ANNUAL REPORT

October 1, 2017 – September 30, 2018

Date: November 9, 2018

Agreement No.: P1496011 00 Grant Term: March 1, 2020

Project Title: Initiation of Thin-Layer Sediment Augmentation on the Pacific Coast

Grantee: U.S. Fish and Wildlife Service, San Diego NWRC

FISCAL REPORT

Fund Source	Amount Awarded	Amount Invoiced for Services through September 30, 2018†	Total Amount Remaining
CDFW GGRF Grant Funds	$1,055,827	$505,111	$550,716
Cost Share	$1,306,048	$1,698,060 *	<$392,012>
Agreement Totals	$2,361,875	$1,953,711	$550,716‡

† Includes Invoice 30-2018
* See itemized cost share expenditures presented in Attachment 1.
‡ Cost Share agreements have already been achieved and are therefore not included in this total.

PROGRAM/TECHNICAL REPORT

Project Overview

The Seal Beach National Wildlife Refuge (Refuge or NWR) Thin-Layer Sediment Augmentation Project is the first project of this kind to be implemented on the Pacific Coast. The primary goal of the project is to test the benefits of this technique as a sea-level rise adaptation strategy for ensuring the long-term availability of coastal salt marsh habitat for carbon sequestration, as well as for the conservation of listed and sensitive species that are dependent on coastal salt marsh habitat for their existence. Design and implementation of the project and its associated research components represents a collaborative effort involving public agencies, educational/research institutions, and volunteers. The project team includes the U.S. Fish and Wildlife Service (Service), Naval Weapons Station Seal Beach, U.S. Army Corps of Engineers (ACOE) Engineer Research and Development Center, U.S. Geological Survey (USGS) Western Ecological Research Center, California Department of Fish and Wildlife, California State Coastal Conservancy, County of Orange Parks, researchers from the University of California, Los Angeles (UCLA), California State University, Long Beach (CSULB), and Chapman University, and volunteers from the Friends of the Seal Beach NWR.

The pre- and multiple year post-augmentation monitoring plan is essential to the project goals of successfully raising the elevation of the marsh plain to support cordgrass and associated salt marsh species, and providing a thin-layer sediment augmentation guidance document that describes this "proof-of-concept" project. The guidance will include a description of the procedures and techniques employed to achieve sediment depths and minimize movement of sediment offsite (including the effectiveness of all tested procedures and lessons learned), details about the lessons learned, and data and overall results of the biological and physical monitoring program. This information will be disseminated to interested parties to facilitate future thin-layer sediment augmentation projects along the California coast.

Summary of Activities Performed from October 1, 2017 to September 30, 2018

The primary focus of the project team during the last year has been recording the changing physical and biological conditions occurring on the project site and control site two years post-augmentation. The process of applying a thin-layer of sediment to the 10-acre project site (Figure 1) was completed in April 2016. This resulted in the placement of approximately 10" of sediment ±2" over approximately 7.87 acres of the planned 10-acre site. Pre-augmentation monitoring of the augmentation site and a nearby 2.5-acre control site was conducted in 2015 and post-augmentation monitoring which is documenting the physical and biological conditions of both sites was initiated immediately following the augmentation process and will continue through 2019.

At two years post-augmentation, the presence of salt marsh vegetation on the augmentation site is slowly expanding. Until recently, annual pickleweed (*Salicornia bigelovii*) and Pacific cordgrass (*Spartina foliosa*) were the only species of salt marsh vegetation repopulating the site, but in spring 2018, the establishment of batis (*Batis maritima*) and perennial pickleweed (*Sarcocornia pacifica*) was confirmed on the site. Tidal channels are slowly developing, and the presence of shorebirds on the site has increased considerably. Eelgrass beds adjacent to the site were surveyed in May and a study of the nutrient content in the applied sediment, funded by the California State Coastal Conservancy, was initiated this year. The nutrient study will assist us in understanding if and possibly how the nutrient content of the sandier than anticipated sediment might be affecting vegetation growth and invertebrate recruitment on the site. Site photos from the period October 2017 to September 2018 are provided as Attachment 2.

Team members participate in joint conference calls at least quarterly and written quarterly updates are provided to the Service by each research team. Additional contacts are made as needed to discuss site changes or to explore other potential research issues.

Land managers and researchers from California, as well as from eastern and Gulf state coastal areas have inquired about the project. Team members continue to participate in seminars and conferences to present the project to a range of interested parties, including pubic agencies, academia, and land managers.

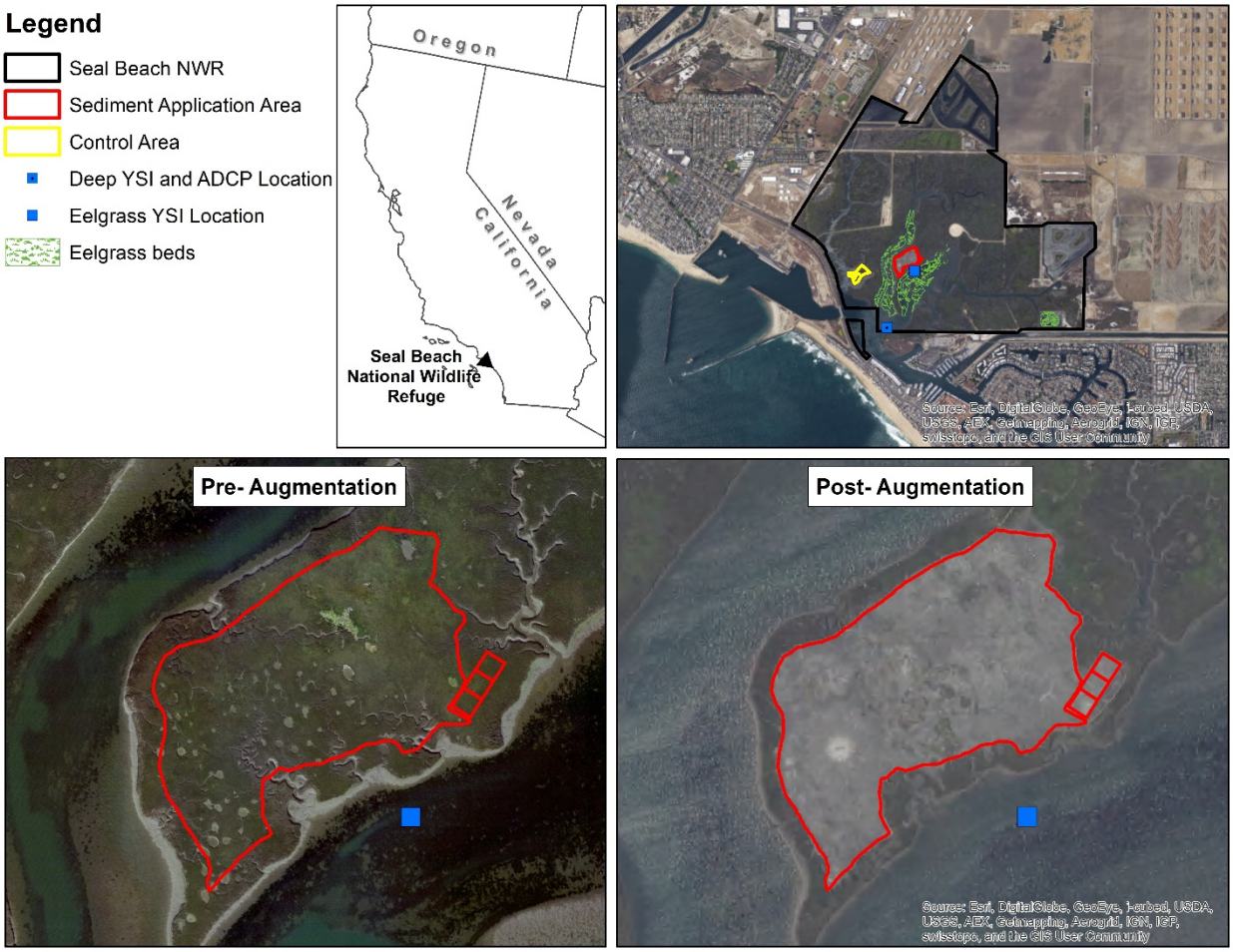


Figure 1. Seal Beach NWR Sediment Augmentation Site Location Map (USGS 2017[1])

<u>October 1 to December 31, 2017</u>

Research and Monitoring Activities and Observations:

1) **<u>Sediment Accumulation/Tidal Creek Accretion</u>**. Researchers from UCLA under the direction of Dr. Rich Ambrose continued sampling feldspar/bulk density (F/B) plots, recording any tidal creek accretion on the augmentation site and the control site, and measuring for any evidence of sediment accumulation.

    a) During the last quarter, sampling was conducted at four creek crossings and 15 feldspar plots. Measurements were also taken at about 70 sediment stakes. The feldspar plots, which were installed in 2015 prior to augmentation, provide a method for measuring sediment accumulation on the control and augmentation site over time. Sediment stakes placed at a known height above the natural substrate provide

[1] Thorne, K.M., N.K. Ganju, C. Freeman, and J.A. Rosencranz. 2017. Final Report: Thin-Layer Sediment Application Pilot Project at Seal Beach National Wildlife Refuge, *Sediment flux and turbidity patterns*. October 12, 2017. USGS, Western Ecological Research Center, Vallejo, CA and USGS, Coastal and Marine Geology, Woods Hole, MA.

a tested method for measuring sediment accretion (accumulation) or erosion, which is determined by measuring the subsequent distance from the substrate surface to the top of the stake and comparing this distance to the original distance.

Samples taken from the feldspar plots are processed for sediment bulk density (the mass of sediment in a specified volume), percent organic carbon, and grain size measurements. Processing for measuring bulk density involves drying and then weighing the core samples taken from the feldspar plots.

b) A major focus this quarter was establishing the current conditions of the small tidal creeks that have begun to form within the augmentation site. This data will enable researchers to document how the creeks reform over time.

In September 2017, the project team conducted a special conference call to discuss tidal creek formation within the site. It was noted that the creeks that have formed are currently inches deep rather than feet deep, as they were pre-augmentation. This was believed to be the result of the continued presence of hay bales at the creek mouths that were placed there to retain sediment on the site during augmentation. After discussing the potential problems associated with restricted tidal flow to portions of the site (e.g., inadequate tidal flows to support the plant growth, the potential for sediment acidification should the sediment dry out), the project team determined that several of the dams should be notched to facilitate better tidal flow across the site. As a result of this discussion, the Refuge Manager, Rick Nye, evaluated the conditions at the ends of the pre-augmentation tidal creeks and identified several locations appropriate for hay bale removal.

During the last quarter of 2017, UCLA researchers performed three site visits to take photographs of various tidal creeks, including some to be notched and some to remain in their current condition. The use of a drone to take these photographs would have been ideal, but due to military airspace and radio frequency restrictions in the airspace above the project site, authorization to use a drone for this work was not pursued.

The photographs were pieced together to create an orthomosaic of each tidal creek and associated elevation data for each creek was recorded. These measurements and images will provide the baseline data (i.e., pre-hay bale removal) from which future conditions can be compared. Similar data was collected for creeks on the control site to understand how tidal creeks in the marsh are influenced by tidal processes, rainfall, and any other physical factors affecting the marsh complex.

2) **Plants and Invertebrates**. CSULB researchers under the direction of Dr. Christine Whitcraft conducted their 18 months-post augmentation fieldwork between October 13 and 16, 2017. This fieldwork included plant surveys and collecting sediment samples to evaluate invertebrate abundance and diversity at the sampling plots located on both the augmentation site and the control site. CSULB also conducted laboratory analysis

involving sorting and identifying invertebrates collected previously from the sites. Fieldwork included monitoring the vegetation community, epifaunal and infaunal invertebrate populations, abiotic properties, and belowground biomass.

Invertebrate sorting and identification for the top 2 cm samples from the site was completed for all samples collected through summer 2017, and processing of the fall 2017 samples was initiated, as was the sorting of the bottom 4 cm samples for all prior time periods. Preliminary data from October 2017 indicated a higher number of invertebrates present on the augmentation site than were present during previous post augmentation sampling efforts. Processing of belowground biomass cores was also completed and the data was entered for analysis.

Additional colonization experiment samples, taken to evaluate any potential differences in colonization due to the high percentage of sand present in the dredged material have been sorted and identified. That experiment is now complete and the data are being analyzed for publication.

Plant surveys conducted in October 2017 revealed that Pacific cordgrass was repopulating low-lying areas throughout the site, but was only present in one of the survey plots. Therefore, results from this period will not fully reflect the current stage of recovery throughout the site. During a site visit conducted on November 21, 2017, numerous annual pickleweed seedlings were observed on the augmentation site (Figure 2).

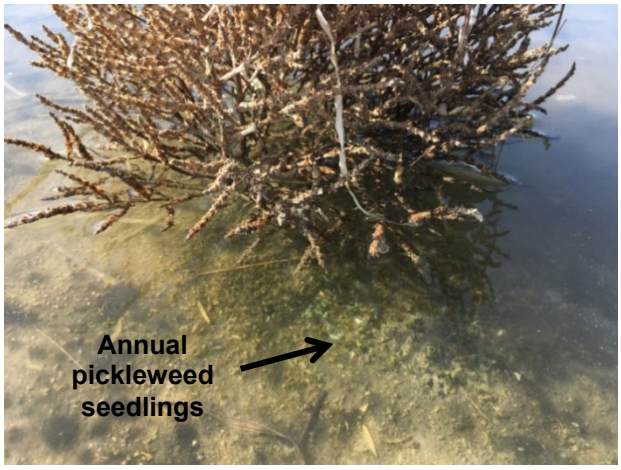


Figure 2. Annual pickleweed inundated by the tides in fall 2017. Numerous seedlings are present below the older plant. Photo: USFWS, R. Nye.

3) **<u>Long Core Analysis</u>**. UCLA researchers under the direction of Dr. Glen MacDonald completed their analysis and prepared the final results of their assessment of pre-augmentation net sediment accretion rates, carbon stock, carbon accumulation rates, and historic sea-level rise on the Seal Beach NWR from historic sediment core data. The final report (Brown et al. 2018[2]) describing the results of the analyses of historic sediment core data from the project site is provided as Attachment 3. This research aimed to assess pre-augmentation net sediment accretion rates, carbon stock, carbon accumulation rates, and historic sea-level rise at the Seal Beach NWR. The major conclusions of the analyses include:

[2] Brown, L.N., S. Avnaim-Katav, G.M. MacDonald. 2018. Seal Beach National Wildlife Refuge Sediment Coring for Long-Term Carbon Sequestration and Environmental Change. UCLA Department of Geography. Los Angeles, CA.

- Sediment records ranging from 380+ 78 years before present (YBP) to 1539+ 71 YBP indicate average sediment accretion rates (as determined by 137Cs and 210Pb dating) was 3.2+ 0.21 mm yr-1. This was true for both the control site and the augmentation site and for radiometric methods.
- Analysis of carbon content in the cores shows that there are approximately 73,536+ 6,635 tonnes of carbon stored at the 390 ha of active salt marsh (top 1 m) at the Seal Beach NWR. Using an estimated value of $15.17 per tonne of CO_2e on the California carbon exchange (10 Jan 2018), the carbon stock at the Seal Beach NWR is worth approximately $1.1 million.
- Average CAR determined from carbon content and age-depth relationships is 116.8+ 1.6 g C m-2 yr-1, with approximately 456.3 tonnes of carbon sequestered by the salt marsh habitat at the Seal Beach NWR every year.
- A seismic event occurred ca. 1450 AD, which corresponds to a previous report by Leeper et al. (2017). The core data indicates that this event was followed by a period in which the salt marsh habitat was recovering from being covered by sandy sediment.

4) **Marsh Elevations**. As noted in the annual report for Oct 2016 through September 2017, the pre- and post-augmentation monitoring effort by USGS of turbidity and sediment fluxes in the tidal channels adjacent to the augmentation site was completed in August 2017; however, USGS continues to collect data related to post-construction marsh surface elevations. On November 11, 2017, data was collected from deep rod surface elevation tables (SETs), such as the plot depicted in Figure 3, and adjacent feldspar plots. Based on the data collected, it appears that the augmentation site continued to decrease gradually in elevation, dropping on average 3.84 mm across all fifteen SETs. The control site showed a small increase in elevation of 1.65 mm across its six SETs. A SET installed elsewhere on the Refuge several years prior to the augmentation project also showed an increase (2.49 mm).

   The mean elevation of the project site immediately following augmentation, as measured at the SETs, increased by 216 mm. the site elevations then decreased between April 2016 and November 2017.

Figure 3. Pickleweed growing in Plot Area SBA1, where a SET and feldspar plot is maintained. Photo: USGS.

5) **Greenhouse Gases**. Chapman University, under the direction of Dr. Jason Keller, conducted fieldwork related to greenhouse gas flux in October and December 2017. On each sampling trip, gas samples were collected from both the control and augmentation site

and redox in surface water was measured in the field. Collected samples were analyzed for carbon dioxide, methane, and nitrous oxide at Chapman University. Surface porewater was also collected and analyzed for chemical properties.
Monitoring indicated that significant methane fluxes were minimal, but there were occasional positive fluxes. Low methane fluxes are common from salt marsh soils. Carbon dioxide fluxes were generally lower from the control site pre-augmentation (possibly due to lower air temperatures during sampling) and were lowest from areas of the marsh that remain ponded after high tides have receded. Following the addition of sediment, the augmentation site had very low carbon dioxide fluxes compared to both the control site and the pre-augmentation conditions on the augmentation site.

To address concerns related to potential acidification of the augmentation site as a result of the high content of sand particles in the dredge material placed on the site, surface water and porewater was also collected to measure and document existing pH levels at both the augmentation site and the control site.

6) **Avian Use**. Shorebirds and other waterbirds were observed on the site by Refuge staff and volunteers in moderate numbers in early October, but subsequent visits in early November and early December yielded no sightings.

As of early December 2017, no observations of light-footed Ridgway's rails occurred within the augmentation site since the augmentation process was completed. Rails were observed near the site, with one rail observed on a nesting platform about 300 meters south of the augmentation site during a high tide survey conducted on November 6, 2017. Three nesting platforms were present at this location, but were not used for nesting during the 2017 breeding season and only one of these nesting platforms was used for nesting during the breeding season immediately preceding the augmentation process. Another group of six nesting platforms is located on the opposite side of the west channel from the augmentation site. Four of these platforms were present in 2015, when two were used for egg nests. Of the six platforms present in that location in December 2017, rails used two of the platforms during the 2017 breeding season. One was used for an egg nest and the other was used for a brood nest.

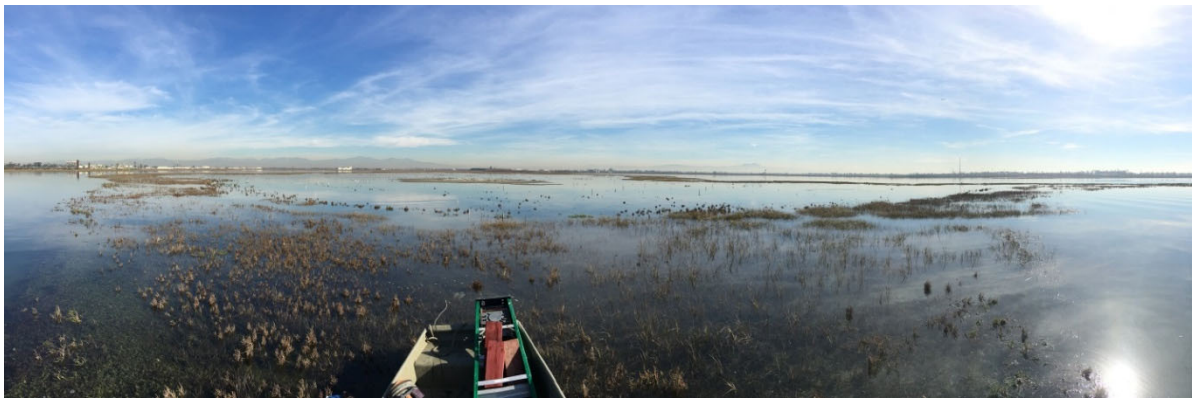


Figure 4. Taken November 2017 during a 5.5-foot high tide looking northeast from the south end of the augmentation site. Note that much of the site is inundated. Photo: USFWS, R. Nye.

January 1 – March 31, 2018

Research and Monitoring Activities and Observations:

1) **Plants and Invertebrates**. CSULB visited the site to evaluate plant growth during this quarter; however, no monitoring data was collected. The first quarter of each year involves only limited monitoring of plants and invertebrates, with the majority of the monitoring occurring between April and June and again between October and November of each year.

   CSULB reported that plant cover continues to slowly increase, with annual pickleweed still the predominate species on the site. Pacific cordgrass continued to be observed growing into the site from the buffer area. To understand how cordgrass might ultimately revegetate the site, a comparison of cordgrass elevations pre- and post-augmentation was conducted on the augmentation site. The results showed that cordgrass was re-growing in areas on the augmentation site at elevations slightly higher than previously recorded on the Refuge in a 2011 USGS survey[3]. The mean was 0.13 meters higher while the maximum present was only 0.03 meters higher showing that cordgrass may have hit its highest possible elevation at 1.51 meters NAVD88. These results are based on a limited number of cordgrass specimens, and those specimens are extending into the site from rhizomes of existing plants located in the adjacent buffer area. Additional analysis will be conducted when cordgrass is more abundant on the site.

   During this quarter, the CSULB team completed the processing of the fall 2016 invertebrate samples and began species identification. The samples remain very different from the preconstruction samples with lowered abundance, lower species richness, and altered community composition, as was expected. However, an increase was observed in invertebrate abundance and species richness since the spring 2016 sampling, when almost no invertebrates were observed. At eighteen months following augmentation (the last time collection occurred), CSULB observed an increase in oligochaetes on the augmentation site; however, these organisms were not yet present at pre-augmentation levels.

   Although cordgrass is not yet presence in the research plots, CSULB conducted photosynthesis analysis on cordgrass located elsewhere within the augmentation site, as well as on the control site. The results showed that cordgrass on the augmentation site, which occurs at higher elevations than the cordgrass on the control site, was photosynthesizing at higher rates than cordgrass on the control site.

2) In early February, the Refuge Manager observed many new pickleweed seedlings sprouting throughout the site (Figure 5), while cordgrass was generally limited to areas

[3] Takekawa, J.Y., Thorne, K.M., Buffington, K.J., Freeman, C.M., and Block G. 2013. Downscaling climate change models to local site conditions: San Diego National Wildlife Refuge Complex. Unpubl. Data Summary Report. U.S. Geological Survey, Western Ecological Research Center, Vallejo, CA. 88pp.

adjacent to the buffer zone and in some low spots on the site where cordgrass was previously present. The locations of cordgrass plants on the site were identified by recording GPS points around the outside perimeter of each cordgrass patch; polygons were then created from those files and added to an aerial photo of the site, as shown in Figure 6.

Figure 5. Numerous annual pickleweed seedlings were observed near last season's plants. Photo: USFWS/R. Nye.

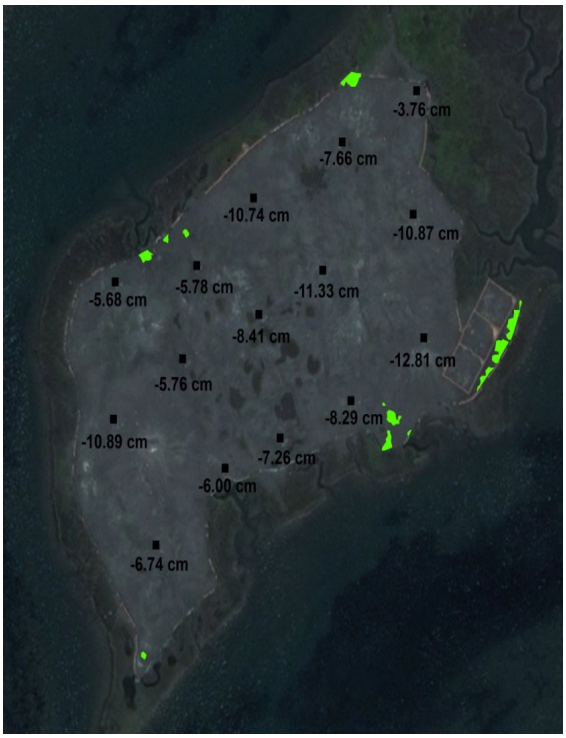


Figure 6. The green areas depict the locations where cordgrass is currently growing on the augmentation site.

The shapefiles were provided to USGS for incorporation into the elevation data obtained from each SET being monitored on the site. The change in elevation across the site following augmentation is also indicated on Figure 6.

3) **<u>Sediment Accumulation/Tidal Creek Accretion</u>**. UCLA conducted several additional site visits during this quarter to complete the process of photographing the four tidal creeks within the augmentation site for the purpose of documenting their physical characteristics (e.g., width, depth, configuration). Hundreds of photos were taken of each creek using a camera on a pole. The photographs were then processed using the Pix4D Mapper program to create an orthomosaic of the augmentation site tidal creeks. The team found that using the camera on a pole process had significant limitations. The use of a drone would have provided better results.

   As illustrated in Figure 7, 34 creeks and 10 dams were located within the augmentation site. Based on discussions with the project team, the Refuge Manager determined three of the existing hay bale/sandbag dams (identified as E, G, and I) should be notched to

allow tidal waters to move more freely on and off the site and to ensure that the entire site is inundated during a normal high tide. Notching was initiated by the Refuge Manager in February 2018. This process involved removing some sandbags from the areas where water was flowing over or through each of the selected dams. One or two layers of sandbags were also removed from the top of the dams.

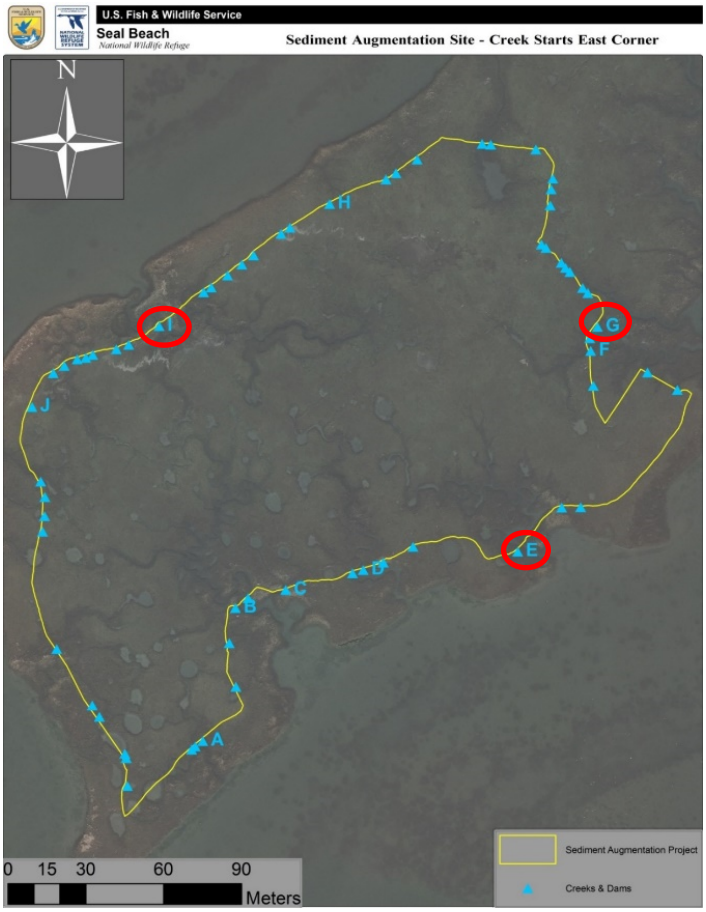


Figure 7. Location of tidal creeks and dams on the augmentation site in September 2017. Note: The dams indicated with red circles (Dams E, G, I) were notched in February 2018, and the underlying aerial photograph represents the site prior to augmentation.

Dam E was notched on February 13, 2018. Nineteen sandbags were removed from the obstructed creek opening and two layers (19 sandbags) were removed from the top of the remainder of the dam, making the top of the dam even with the adjacent sediment layer. Remnants of the hay bales were still present, so all hay bale twine that was found was cut and extracted from the dam and existing landscaping fabric was cut from the notched area. Dam G was notched on February 13 and 15, with all nine sandbags and landscape fabric removed from the dam. There were no hay bales in this area. Dam I was notched on February 21, with 15 sand bags and fabric removed from an area where the tidal creek was flowing through the dam. Additionally, 32 sand bags and fabric were removed from the top two to three layers. Dam I was at least twice as deep as Dam E, which accounts for the large number of sand bags removed from Dam I.

4) **<u>Turbidity/Sediment Flux</u>**. USGS provided their final report on sediment flux and turbidity patterns prior to, during, and post augmentation. The full report (USGS 2017) is provided as Attachment 4; a summary of the report's findings is provided below.

- Turbidity and sediment fluxes were monitored using two high-quality water sensing instruments (YSIs) and an acoustic Doppler current profiler (ADCP) in

the deep channel site (control) and in the eelgrass site (adjacent to the augmentation site) from November 17, 2014 to August 23, 2017.

- Mobilization of equipment and installation of the hay bale barrier began on January 4, 2016. Sediment application occurred between January 18, 2016 and April 4, 2016. Demobilization activities continued through April 7, 2016. Testing of sediment application began on January 18, 2016, with the first significant sediment application occurring on January 22, 2016.
- The contractors placed 55 percent of the dredge material during the last 24 percent of the project timeline due to the switch between an 8” and 12” diameter pipe. USGS calculated an average elevation increase of 8.66 inches across the augmentation site immediately following augmentation.
- Mean SSC at the deep YSI site was 6 and 7 mg/L before and after construction, while post-construction mean SSC at the eelgrass site was 2.4 times greater than pre- construction levels. This is likely due to the resuspension of material mobilized during construction activities as well as the closer proximity of the eelgrass site to the augmentation study site.
- Mean flux measured in the deep channel after demobilization was -0.04 g/m2/s, suggesting that little sediment is flowing out of the marsh complex after sediment application was complete.
- Mean SSC was greatest at both the eelgrass site (16 mg/L) and deep site (33 mg/L) during a storm on Jan 22, 2017, which yielded 9.3 cm (3.7 in) of rain.
- Switching from the 8” to 12” pipe increased sediment application rate, but also increased sediment runoff and local turbidity at the eelgrass site adjacent to the augmentation site.
- Sediment application impacts on water quality was only measured locally, and decreased with distance from application location.
- Monitoring of turbidity and sediment fluxes before, during, and after augmentation indicated that turbidity impacts were localized, relatively small, and short lasting after one year of post demobilization monitoring. The restored marsh surface also seemed to have stabilized during this same time period.
- Switching from an 8” pipe to a 12” pipe increased the rate of sediment application, causing an increase in sediment runoff. This is believed to be responsible for sediment covering an area of eelgrass adjacent to the augmentation site. USGS staff visited the project site and control site in late January 2018 to monitor surface elevations.

5) **Marsh Elevations**. The SETs on both sites which were measured on January 29, 2018, indicated that the augmentation site continued a gradual decrease in elevation dropping on average -0.94 mm across all fifteen SETs; while the control site also showed a small decrease of -1.34 mm across its six SETs. Control SETs have had gains and losses of elevation since installation, but have a mean cumulative increase of 3.22 mm since installation. Augmentation SETs had a mean increase in elevation of 216 mm with sediment application, but had a decrease in elevation of -82.19 mm post sediment application (April 2016 - January 2018; Figure 8).

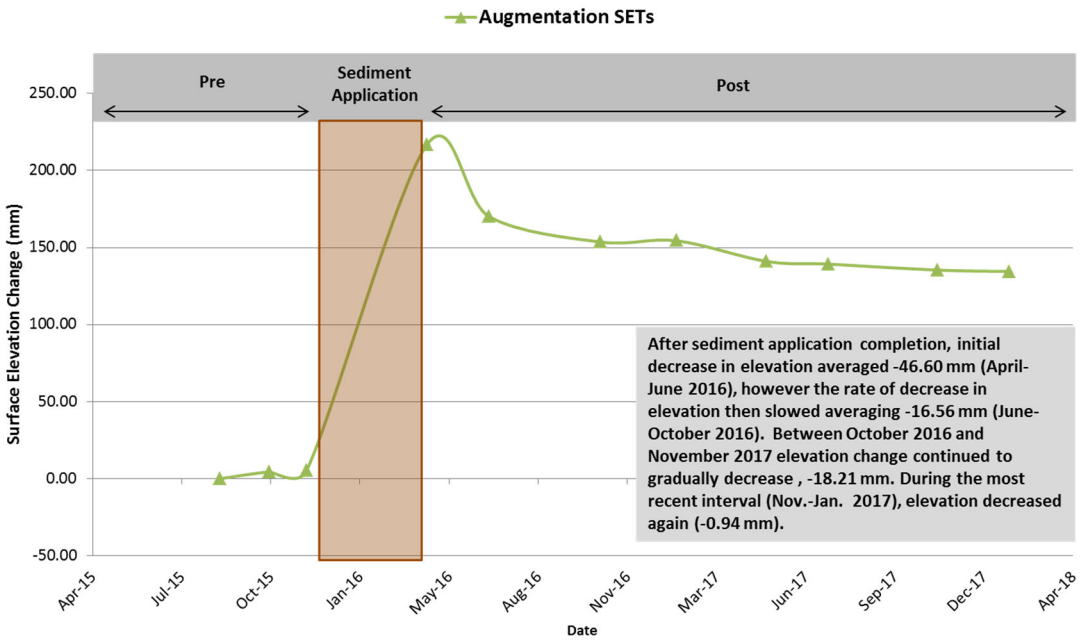


Figure 8. Mean surface elevation change at augmentation site.

The feldspar readings for the augmentation site showed an increase in sediment above the feldspar layer during this time period of 8.61 mm post sediment application (April 2016-January 2018). However, overall post monitoring has showed to this point little overall change in depth of the feldspar layer with a small decrease of -1.92 mm averaged across all 15 SETs. This finding shows that the majority of elevation decreases shown in the elevation pin measurements is most likely due to the original marsh surface compacting below the feldspar marker horizon.

6) **Greenhouse Gases**. Chapman University conducted sampling for greenhouse gas emissions in February 2018. Gas samples were collected from both the control and augmentation sites and analyzed for carbon dioxide, methane, and nitrous oxide. Surface porewater was also collected and redox in surface water was measured in the field.

7) **General Site Observations**. During visits to the site in early January, researchers and the Refuge Manager noted the presence of large areas of black mold or algae scattered throughout the site. In Figure 9, the organism appears as moldy spots on bread, while in other areas it covers the sediment in a thin (1-3mm) layer (Figure 10). Figure 11 depicts a sample at 5 times magnification. Samples were provided to the CSULB Wetlands Ecology Lab and were subsequently identified as cyanobacteria, which normally occur in salt marsh habitat.

Figure 9. Dark spots on the sediment are cyanobacteria.

Figure 10. Close up of the dark spots, note pickleweed seedlings in the cracks.

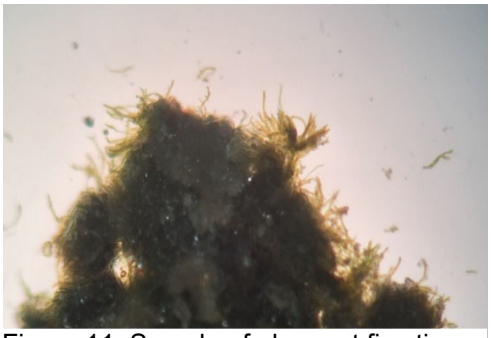


Figure 11. Sample of above at five times the magnification.

8) **<u>Avian Use</u>**. More than 1,000 shorebirds were observed on the augmentation site during monitoring visits in mid-February (Figure 12). On March 13, approximately 300 western and least sandpipers along with about 400 other shorebirds, and one great blue heron were observed on the site.

Figure 12. Shorebirds foraging in the augmentation site after a high tide.

April 1 – June 30, 2017

Research and Monitoring Activities and Observations:

1) **Plants and Invertebrates**. CSULB conducted their spring assessments (two years post sediment augmentation) of invertebrates, plant, and photosynthesis in April 2018. Their work included collecting invertebrate cores, recording plant coverage, conducting plant measurements, and analyzing cordgrass photosynthesis rates. Monitoring indicated that cordgrass was now present in one of the monitoring plots for the first time, presence of annual pickleweed on the site has is greatly increased over last year, and several new plant species were now present in low numbers on the site including *Sarcocornia pacifica* and *Batis maritima* (Figure 13). Cordgrass continues to expand into the site from the edges and is now occurring in greater numbers in some low-lying areas.

Figure 13. *Batis maritima* was observed on the site in April 2018. Photo: C. Whitcraft

The cyanobacteria observed all over the site earlier in the year continues to be present, as seen in the Figures 13 and 14.

Figure 14. Cyanobacteria continue to occupy the surface. Photo: J. Torres

Also noted was an increase in the overall abundance, species richness, and diversity of infaunal invertebrates. The community composition of invertebrates shifted from a dominance of oligochaetes and polychaetes to insects and insect larvae initially, but at eighteen months following augmentation, the increase in oligochaetes on the augmentation site notable, although the abundance and diversity is not yet at pre-augmentation levels. Insect larvae are still more abundant on the augmentation site.

During this quarter, CSULB also completed invertebrate sorting and identification for the top 2 cm samples for all samples collected including fall 2017. Processing for spring 2018 samples was ongoing with 17 of 39 samples sorted to date. Invertebrate vouchers were in process for identification to lowest taxonomic level. In addition, the bottom 4 cm samples for all prior time points continued to be sorted.

CSULB also prepared a pre-proposal to USC SeaGrant related to a grant for future experimental planting work within the project site. Unfortunately, an invitation to prepare a full proposal was not granted. We are considering submission to SeaGrant rapid response, as well as other potential funding sources.

2) **Sediment Accumulation/Tidal Creek Accretion**. Tidal creek formation continued to be a topic of discussion during this quarter. In June, the team reviewed the effects of the notching conducted in February 2018. Based on observations made by Dr. Ambrose in May, the effects appear to be minimal with little change to the configuration and depth of the creeks observed. As a result, additional photomosaics were not conducted by UCLA during this quarter. Creek formation was scheduled for reevaluation in July 2018, at which time the project team would consider the potential need for more significant notching of the tidal creek dams. The ultimate goal is to remove all of the barriers, but it was agreed that this should be done in a manner that allows for monitoring of the effects, as well as to ensure that sediment does not move off the site and impact adjacent eelgrass beds.

   UCLA conducted sampling on the augmentation site and control site for sediment accretion and bulk density. Sediment accretion data was collected by measuring sediment stakes and feldspar (pre- and post-augmentation) plots at augmentation site. Coring to collect bulk density samples were conducted adjacent to the feldspar plots for laboratory analysis. Feldspar/bulk density cores were then processed in the laboratory to measure bulk density, percent organic carbon, and grain size.

   To document the initial changes to the tidal creeks that were previously notched, the UCLA team had planned to create subsequent photomosaics in mid-May, however, site visits indicated little change in creek configuration and depth since the initial notching process. As a result, it was determined that the first analysis of any changes would be conducted using data to be provided in August 2018 when a photogrammetry survey, funded by ACOE, would be conducted to provide updated elevation data for the site.

The photogrammetry survey would provide up-to-date elevations within and adjacent to the tidal creeks following notching and would facilitate a comparison of the elevations pre- and post-notching.

3) **Sediment Nutrients**. During this quarter, the topic of nutrient content within the sediment placed on the site was revisited. The team expressed an interest in examining the nutrient levels in the sediments applied to the site and the potential effect that nutrient levels could have on recolonization of the site by cordgrass and other salt marsh vegetation. This issue has continued to be a question because the grain size of the applied sediment was larger than expected. The team determined that understanding all the potential factors (e.g., elevation, grain size, low or the lack of nutrients) that might inhibit the regrowth of cordgrass on the site should be explored. Dr. Whitcraft and Dr. Keller have stored pre- and post- augmentation samples of sediment, pore water, and vegetation that can be analyzed for nutrient content. Dr. Whitcraft prepared a proposal and cost estimate for conducting the analysis. The California State Coastal Conservancy subsequently agreed to fund the proposal using the remaining funds in their grant for the augmentation project.

4) **Marsh Elevations**. USGS collected data from the SETs and conducted feldspar readings in April and early July 2018. Overall results from elevation pin measurements indicate that the augmentation site experienced a gradual increase in elevation of 1.43 mm averaged across all fifteen SETs over the period April through July 13 (Figure 15), while the control site showed a slightly larger increase of 3.97 mm across its six SETs (Figure 16). The original SETs (n=4), located elsewhere on the Refuge also showed an increase of 3.53 mm.

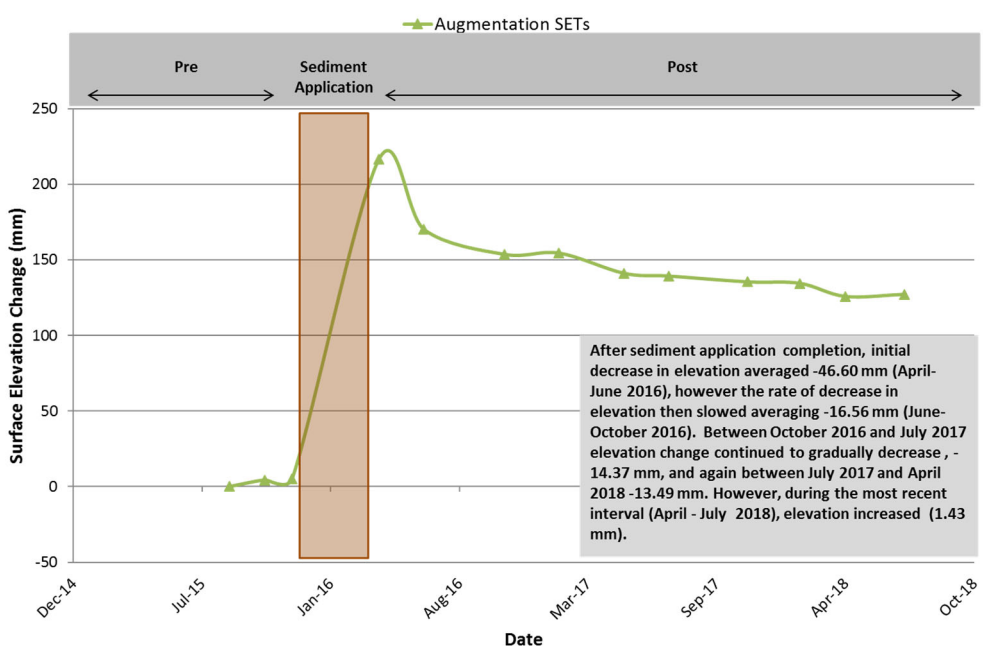


Figure 15. Changes in elevation based on SET readings at the augmentation site.

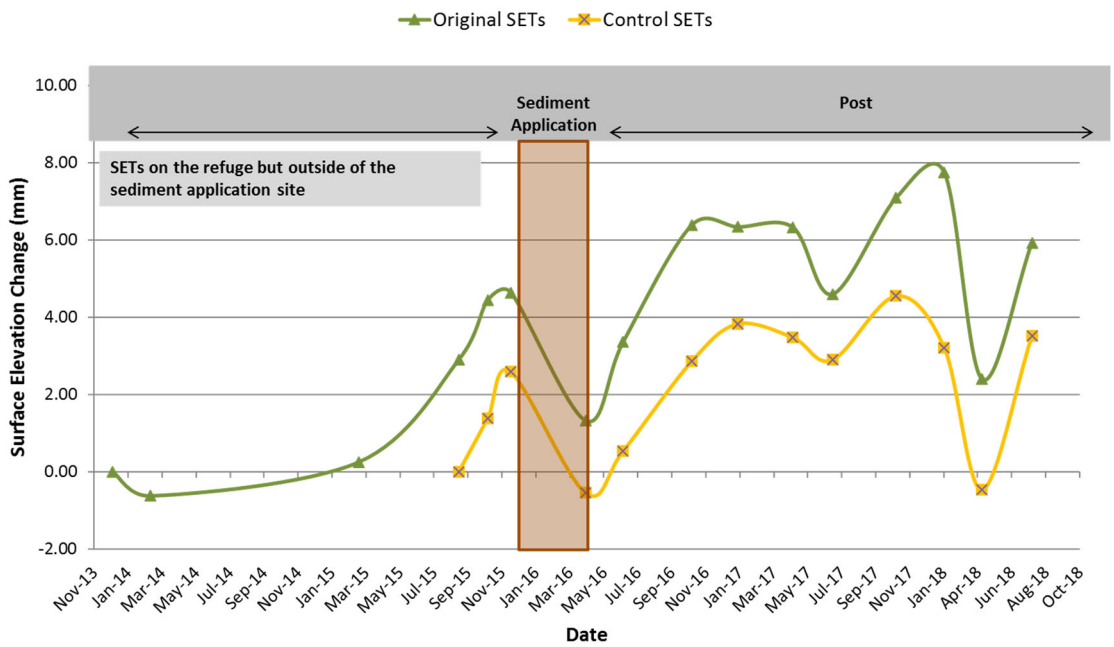


Figure 16. Changes in elevation based on SET readings at the control site.

The feldspar readings showed a decrease in sediment above the feldspar layer during this quarterly time period for the augmentation site with a decrease of -5.97 mm. However, overall post monitoring indicated little overall change in depth of the feldspar layer with a small decrease of -18.21 mm averaged across all 15 SETs. The majority of elevation decreases shown in the elevation pin measurements are most likely due to the original marsh surface compacting below the feldspar marker horizon, while the rest could be due to the compaction and/or loss of the applied sediment.

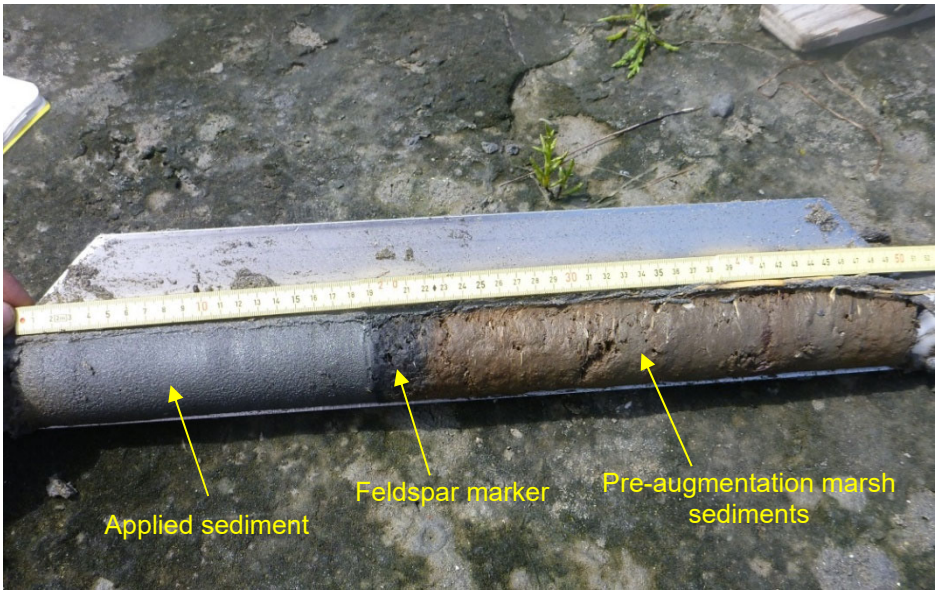


Figure 17. Core sample from a feldspar plot. Photo: USGS

5) **Greenhouse Gases**. Jason Keller (Chapman University) and his team conducted their final sampling related to greenhouse gas flux in April 2018. Gas samples were collected from both the control and augmentation sites and analyzed for carbon dioxide, methane, and nitrous oxide. Surface porewater was also collected and redox in surface water was measured in the field. Measurements indicated that greenhouse gas fluxes at the augmentation site were no higher than those at the control site, with no releases of methane or nitrogen oxide identified.

6) **Eelgrass Surveys**. MTS performed side-scan and SCUBA eelgrass surveys of the study area and reference area on May 14 and 15, 2018, respectively. The goals of the survey were to provide two-years post sediment augmentation eelgrass maps, eelgrass cover estimates, and eelgrass density estimates within each survey area. Results of the surveys are expected in July 2018. Once final, the results of the surveys will be shared with NOAA.

7) **Avian Use**. No birds were identified on the site during the monthly high and low tide surveys. This is due to the timing of the surveys, which are occurring when the site is completely submerged or totally exposed. The Refuge Manager however continues to observe a variety of shorebirds on the site when the tides are more favorable for foraging and loafing. To better capture bird use on the site, the timing of the avian surveys for the project site will be revised and implemented beginning in the next quarter. The new timing for these surveys will continue throughout the remainder of the monitoring program. No light-footed Ridgway's rails were observed on the site during this quarter.

July 1 – September 30, 2018

1) **Eelgrass Surveys**. The report for the year 2 post construction eelgrass study conducted by MTS was completed on July 17, 2018. The results indicated that eelgrass coverage in the adjacent channels 2-years post-augmentation was 96,389 m2 (36.6% cover); pre-construction eelgrass coverage was 110,892 m2 (42.1% cover). The survey indicates that the project appears to have had localized impacts to eelgrass, but recovery continues to be observed. Karen Thorne, USGS, suggested that some of the observed changes in eelgrass coverage could also be the result of ocean conditions (e.g., El Niño and associated higher water temperatures, atmospheric rivers) that occurred at the same time as the project was being implemented. It was also noted that eelgrass in the 7th Street Pond underwent a significant reduction in eelgrass coverage over the last few years and is now recovering. The cause is not clear, but could have been the result of sea turtle foraging and/or ocean factors.

   There is one location adjacent to the project site where the sediment depths are higher than pre-project conditions, resulting in localized impacts to approximately 500 square meters of eelgrass. The survey report has been forward to NOOA Fisheries and the ACOE for evaluation.

2) **Plants and Invertebrates**. Fall sampling of plants and invertebrates was conducted in October 2018. Site observations during this quarter indicate that the site continues to revegetate, but cordgrass recovery is still slow. Revegetation of the site by annual pickleweed continues and its presence is expanding throughout much of the site. Dense pickleweed growth was also observed in spaces between the three experimental test plots where higher elevations of sediment were applied.

3) **Proposal for Supplemental Cordgrass Planting**. During the team's quarterly conference call, the potential for initiating a cordgrass planting program to supplement cordgrass recovery was once again discussed. It was agreed that the proposal should be designed to address specific research questions. Additionally, the cordgrass planting proposal should include details regarding where and how to do the planting (e.g., in one area or in plots). Perhaps areas where cordgrass is already growing should have a lower priority for planting than areas further within the interior of the project. Factors such as the configuration of the plantings (e.g., plugs planted in clumps, plugs spread throughout an area) should also be considered. Team member felt that setting up the planting program as an experiment, would enable the team to observe the survival rates of different planting methods. Incorporating a scientific approach to the planting proposal would also provide valuable information for other land managers considering this process and may provide insight into how to address revegetation in areas where the sand content of available dredge material is higher than that present within the existing marsh plain. This information will be enhanced by the results of the ongoing nutrient study. The proposal would will need to developed and funding identified by late spring/early summer of 2019 in order to begin planting in fall 2019.

4) **Marsh Elevations**. USGS collected data from the SETs and feldspar plots on September 23, 2018. Elevation pin measurements showed that the augmentation site experienced a gradual decrease in elevation of -1.76 mm averaged across all fifteen SETs over this quarterly time period, while the control site showed a slight increase of 0.81 mm across its six SETs. The original SETs (n=4) located elsewhere on the Refuge also showed a larger increase of 2.14 mm (Figure 18). Control SETs have had gains and losses of elevation since installation but have a mean cumulative increase of 4.33 mm from the date of installation (Figure 19). Augmentation SETs had a mean increase in elevation of 216 mm with sediment application, but had a decrease in elevation of -91.23 mm post sediment application (April 2016-Sept 2018; see Figure 18) and therefore a mean cumulative increase in elevation of 125.44 mm.

   The feldspar readings showed a decrease in sediment above the feldspar layer during this quarterly time period with a decrease of -4.67 mm. However, overall post-augmentation monitoring has showed little overall change in depth of the feldspar layer with a small decrease of -22.88 mm averaged across all 15 SETs. This finding indicates that the majority of elevation decreases measured in the elevation pin measurements is most likely due to the original marsh surface compacting below the feldspar marker horizon, although some decease could be attributed to the compaction or loss of the applied sediment.

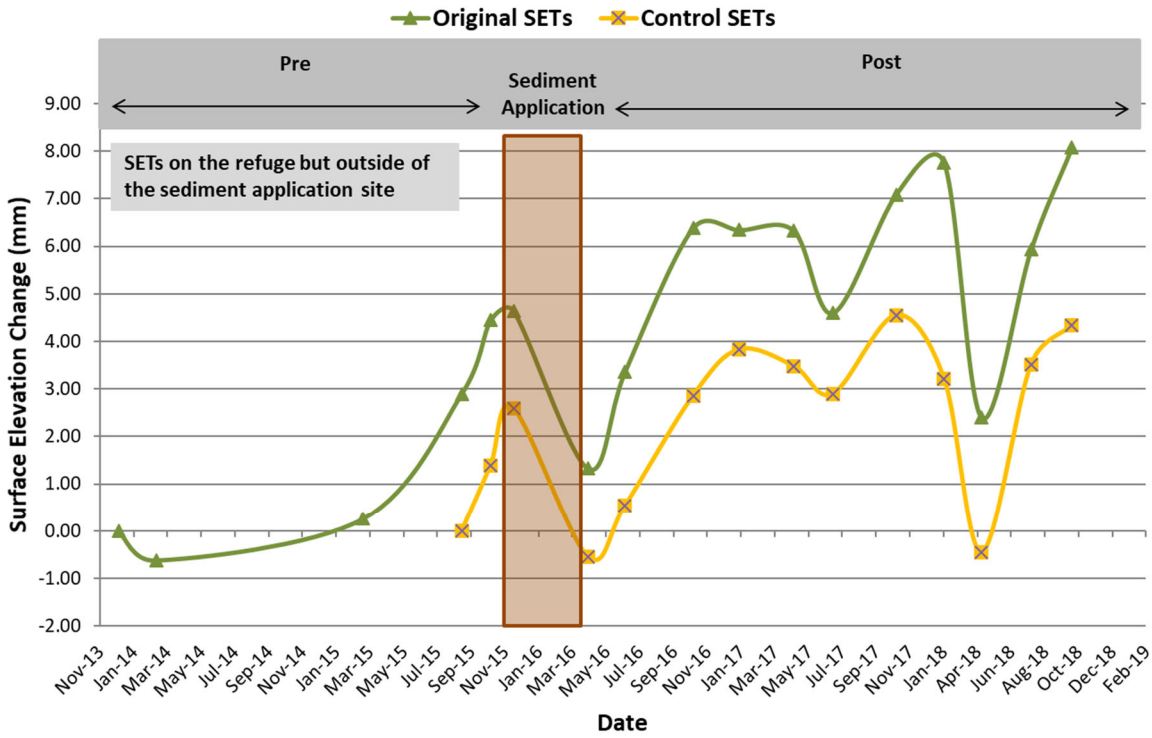


Figure 18. Changes in elevation based on SET readings at the augmentation site.

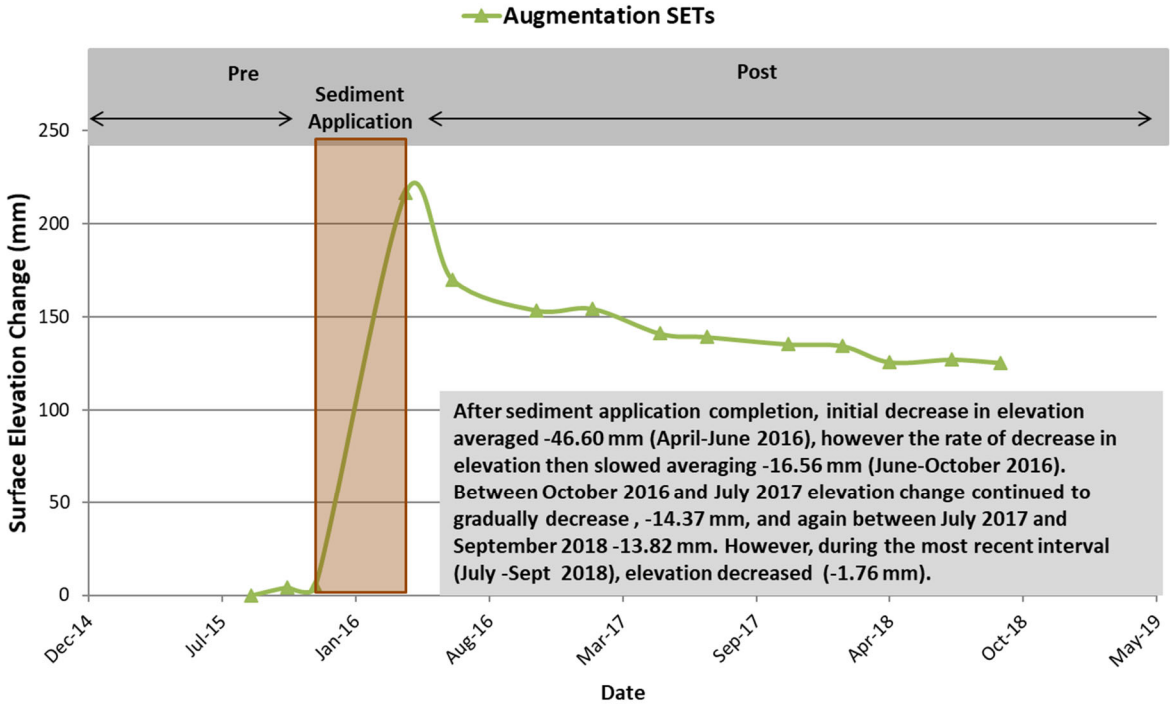


Figure 19. Changes in elevation based on SET readings at the control site.

Feldspar readings at the control site showed a small decrease of -1.49 mm over this quarterly time period, whereas the original SETs feldspar readings showed an average increase of 3.95 mm.

The results continued to show losses and gains in total elevation across the site, indicating that the elevations had not yet stabilized. Minor changes in elevation were recorded at the various SETs, but the results were not trending together. Other SETs monitored by USGS within the Refuge may indicate seasonal changes, but SETs on the augmentation site were more variable. It is unclear why this is occurring. UCLA will review the results of the measurements taken at the sediment stakes, as this information would indicate any changes in elevation at the surface versus the elevations at depth that are provided by the SETs. This information may assist in identifying a possible reason for the variability.

5) **Photogrammetry Flight**. Photogrammetry targets were installed on the augmentation site on August 17, and the photogrammetry flight was conducted Aug 22, 2018. This was the second photogrammetry flight conducted for the project. The first was conducted following completion of the augmentation process to establish the site elevations immediately after augmentation. The second flight will allow the team to determine how the elevations have changes across the site two years post augmentation. The information will also assist the team in the evaluation of tidal creek formation across the site. Funding for both flights was provided by the ACOE Engineer Research and Development Center.

6) **Avian Use**. The Refuge Manager observed high number of shorebirds on the site during this quarter. On August 17, an estimated 1,000 shorebirds were observed during a 2.5-foot rising tide. A light-footed Ridgway's rail was also observed for the first time since augmentation. The rail was seen in the buffer zone adjacent to the site as it moved across the mouth of a tidal creek and disappeared back into cordgrass near the large creek system on the western point of the augmentation site.

Summary of Site Conditions

Site Elevations: The first SET data post-augmentation was collected on April 15, 2016, 72 days later on June 28; a decrease in elevation was measured at all locations. The change ranged from 1" to 2-3". The lack of evidence of sediment moving off the site and the presence of deposition on the feldspar plots supports the conclusion that this decrease was likely from consolidation of the new sediment or compaction of the sediments below the added material.

Post-augmentation elevation surveys were also conducted by GPSi, who flew a photogrammetry elevation survey on April 18, 2016 and delivered a Digital Terrain Model (DTM) as well as shapefile elevation points for interpolating digital elevation models (DEM) for comparison with the pre-augmentation surveys. The post-augmentation surveys showed a mean elevation for the control site of 1.15 meters, whereas the mean elevation for the augmentation site was 1.45 meters. Within the augmentation site, the area affected by the application of sediment had a mean elevation of 1.63 meters, while the buffer area had a mean elevation of 1.30 meters.

In August 2016, the elevation and accretion changes, as measured with SETs and feldspar plots, varied within and between the augmentation site and the control site. The average elevation change for the augmentation site between pre and post augmentation was +23.4 cm (+9.23 in). The control site showed a decrease in elevation of -0.39 cm (-0.16 in), averaged across all six control SETs. Based on the most recent measurements, which were taken in August 2018, the augmentation marsh has experienced a 28.92 mm/yr rate of change due to the sediment application. However, due to subsidence or sediment leaving the marsh the post augmentation time period has a -27.97 mm/yr rate of change. The control site has a 1.02 mm/yr rate of change and the original SETs, located elsewhere in the Refuge, have a 1.48 mm/yr rate of change. These trends are similar for the feldspar data.

GPSi conducted a follow-up photogrammetry elevation survey August 22, 2018. A DTM, as well as shapefile elevation points, have been provided. A summary of this data will be provided in the October 1, 2018 – December 31, 2018 quarterly report.

Invertebrates: The spring 2018 cores taken from the project site indicated an increase in the overall abundance, species richness, and diversity of infaunal invertebrates. The presence of oligochaetes on the augmentation site continues to increase, but has not reached pre-augmentation levels. Insect larvae still dominate at the augmentation site.

Plants: Plant community monitoring is ongoing. The presence of annual pickleweed continues to increase and as of April 2018, cordgrass was confirmed in one of the monitoring plots. Also in April 2018, several other salt marsh plant species were observed growing in the site including *Sarcocornia pacifica* and *Batis maritima*.

Bird Use: Shorebird use of the site continues to increase and in September 2018, a light-footed Ridgway's rail was observed in the area for the first time since the commencement of the augmentation process. The original protocols for conducting avian surveys on the augmentation site were no providing useful data; as a result, monthly site-specific surveys will be conducted. The results from the first set of site-specific surveys are provided in Table 1.

Table 1. Avian Monitoring Results for the July – September 2018

Date	11 July 2018	17 Aug 2018	26 Sept 2018
Time	11:30 AM	10:30 AM	11:00 AM
Tides	0.96m (3.1-ft), falling	0.75m (2.5-ft), rising	1.65m (4.8-ft), falling
Caspian tern			2
Black-necked stilts		4	
Willet		7	
Long-billed curlew		2	
Whimbrel		1	
Ruddy turnstone		3	
Black bellied plover		47	200
Least/western sandpiper	600	500	
Other sandpipers (*Calidris sp.)*		470	

Site Photos: Photos and videos continue to be taken of the site to document changing site conditions. These are archived in the project files and are available upon request. Photos taken between October 2017 and September 2018 are provided as Attachment 2.

Eelgrass Survey: Based on the results of the year 2 post construction eelgrass study conducted by MTS eelgrass coverage in the adjacent channels is continues to recover. There is one location adjacent to the project site where the sediment depths are higher than pre-project conditions, resulting in localized impacts to approximately 500 square meters of eelgrass. It may be necessary to conduct another survey 3 years post augmentation to more fully understand how eelgrass recovery is progressing. The MTS report is provided as Attachment 5.

Project Outreach/Information Dissemination

A webpage (https://www.fws.gov/refuge/seal_beach/what_we_do/ resource_ management/ Sediment_Pilot_Project.html) for the project is maintained on the Seal Beach NWR website. Information about the sediment augmentation project is posted and progress on the project is updated as necessary. Quarterly reports prepared for CDFW are also posted, and photos and links to time lapse photography are provided. The page also acknowledges our funding partners.

Many members of the project team have participated in presentations, seminars, conferences, and webinars. A number of these public outreach efforts are listed below.

- A webinar entitled: Testing a Novel Adaptation Strategy in a California Salt Marsh. Karen Thorne, USGS Western Ecological Research Center, and Evyan Sloane, California State Coastal Conservancy presented the lessons learned from the project to date via a widely noticed webinar held on March 15, 2018 as part of the Restoration Webinar Series. This webinar series is a partnership between the National Oceanic and Atmospheric Administration and the U.S. Fish and Wildlife Service. The webinar was initially viewed by 219 people from 23 states plus Canada, and continues to be available for viewing online at https://fws.rev.vbrick.com/#/videos/071d7a44-047d-46e7-b437-d849648d393c. This link is also provided on the project website.

- On July 11, 2018, the Refuge Manager facilitated a site visit for four high school interns from The Nature Conservancy's (TNC) Leaders in Environmental Action for the Future (LEAF). These young women assisted USGS with recording SET readings on the augmentation site, measuring depths in feldspar plots and conducting coring of sediment in creeks in the buffer zone of the project site.

Figure 20. A LEAF participant assists USGS staff in retrieving a core from a feldspar plot. Photo: USGS

- On August 7, 2018, Rick Nye, the Refuge Manager, conducted an interview with California State University Long Beach Public Affairs to talk about the augmentation project. This interview supplemented a story being written about the Wetlands Ecology Lab's role with the Sediment Augmentation project. Christine Whitcraft, Ph.D. runs this lab. The content of this interview was disseminated by a variety of different news outlets.

  The original write-up was prepared by the CSU Long Beach Office of Public Affairs on August 27, 2017 and is provided as Attachment 6. The article can also be accessed at: http://web.csulb.edu/newsroom/long-beach-state-university-researchers-helping-to-preserve-southern-californias-coastline/

  The Long Beach Post published an article on September 3, 2018 that is provided as Attachment 7. It can be viewed at: https://lbpost.com/news/education/csulb-researchers-seal-beach-wildlife-refuge-sea-level/

  On September 6, 2018, the Long Beach Grunion Gazette published a similar article, provided as Attachment 8 and on September 11, 2018, ABC7 (a television station in Los Angeles) published a video and write up about the project, which can be viewed at: https://abc7.com/society/sea-level-rise-endangering-seal-beach-wetlands-/4206075/

- Elizabeth Murray (ACOE) gave a presentation at the National Conference on Ecosystem Restoration in New Orleans (Aug 26-30, 2018) that address the sediment augmentation process implemented at the Seal Beach NWR.

Status of Ongoing Research

UCLA (SEDIMENT CORING): UCLA researchers under the direction of Dr. Glen MacDonald completed their analysis and prepared the final results of their assessment of pre-augmentation net sediment accretion rates, carbon stock, carbon accumulation rates, and historic sea-level rise on the Seal Beach NWR from historic sediment core data. The final report (Brown et al. 2018) describing the results of the analyses of historic sediment core data from the project site is provided as Attachment 2.

CHAPMAN UNIVERSITY (GREENHOUSE GAS FLUX): Sampling to measure seasonal emissions of CO_2, CH_4, and N_2O and associated abiotic parameters (i.e., water level, porewater salinity, sulfate and nitrate) in the three dominant plant communities at Seal Beach NWR, including the project site pre- and post- augmentation, has been completed. Dr. Jason Keller and his team are completing their analysis and preparing their final report.

UCLA (CHANGES IN MARSH PLAIN POST-AUGMENTATION): Under the direction of Dr. Richard Ambrose, sediment thickness continues to be sampled at multiple locations distributed across the project area. Two types of sampling stations have been established on the marsh plain: consolidated stations including feldspar plots, sediment stakes and bulk density sampling

locations, and sediment stake stations. This research team also continues to monitor and assess newly forming tidal creeks on the site. This data will provide insight into how tidal creeks form or reestablish following augmentation.

CSU LONG BEACH (PLANT AND INVERTEBRATE STUDIES): Dr. Christine Whitcraft (CSULB) and her students continue to monitor plant and invertebrate diversity, abundance, and distribution, as well as associated abiotic parameters (e.g., temperature, porewater salinity, redox), of the control and augmentation sites both pre- and post-augmentation. Plant community sampling locations are co-located with the invertebrate sampling locations, and these locations were selected in collaboration with USGS and UCLA so that the sampling locations overlap with placement of sediment monitoring stakes.

These researchers are also assessing the ability of plants and sediment to store carbon by collecting data on the photosynthetic rate of plants, C:N ratios of plants, plant traits (e.g. leaf area), and isotope ratios in sediment. Initial results indicate that the cordgrass present in the augmentation site and control site is photosynthesizing at comparable rates. Site sampling will occur again in spring 2019.

USGS (SEDIMENT FLUX PATTERNS AND SETS): Between winter 2014 through the end of August 2017, USGS maintained two YSI EXO2 multi-parameter sondes (ysi) to monitor turbidity and a Nortek aquadopp current profiler (ADCP) to monitor inundation and flow velocities within tidal channels located in proximity to the augmentation site. A final report has been issued.

USGS will continue to obtain data from 21 deep rod surface elevation tables (SETs) (15 SETs in the sediment augmentation area and 6 SETs in the control area) installed in August 2015. This information will be used to assess changes in elevation, including accretion and shallow subsidence, before, during, and immediately after sediment application at the sediment augmentation site. Results related to elevation changes at the augmentation site will continue to be compared to data obtained from the control site.

BIRD SURVEYS AND LIGHT-FOOTED RIDGWAY'S RAIL MONITORING: Bird surveys were initially conducted twice monthly, during a high tide and a low tide, however, due to the timing of the surveys, observations were occurring when the site was either completely submerged or totally exposed. As a result, no birds were being recorded on the site during these surveys. To provide better bird data, the Refuge Manager recently initiated site-specific surveys for the augmentation site. These surveys, to be conducted during moderate falling and/or rising tides, will continue throughout the remainder of the monitoring program.

Rail monitoring is conducted as part of a refuge-wide rail monitoring survey. Annual monitoring reports are prepared following the end of the rail nesting season. A high tide count is conducted in fall and a night call survey is conducted just prior to the start of the breeding season. Nesting data is obtained through monthly visits to the nesting rafts. Data for the 2018 nesting season is expected to be available in December 2018.

EELGRASS SURVEYS: As part of our effort to understand the overall physical and ecological responses of the marsh ecosystem, which includes adjacent eelgrass habitat, the project included requirements for pre- and post-augmentation eelgrass surveys. To date four surveys have been conducted: pre-augmentation, immediately following augmentation, and one and two years post-augmentation. Survey results have been provided to CDFW, NOAA Fisheries, and ACOE.

Percentage of Task Completed as of September 30, 2018

Task 1 – Project Management and Administration		65%
Task 2 – Sediment Augmentation		100%
Task 3 – Project Monitoring (overall)		78**%**
1) Carbon Storage/Sequestration Benefits	100%	
2) Plant and Invertebrate Monitoring	65%	
3) Pacific Cordgrass Analysis	65%	
4) Site Elevations	65%	
5) Sediment Analysis (compaction, movement, bulk density)	65%	
6) Turbidity Levels	100%	
7) Bird monitoring	65%	
8) Eelgrass	100%	
Task 4 – Engineering Design/Environmental Documentation (overall)		100%
1) Engineering Plans for Sediment Augmentation Site		100%
2) Environmental Documentation*		100%
*CEQA/NEPA has been completed by SCC/USFWS		
Task 5 – Public Participation/Presentations (overall)		52.5%
1) Oral/Poster Presentations	70%	
2) Workshops and/or Webinars	35%	
Overall Project		**85%**

Deliverables Completed for Each Task

Task 1 – Project Management and Administration

1) Quarterly Progress Report	13 reports (This annual report also serves as the July 1 – September 30, 2018 quarterly report.)
2) Monthly Invoices	30 monthly invoices (include attached)
3) Subcontractor Selection	Orange County Parks & SWIA selected
4) Data Management	preliminary data for monitoring locations
5) Acknowledgement of Credit	ongoing

Task 2 – Sediment Augmentation

1) Sediment Application	completed
2) Adaptive Management	on going
3) Reporting Results/Lessons Learned	in process

Task 3 – Project Monitoring

1) Carbon Storage/Sequestration Benefits	pre-augmentation monitoring completed; long core data processing complete; post-augmentation monitoring underway; long core data final report in preparation
2) Plant and Invertebrate Monitoring	pre-augmentation work completed; post augmentation work underway
3) Pacific Cordgrass Analysis	pre-augmentation work completed; post augmentation monitoring underway
4) Site Elevations	pre-augmentation RTK survey; post-augmentation photogrammetry; SET data downloads continuing; monitoring of feldspar plots continuing
5) Sediment Analysis	initial core samples retrieved; data processing nearing completion; grain size analysis of new sediment nearing completion
6) Turbidity Levels	monitoring completed in August 2017; final report underway
7) Bird Monitoring	pre-augmentation work completed; post augmentation work ongoing
8) Eelgrass	pre-augmentation, post- augmentation and year one and year two post-augmentation surveys completed

Task 4 – Engineering Design/Environmental Documentation

1) Engineering Plans for Augmentation Site	100% engineering plans completed
2) Environmental Documentation*	CEQA/NEPA documents final; ND recorded *for USFWS and Coastal Conservancy

Task 5 – Public Participation/Presentations

1) Oral/Poster Presentations	Presentations ongoing
2) Workshops and/or Webinars	Participated in USACOE webinar; primarily results presentation planned for early 2019

Problems/Delays Proposed Resolution

Sediment Augmentation - As indicated in previous reports, we were not able to fully achieve our sediment augmentation site acreage or uniform coverage objectives for the project site. Unexpected outcomes of the sediment augmentation process included: 1) achieving sediment coverage over at total of 7.87 acres rather than 10 acres as originally proposed; 2) achieving a less uniform coverage of sediment than anticipated (overall coverage was closer to 10” ±2”, rather than 10” ±1”); and 3) the sediment delivered to the site contained a much greater

percentage of sand than the grain size analysis conducted for the dredge sites had implied. Additionally, due to contractor error, a portion of the site received up to 20” of sediment, rather than the 10” identified in the contract. All of these outcomes will be addressed in a forthcoming lesson learned document.

The reduction in acreage covered by sediment can be attributed to needing more sediment to fill in the ponds and creeks within the application area. The fluid nature of the sediment when it was being applied meant that it filled in every low-lying area first. Instead of matching the contour of the site, the sediment filled in such that the surface was level. This resulted in needing more sediment to fill in the low-lying areas in order to get 10” on the marsh plain.

The effects of the variability in sediment thickness will be determined as post-augmentation monitoring continues. Because the research plots for studying sediment depth and elevation were collocated with plant and invertebrate monitoring sites, the differences in sediment depth access the site are not expected to significantly influence study results.

To better understand the sand to silt ratio of the sediments delivered to the site, we identified additional funding that enabled us to conduct grain size analysis of the dredge material that was applied to various portions of the site. This information will be helpful in understanding the timeframes for and species diversity associated with plant reestablishment and invertebrate recolonization.

Changes in Eelgrass Distribution – The post-augmentation and one year post-augmentation surveys indicated a declining trend in the areal extent and density of eelgrass in the project study area, while the reference site showed an increase in areal extent and density one-year post augmentation. There is no definitive evidence at this point that the augmentation process is solely responsible for this decline, and during the one-year post augmentation survey, areas known to be impacted during augmentation were showing signs of recovery. At two years post-augmentation, the affected area is now showing strong eelgrass recovery, but has yet to return to pre-construction levels of eelgrass cover.

Although the eelgrass survey conducted in May 2018 showed improvement in eelgrass coverage, the current coverage does not yet match pre-project conditions. There are various factors that could be affecting coverage, including both project and non-project conditions. To determine if recovery is continuing, we are currently considering conducting another eelgrass survey in May 2019 using some of the remaining funds in the current CDFW grant budget. Since eelgrass loss is occurring in other wetlands along the California coast, continuing with our series of annual surveys may benefit those who are trying to understand changes in eelgrass distribution elsewhere.

Nutrient Analysis in the Augmented Site - Although not currently identified as a problem, the research team has been discussing the importance of understanding the role of nutrients in the sediment that has been added to the project site, particularly because the original intent was to apply sediment with a higher clay and silt content. The results of an analysis of nutrient content in pre- and post-augmentation sediments and in salt marsh plants from the site can inform other

land managers of the relative importance of sediment grain size and nutrient content in sediments to be considered for use in thin-layer sediment application projects. As a result, the California State Coastal Conservancy has allocated their remaining funds for this project to the completion of a sediment nutrient study. The study will analyze material from stored sediment cores and plant tissue taken from the site prior to augmentation, along with sediment and plant samples present on the site today. This study will allow the project team to determine the extent of differences in nutrient content between the native marsh sediment and the new sediment that has been added to the site. It may also provide a better understanding of the relationship between nutrient content and current plant growth on the site.

Tidal Creek Formation – The project team continues to study the importance of tidal creek development in the reestablishment of native plants and invertebrates on the augmentation site. Initial notching did not result in increases in the rate of tidal creek formation, but it also did not result in increases in the loss of sediment from the site. Therefore, additional notching and/or complete dam removals will occur in other areas of the site over next few quarters.

Reestablishment of Cordgrass – Cordgrass continues to return to the site, but not at the rate the anticipated. Therefore, our project team is considering a cordgrass planting proposal that can be implemented in a manner that will provide research value. Factors to be explored could include the benefits of planting in one area or in various plots and planting plugs that are arranged in clumps versus spreading the plugs out. An experimental planting program should also be setup to include monitoring of survival rates of the different planting methods. Because we are dealing with sandy soils, incorporating a scientific approach to the planting proposal could provide other land managers with valuable information.

The team is currently preparing a proposal and will submit it for CDFW's consideration. Our intent is to use some of the remaining funds provided in the project in our current budget for implementing this proposal.

Project Benefits and Results

Thin-Layer Sediment Augmentation. Although it is too early in the project to fully address project benefits and results, we have already learned quite a bit about the sediment augmentation process and can suggest changes to the process that will benefit future projects. Some of this information has already been addressed at various workshops and seminars, as described above. Ongoing analysis of the effects of higher sand content in the sediment used for augmentation will provide important information for future projects, particularly because sediment with a higher sand content may be more readily available for use in thin-layer projects. Early data from the site suggests that some salt marsh vegetation, including cordgrass, can be supported at elevations higher than are currently present within the Refuge. This is important information that can be used to design future thin-layer projects. This and other information will continue to be recorded and disseminated to all interested parties.

Greenhouse Gas Assessment. The results of radiocarbon (^{14}C) dating of long cores taken from the Seal Beach NWR by UCLA researchers indicate an average long-term accretion rate at the Refuge of 1.55 ± 0.16 mm yr^{-1}, which is typical for accretion rates obtained from ^{14}C. In addition, radiocesium (^{137}Cs) and radiolead (^{210}Pb) dating results from three control site and four augmentation site cores had an average ^{137}Cs- and ^{210}Pb-measured accretion for all cores of 3.2 ± .21 mm yr^{-1}, with average ^{137}Cs-measurements showing slightly higher accretions rates (3.2 ± .28 mm yr^{-1}) compared to ^{210}Pb-measurments (3.1 ± .33 mm yr^{-1}) (Figure 3). Variation in accretion rates between control and augmentation for all methods was consistently < 0.5 mm yr^{-1}, and only significant using ^{210}Pb methods.

Using the chronological control obtained from ^{14}C, ^{137}Cs, and ^{210}Pb results, a CAR based on carbon estimates made from loss-on-ignition (LOI)[4] provided an average carbon sequestration for salt marsh habitat at the Seal Beach NWR control site and augmentation site to 100 cm depth of 117 g C m^{-2} yr^{-1}, consistent with rates of carbon sequestration around California[5] of ~100 g C m^{-2} yr^{-1} and global[6] averages of approximately 220 g C m^{-2} yr^{-1}.

The estimated carbon sequestration benefit from the USFWS Seal Beach NWR thin-layer sediment augmentation project is presented in Table 2.

Table 2 – Estimated Carbon Sequestration

Grantee	Project (Abbrev. Title)	Project Acreage	Project Life as defined in proposal	Carbon Sequestered as Reported in the Application	Conversion Process to Arrive at Reported GHG sequestration value	Value to Report on Project Report (MT CO2-e)
U.S. Fish and Wildlife Service	Seal Beach NWR Sediment Augmentation	10 acres	n/a	Carbon storage estimate of 250 Mg C ha^{-1} of tidal marsh (i.e., 917.5 Mg CO2 ha-1) represents avoided emissions - associated with halting loss of tidal marsh at the SBNWR	250 MT C ha-1 * 3.67 = 917.5 MT CO2 ha-1 917.5 MT CO2 ha-1 * (1 ha/2.471 ac) = 371.3 MT CO2 ac-1 371.3 MT CO_2 ac-1 * 10 ac = 3,713.1 MT CO2	3,713

Summarize Benefits to Disadvantaged Communities (not applicable)

List of Proposed Activities and Tasks for 2019

Task 1 – Project Management and Administration

Refuge staff will continue to coordinate individually and through conference calls with researchers and other team members. Invoices and quarterly reports will be prepared. A

[4] Craft, C. B., Seneca, E., & Broome, S. (1991). Loss on ignition and Kjeldahl digestion for estimating organic carbon and total nitrogen in estuarine marsh soils: calibration with dry combustion. *Estuaries*, *14*(2), 175–179. Retrieved from http://link.springer.com/article/10.2307/1351691

[5] Chmura, G. L., Anisfeld, S. C., Cahoon, D. R., & Lynch, J. C. (2003). Global carbon sequestration in tidal, saline wetland soils. *Global Biogeochemical Cycles*, *17*(4), n/a-n/a. http://doi.org/10.1029/2002GB001917

[6] Ouyang, X., & Lee, S. Y. (2014). Updated estimates of carbon accumulation rates in coastal marsh sediments. *Biogeosciences*, *11*, 5057–5071. http://doi.org/10.5194/bgd-10-19155-2013

"lessons learned" document will be completed. Reports summarizing the final results of pre-augmentation monitoring will be reviewed and provided to CDFW.

Task 2 – Sediment Augmentation
This task is now complete.

Task 3 – Project Monitoring

a) Post-augmentation monitoring will continue and expand as the augmentation site continues to revegetate.

b) USFWS staff will continue to work with the researchers to ensure that no impacts to listed or sensitive species occur during post-augmentation monitoring.

c) Annual monitoring reports will be prepared.

d) Monthly bird surveys and annual monitoring of the light-footed Ridgway's rail will continue.

e) Dr. MacDonald and his team at UCLA has completed their final report.

f) Dr. Ambrose and his team at UCLA will continue to analyze core samples from feldspar plots to measure the thickness of sediment over the feldspar. Laboratory analyses of bulk density, grain size, and carbon content (LOI) will also be conducted on core samples taken from the site.

g) Dr. Whitcraft and her staff will continue to conduct post-augmentation sampling and analysis related to plant and invertebrate diversity and abundance, plant photosynthesis, and biomass. Additional research will be conducted in an effort to determine the origin of plants and invertebrates that appear/colonize on the augmentation site (e.g., growing from existing plants/invertebrates and/or new recruits) and to analyze the nutrient content of the sediment pre- and post-augmentation.

h) USGS will continue collecting data from the SETs, but no more turbidity data from the adjacent tidal channels will be monitored.

i) Dr. Keller from Chapman University has completed collecting samples and finalized his analysis of porewater ions (e.g., chloride, sulfate), as well as post-augmentation gas flux at the augmentation site and control site.

j) Another eelgrass survey and report was completed to evaluate eelgrass conditions two years post augmentation. A three years post augmentation survey may be implemented.

k) Time-lapse videos will be continually updated and posted to the Refuge website.

Task 4 – Engineering Design/Environmental Documentation
This task has been completed.

Task 5 – Public Participation/Presentations
We will continue to update the project webpage and participate in conferences and webinars as opportunities arise. Once the "lessons learned" documentation is completed for the sediment augmentation process and we have the results from the spring 2019 monitoring surveys, we initiate additional avenues for disseminating project results.

Description of Amendments and Modifications to Grant

We made a minor modification to the existing grant by redirecting $4,950 of unallocated research funds to additional eelgrass survey work. The reallocation of funds was approved by CDFW on June 10, 2016.

Attachments

1. Cost Share Expenditures Table
2. Site Photos (October 2107 – September 2018) Seal Beach NWR Augmentation Site
3. Sediment Coring for Long-Term Carbon Sequestration and Environmental Change (Brown et al 2018)
4. Final Report: Thin-Layer Sediment Application Pilot Project at Seal Beach National Wildlife Refuge *Sediment flux and turbidity patterns* (USGS 2017)
5. Seal Beach National Wildlife Refuge Sediment Augmentation Second Annual Post-Construction Eelgrass Survey (MTS 2018)
6. CSU Long Beach Office of Public Affairs Interview (August 27, 2018)
7. Long Beach Post Article (September 3, 2018)
8. Long Beach Grunion Gazette Article (September 6, 2018)

Attachment 1
Itemized Cost Share Accounting

Cost Share (June 1, 2015 to September 30, 2018)		
Activity or Item[1]	Funding Source	Expenditure
Total Cost Share from June 1, 2015 to September 30, 2016		
Pre and Post-augmentation monitoring[1]	California State Coastal Conservancy *(revised 6/2018 to exclude funding provided prior to 6/2015; changing expenditure from $177,070 to $173,120)*	$173,120
Purchase boat to access site	USFWS CRI Grant	$2,425
RTK elevation survey	US Army Corps of Engineers	$50,252
USFWS staff time[2]	USFWS CRI Grant	$137,592
Sediment augmentation[3]	Orange County Parks	$670,500
Sediment augmentation	USFWS CRI Grant	$350,000
	Subtotal	**$1,383,916**
Total Cost Share from October 1, 2016 to September 30, 2017		
Post-augmentation monitoring	California State Coastal Conservancy	$231,753
USFWS staff time[2]	USFWS CRI Grant	$22,714
	Subtotal	**$254,466**
Cost Share from October 1 – December 31, 2017		
Post-augmentation monitoring	California State Coastal Conservancy	$38,702
USFWS staff time[2]	USFWS Station Funds	$500
	Subtotal	**39,202**
Cost Share From January 1 – March 31, 2018		
Post-augmentation monitoring	California State Coastal Conservancy[5]	$1,170
USFWS staff time[2]	USFWS Station Funds	0
	Subtotal	**$1,170**
Cost Share From April 1 – June 30, 2018		
Post-augmentation monitoring	California State Coastal Conservancy	$1,046
USFWS staff time[2]	USFWS Station Funds	0
	Subtotal	**$1,046**
Cost Share From July 1 – September 30, 2018		
Post-augmentation monitoring	California State Coastal Conservancy	$17,466
USFWS staff time[2]	USFWS Station Funds	$794
	Subtotal	**$18,260**
	Total Cost Share to Date	**$1,698,060**

[1] Costs associated with bird surveys and light-footed Ridgway's rail monitoring are not included.
[2] This does not include staff time accounted for on monthly invoices; does include Refuge Manager's time for project/researcher coordination (averages a minimum of 6 hours per month).
[3] The bids for sediment augmentation came is much higher than estimated by the project engineer, therefore, some of the cost for sediment augmentation was covered by the Orange County Parks.
[4] As of September 30, 2017, all USFWS CRI Grant funds have been expended and the grant is closed.
[5] All Coastal Conservancy costs were revised in March, 2018 to reflect the full amount expended rather the showing the cost less the 10% held by the Conservancy during each billing (this will avoid confusion in the future).

Attachment 2 - Site Photos (October 2107 – September 2018)

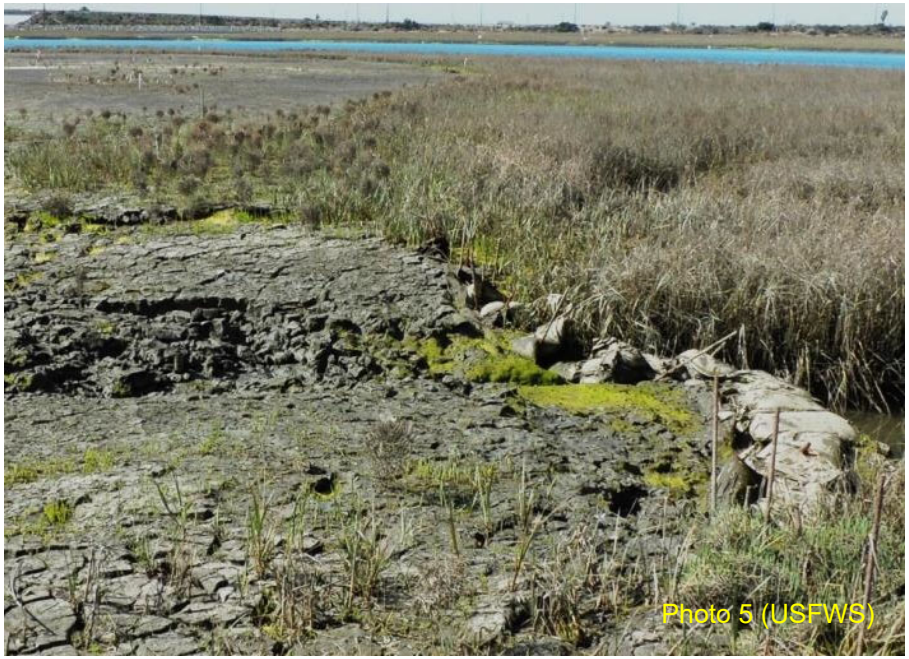
Photos of the Augmentation Site (September – December 2017)

1) Looking towards the pacific highway bridge in September 2017; 2) Tidal creek formation in September 2017; 3) Looking southwest in September 2017 (compare with Photo 13)

Photos of the Augmentation Site (January – March 2018)

4) Dam I in July 2016*; 5) Dam I before notching in February 2018; 6) Dam I after notching February 2018

*Refer to Figure 7 in the Annual Report for the location of Dam I



Photos of the Augmentation Site – April - June 2018

7) USGS monitoring SET plot on the augmentation site; 8) Pacific cordgrass moving into the site from the buffer area; 9) Augmentation site following a high tide

Photo 7 (USGS)

Photo 8 (USGS)

Photo 9 (USGS)

Photos of the Augmentation Site – July - September 2018

10) Tidal creek forming; 11) Pickleweed around test plot perimeter;

12) Pickleweed in USGS SET plot; 13) Augmentation site looking southwest

Photo 10 (USGS)

Photo 11 (USGS)

Photo12 (USGS)

Photo 13 (CSULB)

Attachments 3, 4 and 5 are provided under separate cover due to file size

Attachment 3. Sediment Coring for Long-Term Carbon Sequestration and Environmental Change (Brown et al 2018)

Attachment 4. Final Report: Thin-Layer Sediment Application Pilot Project at Seal Beach National Wildlife Refuge Sediment flux and turbidity patterns (USGS 2017)

Attachment 5. Seal Beach National Wildlife Refuge Sediment Augmentation Second Annual Post-Construction Eelgrass Survey (MTS 2018)

Attachment 6

Long Beach State University Office of Public Affairs

Long Beach State University Researchers Helping to Preserve Southern California's Coastline

Wetlands Ecology Lab part of effort to improve Seal Beach wetlands

LONG BEACH, Calif. (Aug. 27, 2018) - Long Beach State University researchers and federal wildlife officials have begun to see encouraging results — growths of green Pacific cordgrass — after undertaking a pilot program to rebuild a threatened salt marsh with sediments dredged up from a local harbor.

The project site encompasses about eight acres of salt marsh within the boundaries of Seal Beach National Wildlife Refuge. The effort to rebuild the marsh has potential to restore habitat for the light-footed Ridgeway's rail, an endangered bird. It also promises to show whether similar projects can protect coastal marshlands from being lost to a double whammy of rising sea levels and sinking land.
Protecting coastal lands is not only important for wildlife, but humans who live and own property near the seaside.

"Wetlands provide a lot of protection and buffering for the communities that are behind the wetlands," said Christine Whitcraft, associate professor of biological sciences and director of Long Beach State's Environmental Science and Policy program.

VIDEO: Associate professor Christine Whitcraft explains why wetlands are important. Whitcraft manages the campus' Wetlands Ecology Lab, where researchers are helping the project team's work.

Workers sprayed a 10-inch layer of dredged materials from the bottom of Huntington Harbour to the Seal Beach project site during the first half of 2016. The sediments have since settled to a lower elevation, and some Pacific cordgrass has since sprouted along the edges of the project site. Another plant species, called pickleweed, also grows throughout the project site.

Cordgrasses are important, Whitcraft explained, because plant cover shades the sand, preventing the surface from becoming hard and salty. A cooler and less saline environment benefits invertebrates, such as earthworms. Those creatures are important food sources for birds.

VIDEO: Associate professor Christine Whitcraft explains the restoration project.

Success in Seal Beach could also provide new insights to conservationists working to preserve other coastal habitats.
“Our primary mission here is to protect what’s left of the coastal wetlands in California,” said refuge manager Rick Nye of the Seal Beach National Wildlife Refuge.
Besides the fact that many people enjoy living near the kind of green spaces that coastal wetlands provide, wetlands also play a role in filtering pollutants, absorbing storm flows and storing carbon, Nye said.

Rising sea levels are a widespread concern in the Golden State. State government’s fourth Climate Change Assessment, published Monday, called attention to several dangers emerging from a warning climate. On the subject of sea level rise, the assessment warns 31 to 67 percent of Southern California beaches may vanish by the year 2100 unless people take significant steps to halt erosion.

Researchers monitoring the Seal Beach site compare how plants and animals are faring at the augmentation site and a nearby control area, student researcher Chloe Van Grootheest said. They do so by analyzing photosynthesis activity among cordgrass at either site, measuring temperature and salinity, as well as taking sediment samples back to the Wetlands Ecology Lab to see what kind of creatures are living below the surface.

“It’s slowly but surely coming back,” Van Grootheest said. “We have the low plant cover coming in and we have the larval insects that are here.”

In addition to Long Beach State University personnel, the research team also includes members from the U.S. Geological Survey, UCLA, Chapman University, Huntington Beach Wetlands Conservancy and Friends of Seal Beach National Wildlife Refuge.
Funding and other support comes from the U.S. Fish and Wildlife Service, California Coastal Conservancy, OC Parks, California Department of Fish and Wildlife and U.S. Army Corps of Engineers.

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About the campus: Long Beach State University is a teaching-intensive, research-driven university committed to providing highly valued undergraduate and graduate degrees critical for success in the globally minded 21st century. Annually ranked among the best universities in the West and among the best values in the entire nation, the university’s eight colleges serve more than 37,500 students. The campus values and is recognized for rich educational opportunities provided by excellent faculty and staff, exceptional degree programs, diversity of its student body, fiduciary and administrative responsibility and the positive contributions faculty, staff, students and more than 300,000 alumni make on society.

For videos, go to - http://web.csulb.edu/newsroom/long-beach-state-university-researchers-helping-to-preserve-southern-californias-coastline/

Attachment 7

LONG BEACH POST (THIS ARTICLE ALSO INCLUDED VIDEOS OF THE AUGMENTATION PROCESS)

GO TO: https://lbpost.com/news/education/csulb-researchers-seal-beach-wildlife-refuge-sea-level/

- ENVIRONMENT

September 3, 2018

CSULB researchers help rebuild Seal Beach wetlands threatened by rising sea levels

by Valerie Osier *in* Education

Wetlands are supposed to be, well, wet.

But not too wet, or else the plants drown, endangered birds don't have a place to nest and the marshes fail to protect coastal homes from storm surges.

It's exactly what was happening at the Seal Beach Wildlife Refuge—at least until researchers from Cal State Long Beach and the U.S. Fish and Wildlife Service got involved with a new technique to raise the floor of the marsh.

Christine Whitcraft, director of CSULB's Environmental Science and Policy program, said coastal wetlands are some of the most productive habitats in the world: they filter water run-off, provide a space for fish to breed and the plants absorb excess water as they provide a buffer from ocean storm surges.

"The challenge is, despite this importance, we've still lost a lot of wetlands from human interference," Whitcraft said.

That human interference was highlighted in a 2013 study that showed the sea level rise rate in the Seal Beach marsh was three times higher than the national average, Whitcraft said. In addition to sea level rise, the marsh was getting deeper because natural rivers —now concrete channels—no longer regularly deposit mud into the marsh.

With the combination of rising water and eroding marsh floors, plants crucial to the wetlands ecosystem can't get established and aren't tall enough to let birds keep their nests during high tides, particularly the endangered light-footed Ridgeway's rail.

To combat the drowning of the marsh, researchers sprayed dredged mud from the bottom of Huntington Harbor during the first half of 2016 to raise the marsh by 10-inches.

This was the first sediment augmentation study done in Southern California. It's a relatively new technique, Whitcraft said, with a handful of studies conducted in the East and Gulf coasts and one recently in the San Francisco Bay Area.

Since the sediment spraying in 2016, the researchers have been waiting and monitoring the eight-acre site. Only recently have they started to see plants sprouting and invertebrates like earthworms coming back to the site.

"It is recovering at the rate we expected it to, but it wont be back to a marsh for a few years," Whitcraft said.

The project is a possible solution to a small piece of a big issue, making the success even more exciting, she said.

"I think when people hear of sea level rise, it can seem daunting," she said. "It's nice to be engaged in the process of designing solutions for large scale environmental problems."

—Photo courtesy Long Beach State University

BACK TO LIFE. Marshland in the Seal Beach Wildlife Refuge is getting a boost from Long Beach State researchers.

Seal Beach Wetlands Sees Scholarly Boost

By Gary Metzker
CONTRIBUTOR

The Seal Beach National Wildlife Refuge is coming back to life, thanks to the work of Long Beach State researchers and federal wildlife officials.

The project site embraces about eight acres of salt marsh and the effort to rebuild the marsh has potential to restore habitat for the light-footed Ridgeway's Rail, an endangered bird. It also promises to show whether similar projects can protect coastal marshlands from being lost to the challenges of rising sea levels and sinking land.

The most encouraging results, according to the scientists, have been the growths of green Pacific cordgrass (spartina foliosa) and pickleweed (salicornia virginica), throughout the site.

Christine Whitcraft, associate professor of biological sciences and director of Long Beach State's Environmental Science and Policy program, said cordgrasses are important because plant cover shades the sand, preventing the surface from becoming hard and salty. A cooler and less saline environment benefits invertebrates, such as earthworms, because those creatures are important food sources for birds.

"I have been working in Southern California wetlands for almost 20 years," Whitcraft emailed from Perth, Australia, where she is participating in a conference. "I have worked with numerous land owners and managers on applied restoration projects. Wetlands provide a lot of protection and buffering for the communities that are behind the wetlands."

Whitcraft, who has been at Long Beach State since 2008, manages the Wetlands Ecology Lab on campus, where researchers are helping the project team's work.

"So here in Southern California we have a very urbanized coast, which means that our wetlands have been really altered by our activities," she said. "That has led to wetlands sinking and that means that it can't do as good of a job dealing with sea level rise."

When the managers at Seal Beach National Wildlife Refuge were looking for people who could assist with invertebrate and plant monitoring, they reached out to Whitcraft as a local expert.

"We're starting to see a low percentage cover of plants coming back and we're starting to see invertebrates on the surface and in the mud," she said. "That means once those start to come back, the other animals that rely on the invertebrates, like fish and birds, can start to use the marsh again."

Workers sprayed a 10-inch layer of dredged materials — a mix of sand and mud — from the bottom of Huntington Harbour to the Seal Beach project site during the first half of 2016. That sediment has since settled to a lower elevation, and some Pacific cordgrass has since sprouted.

Rising sea levels are a widespread concern in California. The state's latest climate change assessment called attention to sea level rise as the report warns 31 to 67 percent of Southern California beaches may vanish by the year 2100 unless people take significant steps to halt erosion.

In addition to Long Beach State University personnel, the research team also includes members from the U.S. Geological Survey, UCLA, Chapman University, Huntington Beach Wetlands Conservancy and Friends of Seal Beach National Wildlife Refuge.