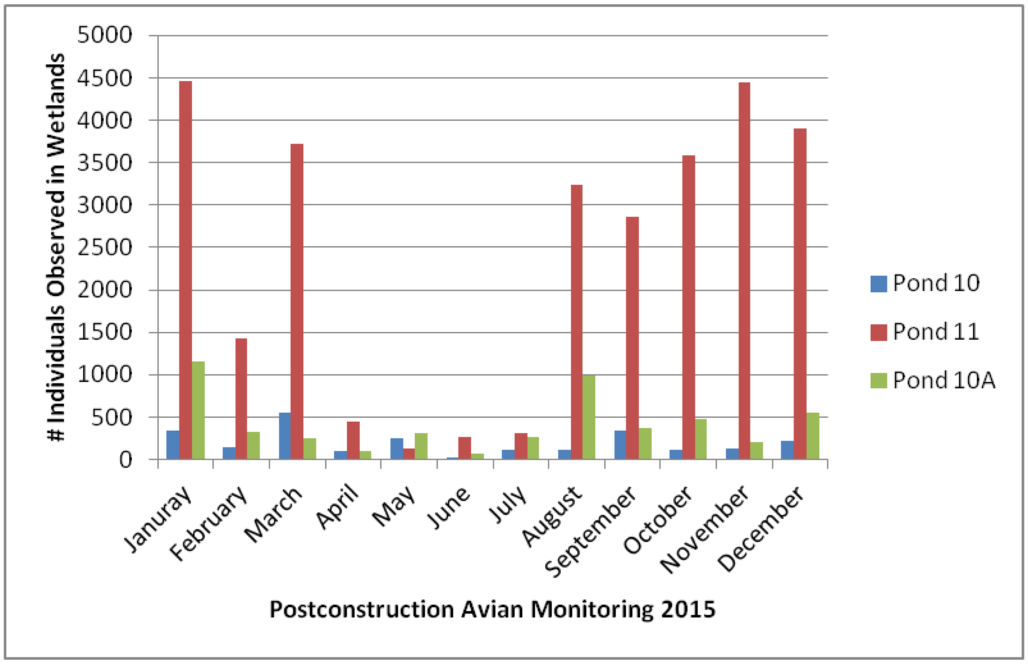

Figure 51. Number of Individual Birds Observed in Wetland Habitats – 2015

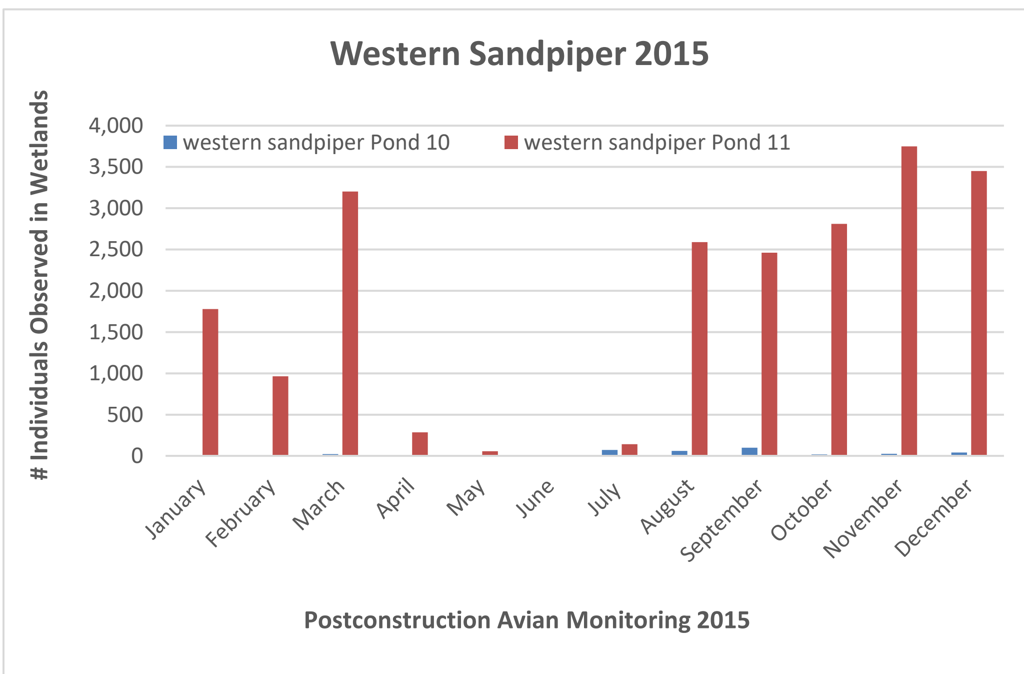

Figure 52. Number of Individual Western Sandpiper Observed in Wetland Habitats In Ponds 10 and 11 – 2015

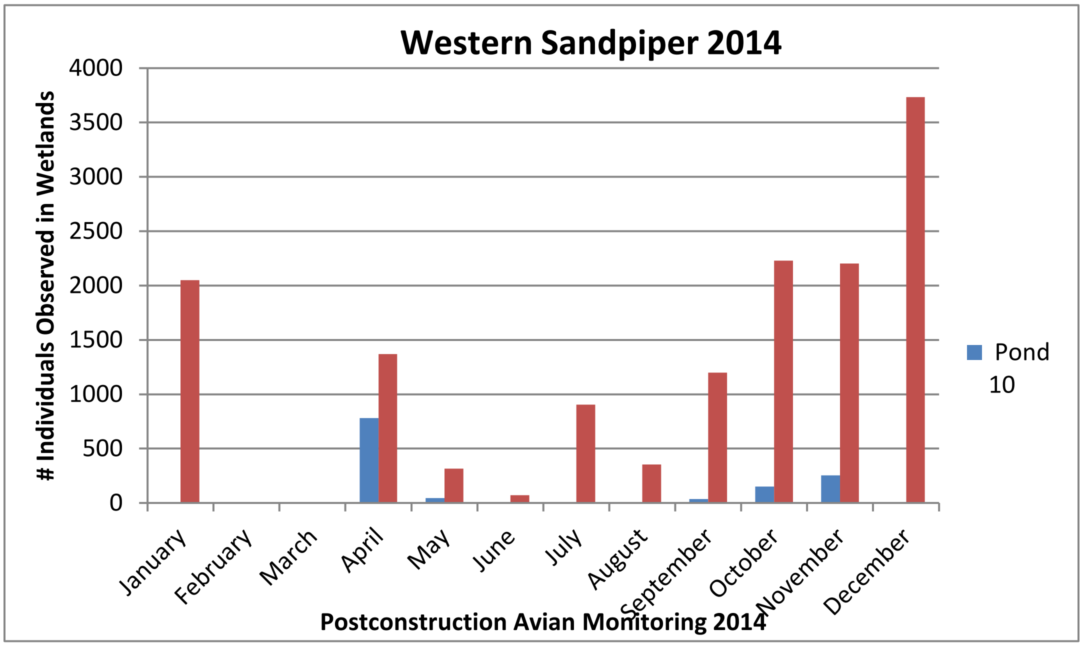

Figure 53. Number of Individual Western Sandpiper Observed in Wetland Habitats In Ponds 10 and 11 - 2014

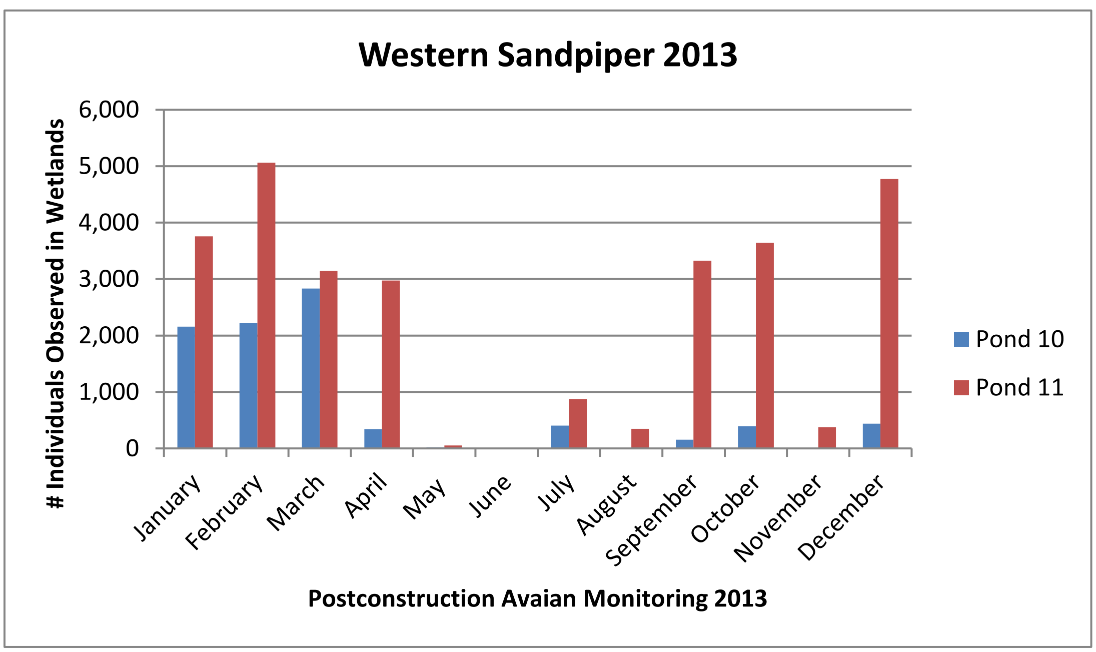

Figure 54. Number of Individual Western Sandpiper Observed in Wetland Habitats In Ponds 10 and 11 - 2013

During project planning, there was some concern voiced that converting ponds 10 and 11 to intertidal habitats would alter the avian use of the dike between the two ponds. Although the data set is large, spans several years and many months, and is difficult to demonstrate visually, analysis of raw bird count data illustrates the changes in avian use of the dike. Analysis of data collected prior to after construction of the western salt project showed the following patterns in avian use of the dike:

- In 2009 and 2010, prior to construction of the project, the dominant avian species observed on the dike (as opposed to in the water near the dike) were brown pelican, double-crested cormorant, western gull, elegant tern, western sandpiper and black-bellied plover. For example, in September 2009, 216 brown pelican, 119 double-crested cormorant and 220 elegant tern were observed. In December 2009, 350 black-bellied plover, 52 double-crested cormorant, and 230 western sandpiper were observed. In September 2010, 105 brown pelican, 303 double-crested cormorant, 115 elegant tern and 53 western gull were observed.

- By 2012, the first year after construction, changes in avian use of the dike were apparent. On four survey dates (May, June, July and November) no birds were observed on the dike. A total of 10 brown pelican and 5 double-crested cormorant were observed on the dike over the entire year. Observations were dominated by black-bellied plover and western sandpiper, primarily during January when their numbers were 228 and 650, respectively.

- By 2014, no birds were observed on the dike on 10 of the 12 surveys. Sixteen black-bellied plover, 5 dowitcher sp., and 2 snowy egret were observed on the dike in December. In 2015, a few miscellaneous species were observed in low numbers, including 10 brown pelican and 5 cormorant in January.

Conversion of the two ponds from open water to intertidal marsh and mudflat has dramatically altered the avian use of the dike. The large, piscivorous birds, such as brown pelican and double-crested cormorant, no longer use the dike in the manner that they did prior to conversion. This is most likely due to the loss of open water and the fish associated with that open water. With the ponds now tidal with increasing area and density of salt marsh vegetation, these species appear to have relocated to other areas within the bay or open coast.

4.0 CONCLUSIONS

Many of the goals and objectives developed for the Project were either met in Year 4 (2015) or are expected to be met in subsequent years. Goals and objectives that are considered met include:

- Complete the permitting, final design, and site preparation, including all excavation, clean-up, and grading, necessary to restore and enhance 160 acres of coastal wetland and upland habitat in south San Diego Bay by March 1, 2011.

This overarching goal is considered met with the exception that project delays resulted in a completed project by December 2011.

- By the end of 2016 achieve approximately 89 acres of functional estuarine intertidal emergent wetlands, approximately 41 acres of estuarine intertidal non-vegetated wetlands, approximately 28 acres of estuarine subtidal wetlands, and 10 acres of palustrine scrub-shrub vegetation.

This overarching goal is considered to be on track for achievement by the end of 2016.

- Within the western salt ponds, by March 2013, achieve successful recruitment of benthic invertebrates and fish within Pond 11 to support migratory shorebirds and foraging ground-nesting seabirds.

This objective has been met.

- Within the western salt ponds, by March 1, 2011 complete the dredging and filling activities required to achieve elevations within Pond 11 that will support a mix of shallow subtidal, intertidal mudflat, cordgrass-dominated salt marsh, and pickleweed-dominated salt marsh habitats (estuarine intertidal emergent, non-vegetated, and subtidal wetlands) and breach the pond levee to restore tidal influence to the 106-acre pond.

This objective is considered met with the exception that project delays resulted in a project completion date of December 2011.

- Within the western salt ponds, by the end of 2016, achieve 50 percent coverage of cordgrass (*Spartina foliosa*), with at least 25 percent of the plants in excess of 60 centimeters (cm) in height, over approximately 30 acres within the tidally restored pond.

While this objective was considered to be on track for achievement by the end of 2016, die-off of above ground cordgrass occurred in test plots and, presumably, in the remainder of the marsh in Pond 10 in 2015. Cordgrass appears robust during the 2016 growing season and may expand its current distribution. However, based on visual estimates of cordgrass cover and height, it is evident that there is less than 30 acres comprised of 50% coverage of cordgrass and less than 25% of plants in excess of 60 cm.

- Within the western salt ponds, between March 2011 and February 2012, monitor and record through monthly visual surveys, the recruitment of vegetation and benthic invertebrates, bird use, and any changes in bathymetry within the pond. Based on these observations, develop recommendations for how the design of future phases of salt pond restoration in San Diego Bay could be adjusted to more effectively achieve restoration objectives.

This objective is considered met with the exception that annual monitoring occurs between January and December. Recommendations for future phases of salt pond restoration in San Diego Bay will be developed at the end of the monitoring program.

- By March 1, 2011 lower approximately 3 acres within the western basin of the Chula Vista Wildlife Reserve to achieve a typical marsh plain elevation of +4.5 feet Mean Lower Low Water (MLLW) (an elevation appropriate for supporting estuarine intertidal emergent wetlands) and expand the existing tidal channel by removing 3,000 cubic yards of sediments to create deeper, more well defined tidal creeks within the western basin, thus enhancing the remaining wetland habitat.

This objective has been met.

- By the end of 2016, achieve 50 percent coverage of cordgrass and pickleweed over the 3-acre excavation area of the Chula Vista Wildlife Reserve and improve vigor and plant diversity throughout the remaining 16 acres of estuarine intertidal emergent wetlands within the basin.

This objective was considered to be on track for achievement by the end of 2016. However, the final monitoring report for the five Year effort conducted by Merkel & Associates determined cover by cordgrass to be less than 2%. Thus, this objective has not been met.

- Restore wetland elevations and channel bathymetry in Ponds 10 and 11 to within plus or minus 10% of the design plan by June 2011.

This objective has been met.

- Achieve 50% vegetation cover by wetland vascular plants in at least 30 acres of Pond 10 by June 2016.

This objective is considered to be on track for achievement by the end of 2016.

- Within Ponds 10 and 11 demonstrate presence of one or more of the target species (flatfish and elasmobranchs) by 2013.

This objective has been met.

- Restore wetland elevations and channel bathymetry the restored Chula Vista Wildlife Reserve basin to within plus or minus 10% of the design plan by June 2011.

This objective has been met.

- By 2016, restore typical marsh vegetation coverage at the Chula Vista Wildlife Reserve, using marsh coverage at Tijuana Estuary as a target;

This objective has not been met.

- At the Chula Vista Wildlife Reserve demonstrate presence of one or more of the target species (gobiidae and topsmelt) by 2013.

This objective has been met.

- By March 2013, achieve successful recruitment of benthic invertebrates and fish within the western basin of the Chula Vista Wildlife Reserve to support migratory shorebirds and foraging ground-nesting seabirds.

This objective has been met.

- Restore tidal amplitude in Ponds 10 and 11 to approximately equal the tidal amplitude in the Otay River; restore tidal amplitude in Pond 10A to a slightly muted amplitude relative to the Otay River by 2012.

This objective has been met.

- At the Chula Vista Wildlife Reserve, restore tidal amplitude to approximately equal the tidal amplitude in San Diego Bay by 2011.

Low tides are moderately to severely truncated within the channels of the restored basins, suggesting that these channels do not drain completely. This may be caused by shoals forming at the connections to the bay. Further monitoring will assess the presence of shoals and the effect on Project success.

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