North Campus Open Space Restoration Project

Monitoring Report: Year 4 (2021)

UC SANTA BARBARA

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EXECUTIVE SUMMARY

Born out of a vision shared by the local community, students, faculty, researchers, and state and federal agencies, the North Campus Open Space (NCOS) restoration project has created more than 40 acres of estuarine and palustrine wetlands that historically comprised the upper portion of Devereux Slough that was filled in the mid-1960s to create the Ocean Meadows golf course. The project is also restoring more than 60 acres of upland habitats that include native grassland, coastal sage scrub, riparian, oak chaparral woodland, vernal pools and patches of annual wildflowers in clay and sandy soils. Led by UC Santa Barbara's Cheadle Center for Biodiversity and Ecological Restoration (CCBER), the NCOS project involves collaboration with other UCSB departments, faculty, student, and local community groups as well as contractors and government agencies. In addition to wetland and upland habitat restoration, the project has successfully reduced flood levels, supports threatened and endangered species, incorporates public access, and provides educational opportunities. Ancillary benefits of the project include carbon sequestration, preservation of local genotypes, and protection of adjacent ecological values and infrastructure through a design that integrates sea level rise considerations.

Currently in its fourth year of implementation and with planting of the project site more than 95% complete, project efforts are now focused primarily on maintenance, continued monitoring, new research projects, and supplemental planting to add diversity, including special status species such as the federally endangered Ventura marsh milk-vetch (*Astragalus pycnostachys* var*. lanosissimus*). This report describes the methods and results of monitoring for the first four years of the project, with a primary focus on the fourth year (2021). This work documents the progress of the project and supports longer-term research and monitoring programs. Results from the fourth year of monitoring show substantial progress towards the project's restoration goals, with many being met or exceeded. A few of the results that are not met were likely affected by the reduced staffing associated with the COVID-19 pandemic as well as the low water levels resulting from the drought conditions of 2021. Here follows a brief summary of the topics covered in this report.

Photo-Documentation

Comprehensive photographic documentation of the transition and development of the entire NCOS project site has been carried out on a quarterly basis since December of 2016. This report describes the methods for capturing photos and includes a map of the photo point locations on the project site along with a set of representative photos in Appendix 1. These photographs provide a visual record of the transformation of the site from a bare landscape at the end of 2017 to almost completely established salt marsh and transitional habitats, and well-developed perennial grassland on the Mesa by the summer and fall of 2020. 2021 photos show the addition of benches to overlook sites and continued plant development.

Vegetation

All habitats/plant communities have less than 1% cover of high risk invasive species in the sampled quadrats as determined by the California invasive plant council (Cal IPC). Most habitats met the year 4 success criteria for total vegetation cover and/or relative percent native cover. Minor exceptions are that year 4 criteria were not met for total and relative native vegetation cover in the brackish marsh and grassland habitats, and relative native cover was not met in the peripheral uplands and sandy annual habitats. In general, these are a result of the transects not reflecting the larger site conditions for that habitat and the fact that the graduated success criteria for these habitats also got much stricter in the fourth year. So, while they do not all meet the success criteria, there is still a thriving native plant community present in all the monitoring locations. There have been 89 native species identified in the quadrat transect monitoring over the past four years. One species of interest is the Ventura marsh milk-vetch (*Astragalus pycnostachys* var *lanosissimus*). NCOS is home to the largest population of the federally endangered Ventura marsh milk-vetch growing with no irrigation or protection from herbivory. In the 2021 monitoring year, the Ventura marsh milk-vetch habitat reproduced prolifically at several additional locations at NCOS where seeds were distributed. In addition, multiple species recognized by the California Native Plant Society as special status species are establishing robust populations, including southern tarplant (*Centromadia parryi* var. *australis*) and Parish's glasswort (*Anthrocemum subterminale)*. In 2021 an expert botanist identified the native species *Spergularia macrotheca* on site which looks very similar to the non-native *Spergularia sp*. It is possible that Spergularia variants were mis-identified as the nonnative in some of the surveys. We were able to reevaluate for the salt marsh habitat, however it was too late in the growing season to confidently reevaluate other habitats. This new identification could have also affected data in earlier years.

Wildlife

In the fourth year of wildlife monitoring at the NCOS project we documented: three burrowing owls over-wintering in the hibernacula and recently created owl burrows installed on the Mesa in 2020, and one burrowing owl was seen in October 2021. While there were no Western Snowy Plovers sighted on the sand flat at NCOS this year, the western snowy plover had a successful breeding season on the beach at Coal Oil Point, which is their preferred habitat. Lastly, several Belding's savannah sparrow pairs were observed at NCOS and one nest with 3 eggs was spotted, indicating that NCOS is providing breeding support for this state endangered species. Belding's savannah sparrows have also been spotted on site for the last 3 years with evidence of breeding.

Monthly bird surveys in year four had an increase from year three in terrestrial insectivores, seed and fruit eaters, and omnivores and hummingbirds. Many other guilds of birds showed small increases as well. There was a decrease in shorebird and waterfowl and allies- likely caused by the drought conditions which resulted in fewer months of wetland flooding than in 2020. A comprehensive observational study using camera traps has documented extensive use of the habitat features known as "hibernaculum" on site with over 23 species and 5 primary resident species: during the day, ground squirrels and western fence lizards are common, and during the night, mice and rabbits are most frequently observed. Burrowing owls are observed day and night. Lastly, deer mice and harvest mice populations were documented in a capture and release monitoring program in the grassland and salt marsh habitats in the fall and spring of 2020-21.

Hydrology and Water Quality

Several components of our monitoring program are focused on the hydrology and water quality of Devereux Slough and the tributaries that feed into the restored estuary. Monitoring data collected in year four indicate that the estuary continues to perform as expected in terms of an increased water-holding capacity, reduced flood levels and an increased tidal prism. The effect that the estuary has on surrounding lands was recognized by FEMA. In September 2021, FEMA officially issued a LOMR (Letter of Map Revision), which formally documents a change to the flood hazard zone of an area. The flood hazard zone is the extent of a particular landscape subject to a 1% chance of flooding in a year. This was exciting news, as reducing flood impact as a mitigation to climate change was one of the major goals of this project.

There was less than 9 inches of rain in the 2021 water year, which affected many other aspects of the monitoring program such as plant growth and animal activity. The hydrology of the 2021 water year was unlike any of the previous years that we have monitored. There were only three measurable storms, including one storm in January which produced 5.36 inches of rain, or 59% of the total annual precipitation which resulted in an early breach of the sandbar. A subsequent lack of late season rain led to the upper portion of the slough becoming almost completely dry by the end of September. According to the County of Santa Barbara, the 2021 water year had only 48% (9 inches) of the typical rainfall in the area[1]. These factors resulted in a long period of stratification of dissolved oxygen and salinity in the slough through the winter, and very high salinity levels late in the water year.

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[1] Santa Barbara County Water Resources. (n.d.). *Countywide Percent-of-Normal Water-Year Rainfall*.

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1. INTRODUCTION AND PLANTING SUMMARY

The University of California, Santa Barbara (UCSB) North Campus Open Space (NCOS) is a 136-acre site located northwest of the main university campus. Bordered by the UC's Coal Oil Point Nature Reserve to the south and the City of Goleta's Ellwood Mesa/Sperling Preserve to the west, the NCOS site expands upon a contiguous block of open space and wildlife habitat, with residential neighborhoods to the north and east. Funded by federal, state and local agencies, the NCOS project's goals include flood reduction, wetland and upland habitat restoration, support for threatened and endangered species, public access and the provision of educational opportunities. Ancillary benefits of the project include carbon sequestration, denitrification, preservation of local genotypes, and protection of adjacent ecological values and infrastructure through a design that integrates sea level rise considerations. The focal point of the project is the restoration of more than 40 acres of estuarine and palustrine wetlands that were historically part of Devereux Slough and were filled in the mid-1960s to create the Ocean Meadows golf course. The project is also restoring more than 60 acres of upland habitats that include native grassland, coastal sage scrub, riparian, oak chaparral woodland, vernal pools and patches of annual wildflowers in clay and sandy soils. Led by UC Santa Barbara's Cheadle Center for Biodiversity and Ecological Restoration (CCBER), the NCOS project involves collaboration with other UCSB departments, faculty, student, and local community groups as well as contractors and government agencies.

The formal, "on the ground" restoration of NCOS began in February 2017 with the removal of most of the exotic trees on the former Ocean Meadows golf course. The grading and movement of soil on the site occurred from April to October 2017. This project aims to restore local genotypes, rare plant communities and hydrologic function to the site. To do so, over 350,000 cubic yards of soil were removed from the upper arms of Devereux Slough to restore historic wetland functions. Excavated soils removed from the wetland were recycled and placed on the adjacent land to restore the historic mesa. This was followed by the construction of a multi-use trail, two bridges, and a boardwalk and culvert crossing that were completed in June 2018. Descriptions of the target habitats to be restored and/or enhanced are provided in Section 3 of the Restoration Plan. The plan recognizes that changes or modifications in the locations and extents of habitats could occur depending on the post-grading conditions of the site. Minor changes made in some of the vegetation communities are described in the year 3 monitoring report (https://escholarship.org/uc/item/7bq618m8). A map of the NCOS project in Figure 1 reflects the current extent of habitats being restored and enhanced along with the as-built elevation contour lines (one-foot interval), constructed trails, bridges and crossings.

Year 1 Planting Summary

During the first year of restoration (September 2017 – October 2018), more than 185,000 locally sourced native plants comprised of 45 species were installed across 40 acres, covering 75 percent of the Peripheral Upland Mosaic and Salt Marsh habitats. In December 2017, an inoculum containing seeds and dormant invertebrates from existing and adjacent vernal pools was spread in the eight vernal pools created on the Mesa area of NCOS. In addition, throughout the winter and spring of 2018, grasses such as *Hordeum brachyantherum* ssp. *brachyantherum* and *Stipa pulchra* were planted along the margins and between the vernal pools. Approximately 25 percent (3.9 acres) of the Native Perennial Grassland habitat (the eastern portion) was drill seeded with 4 lbs. per acre of *Stipa pulchra* seed in October 2017, and the remaining area (9.1 acres) was drill seeded with 6 lbs. per acre of seed in October 2018. More than 100 tree saplings comprised of six species were installed in the new riparian habitat along the Whittier Channel in the northeastern area of NCOS, and while no planting occurred in the other target habitats, a small number of native plants sprouted voluntarily in many areas of the project site.

Year 2 Planting Summary

The second year of restoration had an addition of more than 100,000 plants and added 15 more species to the project site, bringing the overall total to nearly 290,000 individual seedlings of 60 species planted. The primary planting of the Salt Marsh and Transitional habitats as well as the Peripheral Uplands was completed. An additional 33 trees and more than 2,100 understory plants (20 species) were installed in the riparian habitats along Phelps Creek and Whittier Channel. 95 coast live oak (*Quercus agrifolia*) trees were planted in pockets along the north facing slopes of the Mesa (identified as Oak Woodland/Chaparral in the map in Figure 1) as well as in a few locations in the Peripheral Uplands near Phelps Creek. Planting of the Coastal Sage Scrub habitat along the Mesa slopes occurred in the summer and fall.

Year 3 Planting Summary

Planting efforts in the third year of the project (2020) focused on continuing the development of Coastal Sage Scrub (CSS) communities around the site, particularly in the area to the west of the vernal pool swale on the Mesa. We refer to this part of NCOS as the EEM zone as its restoration is funded by a grant from the California Natural Resource Agency's Environmental Enhancement and Mitigation program. Nearly 7,000 plants comprised of 13 CSS-associated species and 1,200 *Stipa pulchra* were planted in this area. Other areas of focus included the Peripheral Uplands in the northwestern arm (5,300 plants from 14 species) and additions to sections of the transitional/high salt marsh (4,100 plants from 5 species). We also enhanced the grassland habitat on the Mesa by seeding and planting nearly 7,000 seedlings of five wildflower species, and we established the Discovery Trail and Visitor Plaza pollinator garden with more than 4,000 plants from 51 species (two additional species volunteered: *Datura wrightii* and *Lupinus succulentus*).

Twenty-nine coast live oak trees were planted in year three: twenty in a cluster on a slope in the EEM zone and nine in the pre-existing riparian woodland adjacent to Venoco road. This brought the total number of trees planted to 240, 166 of which are coast live oaks.

The successful establishment of the largest population (more than 400 individuals) of the federally endangered Ventura marsh milk-vetch (*Astragalus pycnostachys* var*. lanosissimus*) is an exciting achievement in third year of the NCOS project. Eighty-five percent (404 of 495) of the originally planted seedlings survived to reproductive age and 75 seedlings from the 2020 cohort of offspring that successfully germinated in the spring were thriving in the fall. The success of this establishment prompted the collection of five cups of seeds in the fall that were dispersed in five other locations on NCOS that could potentially support the species. Recent monitoring in March of 2021 had more than 2,151 seedlings growing from the 2021 cohort, including 151 in the areas where seeds were dispersed in the fall of 2020. A detailed report on the establishment and monitoring of Ventura marsh milk-vetch at NCOS is available on the CCBER eScholarship webpage (escholarship.org/uc/item/91f243kg).

In total, we added more than 30,000 plants and 21 species in year three, bringing the overall total for the project so far to more than 320,000 plants comprised of 81 species.

Year 4 Planting Summary

The fourth year of restoration shifted to focus more on weeding non-native plants. With this shift in focus there were still over 20,000 plants and 29 species planted in year 4 bringing the overall total to over 342,000 seedlings planted. There were no additional trees planted in year four. Of all the seedlings planted, 80% were planted in the Mesa area focusing on the vernal pool habitat, 17% were on the salt marsh transition and the remaining 3% of seedlings were planted in the peripheral uplands. The federally endangered Ventura marsh milk-vetch (*Astragalus pycnostachys* var. *lanosissimus*) continues to thrive and has expanded its boundaries through natural seeding. Monitoring of this area are still underway, the count of individual species has not yet been complete, however it is clear by visual assessment that the Ventura marsh vetch has expanded its boundaries since year 3.

Construction of the donor funded NCOS Field Lab has been completed and now serves as a location for faculty and students to complete research focused on NCOS. The lab has been used as a location for sorting and identifying aquatic macroinvertebrate and phytoplankton. The Duttenhaver outdoor classroom and refurbished parking lot project construction began in November 2021 and once completed will support environmental education at all levels.

Report Structure and Content

This report describes the NCOS monitoring program, methods and protocols, and includes data primarily from the fourth year of monitoring (October 2020 to October 2021) along with some data from year 1 (September 2017 to October 2018), year 2 (October 2018 to October 2019) and year 3 (October 2019- October 2020) for comparison. We also discuss the progress of restoration and monitoring through the fourth year.

Monitoring and research efforts as well as data presented in previous reports that are not included in this year 4 report include the development of the bathymetry of the wetland, and studies on sediment accretion, carbon sequestration, trail use surveys, bat species surveys and greenhouse gas fluxes of the wetland. This data can be found in Appendix 7. Some of these ongoing projects were put on hold in 2020 due to the onset of the coronavirus pandemic. We plan to re-measure the elevation cross-sections of the wetland again in 2022 and extract the first set of cores from the sediment accretion monitoring plots in early 2023, which will be five years since the plots were established. Most of the components of monitoring described in this year 4 report will continue for another year through 2022.

The monitoring efforts described herein include:

- Photo-documentation
- Vegetation, including trees
- Wildlife, including bird surveys, special status species, aquatic arthropods, small rodents, and reptiles
- Hydrology and water quality of Devereux Slough, the restored vernal pools on the Mesa, and groundwater at NCOS

- Characterization of project efforts

Key data and related information about the project are posted on the EcoAtlas website (www.ecoatlas.org/regions/ecoregion/statewide/projects/9462), and monitoring reports and associated data are also available through the eScholarship (escholarship.org/uc/ccber) and CCBER's website (www.ccber.ucsb.edu/ecosystem/management-areas/north-campus-open-space).

Figure 1. Map of the habitats/vegetation communities at the North Campus Open Space restoration project.

2. PHOTO-DOCUMENTATION

Photo-documentation was established in the NCOS Restoration Plan as one of the methods for monitoring the progress of the project, including the development of the wetland and changes in the size and cover of vegetation being restored across the different habitats. The locations of photo points were initially established, and the first set of photos were taken in December 2016, prior to the start of the project. Subsequent photo-documentation monitoring has been conducted on a quarterly basis. Photos at select photo points are included in Appendix 1.

At up to 46 points distributed across the site, one to seven photographs are taken depending on what is required to capture all aspects of the site that are visible from each point (see Figure 2 for a map of the photo monitoring points). Each photo is labeled with the photo point number, direction (N, SE, W, etc.), and the date the photo was taken (*e.g*. NCOS_08_N_20190417). Photo point numbers ending with the letters 'a' and 'b' are where photos are taken of the same general area but from different views or angles (*e.g*. 09a and 09b, 28a and 28b).

Through the early stages of the restoration project, we made a few minor revisions in the number and location of photo points and the frequency of photos at some points. In year 3 of the NCOS monitoring, we added a point (number 44) and additional photos at points 36 and 38 to include better coverage of the development of the Visitor Plaza and Discovery Garden as well as forthcoming changes to the parking lot and area west of the ROOST maintenance building.

Comparative photos from four points of each of the last four years are included in Appendix 1 of this report. The complete set of photos can be accessed from an interactive web map here, and full details of the data set, including methodology, revisions, and urls for the web map and complete set of photos are available in a data description document on the CCBER eScholarship webpage (escholarship.org/uc/item/5zf6d6q3).

Figure 2. Map of photo monitoring points at the North Campus Open Space restoration project.

3. VEGETATION

Vegetation Monitoring Methods

The establishment of native vegetation is usually the foundation and the most visible and commonly measured component of a restoration project. The initial vegetation monitoring plan and goals for the NCOS project are described in the Restoration Plan, which allowed for modifications to adapt to potential post-grading changes in the location and extent of habitats. The modified monitoring plan and schedule is outlined in Table 1. The goal of this monitoring is to record changes in the absolute cover of native and non-native vegetation in each habitat by species as well as the percent cover of thatch, bare ground, and other cover such as mulch/woodchips or algae, all of which can provide habitat in one form or another for different organisms and potentially increase the level of biodiversity across the site. Habitats comprised primarily of low growing vegetation, such as grasslands and wetlands, are monitored with quadrat transects (QT), and habitats with taller vegetation are monitored with point-intercept transects (PIT). Trees are monitored individually. The vegetation success criteria for the project are assessed at the end of this report section.

Quadrat Transects (QT)

In the eight habitats dominated by short or low-growing vegetation permanent transects are monitored with a one-square-meter quadrat, alternating between the left and right side of the transect line. For the vernal pools, given their small extent relative to other habitats and plant communities, the quadrats are placed every two meters. The length of transects and number of quadrats across vernal pools and the seasonal pond depend on the overall shape and extent of these habitats. All other QT quadrats are spaced 3 meters apart and the transects are 30-meters long. The first quadrat is centered to the left of the starting point at each transect, which results in 11 quadrats for each 30-meter transect. The quadrats are subdivided into 100 ten-centimeter squares and Daubenmire cover classes are used to estimate the cover of each species in the quadrat. We also record the percent of the quadrat that contains thatch (dead vegetation from the previous year's growth), and other cover types such as algae, moss, biocrust, mulch, erosion control netting, and black plastic for weed control. Bare ground is recorded only where there is no other cover in the quadrat.

Point-Intercept Transects (PIT)

This method is used for vegetation communities with larger growth forms, such as Coastal Sage Scrub (CSS) and Riparian. It records the presence of species in the canopy (above two meters) and sub-canopy (below two meters) at every (1) meter along the permanent, 30-meter transect. Including the starting point, this results in a total of 31 points for each transect. The vertical "point" at each meter along the transect is represented by a two-meter tall, half-inch diameter wood dowel with a laser attached to the top for extending the point through the canopy. Each species that touches or intersects the dowel in the sub-canopy is recorded once and each species that intersects the laser in the canopy is recorded once. Therefore, an individual tree or tall shrub is recorded present in both the canopy and sub-canopy if it intersects the point in both strata. When no vegetation crosses the point in the sub-canopy, other cover such as thatch or mulch is recorded or bare ground if there is no cover.

Table 1. Vegetation monitoring plan for the habitats/vegetation communities at the North Campus Open Space restoration project. Figure 3 contains a map of the habitats and monitoring transects.

Habitat / Vegetation Community	Acres	Method	Survey Month	Number of Transects / Quadrats and Trees
Grassland and Mosaic Habitats				
Perennial Grassland (Mesa)	16.8	QT	July	8 / 88
Peripheral Upland Mosaic (Grassland/Scrubland/Bioswale)	8.8	QT	June	7 / 77
Sandy Annuals	1.2	QT	June	1 /11
Wetlands				
Fresh-Brackish Wetlands: Remnant Brackish Marsh & New Seasonal Pond	1.5	QT	July/August	1 / 11 1 / 15
Vernal Pools (8 pools)	1.3	QT	June	1 lengthwise transect with a minimum of 5 quadrats per pool, every other meter.
Salt Marsh – Restored low (approx. 6-8 ft.) and mid (approx. 8-12 ft.) elevations, and Transitional/High Salt Marsh at 10-15 and 15-18 feet in elevation	38.7	QT	August	6-8 ft. 7 / 77 8–12 ft. 7 / 77 10-15 ft. 5 / 55 15-18 ft. 3 / 33
Salt Marsh – Pre-existing Remnant	0.9	QT	August	2 / 22
Shrublands and Woodlands				
Coastal Sage Scrub (CSS) Mosaic (incl. Chaparral / Oak Woodland)	10.7	PIT, Individual Trees	June/July	7 transects, ~ 105 trees
Riparian Woodland – Pre-existing	1.5	PIT	June/July	2 transects, 9 trees
Riparian Woodland – New (Phelps Creek and Whittier Channel)	1.7	PIT, Individual Trees	June/July	2 transects, ~ 130 trees
Open Ground / Sparsely Vegetated				
Sand Flat/Snowy Plover Habitat	3.2	QT	September (post-plover breeding season)	2 / 22

Transect Locations & Orientations

Figure 3 contains a map of monitoring transects and habitats/vegetation communities. Transect locations were established by generating a randomly placed starting point using GIS. Points were kept a minimum of 60 meters apart and 10 meters from the edge of the habitat/plant community. A 90-square-meter grid was used to divide the larger habitats (CSS Mosaic, Perennial Grassland, Peripheral Upland Mosaic, Salt Marsh, Transition/High Salt Marsh, and the Sand Flat) into similarly sized sections, each separated by a 10-meter buffer, and the randomly placed transect starting points were generated within these sections. This helped provide a more spatially balanced distribution of monitoring transects in these larger habitats/plant communities.

In addition, we stratified the Salt Marsh and Transitional/High Elevation Salt Marsh into two bands based approximately on elevation, with some overlap. This could enable us to detect differences that may occur in species composition and coverage with changes in elevation. These transects are identified in the map in Figure 3 as follows: SML (low elevation salt marsh at 6-9 feet), SMM (mid-elevation salt marsh at 9-12 feet), SMT (transition/high salt marsh at 10-15 feet), and SMTH (transition/high salt marsh at 15-18 feet).

In the field, the locations of some of the transect starting points were initially adjusted slightly if they landed on irrigation infrastructure, a soil accretion, carbon sequestration monitoring plot, or other features where disturbance should be avoided. The direction or bearing of transects was determined by a combination of factors: the distance of the starting point from the edge or boundary with adjacent habitats; the width of the habitat area around the point (if 30 meters or less, then the transect direction would be limited to run approximately parallel to the edges of the area); and if the transect would cross any features where disturbance should be avoided (*e.g*. sediment accretion or carbon sequestration monitoring plots). The start and end points of all transects are marked in the field with a labeled tag attached to a one-inch diameter PVC tube placed over rebar and protruding about one foot above-ground.

Trees

All trees planted at NCOS are monitored annually by measuring the height and diameter at breast height (DBH) in inches, and assessing tree vigor using a rating scale of 1 to 4, where 1 = high vigor with new growth; 2= medium vigor with some stunting, yellowing, or less vigorous growth; 3= poor, appearing nearly dead or dying; and 4 = dead. We estimate the height of tall trees by reading a six-foot long pole marked with inches and feet that is held upright above a height of seven feet.

Data Collection & Management Methods

At the start of each monitoring season, all surveyors are trained and calibrated on cover estimation and species identification as part of the QA/QC program. Transect and quadrat data are recorded using the ESRI Survey123 app on tablets, while the individual tree monitoring data is recorded in Google Sheets. Photographs of each transect are taken from the starting point. Occasional plants that cannot be identified in the field are photographed and later identified as best as possible by staff with greater botanical knowledge. The data are reviewed as soon as possible after collection and any issues such as data entry errors, missing or duplicate quadrats are corrected through consultation with field staff. All data are collated, reviewed, managed, summarized, and plotted using Microsoft Excel and R Studio.

Figure 3. Map of the vegetation monitoring transects at the North Campus Open Space restoration project.

Vegetation Monitoring Data

Native Vegetation Summary

The mean percent of absolute and relative native vegetation leveled off in the fourth year of monitoring for most habitats. It appears that the established vegetation reached an equilibrium with slight increases or decreases in native and non-native vegetation seen in most habitats. The fourth year of monitoring followed an extremely dry year - which could have affected the growth and survival rate of many species. All plots that had less than 10% non-native species in year three monitoring continued to be dominated by natives with no significant increase in non-natives. A few sites that had a high percentage of non-natives in year three monitoring had an increased cover of non-native species in year four. This could be a lagged result of the reduced weeding effort in 2020 due to the impacts of the COVID-19 pandemic. Since there was a period in spring of 2020 that no staff or students were on site and little weeding was implemented, some weeds were able to go to seed before we could catch them, and then sprouted in the 2021 growing season. The results of year four vegetation monitoring shows that sites with an initial low presence of non-natives remained consistently low, which indicates that once non-natives are eradicated, there is the potential to have a stable ecosystem with little management.

Riparian woodland canopy is 100% native and the sub canopy has less than 10% non-native cover. All salt marsh habitats continued to be dominated by natives as they were in year three, with only slight fluctuations of native and non-native distribution. The diversity of native species is relatively similar to last year's results. Overall, the total number of native species is 88, 15 more than were seen in 2020.

Pickleweed, *Salicornia pacifica*, was recorded the most frequently in 2021. This species accounted for 30% of saltmarsh native habitat and 24% of Seasonal Freshwater Pond habitat. *Distichlis spicata* and *Symphyotrichum subulatum* were the second and third most common species respectively. *Stipa pulchra* had the highest percent cover in native grassland habitats. The decrease in total percent cover of native species in the grassland habitat may reflect the fact that a portion of the grassland was mowed earlier in the year to reduce seed set by *Festuca perennis*, and so the biomass of native plant cover was reduced relative to un-mowed grassland conditions. Table A2.1 in Appendix 2 contains a list of all native species recorded in each habitat for each year of monitoring.

Non-Native Vegetation Summary

There was little change in the absolute and relative percent of non-native vegetation cover in year four. Most habitats exhibited a slight decrease in non-native vegetation cover. The largest increases in non-native vegetation were recorded in the Perennial Grasslands and Sandy Annual plant communities (Figures 4 and 6). This reflects the rapid establishment of several annual non-native grasses including *Festuca perennis*, *Festuca myuros* and *Brachypodium distachyon* as well as colonization by nitrogen fixing weeds such as *Melilotus indicus* and *Trifolium tomentosum* that may have colonized from the construction equipment from northern California. The expansion in cover may have been precipitated by the impact of significantly reduced staffing during the first four months of the COVID-19 pandemic in spring (aka peak weed season) 2020, which affected our capacity to control non-native plants before they went to seed.

We recorded a decrease in non-native species diversity. Total non-native diversity has decreased with 66 species identified in year 4 and only 1 new species that had not been seen previously as opposed to the 77 species and 9 new non-natives seen in year 3. Peripheral upland mosaic had the largest decrease in non-native diversity followed by fresh/ brackish pond and remnant salt marsh. Most of the other habitats had similar or slightly more non-native species present.

Cortaderia selloana, ranked as “High” on the Cal-IPC inventory was recorded in one of the Pre-existing Riparian Woodlands in 2020. It covered 4.3 percent of the Pre-existing Riparian Woodland habitat. This year, *Cortaderia selloana* was not recorded at all in the Pre-existing Riparian Woodland habitat. In fact, there was only one recording of *Cortaderia selloana* in all of the 649 quadrats. The single sighting that was identified covered less than 0.01% of total cover of that habitat. Other species on the Cal-IPC inventory included 14 ranked as “Moderate” and 13 as “Limited”. The number of species seen that are ranked as invasive according to Cal-IPC decreased between year 3 and 4. Italian rye grass, *Festuca perennis* (ranked “Moderate” by Cal-IPC), was the most frequently recorded invasive species in 2021. Festuca perrenis has always been prevalent at NCOS, however it has increased greatly over the years. It appeared in 136 quadrats the first year, 174 the second year 185 the third year and it was recorded in 233 quadrats in the fourth year. Two other non-natives recorded in more than 100 quadrats and that each accounted for more than ten percent of non-native cover and three percent of all vegetation cover include *Spergularia sp* and *Plantago coronopus*. Though in September 2021 an expert botanist identified the native species *Spergularia macrothec*a on site which looks very similar to the non-native Spergularia species. It is possible that Spergularia was mis-identified as the non-native in some of the surveys. We attempted to go back and re-evaluate: however the flowering season had ended making the distinction between the two species difficult. The re-evaluation was only successful in the salt marsh habitats. A transect-by-transect examination of the dominant invasive species reflects significant variation within and between habitats reflecting the patchiness of certain pockets of invasive plants on the site. Table A2.2 in Appendix 2 contains a list of all non-native species recorded in each habitat for each year of monitoring, and the species with Cal-IPC ratings are indicated.

Bare Ground, Thatch, and Other Cover

With the significant increase in vegetation cover recorded in 2020 and 2021, the relative cover of bare ground decreased and continues to stay below 50 percent in all restored habitats, except the Sand Flat (76%) and Vernal Pools (52%). These habitats are expected to retain between 30% and 40% bare ground in the form of mud flats or salt flats, particularly in areas that are covered by deeper water for longer periods of time. The largest decrease in bare ground (10%) was in the coastal sage scrub habitat. Percent bare ground was already low in other habitats in the 2020 monitoring season, and continued to decrease slightly in all habitats.

The relative cover of thatch, which we define as dead vegetation from the previous year’s growth (some of which was mowed or trimmed), increased in most habitats in 2021. Some increase in thatch cover is expected as vegetation continues to develop and increase across the site. The habitats where we observed the greatest increase in thatch cover in year four include: the transition/ high salt marsh (23% more) perennial grassland (13% more) and restored/ transition salt marsh (9% more).

Other cover, which primarily consists of mulch, erosion control wattles, and/or dried algae that occurs in seasonal ponds and wetlands, decreased in most habitats. As with bare ground, this decrease is expected as vegetation continues to develop and increase in cover. In habitats such as the Seasonal

Fresh/Brackish Pond, Remnant Brackish Marsh, and Restored Salt Marsh, we may see the amount of dried algae cover fluctuate each year, depending on the amount of rainfall and/or the rate that water in the ponds and wetlands evaporates. This type of cover, along with other dead plant matter, provides foraging habitat for invertebrates such as ephydrid flies, amphipods, and snails (as mentioned in the Restoration Plan). The Other cover category did increase in the seasonal fresh/ brackish pond likely due to the low water level during monitoring. It also increased in the coastal sage scrub and new riparian habitat due to the application of wood chip mulch to reduce weed competition.

Figure 4. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the Native Perennial Grassland habitat at the North Campus Open Space restoration project. In plot (a), the numbers above the bars are the number of native and non-native species recorded each year.

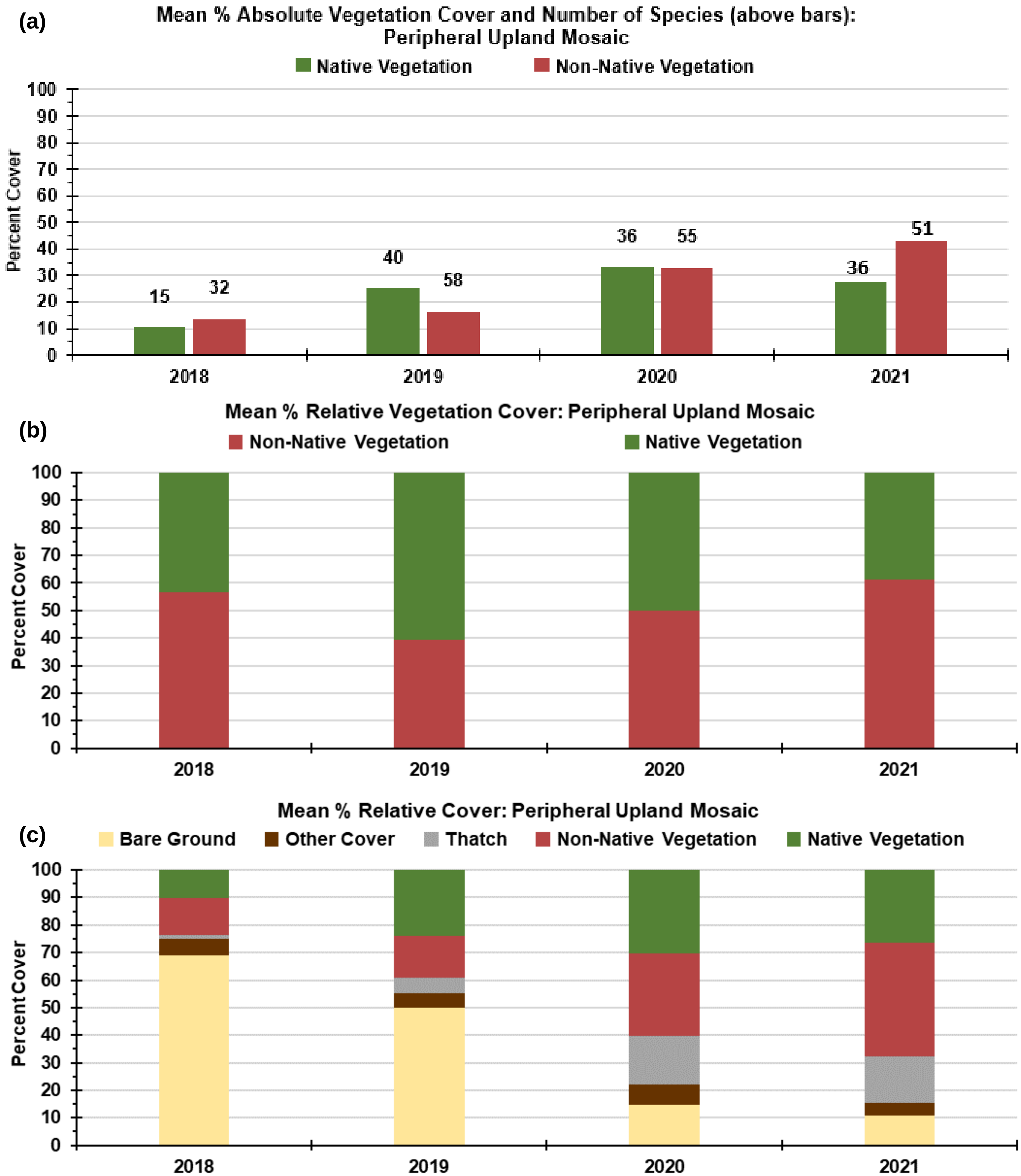

Figure 5. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the Peripheral Upland Mosaic habitat at the North Campus Open Space restoration project. In plot (a), the numbers above the bars are the number of native and non-native species recorded each year.

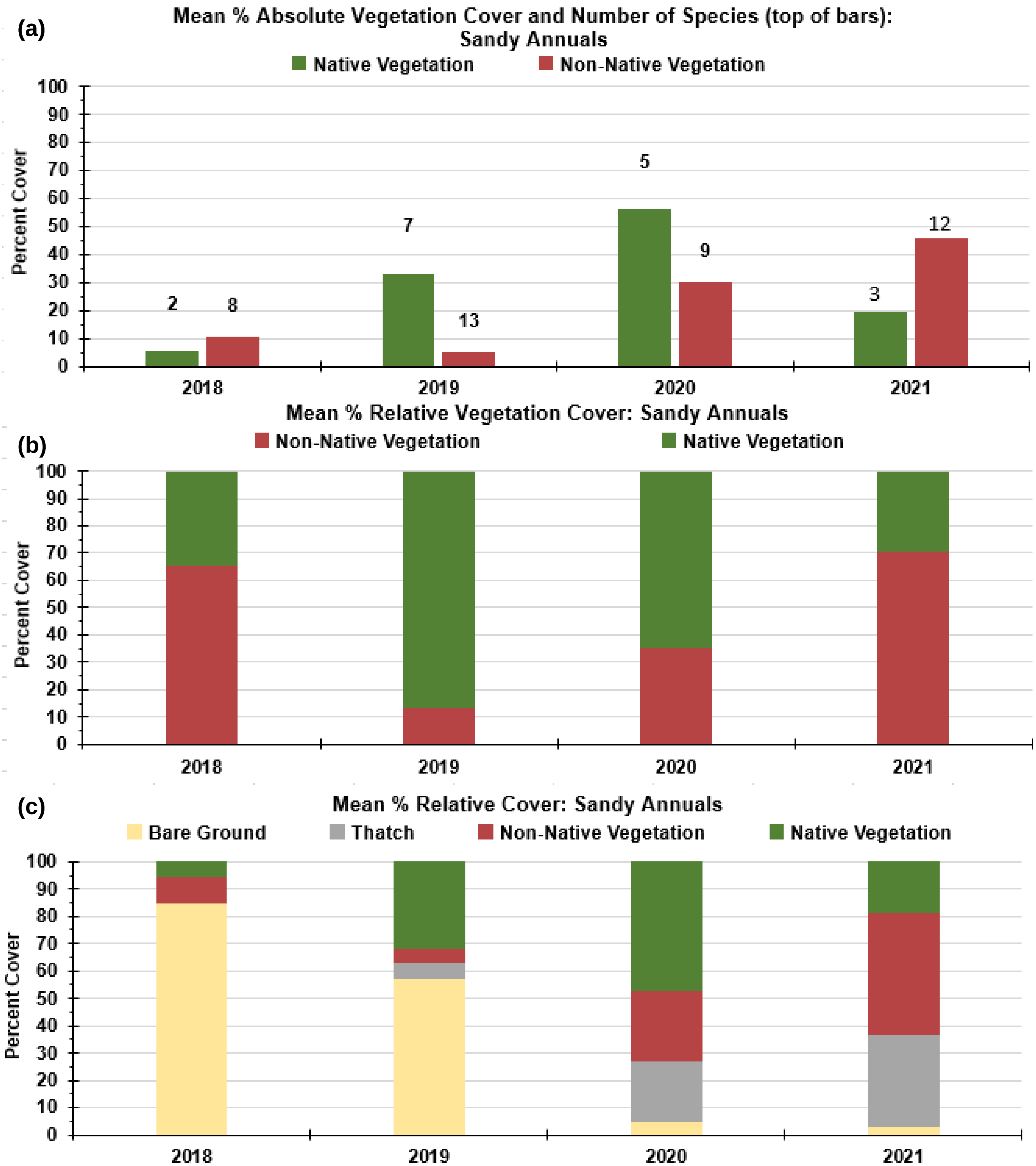

Figure 6. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the Sandy Dune Annuals habitat at the North Campus Open Space restoration project. In plot (a), the numbers above the bars are the number of native and non-native species recorded each year.

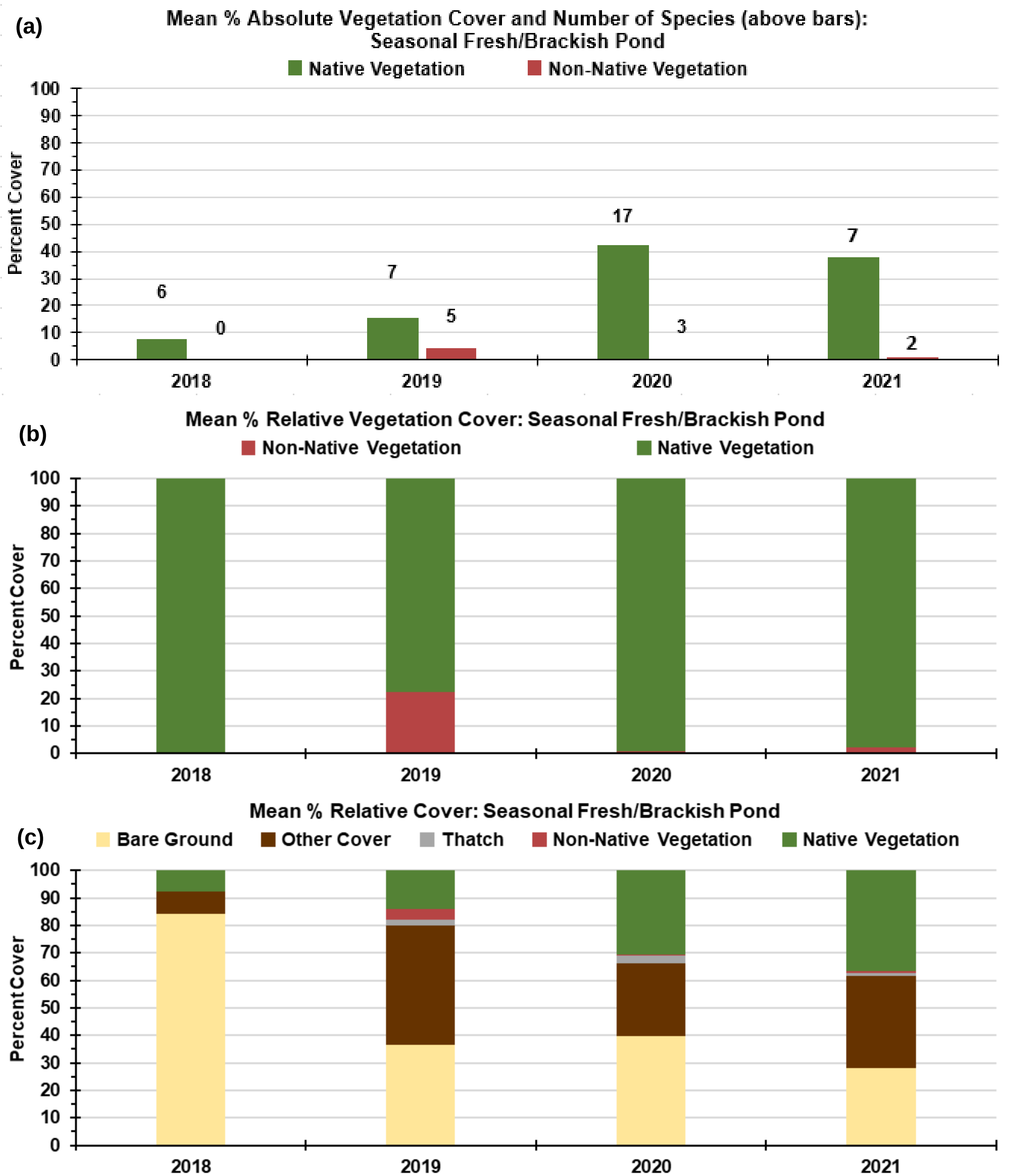

Figure 7. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the Seasonal Fresh/Brackish Pond habitat at the North Campus Open Space restoration project. In plot (a), the numbers above the bars are the number of native and non-native species recorded each year.

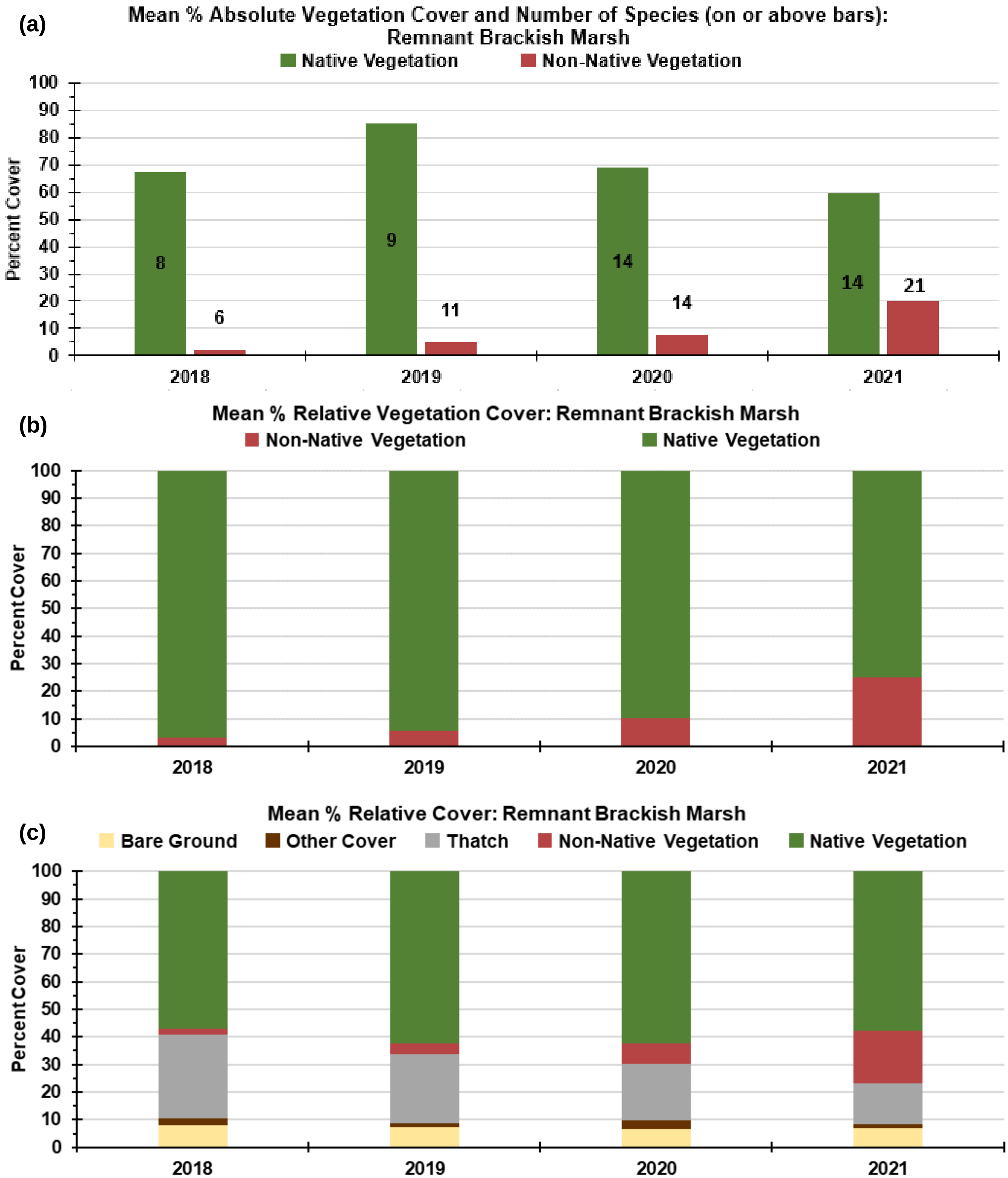

Figure 8. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the Remnant Brackish Marsh habitat at the North Campus Open Space restoration project. In plot (a), the numbers above the bars are the number of native and non-native species recorded each year.

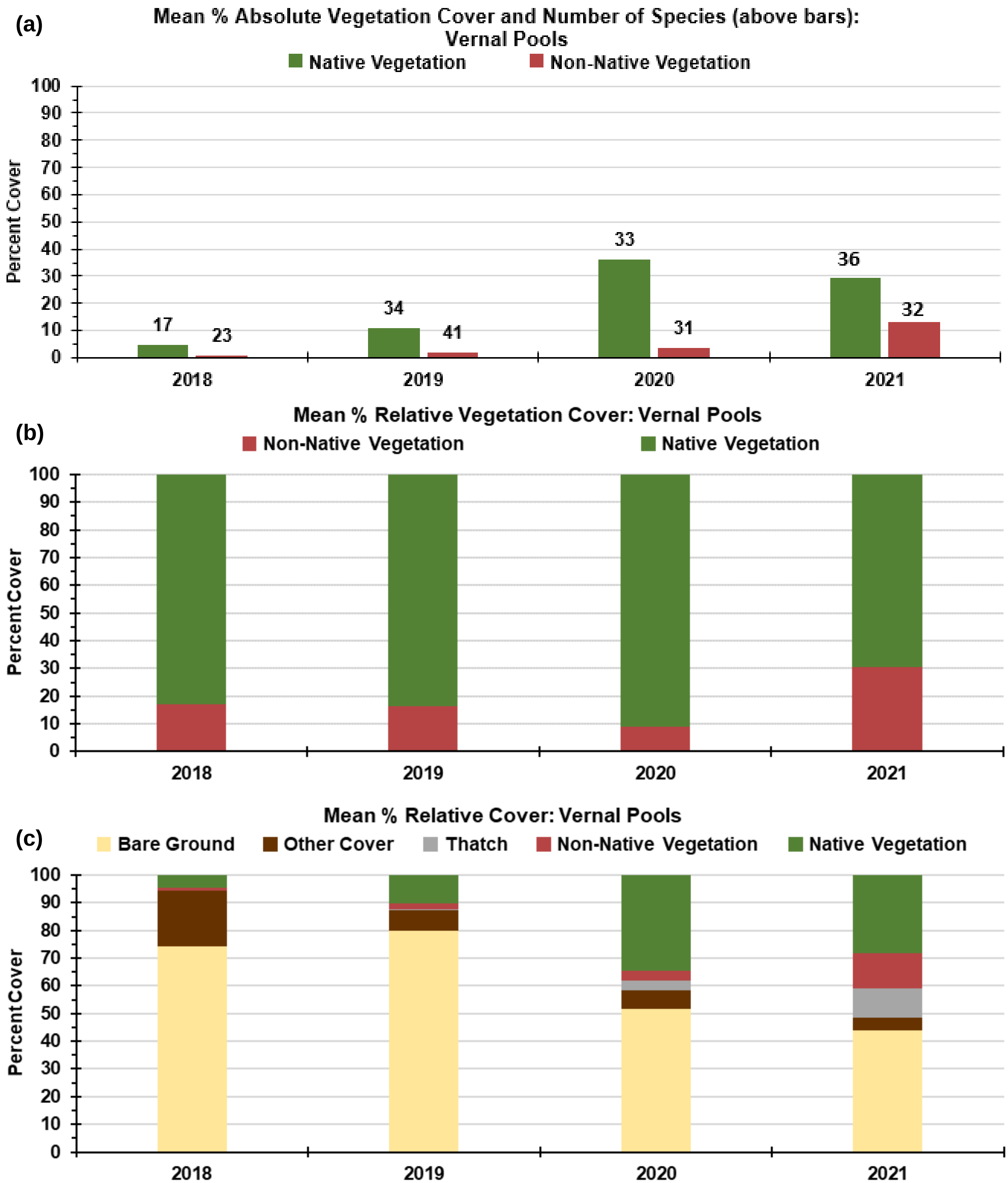

Figure 9. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the eight vernal pools on the mesa of the North Campus Open Space restoration project. In plot (a), the numbers above the bars are the number of native and non-native species recorded each year.

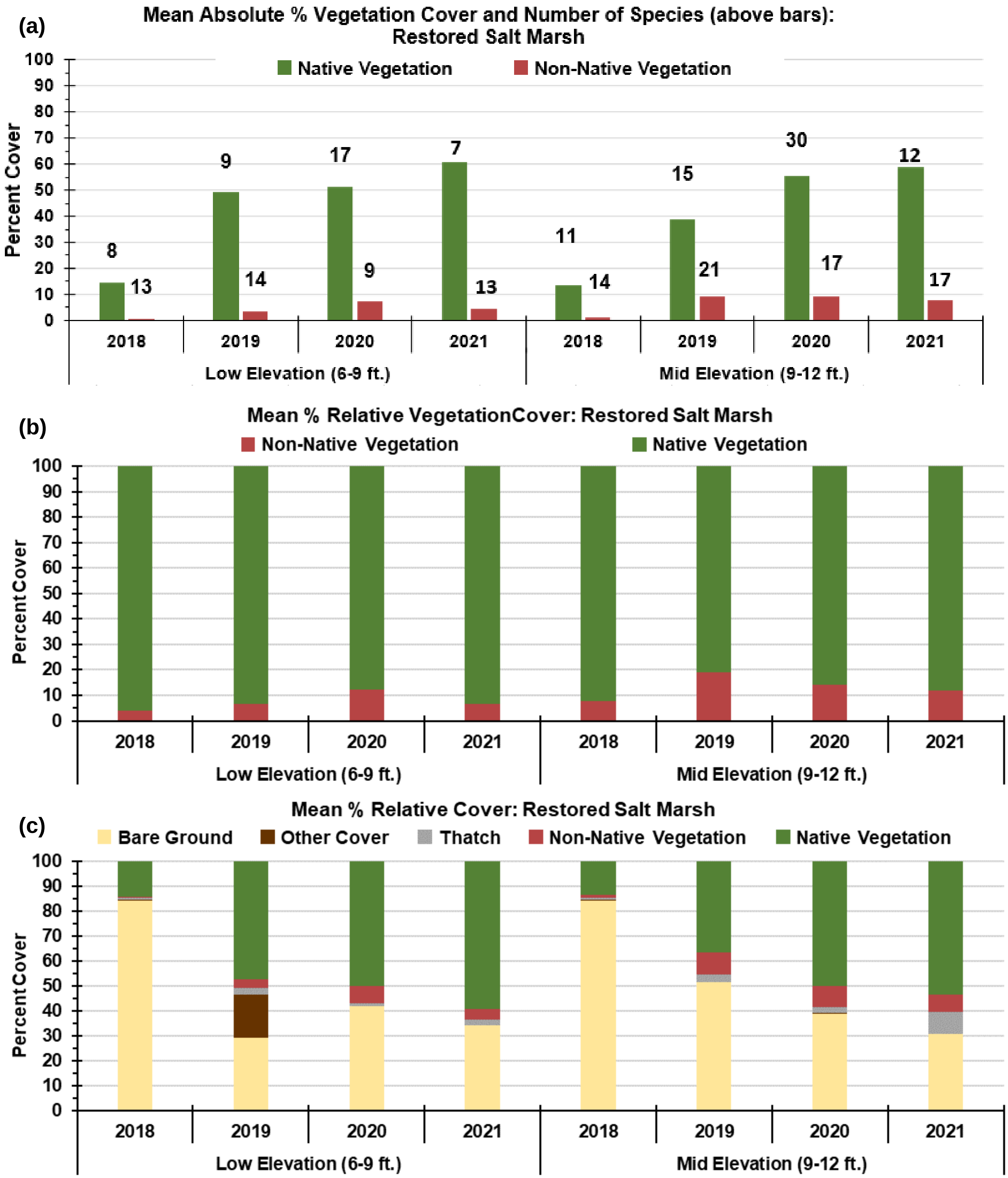

Figure 10. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the Low and Mid Elevation Restored Salt Marsh habitats at the North Campus Open Space restoration project. In plot (a), the numbers above the bars are the number of native and non-native species recorded each year.

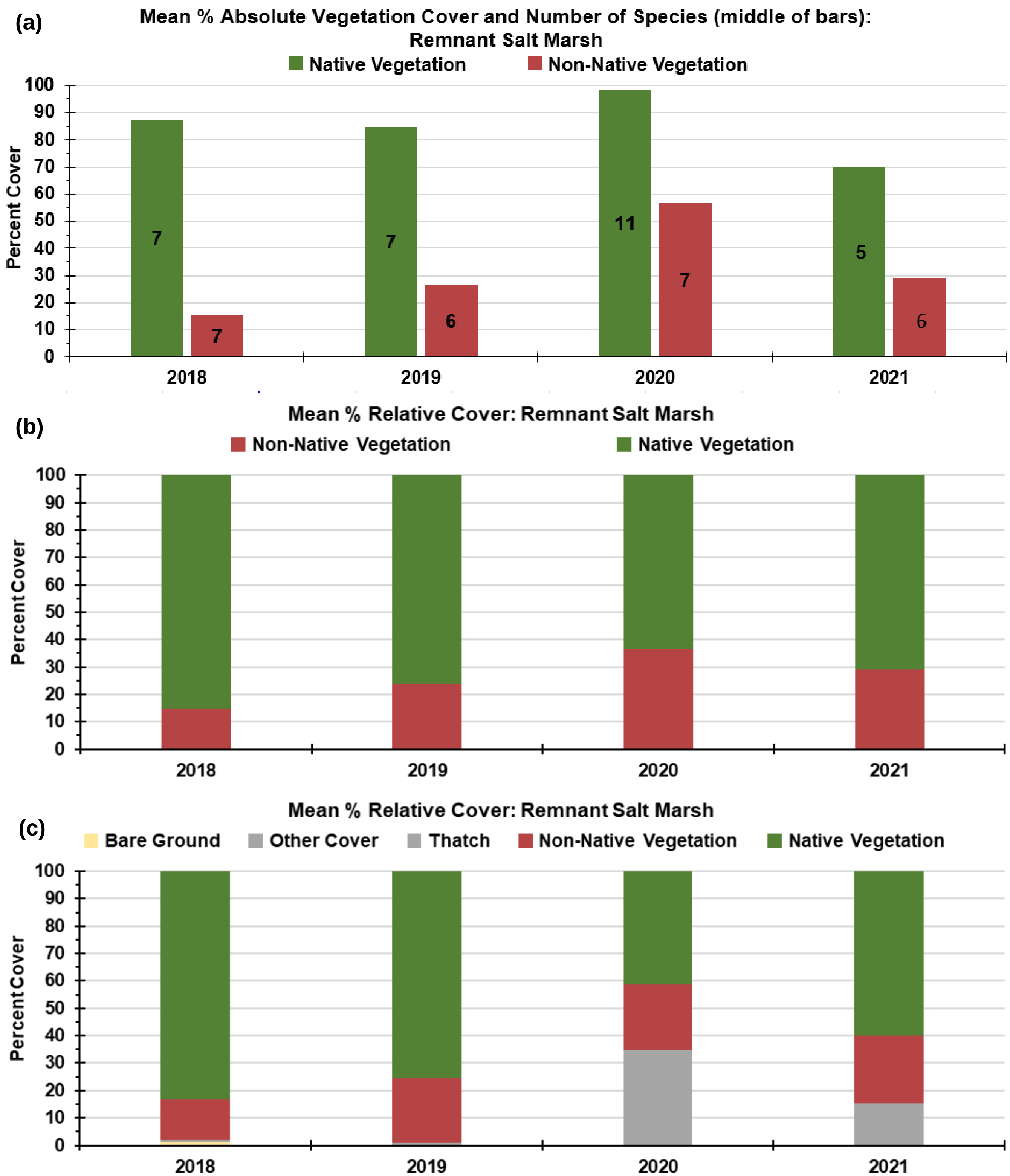

Figure 11. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the Remnant Salt Marsh at the North Campus Open Space restoration project. In plot (a), the numbers above the bars are the number of native and non-native species recorded each year.

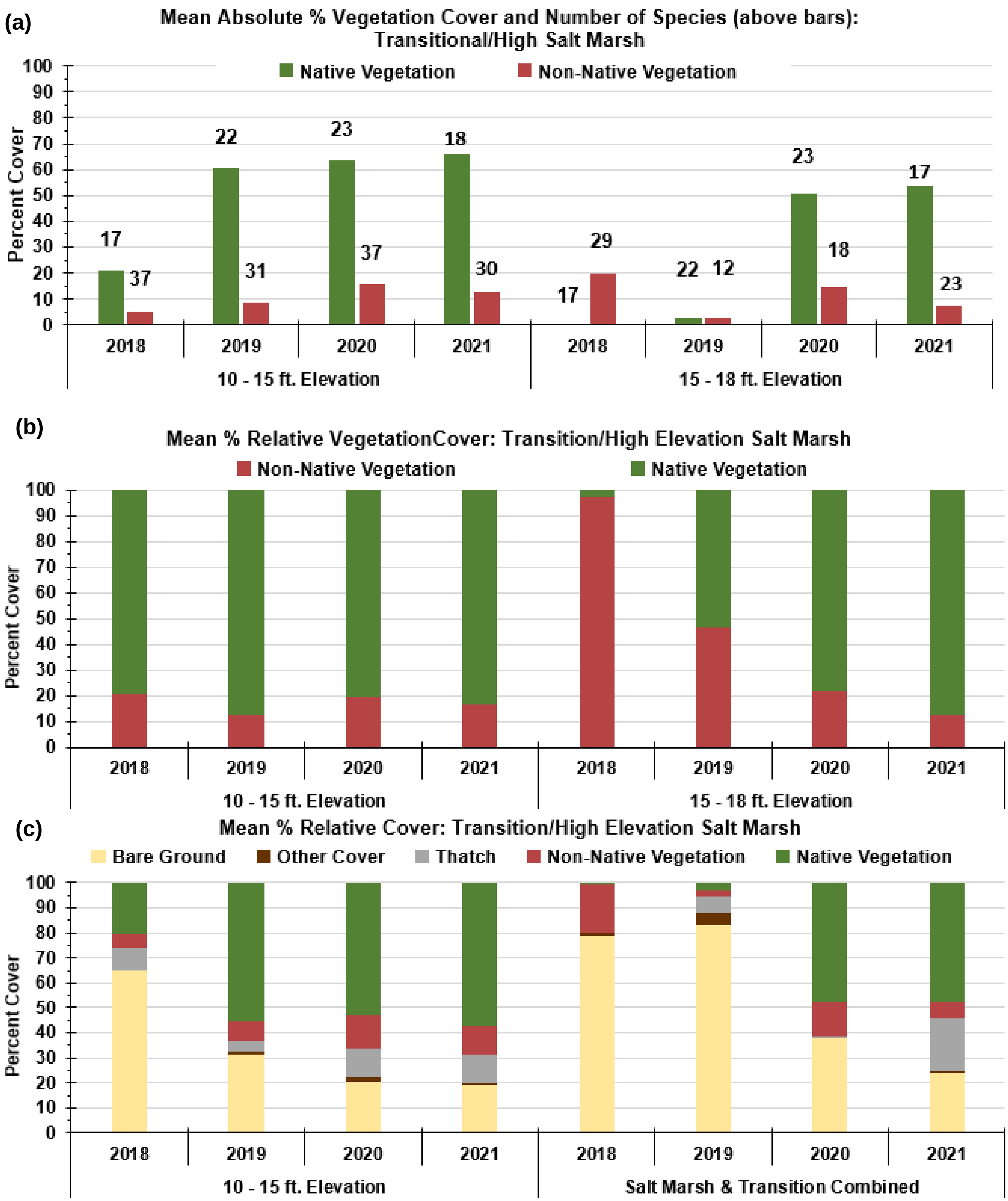

Figure 12. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the two elevation bands of Transition/ High Salt Marsh habitat at the North Campus Open Space restoration project. In plot (a), the numbers above the bars are the number of native and non-native species recorded each year.

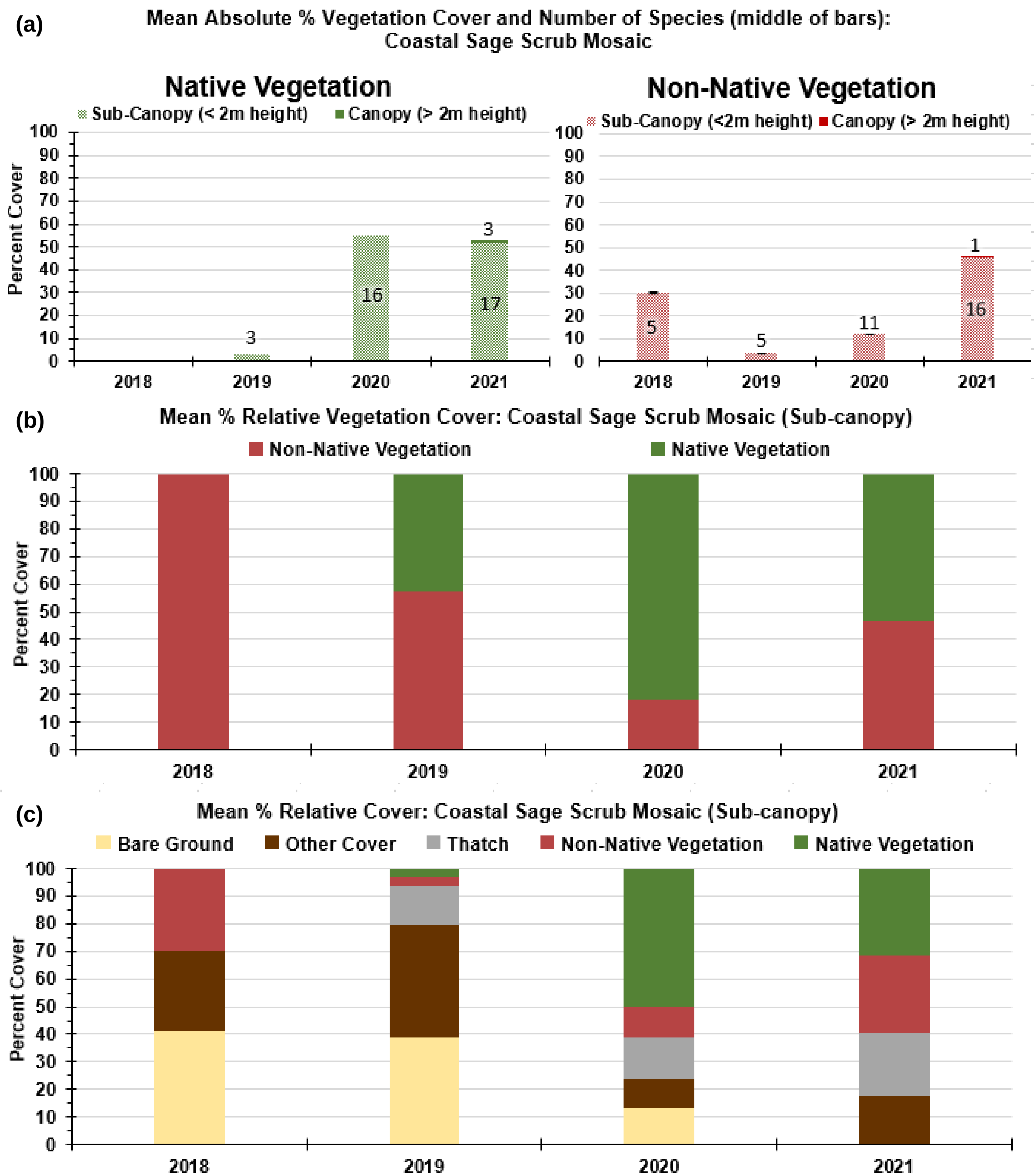

Figure 13. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the new Riparian Woodland habitats (sampled using point of intercept transect) at the North Campus Open Space restoration project. In plot (a), the numbers on the bars are the number of native and non-native species recorded each year. Canopy and sub-canopy vegetation are summed for the relative total vegetation cover in plots (b) and (c).

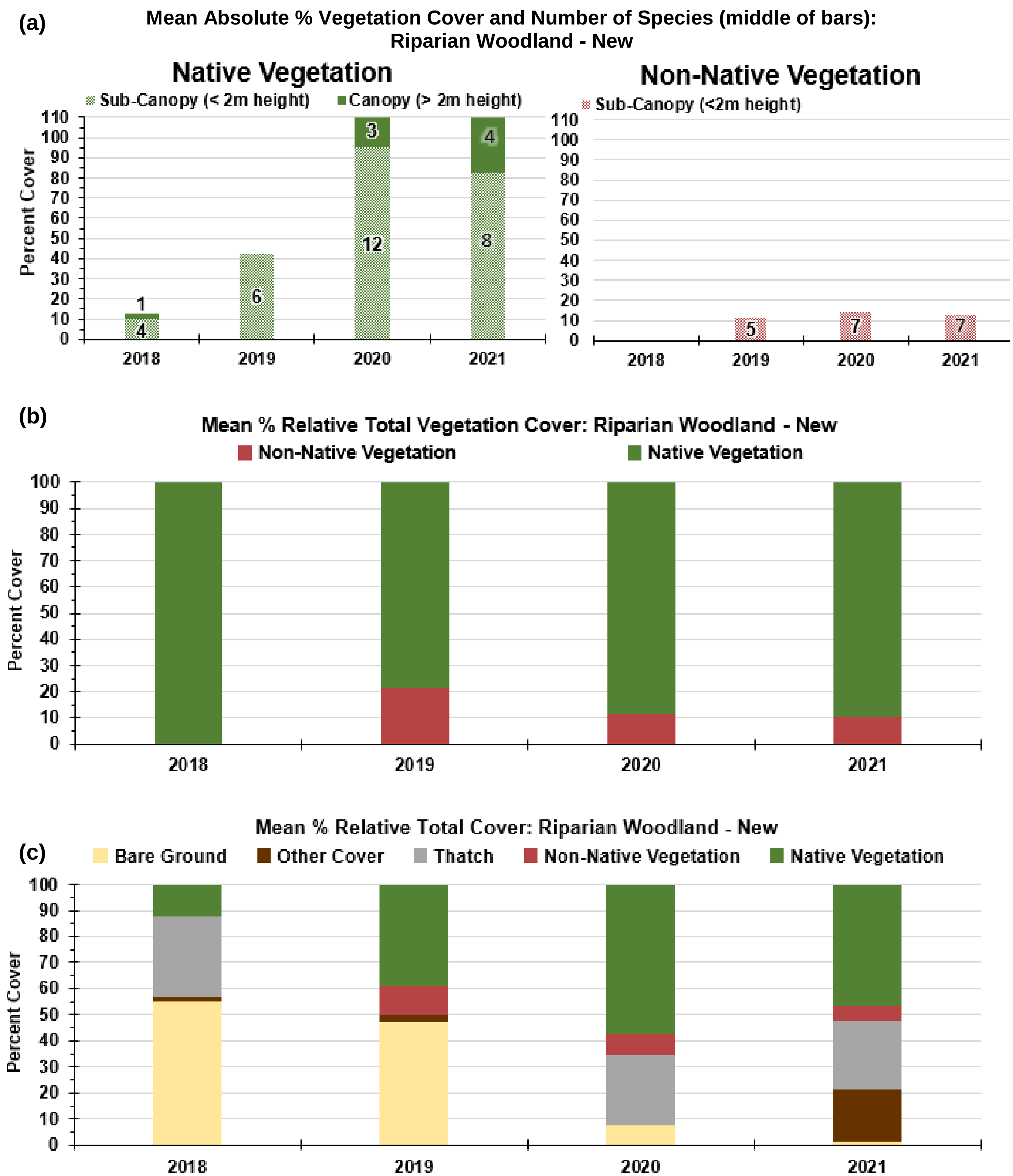

Figure 14. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the new Riparian Woodland habitats (sampled using point of intercept transect) at the North Campus Open Space restoration project. In plot (a), the numbers on the bars are the number of native and non-native species recorded each year. Canopy and sub-canopy vegetation are summed for the relative total vegetation cover in plots (b) and (c).

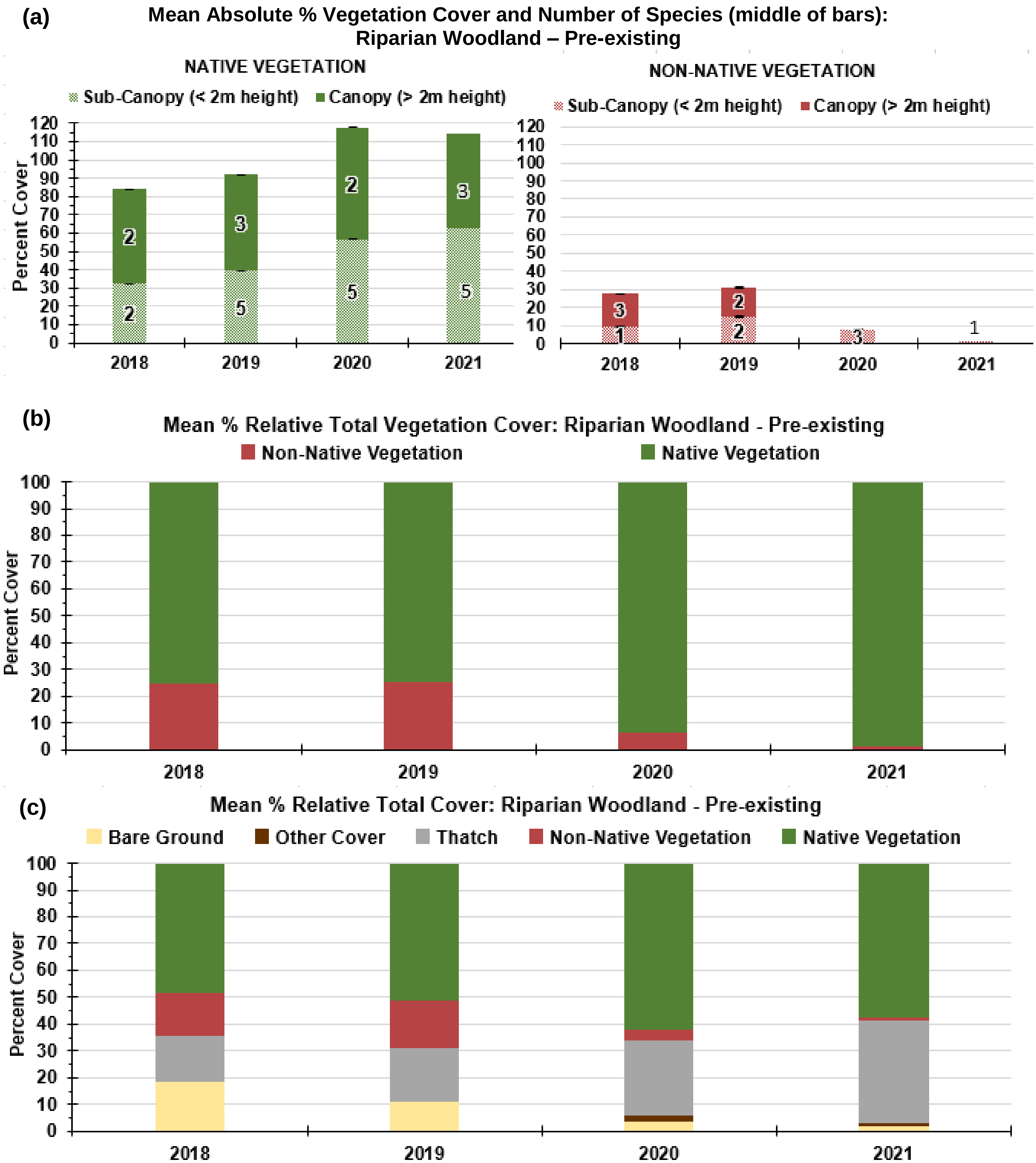

Figure 15. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the pre-existing Riparian Woodland habitats at the North Campus Open Space restoration project. In plot (a), the numbers on the bars are the number of native and non-native species recorded each year. Canopy and sub-canopy vegetation are summed for the relative total vegetation cover in plots (b) and (c).

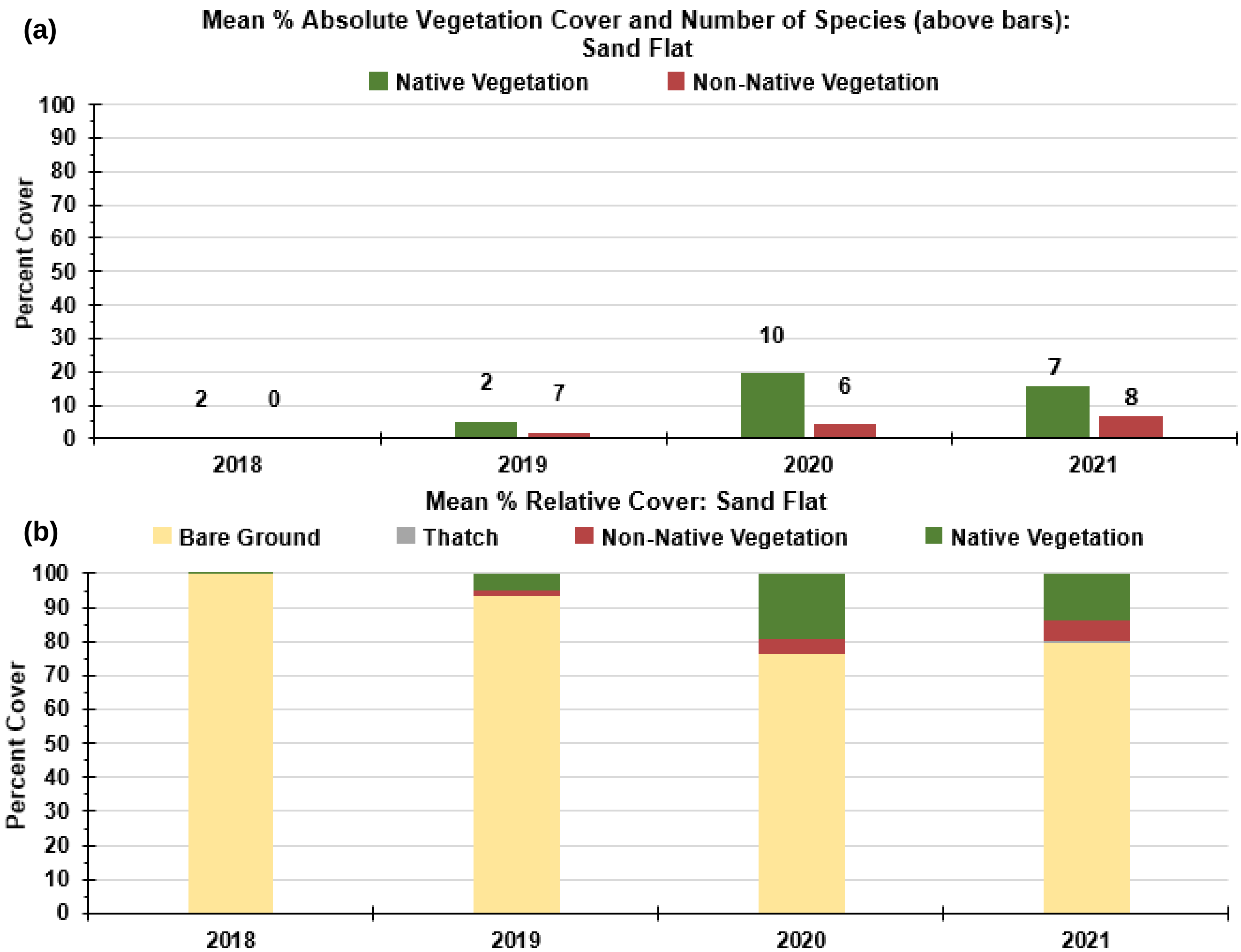

Figure 16. Mean percent of (a) absolute cover of native and non-native vegetation, and (b) relative cover of vegetation, thatch, other cover types, and bare ground in the Sand Flat habitat at the North Campus Open Space restoration project. In plot (a), the numbers above the bars are the number of native and non-native species recorded each year.

Vegetation Success Criteria

The NCOS Restoration Plan identifies four vegetation success criteria, or objectives, for each of the first five years of restoration planting in the primary target habitats/plant communities:

- the percent of total vegetation cover,
- the relative percent of total vegetation cover by native species,
- the relative percent of total vegetation cover by invasive species rated as “High” by the California Invasive Plant Council (Cal-IPC), and
- the diversity of native species.

Table 2 lists the criteria values for each target habitat/plant community and contains the monitoring data associated with each criterion. The table includes the addition of the Peripheral Upland Mosaic habitat and the separation of the Riparian and Fresh-Brackish Marsh habitats.

Despite the variation in timing of native vegetation restoration and establishment in each plant community (*e.g*., planting of the Coastal Sage Scrub Mosaic began near the end of the second year of the project), the monitoring data collected in 2021 shows that at least three out of four success criteria were met in all habitats except Native perennial grassland, and sandy dune annuals in the fourth year of restoration. One of the biggest drops in % Native relative cover was in the sandy dune annuals which only has one transect location resulting in a small amount of data compared to other sites. A visual assessment of the sandy annual site reveals that it is dominated by native annuals in all areas except the transect. Sandy Dune Annuals was also the only habitat to not meet the Diversity of native species suggested by the success criteria.

To date, our vegetation monitoring has recorded a few instances of an invasive non-native species rated as “High” by Cal-IPC at NCOS. We recorded one individual seedling of *Tamarix ramosissima* in a vernal pool in 2019, one small cluster of pampas grass (*Cortaderia selloana*) was recorded years 1, 2, and 3 in one of the pre-existing riparian woodlands near the center of the project site (see transect RWP-02 in the map in Figure 3) and one individual seedling of pampas grass in the perennial grassland habitat in 2021. The cover of pampas grass relative to total vegetation cover estimated from the two pre-existing riparian transects was less than five percent in year three (2020), and it was successfully eradicated from the riparian habitat in 2021.

Table 2. Comparison of vegetation monitoring data with proposed minimum success criteria for target habitats/plant communities from the Restoration Plan for the North Campus Open Space project. The proposed minimum criteria are in italicized font in the five columns in the middle of the table and the monitoring data is in the columns on the right-hand side of the table. Table cells that are bold and green indicate monitoring data that meets or exceeds the corresponding criteria for each year.

	Proposed Minimum Criteria					Monitoring Data				
	Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*	2018	2019	2020	2021	2022
Native Perennial Grassland										
% Total cover	*35*	*45*	*60*	*70*	*80*	12	24	58	58	
% Native Relative	*50*	***60***	***70***	*70*	*70*	19	**65**	**79**	51	
% Invasive Relative	***<5***	***<5***	***<5***	***<5***	*<5*	**0**	**0**	**0**	**0**	
Diversity (Native Species)	***3***	***4***	***6***	***7***	*7*	**8**	**18**	**21**	**25**	
Peripheral Upland (Mixed Grassland/Shrubland)										
% Total cover	*35*	*45*	***60***	***70***	*80*	24	42	**66**	**71**	
% Native Relative	*50*	***60***	*70*	*70*	*70*	43	**61**	50	39	
% Invasive Relative	***<5***	***<5***	***<5***	***<5***	*<5*	**0**	**0**	**0**	**0**	
Diversity (Native Species)	***3***	***4***	***6***	***7***	*7*	**15**	**40**	**36**	**35**	
Salt Marsh										
% Total cover	*30*	***40***	***60***	*70*	*70*	15	**50**	**62**	68	
% Native Relative	***70***	***80***	***80***	***80***	*90*	**94**	**88**	**87**	**91**	
% Invasive Relative	***<5***	***<5***	***<5***	***<5***	*<5*	**0**	**0**	**0**	**0**	
Diversity (Native Species)	***4***	***6***	***7***	***7***	*8*	**11**	**15**	**30**	**13**	
Transitional/High Salt Marsh										
% Total cover	*30*	***40***	***50***	***60***	*65*	24	**46**	**74**	**72**	
% Native Relative	***50***	***60***	***65***	***70***	*80*	**55**	**86**	**79**	**80**	
% Invasive Relative	***<5***	***<5***	***<5***	***<5***	*<5*	**0**	**0**	**0**	**0**	
Diversity (Native Species)	***8***	***8***	***10***	***12***	*15*	**20**	**22**	**28**	**28**	
Fresh/Brackish Marsh (Seasonal Pond)										
% Total cover	*50*	*50*	*60*	*70*	*80*	8	20	43	39	
% Native Relative	***70***	***70***	***70***	***80***	*80*	**99**	**78**	**99**	98	
% Invasive Relative	***<5***	***<5***	***<5***	***<5***	*<5*	**0**	**0**	**0**	**0**	
Diversity (Native Species)	*7*	***7***	***10***	***12***	*14*	6	**7**	**17**	**14**	

	Proposed Minimum Criteria					**Monitoring Data**				
	Year 1	***Year 2***	***Year 3***	***Year 4***	***Year 5***	**2018**	**2019**	**2020**	**2021**	**2022**
Vernal Pools										
% Total cover	*30*	*40*	***40***	*45*	*50*	6	13	**40**	42	
% Native Relative	***70***	***70***	***70***	*80*	*80*	**83**	**84**	**91**	69	
% Invasive Relative	***<5***	***<5***	***<5***	***<5***	*<5*	**0**	**0**	**0**	**0**	
Diversity (Native Species)	***7***	***7***	***10***	***12***	*15*	**17**	**28**	**33**	**33**	
Sandy Dune Annuals										
% Total cover (variable by season)	*20*	***25***	***30***	***35***	*40*	16	**38**	**86**	**56**	
% Native Relative	*50*	***60***	*70*	*70*	*80*	35	**87**	65	17	
% Invasive Relative	***<5***	***<5***	***<5***	***<5***	*<5*	**0**	**0**	**0**	**0**	
Diversity (Native Species)	*3*	***3***	***4***	*5*	*5*	2	**7**	**5**	3	
Coastal Sage Scrub/Chaparral Mosaic										
% Total cover	*30*	*40*	***50***	*60*	*65*	30	7	**66**	**79**	
% Native Relative	*50*	*60*	***65***	*70*	*80*	0	43	**83**	59	
% Invasive Relative	***<5***	***<5***	***<5***	***<5***	*<5*	**0**	**0**	**0**	**0**	
Diversity (Native Species)	*8*	*8*	***10***	***12***	*15*	0	3	**16**	**16**	
Riparian										
% Total cover	*50*	***50***	***60***	***70***	*80*	13	**53**	**90**	**88**	
% Native Relative	***70***	***70***	***70***	***80***	*80*	**100**	**81**	**88**	**85**	
% Invasive Relative	***<5***	***<5***	***<5***	***<5***	*<5*	**0**	**0**	**0**	**0**	
Diversity (Native Species)	*7*	*7*	***10***	***12***	*14*	4	6	**12**	**12**	

Tree Monitoring Data

No new trees were planted in 2021; however, monitoring of the height, diameter at breast height (DBH), and vigor of 243 trees that were planted in year 1-3 of the restoration project continued. Fifteen narrowleaf willows (*Salix exigua*) originally planted in the first year of the project were excluded from this study because they were removed from a portion of the Whittier Riparian area that was graded for the creation of the Discovery Trail and Interpretive Garden. Narrowleaf willow has significantly expanded its extent in adjacent areas of the Whittier Channel.

Three trees were found to be dead in year 3 monitoring (vigor rating of 4): two white alders (*Alnus rhombifolia*) in the new riparian woodland adjacent to the Phelps Creek outlet and one Coast Live Oak on the mesa. Two more trees were found dead in year 4 monitoring: one coast live oak in the new riparian woodland adjacent to Phelps Creek and one white alder in the new riparian woodland of Whittier channel. Their deaths are associated with a dysfunctional irrigation system and the trees were replanted in fall 2021.

Overall, every year of monitoring had an increase in growth for all six species. A comparison of the year three and year four data for trees planted (238 out of 243, with five dead trees excluded) shows an increase in overall mean height by 16 inches-from an average of 81 to 97 inches. There was also an increase in mean DBH from 0.63 to 1.05 inches. The mean overall vigor rating stayed relatively the same. The species that exhibited the greatest increases in mean height and DBH in year four include Arroyo Willow (*Salix lasiolepis*), California Sycamore (*Platanus racemosa*), and White Alder (Alnus rhombifolia) (Figure 18). This is the same trend seen in year 3.

The vigor of trees planted at the Whittier location is the most robust (1.02), the vigor at the mesa location is also quite good (1.22). DBH is highest for the white alder at Whittier creek at an average DBH of 4 inches. White alder at Whittier grows at an astonishing rate compared to other species and locations with an average increase in height of 53 inches (4ft, 4 inches) from year 3 to year 4. This is nearly double the average of any other species or location. The White Alder are significantly taller than other species however it appears that when they get to a certain height (around 280 inches) they begin to increase its diameter more than height (Figure 19).

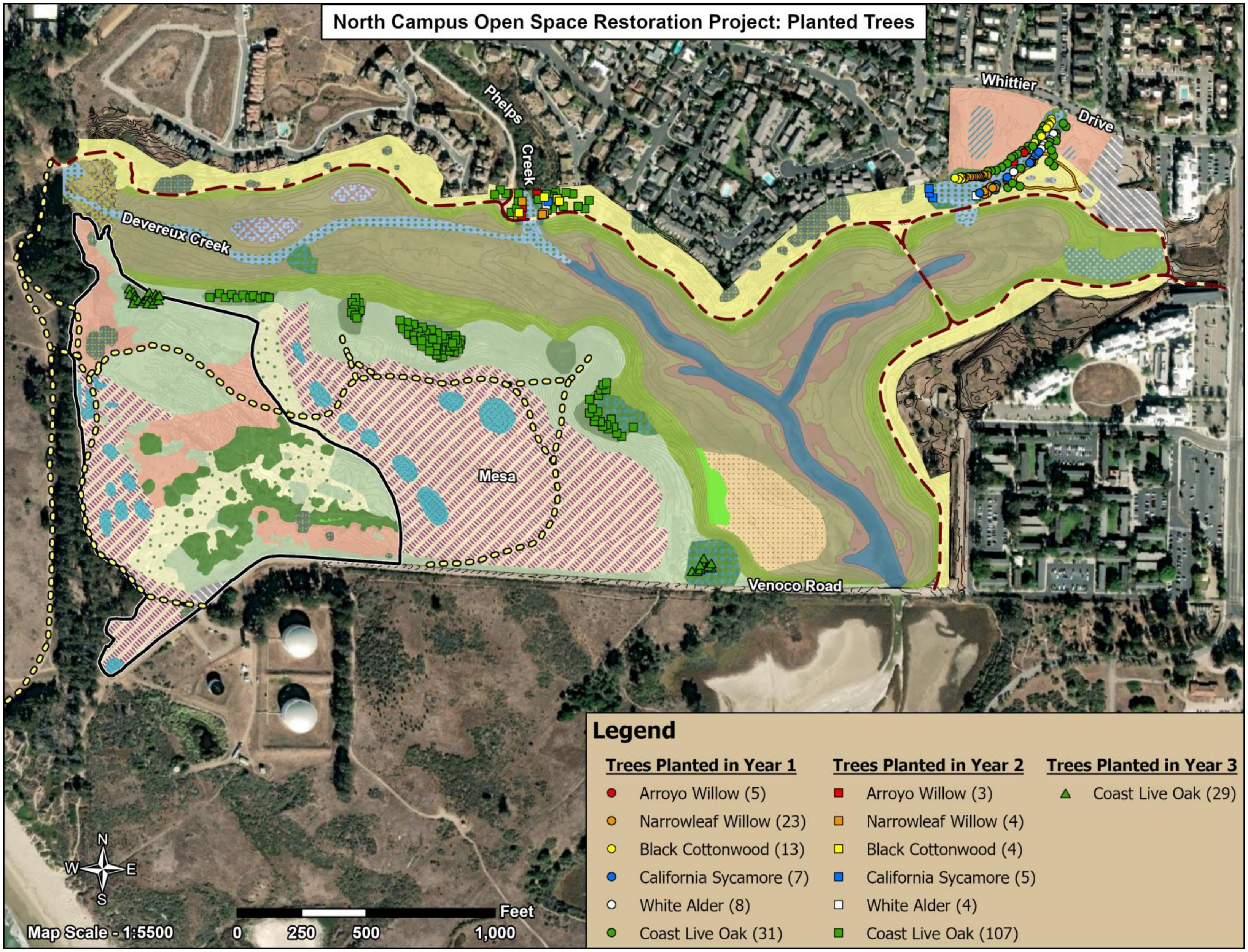

Figure 17. Map of trees planted during the first three years of the North Campus Open Space restoration project. See Figure 1 for a legend of the habitats/plant communities and trails.

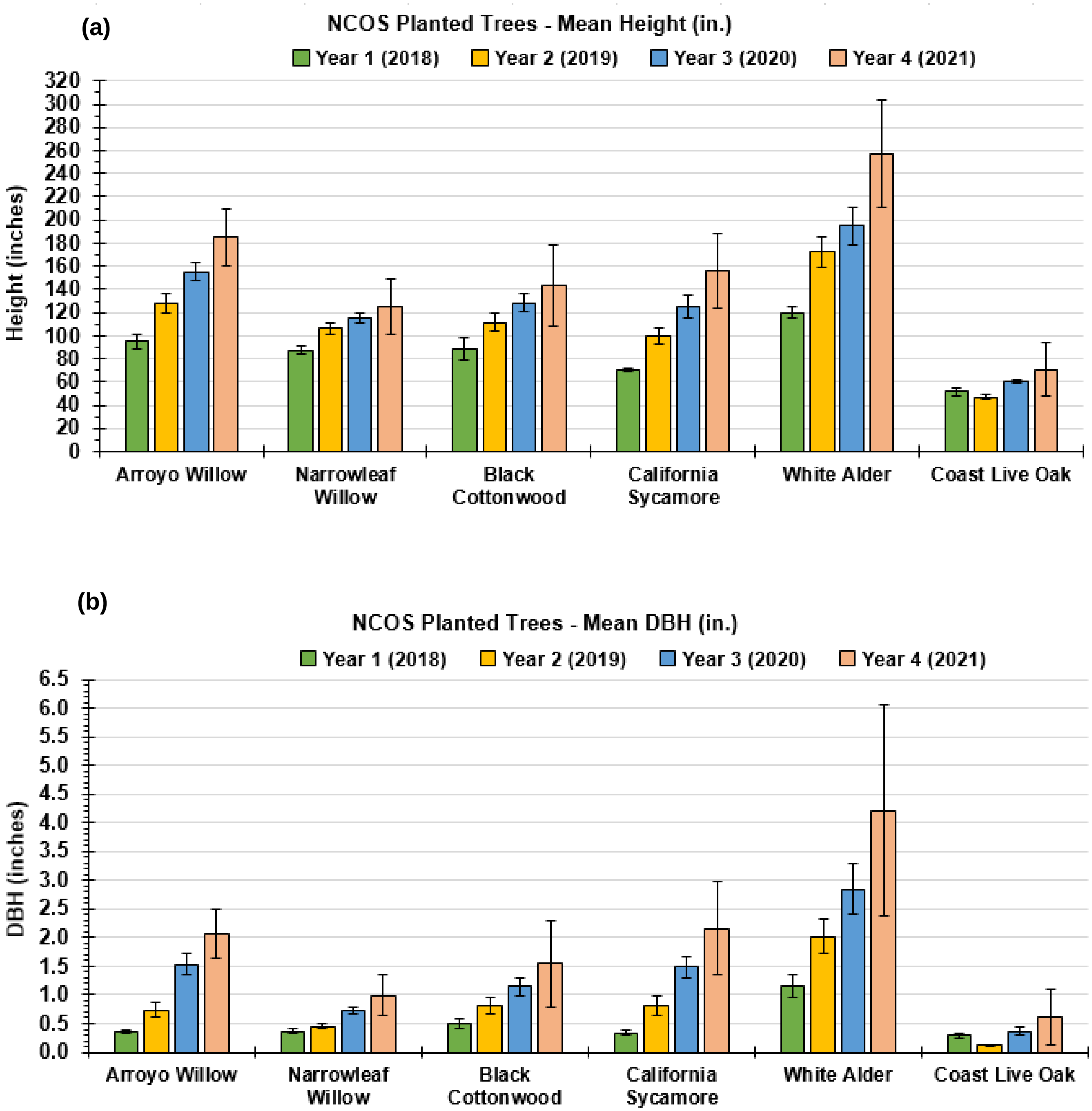

Figure 18. Bar charts of (a) the mean height (inches) and (b) mean diameter at breast height (inches) of six tree species planted during the first and second years of the North Campus Open Space restoration project. Error bars are +/- one standard deviation of the mean.

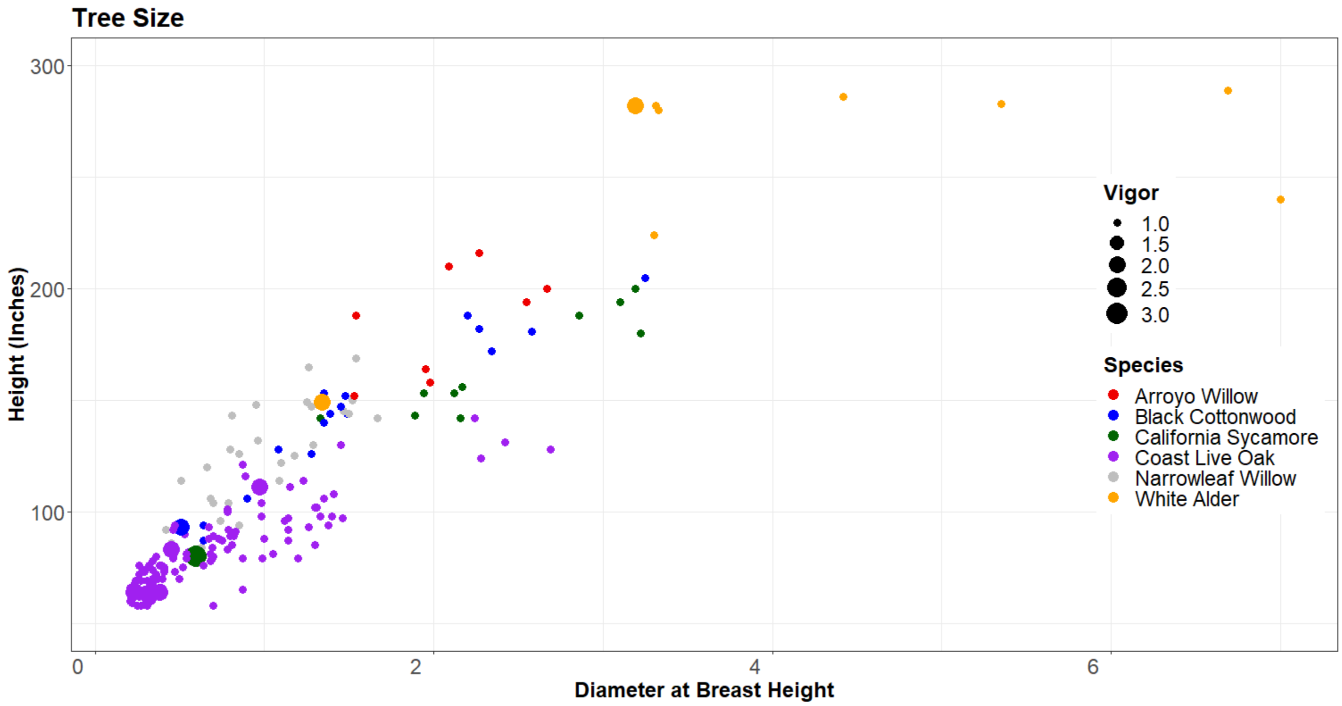

Figure 19. Scatter plot of tree height and diameter. This figure represents all living planted trees that are part of the study within the NCOS property in year 4. The size of point represents the vigor or health of the tree, 1 represents the healthiest tree, while 4 represents a dead tree (note dead trees are removed from this figure).

4. WILDLIFE

Wildlife monitoring efforts at NCOS are focused primarily on monthly bird surveys and targeted surveys for sensitive and special status species such as the federally endangered Tidewater Goby, the threatened Western Snowy Plover, and the California state endangered Belding's Savannah Sparrow. Certain aspects of NCOS are designed and managed specifically to support these and other special status species such as the Burrowing Owl. The status of these species at NCOS are described later in this section.

Additional studies and surveys that examine and document the development of the greater food web at NCOS are focused on wildlife such as arthropods, small rodents, and reptiles. These projects are briefly described at the end of this section.

Bird Survey Methods

CCBER has conducted monthly bird surveys at the project site since September 2017. The surveys are conducted in the morning, beginning within one hour of sunrise, and typically taking two to 2.5 hours to complete. Beginning at the Venoco access road bridge near the southeast corner of NCOS, two teams of observers walk eastern and western routes around the site, typically meeting at the end of the survey near the trail bridge over Phelps Creek along the northern side of the site. At least one expert birder takes part in each survey, helping to verify species identification and counts.

Using binoculars, spotting scopes and the GIS app ESRI Collector on a tablet, each team records every species of bird seen or heard on site, including birds flying between habitats or structures on or adjacent to the site. The ESRI Collector app also automatically records the route walked by each of the two teams. Each observation recorded in the app includes a minimum of the following information: the location and substrate/habitat of the observation, bird species (common name), and count (number of individuals of the species for the observation). Observations of birds seen previously during the survey in a different habitat, or that may have been observed by both teams are recorded as "Repeat Observations". Additional information that may be recorded includes sex (male, female, or juvenile), evidence of breeding activity, and any other notes about the observation such as unusual or notable behavior and descriptions to help with uncertain identification of birds. The elevation of the water in the slough (read from a staff gauge at Venoco bridge) and the weather conditions (temperature, wind speed and direction, cloud cover and precipitation) are recorded at the beginning and end of the survey. An example of a map of the observations and routes recorded using the ESRI Collector app for a typical survey is presented in Figure 20.

After the survey is completed, the total count of each species observed is reviewed and revised if needed by the expert birder and each team leader. Lastly, the final, reviewed list and count of species observed for each survey, excluding repeat observations, is uploaded to the Cornell Lab of Ornithology's eBird repository.

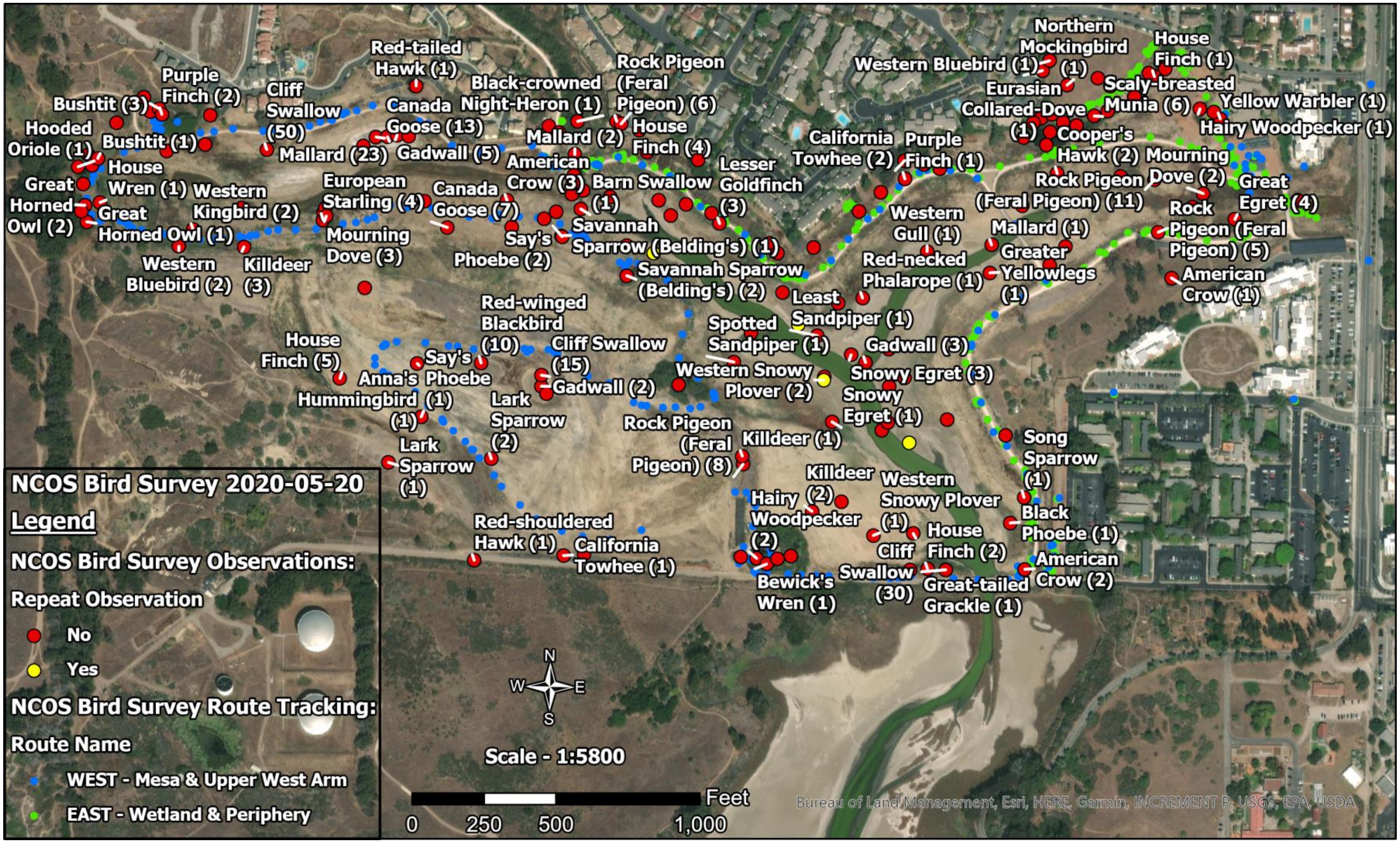

Figure 20. Map of observation data and routes from a bird survey of NCOS conducted on May 20, 2020. Using the ESRI ArcGIS Collector app on tablets, the observation data is manually entered by a member of each team and the route tracking is automatically recorded every 30 seconds. Many, but not all of the observation points from this survey are labeled in the map, including two locations where Savannah Sparrow (Belding's) and Western Snowy Plover were seen.

Bird Survey Data & Trends

Guilds and Data Metrics

To facilitate an efficient means of summarizing, analyzing, and interpreting the bird survey data, we categorized the species observed into 13 guilds based on their primary habitat and/or food source, or ecological niche. We have split the large and diverse insectivore guild into two starting in monitoring year 3, separating species that are predominately aerial insectivores (*e.g*. swallows and flycatchers) into an insectivores – aerial guild, and all others into an insectivores – terrestrial guild (e.g. blackbirds, sparrows, woodpeckers, and wrens).

In year 1 and 2, we presented the cumulative total count of birds in each guild observed each year (September through August). The cumulative total count for a survey year is not a measure of the abundance of birds on NCOS. In this report, we present the data in terms of the mean counts per monthly survey. This metrics represent the approximate abundance and variation of birds on the site throughout each year. In addition, we report the total number of species observed and the percent of total observations by guild for each of the four years of survey data collected from September 2017 through August 2021.

Comparison of Survey Years

Bar charts comparing the mean count per survey and the total number of species observed in each guild are presented in Figure 21. In Figure 22, pie charts show changes in the percent of total observations per guild in each year, and Appendix 3 contains a list of all species observed in each survey year grouped by our guilds and sub-classified into eBird Species Groups as defined by the "eBird Clements v2018 integrated checklist (August 2018)".

The overall mean number of birds observed per survey increased, from 400 in year one to 521 in year two, and then to 677 in year three (September 2019 – August 2020) but dropped to 470 in year 4. The increasing trend is primarily driven by large annual increases in the mean counts of the two Insectivore guilds and especially the Waterfowl & Allies guild (Figure 21). In fact, two Insectivore species (Cliff Swallow and White-crowned Sparrow) and three Waterfowl & Allies species (American Coot, Canada goose, and Mallard) account for most of the increase in these two guilds (see Appendix 3). The year 4 decrease in birds observed is likely due to the low water levels associated with an early (January) breach of the slough mouth and the lack of ensuing rain. The year 4 estuary water level was the lowest out of all monitored years in all months except March and April (figure 23). We suspect that the water levels are correlated to the decrease in bird observation because we saw the greatest decrease in groups dependent on water. Most notably there was a significant decrease in 'Gulls, Terns and Skimmers', 'Herons Egrets and Ibis' and the 'Waterfowl and Allies' group. There was an increase in Cormorants, Hummingbirds, Omnivores, and raptors from year 3 to year 4. Figure 24 shows the relationship between waterfowl and friends, season, and water elevation (for all years of data). There is both the highest diversity and the highest bird count in winter months when water elevation is high. The increase in birds in the winter is somewhat expected due to migration patterns. Fall and Summer bird numbers and diversity is also higher when water levels are higher. The extremely high number of birds observed in March 2020 (figure 24) that results in a steep negative trend line for the spring data is largely due to the observation of 189 American Coots and 115 Northern Shovels. Thus the determination of when 'spring' begins affects this trend line for the spring data.

While there were fewer sightings of most species of shorebirds in year 4 compared to year 3, Western Sandpiper sightings more than tripled and peep sp sightings increased 7 fold compared to year three. These two species forage in shallow water and, due to the low water stage, there were more locations providing appropriate habitat.

The total number of species observed increased from 104 in year one to 129 in year two, 128 species in year three and 115 species in year four. Though we did not observe an increase in the number of species in the third and fourth year of surveys, we did record several species not seen in previous years. Species that were spotted for the first time in year four include the Great-tailed Grackle, Common Raven, Peregrine Falcon and American Goldfinch. Collectively, 169 species have been recorded over the four years of surveys. This covers 78 percent of the 216 species reported to the eBird repository for this site since 2018 (ebird.org/hotspot/L820867?yr=all&m=). E-bird data reflects unique species that are often on the site for short periods of time and may not be captured in the monthly bird surveys such as American Bittern. Trends in the total number of species and the percent of total observations per guild are similar to the mean monthly counts, though at a smaller degree of change between years (Figures 21 and 22).

Discussion of Slough Water Level Influence on Bird Trends

One factor that may influence the trends observed in the third and fourth year of surveys is the water level. There was a large increase in waterfowl and allies, and herons, egrets and ibis's groups and a moderate increase in nearly every other bird group in year 3. This is likely because the water level in year three was significantly higher than any other year in most months due to the fact that the estuary filled in January and did not breach until mid-March in 2020. In the 2021 water year the estuary breached in January and never refilled leaving the water level much lower. Year four resulted in a sharp decrease in abundance of waterfowl and Allies and a modest decrease in nearly every other bird category excluding omnivores, raptors, and hummingbirds. Much of year four had drought conditions with water levels below what was observed in year three for all months except March and April (Figure 23). See appendix 3 for a full list of bird sightings from NCOS monthly bird surveys.

Comparison with Reference Site

To the south of NCOS, and encompassing the majority of Devereux Slough, Coal Oil Point Reserve (COPR) is an important reference site for most of the bird species that we expect to see at NCOS as the restoration progresses. Monthly bird surveys at COPR are usually conducted within two days of the NCOS surveys. However, surveys were not conducted at COPR during most of 2020 due to restrictions associated with the COVID-19 pandemic. We have compared bird species abundance and diversity at the two sites for the first two years of surveys at NCOS. Excluding the beach habitat at COPR, the two years of survey data showed that the sites are generally similar in overall diversity and abundance. In the second year of surveys, COPR had a greater abundance of Shorebirds, Herons/Egrets, and Cormorants, while NCOS had more Insectivores and Seed/Fruit eaters. This comparison of bird survey data from the two sites is described further in a short article on the CCBER website (www.ccber.ucsb.edu/news-events/2nd-annual-ncos-vs-copr-bird-survey-roundup).

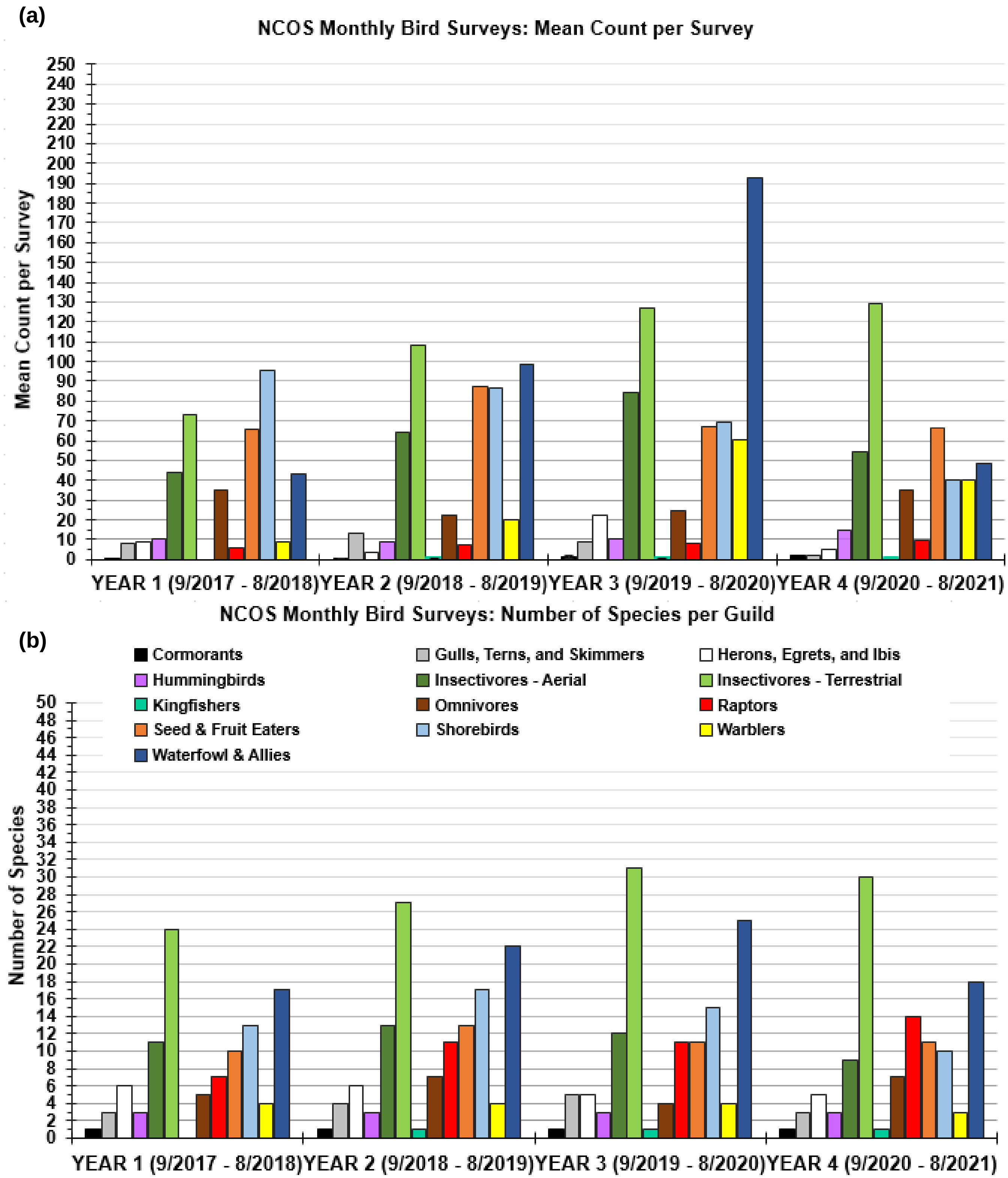

Figure 21. (a) Mean of counts per survey of birds in 13 guilds (legend in chart (b)) observed in each year (September through August) of monthly surveys at NCOS. (b) Total number of species observed in 13 guilds in each year of monthly bird surveys at NCOS.

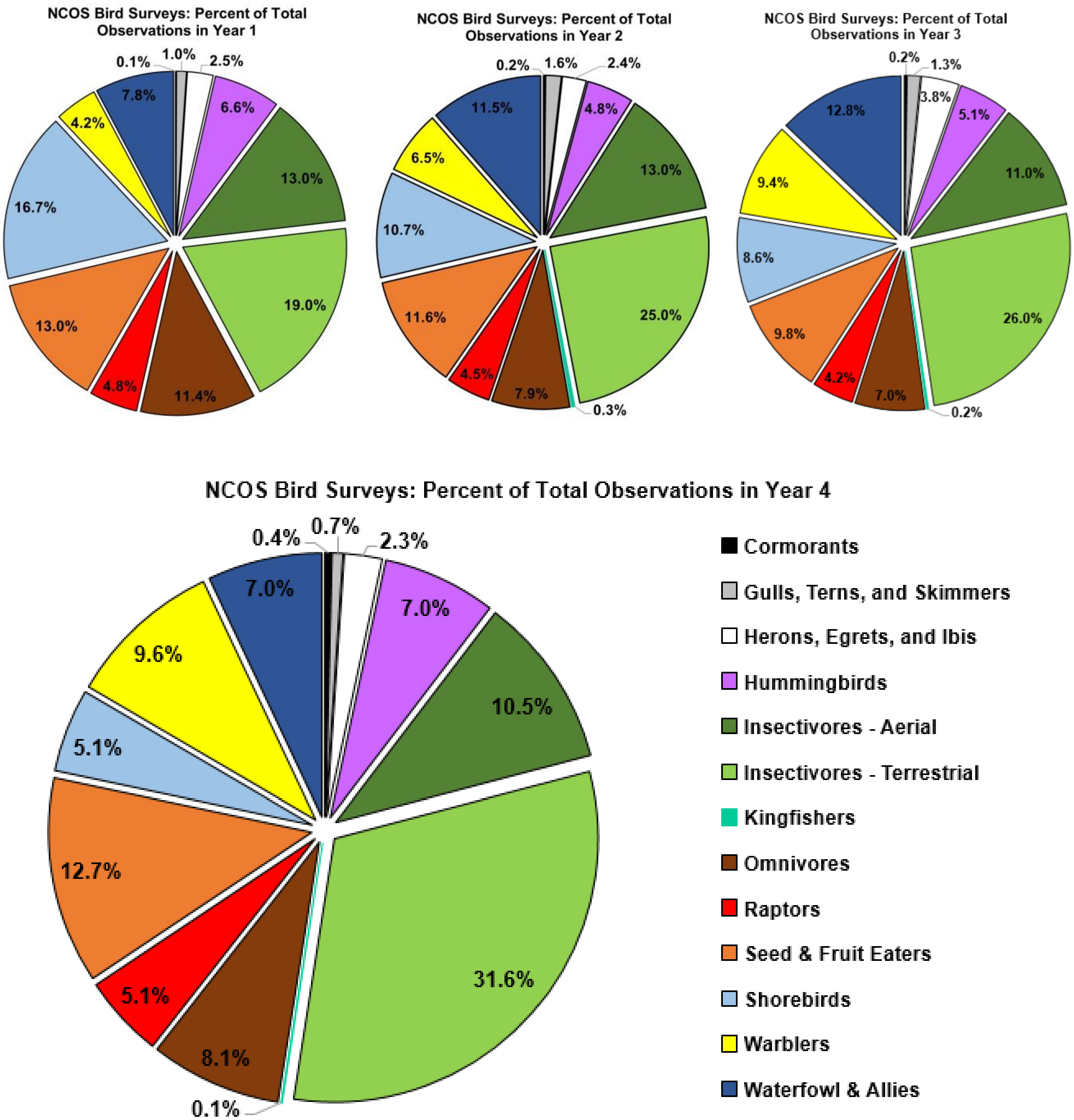

Figure 22. Pie charts of the percent of all observations by guild in each year (September through August) of monthly bird surveys at NCOS.

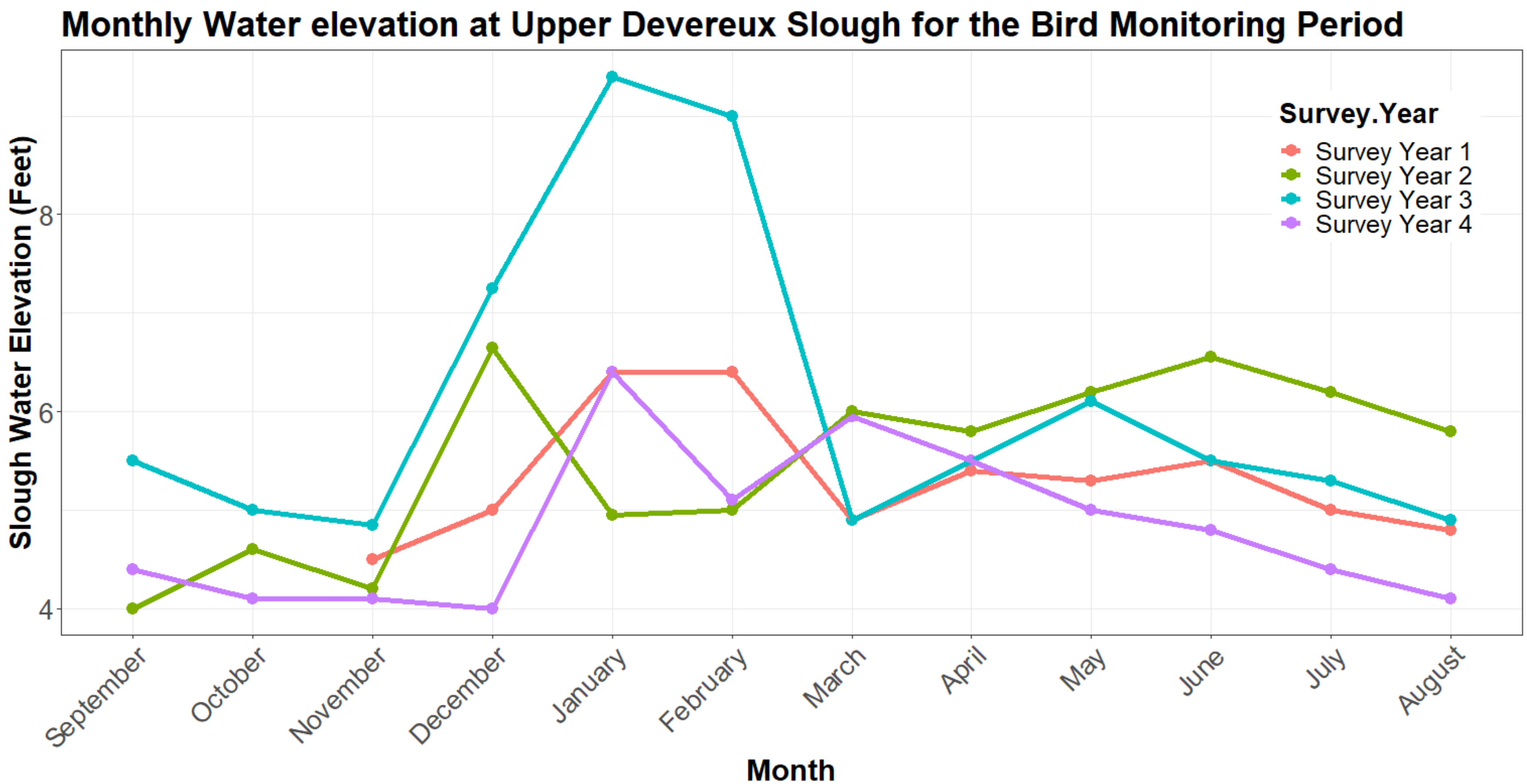

Figure 23. Line graph comparing the water surface elevation (in feet) of the upper Devereux Slough for each year (September through August) of monthly bird surveys at NCOS. Year 1 (2017-18), Year 2 (2018-19), Year 3 (2019-20), Year 4 (2020-21).

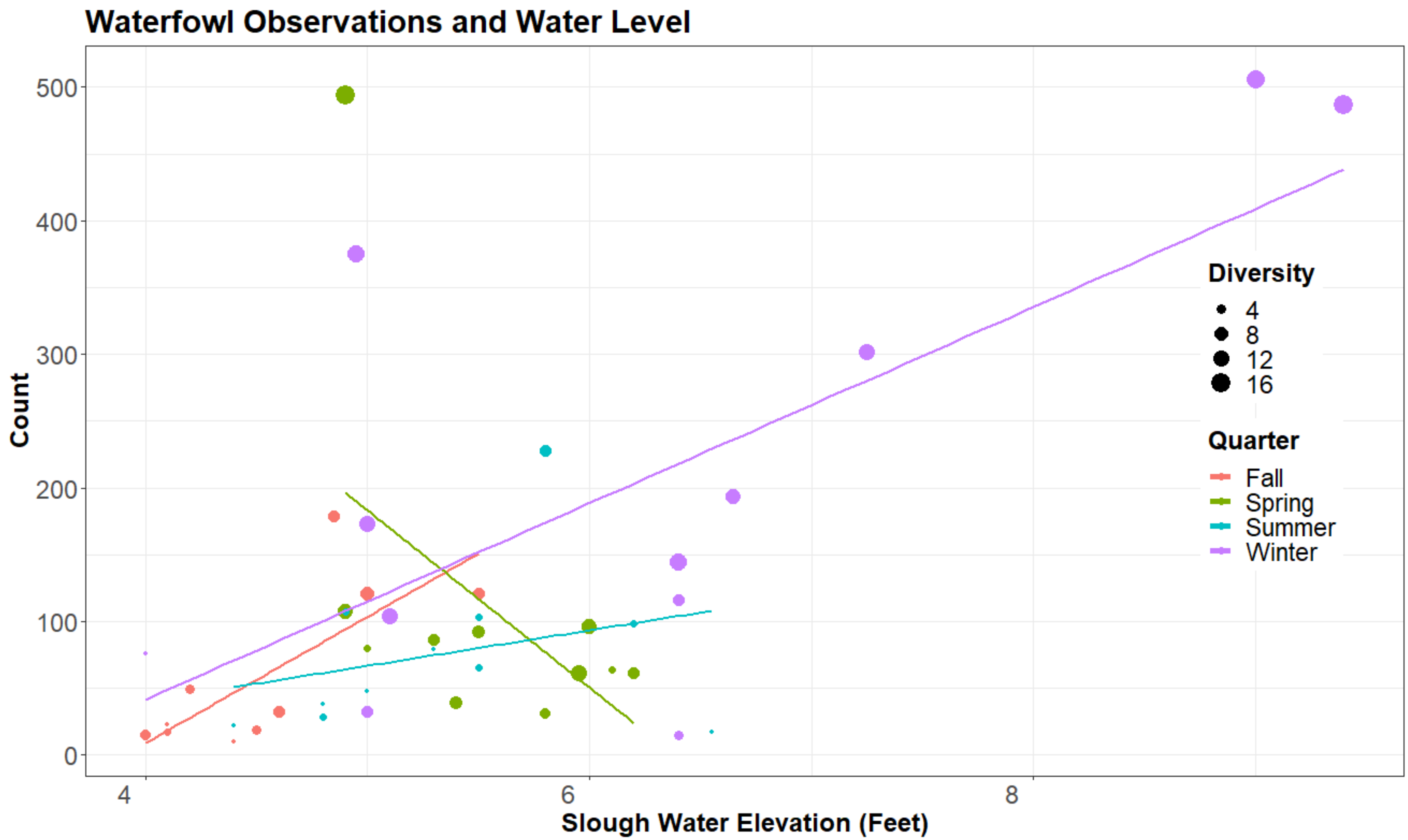

Figure 24. Number of waterfowl observed in monthly surveys from 2017-2021 and a linear trend line for each season. The size of each point represents the number of species seen in that survey. Season has a strong effect on observations because of migration patterns.

Figure 25. Aerial photos of North Campus Open Space by Bill Dewey. Top: December 2019 showing the high-water level; Bottom: August 2021 showing the low water level.

Special Status Birds

Three bird species of particular interest at NCOS include the threatened Western Snowy Plover, the California state endangered Belding's Savannah Sparrow, and the Burrowing Owl, a species of conservation concern nationally and in California. Certain areas of NCOS are designed and managed with a focus on providing suitable and secure habitat for these species, such as the sand flat for supporting breeding by the Western Snowy Plover, the large areas of undisturbed salt marsh for the Belding's Savannah Sparrow, and multiple hibernaculum and burrows for the Burrowing Owl.

Western Snowy Plover's were recorded on site in the first three years of the survey. Breeding attempts have occurred in each of the first three years, with one unsuccessful nest in 2018, two in 2019 and one in 2020 that produced at least one fledgling, though it is uncertain whether it survived. No Western Snowy Plovers attempted nesting on site in the fourth year of surveying, despite our efforts to optimize the habitat by disking to remove vegetation. One likely explanation for the absence of Western Snowy Plover nesting at NCOS is the simultaneous optimization of snowy plover habitat at Coal Oil Point at the beach. Coal Oil Point Reserve management began crow control in early 2021, reducing the potential for snowy plover chick predation at the beach. The beach gets regular energy and food supplements from deposited kelp wrack and when predation is reduced, is a more ideal plover habitat.

Belding's Savannah Sparrow have been recorded in each year of surveys, particularly in the spring and summer. There have been multiple observations with counts of more than one individual, with five being the highest count recorded to date. In the May 2020 survey, we recorded three separate observations of males singing and in fall 2021 we found a nest demonstrating breeding activity on site by this somewhat encrypted species.

On the top and slopes of the mesa, about 50 of the 65 hibernacula habitat features were installed at the start of the project with Burrowing Owl in mind as well as to provide refuge for other species while vegetation became established. At least one overwintering Burrowing Owl was recorded during surveys from October to March in the fourth year of surveying. A total of 9 observations of Burrowing Owls were recorded in the fourth surveying year- this is an increase from previous years. In October of 2020, we installed six artificial burrows specifically designed for Burrowing Owl on the mesa, and we have recorded two owls using these features in the year three survey and three owls using these features in the fourth year of surveying.

Figure 26. Top Left image: Western Snowy Plover adult and chick on the sand flat at NCOS in June 2020 (photograph by Mark Bright). Top Right image: A Belding's Savannah Sparrow seen during a monthly bird survey at NCOS in November 2018. Bottom Left image: Belding's Savannah Sparrow nest with 3 eggs found at NCOS in 2021. Bottom Right image: Burrowing Owl spotted at NCOS in October 2021.

Figure 27. Top image: One of three pairs of artificial burrows constructed on the mesa of NCOS in the summer of 2020. Bottom image: A Burrowing Owl at an artificial burrow entrance in November 2020.

Breeding Bird Observations

During the monthly surveys, an effort is made to record observations of breeding behavior such as gathering or carrying nest material, courtship/territorial displays or singing, copulation, and actual nests with eggs or chicks, or dependent fledglings with adults. With four years of data, we now have observations of breeding behavior recorded for 28 species, including observations of breeding behavior of 4 new species in 2021. There is an average of 12 species and 24 breeding behavior observations per year (Table A3.2 in Appendix 3).

Another source for records of breeding behavior at NCOS is the Santa Barbara Audubon Society's Breeding Bird Study database. The data extracted from this database for NCOS is like the monthly bird survey data, with a total of 26 species exhibiting breeding behavior at the site since 2018 at an average of 15 species and 30 observations per year. 2021 observations show 25 species and 38 observations of breeding at NCOS. This database does include some of the records from our monthly bird surveys (Table A3.2 in Appendix 3).

Special Status Aquatic Species

To fulfill project grant and permit monitoring requirements, and for general interest, CCBER has conducted pre- and post-construction surveys for three sensitive and special status aquatic species: California Red-legged Frog, Tidewater Goby, and Southwestern Pond Turtle. Surveys completed in the years 2016-2020 were led by a permitted biologist, Rosemary Thompson (federal permit TE-815144-9, state permit SC-002731) and in 2021 the survey was led by permitted biologist Hannah Donaghe (federal permit TE14532C-1, state permit S-201000002-20167-001), with the assistance of CCBER staff.

None of the surveys conducted found presence of the California Red-legged Frog or Southwestern Pond Turtle. One survey, conducted in October 2019 recorded the presence of 5 Tidewater Goby in the lower slough, this is described in the technical report included in the year 2 NCOS monitoring report (escholarship.org/uc/item/5sj929vh). All other surveys (2017, 2018, 2020 and 2021) did not find any Tidewater Gobies present. The survey conducted in July 2020, unlike prior surveys, did not include the lower portion of Devereux Slough that lies within Coal Oil Point Reserve due to restrictions associated with the COVID-19 pandemic. A Technical Memorandum about the results of the August 2021 survey is provided in Appendix 4 of this report.

Outside of the surveys described above, CCBER staff have observed a Southwestern Pond Turtle prior to construction in the area where Phelps Creek flows into NCOS, and periodically in the same area since the first post-construction sighting in November 2018. The last documented sighting of the species was in March of 2019.

Invertebrate Surveys & Studies

Terrestrial Arthropod Surveys, Monitoring, and Collection

A survey of primarily terrestrial arthropods, using four sampling methods, was conducted in the spring and summer of 2016 as a pre-restoration "snapshot" of arthropod diversity and abundance in the six dominant vegetation communities. The results of this project are continuing to be compiled and have led to multiple subsequent and ongoing undergraduate and graduate student research projects. A similar, post-restoration survey may be conducted after plant communities and habitats have become established across the site.

In the meantime, monthly targeted sampling of bees using several grids of yellow, white, and blue colored pan traps began in October 2018 at NCOS and other sites with varying levels of restoration or ecosystem management both on and off the UCSB campus. While the monthly bee sampling and related arthropod field work were suspended in March of 2020 due to the COVID-19 pandemic, the identification and quantification of samples in the collection has been able to continue. To date, classification of the specimens collected during the 2016 survey and the monthly bee sampling has identified 158 taxa (including subspecies and variants) on NCOS and surrounding land, 40 of which were directly on CCBER property. This list is available on CCBER's Symbiota database here.

Aquatic Macroinvertebrate and Zooplankton Study

A study comparing the aquatic macroinvertebrate species of the newly restored wetlands at NCOS with long established wetlands in the adjoining Coal Oil Point Nature Reserve (COPR) began in the spring of 2018 through a collaboration with the Santa Barbara Audubon Society and the COPR Nature Center. Several undergraduate interns and volunteers collect aquatic macro invertebrate samples using the filtered bucket method and occasionally soil core samples at 6 sites once per academic quarter (four times per year). The samples are preserved, sorted and identified by students and analysis is done for each location. There are five locations in the main wetland channels and creeks of NCOS as well as one of the seasonal ponds in the western arm and two vernal pools on the mesa. These samples are compared with samples collected from up to five sites in COPR (three in the lower Devereux Slough and two from seasonal freshwater ponds).

The sampling conducted in 2018 found up to 13 taxa at NCOS dominated by four types overall (Copepoda, Corixidae, Ostracoda, and Cladocera), with an additional four taxa having relatively high abundance in benthic samples (Chironomidae, Ceratopogonidae, Ephydridae, and Nematoda). In comparison with COPR, the study has found that NCOS appears to have equivalent, if not slightly greater species richness and evenness. A detailed report on the analysis of aquatic invertebrates collected in 2018 is available on eScholarship (escholarship.org/uc/item/59c872mm).

The compilation, analysis, and summarization of data from the 2019 samples is in process, and sample collection was suspended for most of 2020 due to the pandemic. Sample sorting and identification has been significantly slower in 2021 due to the pandemic, however samples have been collected and preserved in each quarter for future processing and analysis. The 2019 aquatic macroinvertebrate report will be published as a separate document to eScholarship in early 2022.

Small Rodents, and Reptiles

Beginning in November 2019, CCBER initiated an education-focused program to assess and monitor the presence and abundance of small rodents and reptiles in the Salt Marsh and Native Grassland habitats on and adjacent to the NCOS mesa. One of these projects is a collaboration with the lab of UCSB Ecology, Evolution and Marine Biology Associate Professor Hilary Young and conducted under approval of Institutional Animal Care and Use Committee (IACUC) protocol 908.1. The objective is to provide an educational experience in ecology for students while monitoring changes in the abundance and diversity of small rodents as the restoration progresses. The surveys are conducted by setting out three grids of 20 Sherman Live traps for four nights in a row in each habitat. The traps are baited and cotton balls are added to offer additional shelter and protection for captured animals through the night. All traps are checked early in the morning to avoid heat stress, and any animals captured are quickly identified, measured (length and weight) and marked with an ear tag or sharpie marker on the foot before they are released. Starting in fall 2019 we conducted a spring and fall survey each year. Two common mouse species, Deer mice (*Peromyscus maniculatus)* and Harvest mice *(Reithrodontomys megalotis),* were captured, with greater numbers of individuals captured in the Salt Marsh than in the grassland.

Results from the spring 2021 survey indicate that the same mice species are appearing in the traps. One Deer mouse with an ear tag from Fall 2020 was recaptured in the April 2021 survey. Two more mice with ripped ears- likely from previous tags- appeared in the April 2021 survey. In the 2021 survey deer mice account for 88% of the species captured while harvest mice account for the other 12%.

In October 2020, we established a student-led, long-term monitoring project that involves counting and identifying vertebrates and invertebrates under 44 coverboards distributed across the mesa and transition/high salt marsh zone along the southwestern half of NCOS. While this monitoring project is focused primarily on reptiles such as lizards and snakes, all other vertebrates and invertebrates encountered are being recorded and compared with data from pre-project coverboard surveys. The main purpose of this project is to compare small animal presents in a variety of habitats with different histories of disturbance and restoration. Both of these small rodent and reptile monitoring projects are continuing in 2021 and we expect to have more data to report on next year. In addition, a camera trap and tracking tube observational study on the use of hibernaculum features was conducted in the later winter and spring of 2021 by a student who presented his results at the Ecological Society of America Conference in August 2021. This study identified 23 species of vertebrates using these rock features with 5 common species. Fence lizards and ground squirrels used the features during the day and mice and rabbits were more frequently observed at night. Burrowing Owls used the sites in the day and night.

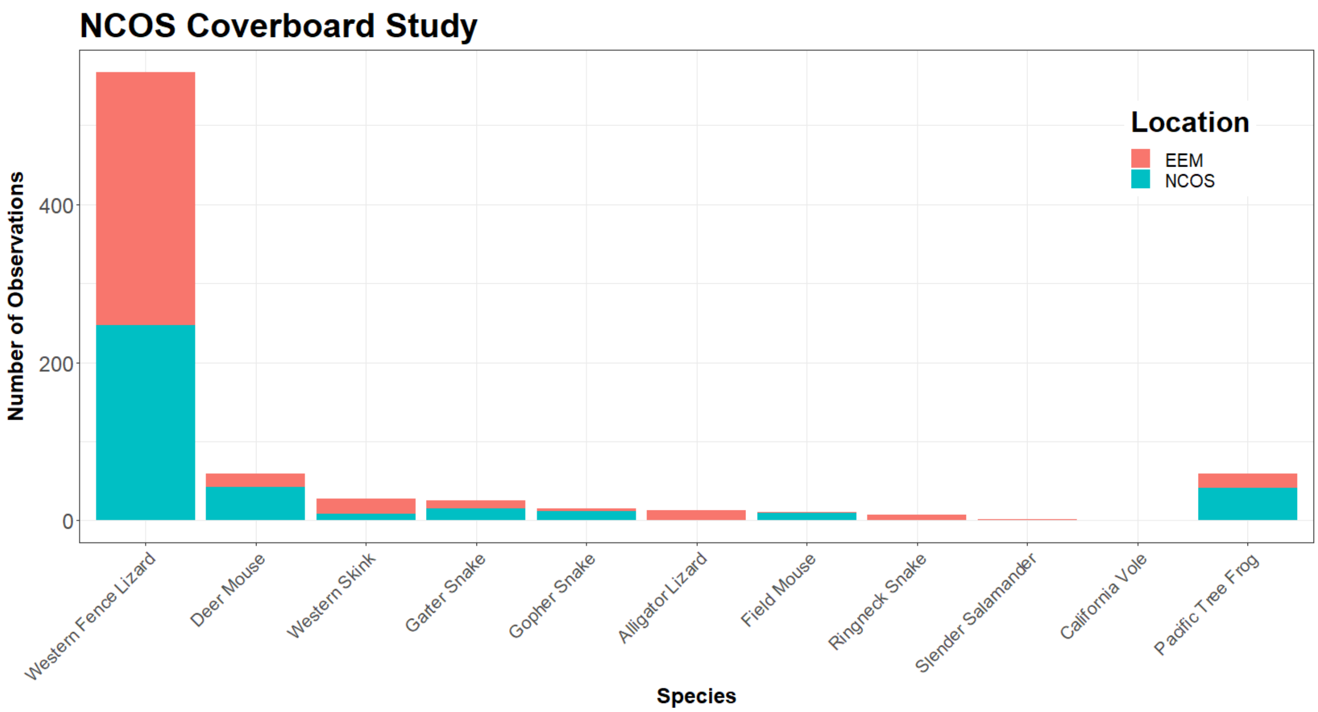

Figure 28. Results from 1 year of the coverboard study October 2020-October 2021. There are 22 NCOS coverboards and 22 EEM coverboards. EEM is the 25 acre ungraded portion of the larger project and NCOS is the graded portion.

5. HYDROLOGY AND WATER QUALITY

Hydrology and water quality monitoring at North Campus Open Space contributes to several objectives of the restoration project, such as: documenting the reduction of flood levels, monitoring the development and functionality of wetland habitats such as Devereux Slough and the newly created vernal pools, and developing long-term datasets that help improve knowledge and understanding of coastal ecosystems and how they may be affected by predicted future sea-level rise.

In this section, we describe the monitoring methods and data for the following:

- various aspects of the hydrology of Devereux Slough,
- the hydrology of the vernal pools created on the NCOS mesa,
- the hydrology and salinity of groundwater at the restoration site,
- dissolved oxygen and salinity levels at different locations and depths in the slough,
- the concentrations of nutrients and suspended solids in storm water entering and flowing out of Devereux Slough.

The hydrology of water Devereux slough in the 2021 water year was much different than that of the 2020 water year. The 2020 water year had the highest water level for most months compared to other monitoring years, while the 2021 water year had the lowest water level in most months. In the 2021 water year there were 3 storm events, one in December 2020, one in January 2021 when the mouth breached and only minor rains afterwards that did not re-fill the estuary. After January of 2021 there was very little precipitation. This resulted in drought like conditions and the slow continuous drop in water levels for the rest of the water year due to evaporation. Vernal pools at NCOS were only observed to have consistent water in them for approximately 65 days between January 29th and April 8th. The lack of significant rain after January led to a very low water level and very high salinity in the slough by late summer and early fall. In fact, much of the upper portion of the slough became almost completely dry by the end of September.

Ground water measured at 19 wells on site showed expected results given the local rain patterns. Depth to ground water and salinity were responsive to rainfall events; showing a decreased depth to ground water and decreased salinity following a rain event. Showing a similar pattern to surface water, depth to ground water and salinity increased slowly after the last major rainfall event of the water year (Figures 39-42).

Devereux Slough Hydrology

Monitoring the hydrology of Devereux Slough contributes to several of the North Campus Open Space restoration project's goals as well as research interests. One of the main goals of the restoration project is to restore the natural flood plain function of the wetland and, consequently, to lower flood levels that previously affected the developments adjacent to the tributaries of the wetland.

The hydrology data is also important for documenting the increased water holding capacity of Devereux Slough, and the timing, frequency, and duration of tidal flux. There is a berm that typically breaches once a year causing Devereux slough to become tidal. In the 2021 water year the large storm in January caused the berm to breach and Devereux Slough remained tidal for 20 days. The tidal patterns seen in 2021 were different than in the previous 2 years. In 2019 and 2020 once the slough broke and became tidal it would remain tidal for about 5 days during high tide and then no longer show signs of being tidal until the next predicted high tide. This pattern of becoming tidal for a few days and then not lasted for about 2 months. In 2021 the slough remained consistently tidal for 20 days and showed only slight signs of tidal influence for 3 days in March with no signs of tidal influence thereafter. In addition to monitoring water levels, CCBER is collecting data on flow rates in the main tributaries that enter the slough. The purpose of this is to quantify the fluxes of nutrients and sediment entering the system, to understand the erosional impacts of upstream development and associated imperviousness, and to document storm intensity, which is predicted to increase with climate change. The surface water level and flow rate monitoring methods and data are described in the following two sections.

Surface Water Levels - Methods

Throughout the third and fourth year of the restoration project, surface water levels at NCOS were monitored using pressure transducer loggers deployed at seven locations:

- Devereux and Phelps Creeks,
- the storm drain outfall that flows into Whittier Channel and in Whittier Pond,
- the upper eastern arm of the restored slough where it is crossed by the long trail bridge,
- Venoco Road bridge where the restored upper slough meets the extant lower slough,
- and in the lower slough at the pier.

The logger in the lower slough is a multi-parameter YSI EXO1 sonde and all others are Solinst Leveloggers. The Leveloggers are set at a fixed depth within a few inches of the bottom or floor of the channel or pond. The approximate elevation (in North American Vertical Datum 1988, NAVD88) of the deployed leveloggers has been determined using either a Real Time Kinematic GPS unit, or by measuring the difference in elevation relative to the nearest reference point. Following an adjustment in August 2019, the elevation of the bottom of the EXO1 sonde was estimated to be 2.25 feet above sea level. The depth sensor on the sonde is 13.75 inches above the water quality sensors, which means the elevation of the depth sensor equates to approximately 3.4 feet elevation. Table 4 lists the locations and elevations of the loggers and Figure 29 contains a map of the locations of the loggers and other hydrology and water quality monitoring sites.

Table 4. Deployment location and elevation (in feet NAVD88) of pressure transducer loggers (YSI EXO1 and Solinst Leveloggers) that record water levels every 15 minutes in Devereux Slough and the North Campus Open Space. The deployment locations are indicated in the map in Figure 27.

Deployment Location	Logger Elevation (ft. NAVD88)
Devereux Slough Pier (YSI EXO1 sonde)	Water quality sensors: 2.25, depth sensor: 3.4
East Arm Trail Bridge	3.96
Phelps Creek - Marymount Bridge	9.99
Venoco Bridge - north side	2.84
West Arm - Devereux Creek	8.41
Whittier Storm drain	10.41
Whittier Pond	5.04

All loggers record the water level every 15 minutes. The EXO1 sonde automatically compensates for barometric pressure while the data recorded on the Solinst loggers are compensated using barometric pressure data recorded with a “Barologger” deployed on site. Water level data is converted to water surface elevation (WSE) in feet (NAVD88) using either the known elevations of the loggers (for Leveloggers) or regular readings of a WSE staff gauge (for the EXO1 sonde data). Note that the barometer used to compensate the levellogger data was out for service from 3/16/2021- 5/12/2021 and barometric pressure was taken from COPR weather station downloaded from NOAA for these dates. A subset of data was used to compare the barometric pressure from our Barologger and the downloaded COPR data for a one-month period (5/12/2021-6/12/2021). Results show an average difference in water level equivalent between the two barometric pressure compensations of 0.049 inches and is unlikely to affect the compensation process.

In addition, elevation profiles of the beach berm at the mouth of the slough are measured at least twice per year. This contributes to the development of a long-term database that documents how the wetland functions under wet and dry conditions and improves our understanding of breaching and tidal patterns as well as evaporation and low flows. The data will also be valuable for documenting potential future changes in sand berm elevation associated with sea level rise.

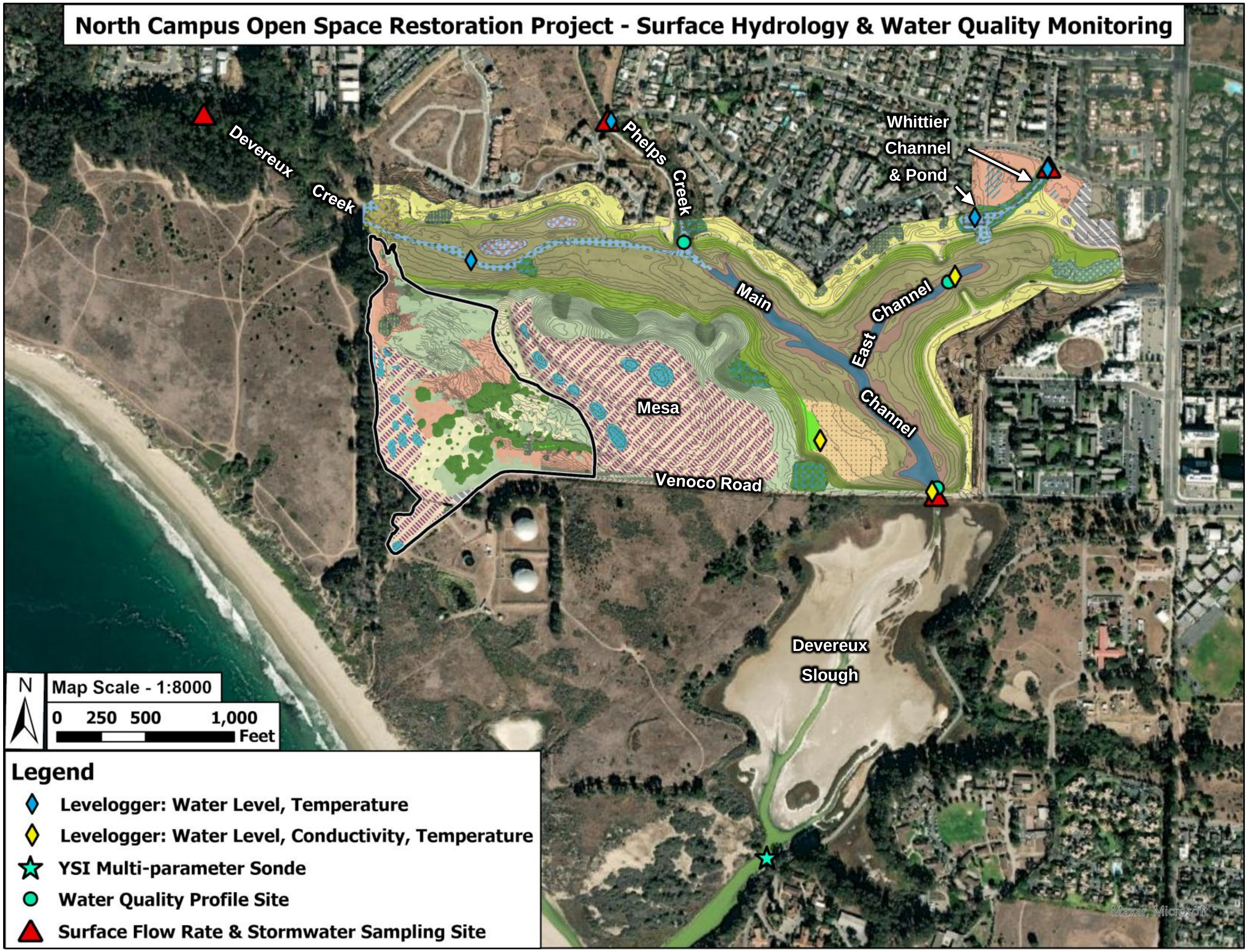

Figure 29. Map of the surface hydrology and water quality monitoring sites at North Campus Open Space and lower Devereux Slough. See Figure 1 for a legend of the habitats/vegetation communities.

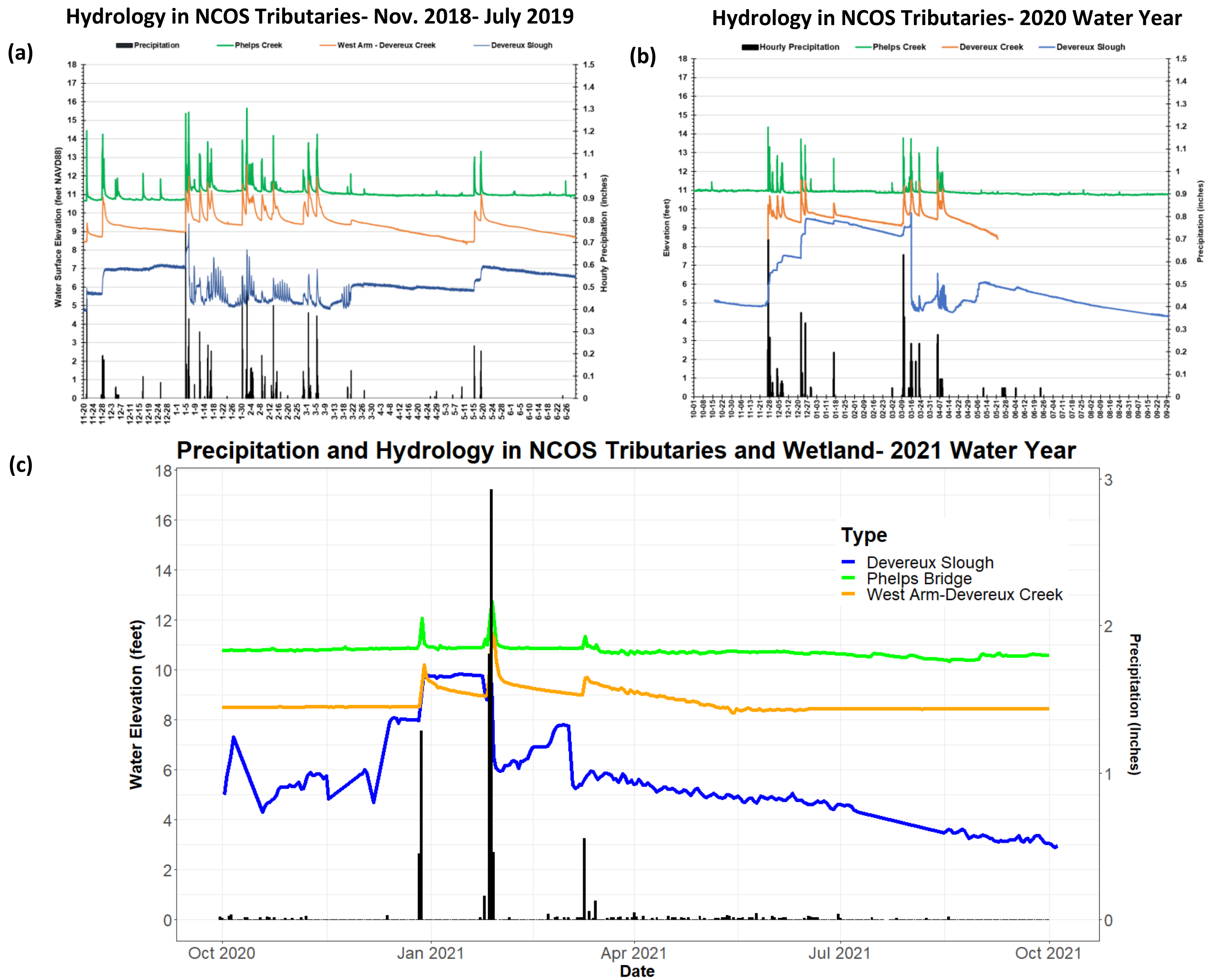

Figure 30. Water elevation collected from leveloggers located at 2 NCOS tributaries and the Wetland (Devereux Slough). Rainfall from NOAA for Water year (a) 2019 (b) 2020 and (c) 2021.

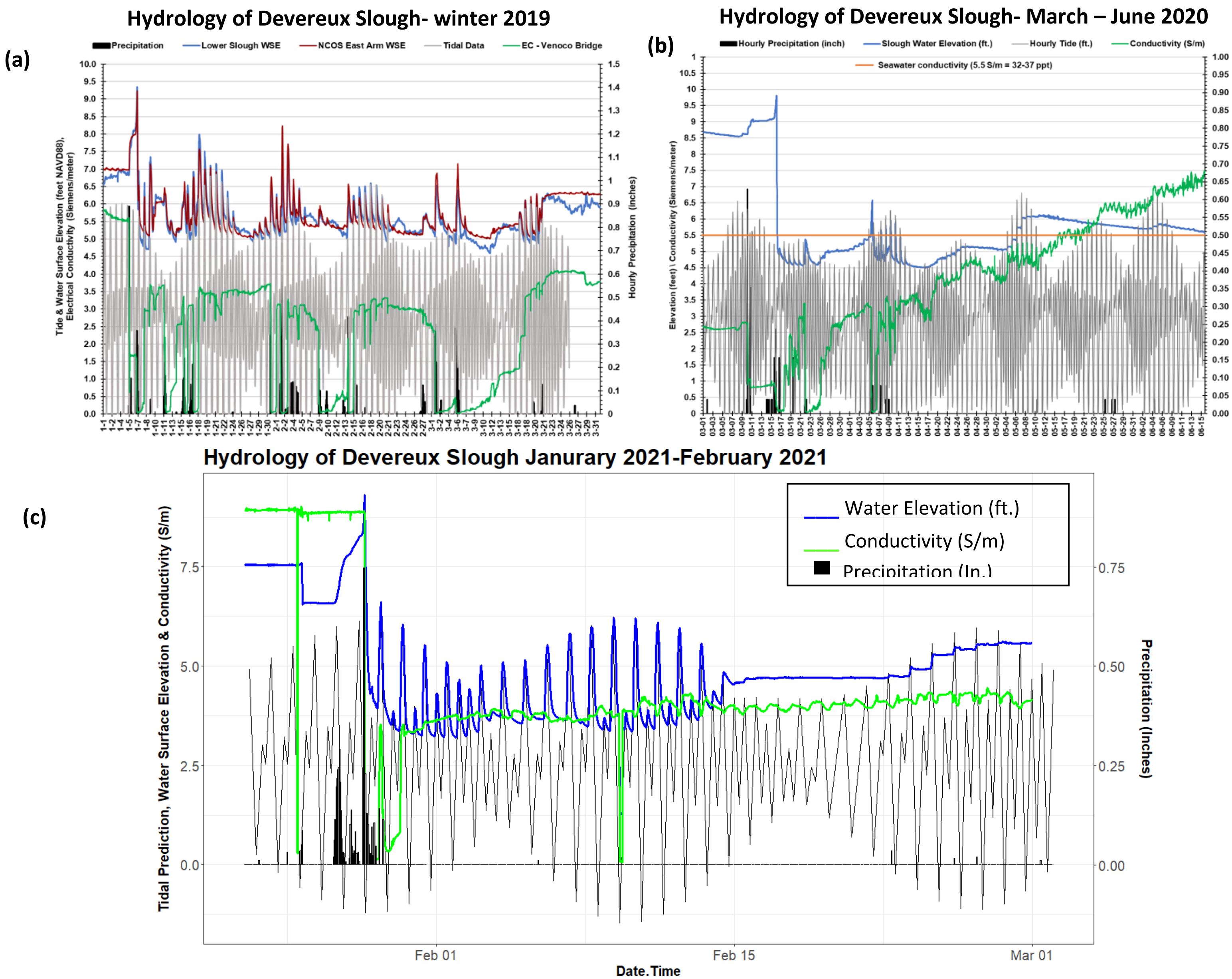

Figure 31. Water elevation and conductivity collected from YSI Sonde located at Devereux Slough. Tidal predictions and rainfall from NOAA for Water year (a) 2019 (b) 2020 and (c) 2021.

Surface Water Levels

Prior to the NCOS restoration project, half of the wetland's potential water-holding capacity was supplanted by fill soil deposited to create the Ocean Meadows golf course. This led to flooding of the golf course and adjacent low-lying areas near homes where the incoming creeks entered the site. As we described in previous NCOS monitoring reports, our hydrology data shows that the amount of water level rise in Devereux and Phelps Creeks during storms has decreased from pre-project levels by at least a foot for comparable storm intensities. The efforts of this project earned major recognition in September 2021 when FEMA officially issued a LOMR (Letter of Map Revision), which formally documents a change to the flood hazard zone of an area. The flood hazard zone is the extent of a particular landscape subject to a 1% chance of flooding in a year. Structures within the Flood Hazard Zone are required to secure flood insurance if they have federally backed mortgages. Because of the project efforts and this official revision some local residential communities are no longer considered to be in a flood hazard zone. The full article can be found on the [CCBER webpage](#).

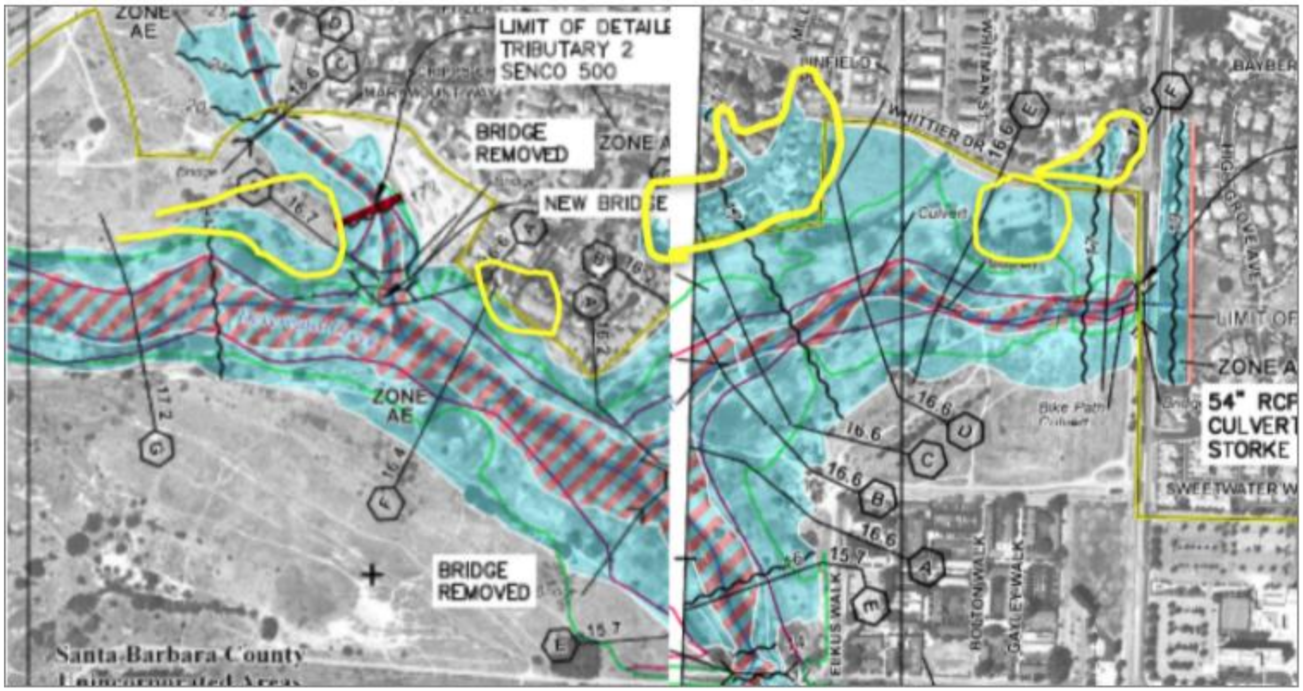

Figure 32. Pre-project flood hazard map that shows the proposed revision as a faint green line and residential areas to be removed from the flood hazard zone with the yellow highlighting.

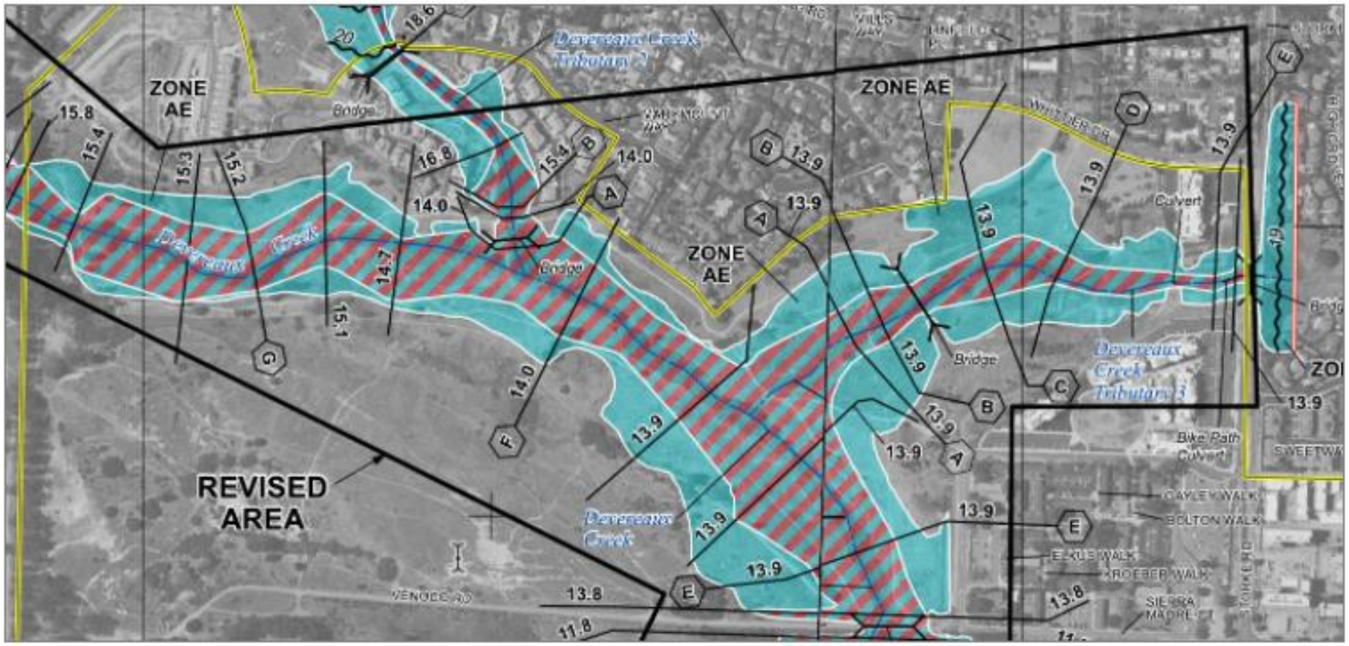

Figure 33. Revised flood hazard map illustrating the flood reduction benefits of the NCOS project.

Surface Water Flow Rates

Measurements of the flow rates of surface water in the two creeks (Devereux and Phelps) and the storm drains entering NCOS provides information for calculating the velocity and volume of water entering the system during storms or other runoff events. We plan to synthesize this information in 2022 along with water quality data in order to calculate nutrient and sediment fluxes during storm events.

Surface flow surveys at NCOS are usually conducted during or immediately after a rainfall event that produces measurable runoff. A Marsh-McBirney Model 2000 flow meter attached to a metric wading rod is used to record water velocity in meters or feet per second, which is measured at multiple depths in the middle of equal-sized segments (usually 50 cm) along a transect across the entire creek or channel. The number of velocity measurements depends on the shape or type of stream or conduit, whereas outfalls from circular culverts or storm drains are measured differently than “natural” or trapezoidal streams. The velocity measurements for each segment is multiplied by the segment area to obtain a rate of flow that is summed for all segments to obtain an overall flow rate in cubic meters per minute and/or cubic feet per second for the stream or storm drain. To calculate flow rate curves for use in hydrology and water quality analyses, we are endeavoring to collect velocity measurements during different flow rates or at different water stage levels. This monitoring is conducted by two CCBER staff, one standing in the stream with the wading rod and flow meter, while the other records the velocity measurements, depth and transect distance from the bank.

Pre-project surface flow was measured in 2016 in Phelps Creek, at the Whittier Drive storm drain outfall, at culverts that controlled the flow of Devereux Creek into the former golf course, and at the weir that separated Devereux Creek from the slough (water flowing over the top of the weir and through the culvert were both measured). Since the completion of the grading phase of the project, surface flow has been measured in Phelps Creek once in 2018, twice in 2019, and once in 2021, in Devereux Creek near Coronado Drive in 2018, and downstream of Venoco Bridge in 2019 to estimate the flow rate into the lower slough. In the winter of 2019-2020, during the third year of the restoration project, we measured flow at the Whittier Drive storm drain outfall and in Devereux and Phelps Creeks.

The red triangle icons in the map in Figure 29 correspond to the locations where flow measurements are collected. Table 5 contains the parameters and flow rates measured at Devereux Creek, Phelps Creek and Venoco Bridge, while Table 6 contains the data collected at conduit sites such as the Whittier Drive storm drain outfall. We will continue to collect flow measurements as opportunities arise to increase the robustness of flow rate curves and estimates of runoff velocity, volume and fluxes during different storm events.

We plan to increase the number of flow measurements taken in the 2022 water year, to try to capture a larger range water level at the time of flow measurements. Figure 32 shows the most frequently measured water levels during the 2021 water year at four of the locations measured for flow rate. We have already captured the flow rate from storm events with varying intensities. In addition to continuing to collect flow rates during storm events, in the 2022 water year we plan to collect more measurements at base flow

Table 5. Surface water velocity and flow rates measured in Phelps Creek, Devereux Creek and in the main wetland channel flowing into the lower Devereux Slough. This flow data is collected as part of the hydrology monitoring program at the North Campus Open Space restoration project.

Date	Time	Width of Stream (m)	Water Stage (cm)	Water Stage (ft)	Area of Flow (m^2)	Mean Velocity (m/s)	Overall Flow Rate (CMM)	Overall Flow Rate (CFS)	Comments
PHELPS CREEK, at Marymount Bridge									
03/07/2016	13:30 - 14:30	4.0	91	2.99	2.54	0.07	12.79	7.53,	Segments were 1 meter wide. Uncertain of accuracy of this measurement.
01/09/2018		4.3	106	3.48	3.09	0.08	23.31	13.71	Segments were 2 ft wide. Uncertain of accuracy of this measurement.
02/13/2019	12:00 - 13:00	3.3	74	2.43	1.68	0.01	1.54	0.90	Segments were 50 cm wide.
02/14/2019	10:40 - 11:00	4.3	99	3.25	2.60	0.01	2.34	1.38	Segments were 50 cm wide.
03/17/2020	9:40	3.5	82	2.69	1.84	0.02	3.09	1.82	Segments were 50 cm wide.
3/10/2021	10:25- 10:45	3.25	40	1.3	1.63	0.01	1.023	0.602	
DEVEREUX CREEK, near Colorado Drive									
03/21/2018	15:20 - 16:05	2.7	89	2.92	1.88	0.16	20.01	11.78	Segments were 30 cm wide.
03/16/2020	10:48 - 11:23	3.08	66	2.17	1.48	0.14	13.38	7.87	Segments were 50 cm wide.
DEVEREUX SLOUGH - MAIN CHANNEL (downstream of Venoco Bridge)									
02/14/2019	11:20 - 12:40	10.5	101	3.31	7.69	0.16	71.9	42.31	Segments were 50 cm wide.

Table 6. Surface water velocity and flow rates measured at the Whittier Drive storm drain outfall and at culverts that were in place before restoration for controlling the flow of Devereux Creek through the former golf course. This flow data is collected as part of the hydrology monitoring program at the North Campus Open Space restoration project.

WHITTIER DRIVE STORM DRAIN OUTFALL								
Date	**Time**	**Diameter (ft)**	**Level of water (ft)**	**Level / Diameter Ratio**	**Flow Unit Multiplier (K)**	**Mean Velocity (ft/sec)**	**Flow Rate (CFS)**	**Comments**
03/07/2016	14:30 - 15:00	3.64*	2.61	0.717	0.6054	0.1214	1.5065	Used 2-D method with 0.2, 0.4, and 0.8*depth velocity measurements along center line, half lines, and left corner. Right corner was only 0.4 * depth.
12/04/2019	12:00 - 12:35	3.64	1.62	0.45	0.3428	0.0713	0.5017	Used 2-D method, with velocity measurements at 7 depths along center line, 0.2, 0.4 and 0.8*depth along left and right half lines, and one 0.4*depth measurement in each corner.
PRE-PROJECT - DEVEREUX CREEK CULVERTS								
03/11/2016	14:00 - 14:15	1	1	1	0.7854	4.306	5.233	Upper Culvert
03/11/2016	14:00 - 14:15	1	1	1	0.7854	4.101	4.984	Lower Culvert
03/11/2016	15:45 – 16:00	1	1	1	0.7854	4.396	5.342	Culvert under sill that emptied into slough north of Venoco Bridge.

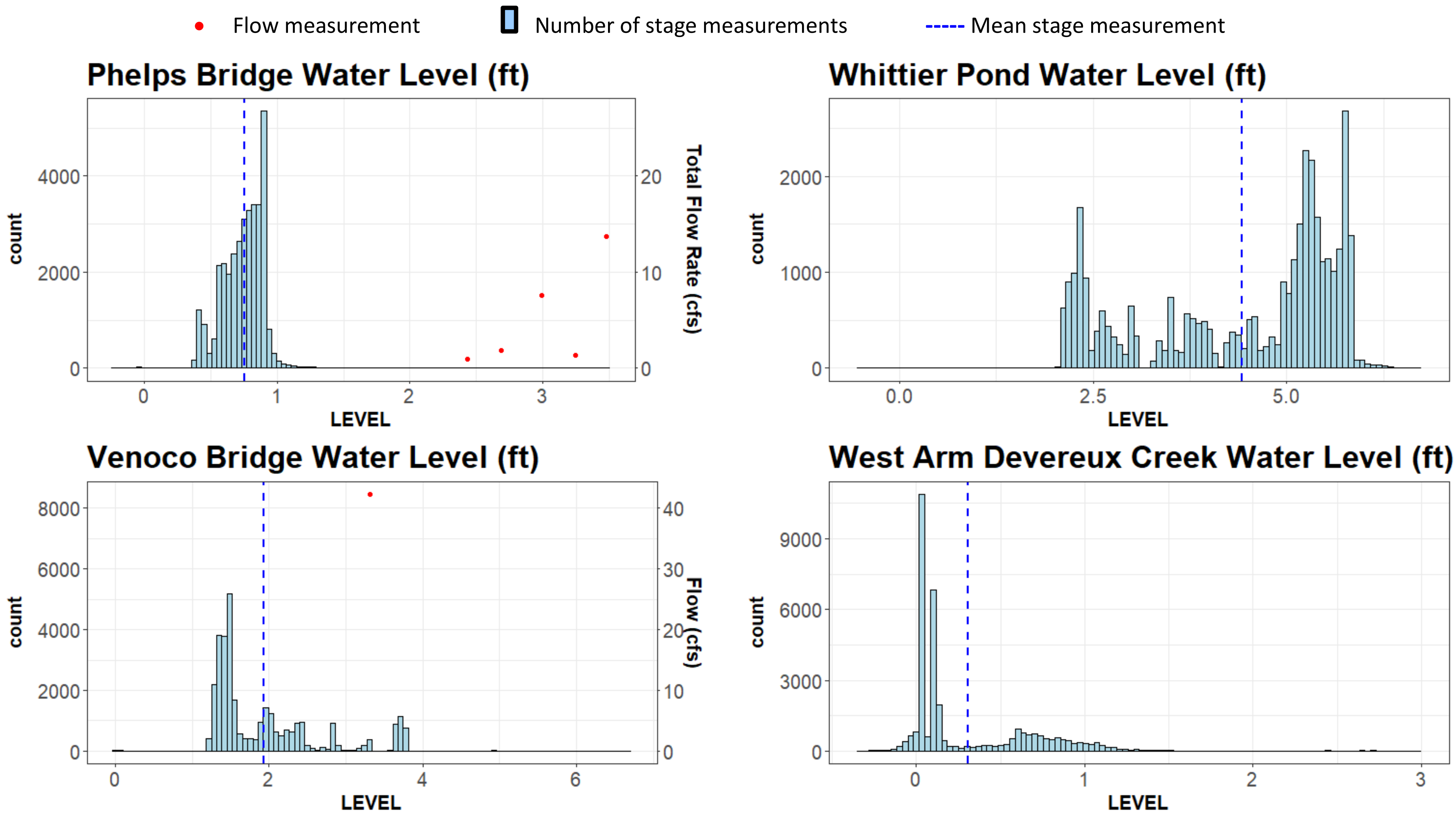

Figure 34. Frequency of water level and four locations taken from Sonlist leveloggers every 15 minutes in the 2021 water year. The dark blue line represents the mean water level at each location. The red points represent the level at which flow rate has been collected.

Vernal Pool Hydrology

Vernal pool hydrology monitoring consists of standardized recording of water levels in the restored pools created on the NCOS mesa to assess their development and ecological functionality. Water levels in the eight vernal pools created on the mesa (see map in Figure 33) are monitored on a weekly basis starting when the pools begin to hold water after the first rains of the wet season and continuing until the pools become dry. Water levels in the pools are measured to the nearest quarter inch by reading a ruler attached to a pvc pipe that is installed at the deepest area of each pool. This monitoring is conducted by CCBER staff and student interns.

The fourth year of vernal pool hydrology monitoring (water year 2021) began on Janurary 29, 2021 at the end of the second significant rainfall of the wet season. This was a very heavy rain event causing the vernal pools to stay wet for over a month with no other rain events. A much smaller rain event in the beginning of March caused the vernal pool water level to level off, but did not provide enough precipitation to increase the water levels. Overall vernal pools 4 and 8 stayed consistently wet for over a month while vernal pools 1 and 2 stayed consistently wet for more than 2 months. In 2019 and 2020 pool 4 and pool 8 were saturated from a storm event and dried up between events before refilling from the following event. Vernal pools are considered functional when they hold a minimum of a few inches of water for at least 100 days. Since 2021 was a very dry year and there was no significant rain events after January none of the vernal pools were inundated for more than 100 days.

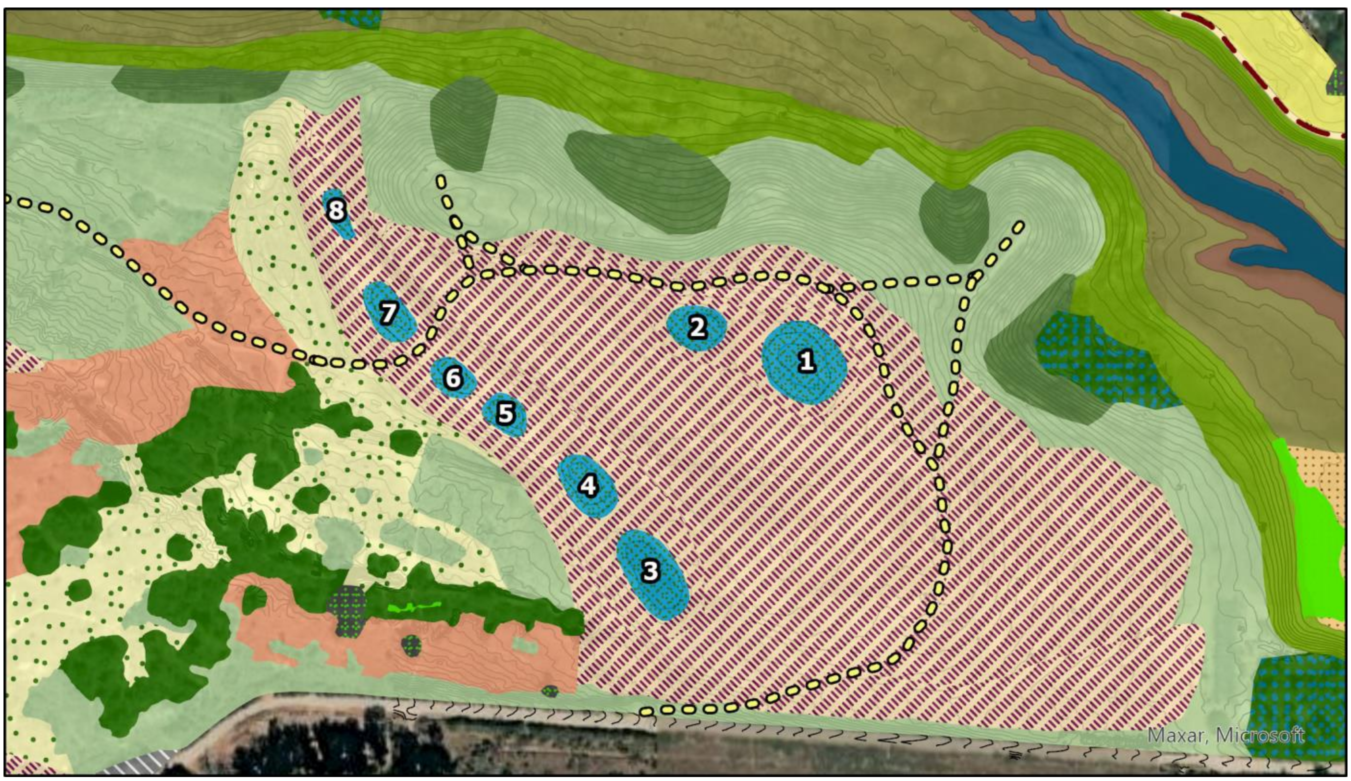

Figure 35. Map of the mesa area of North Campus Open Space with the restored vernal pools labeled with their number. See Figure 1 for a legend of habitat features/plant communities.

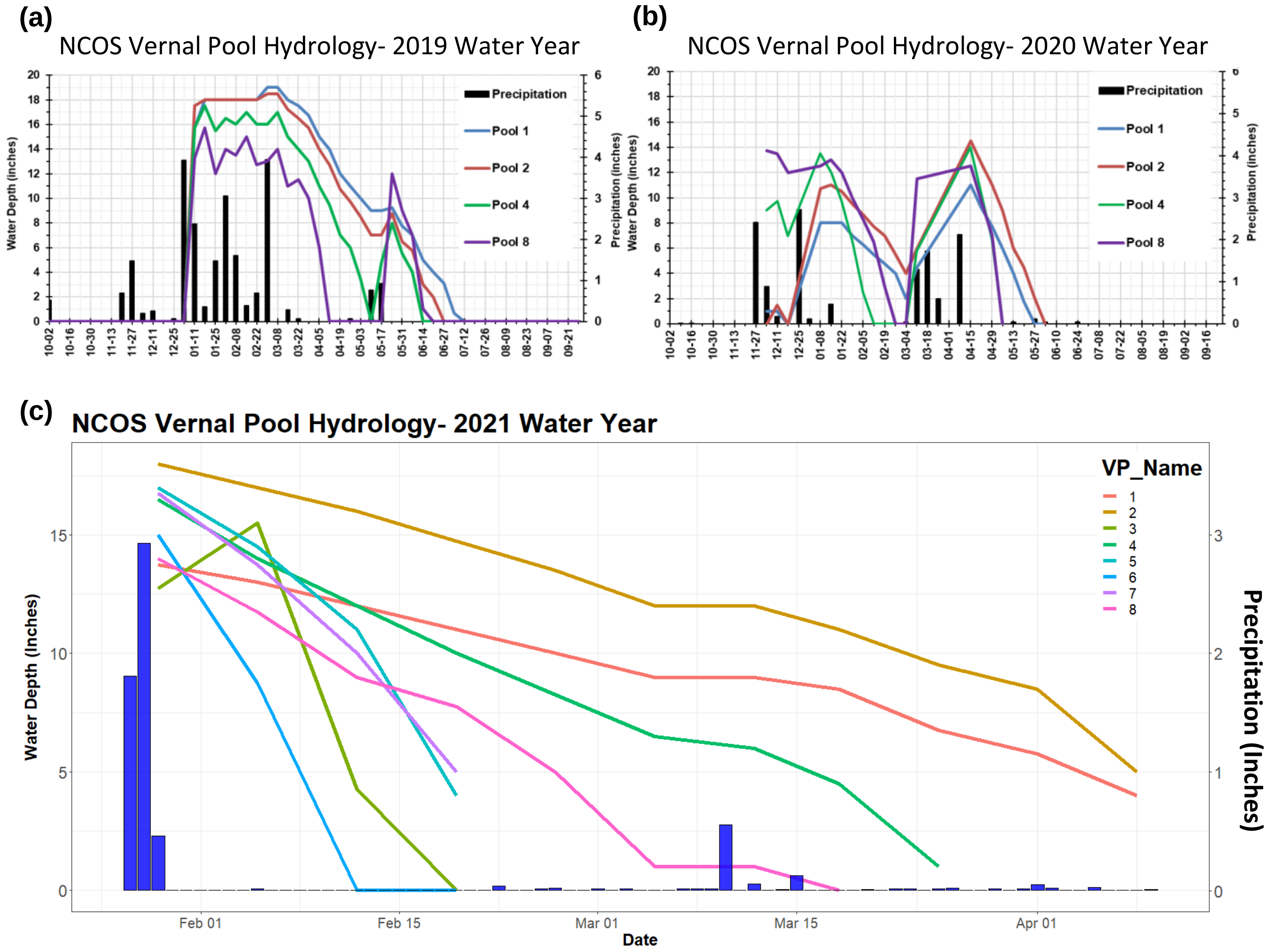

Figure 36. (a) Hydrograph of weekly water depth (inches) in four of the restored vernal pools on the North Campus Open Space (NCOS) mesa in the 2019 water year and (b) Hydrology of Vernal pools in the 2020 water years (October 1st to September 30th). (c) Hydrology of all 8 vernal pools at NCOS during the wet season. Precipitation in inches is recorded at a NOAA climate station on Coal Oil Point Reserve. Vernal pools are measured weekly at the deepest point.

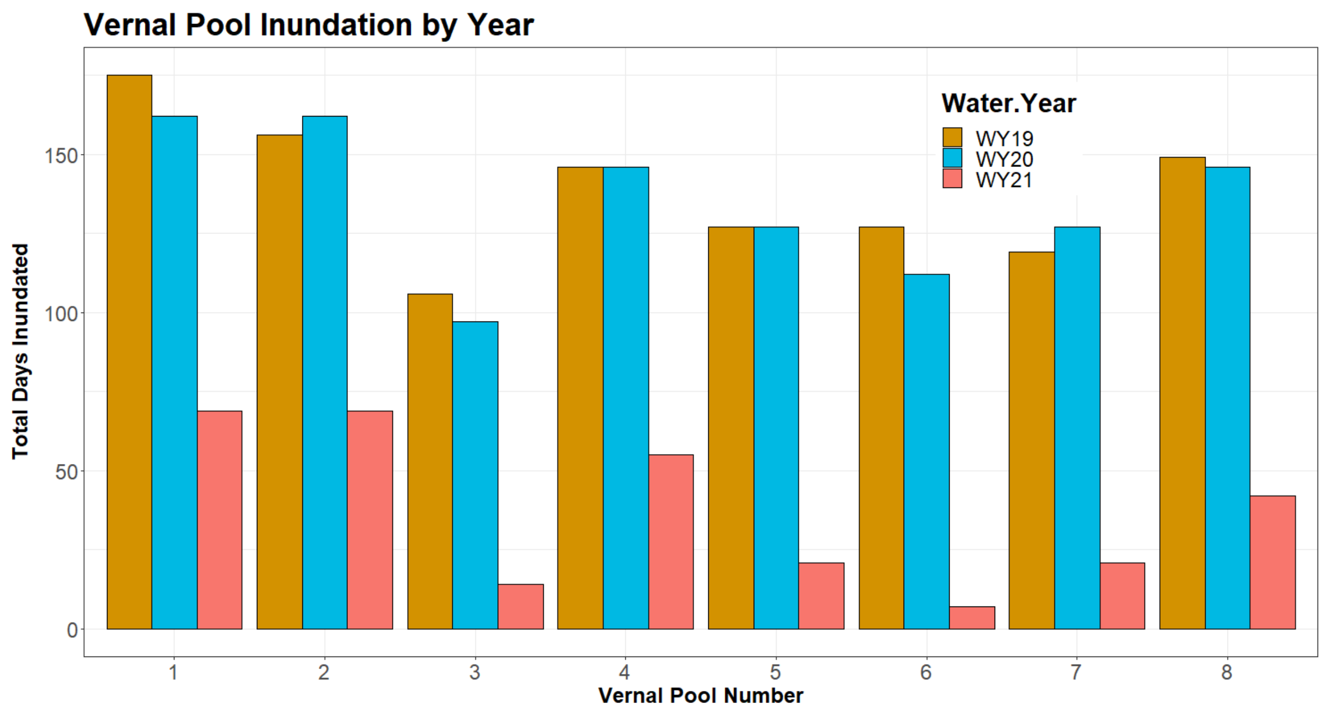

Figure 37. Number of days that Vernal Pools are inundated for each water year monitored. Vernal pool water depth is determined by CCBER field staff and is monitored once per week. If vernal pools dry out between rain events, it is assumed that they are dry for 5 days, since days that are not monitored are not accounted for. Successful vernal pools should stay inundated for 100 days or more.

Groundwater Hydrology & Salinity

Monitoring of groundwater hydrology and salinity at the North Campus Open Space restoration site began in 2011, a few years before the project, to collect data that helped inform aspects of the restoration design and plan. After the soil movement and grading of the project site was completed, we resumed this monitoring in 2018 to continue building a long-term data set that informs our understanding of how groundwater hydrology and salinity may change following the restoration, may influence plant survivorship and growth, and may eventually change due to predicted sea level rise.

Groundwater Methods

Groundwater salinity and depth below surface are monitored in up to 12 piezometers, or monitoring wells, some of which have been installed across the greater project area since 2011. A map of the well locations and their elevations is provided in Figure 35. In February 2018, seven of the wells that had been removed for the grading of the project site in 2017 were reinstalled. Four of these wells were installed in the same locations as before the restoration project (wells 14, 15, 17 and 19). Groundwater salinity and depth below surface are typically monitored every two weeks throughout the year in seven of the wells that surround the salt marsh (wells 13-19) and in well 7 near the vernal pools. Given its close proximity to the Western Snowy Plover habitat and the main Ventura marsh milk-vetch (VMMV) restoration site, well 12 is monitored using a Solinst Levelogger that records the water level and conductivity every 15 minutes. This enables the collection of high-resolution data that is helpful for planning and management of the VMMV site and significantly reduces the frequency of visits to the well, thereby minimizing disturbance of the Western Snowy Plover area. The other wells that are further away from the wetland and mainly at higher elevations (1, 3, 6, and 8) are typically monitored every two weeks once water is detected in the winter and continuing until they become dry.

To determine the depth to groundwater from the surface at each well (except well 12), a measuring tape with a line drawn with a wet erase marker is inserted to the bottom of the well and the distance (to 1/16 of an inch) where the marker line is washed off is recorded. This measurement is subtracted from the total depth of the well, excluding the height of the riser above ground, to obtain the distance of the groundwater table below the surface. The elevations of the wells (in feet NAVD88) have been recorded using a Real Time Kinematic (RTK) GPS, and this information is used to calculate changes in the approximate elevation of the groundwater at each well. Groundwater salinity (in parts per thousand, ppt) is measured by collecting a small sample in a vial attached to a weighted rope and applying the sample to a refractometer. This monitoring is conducted primarily by student interns and/or community volunteers.

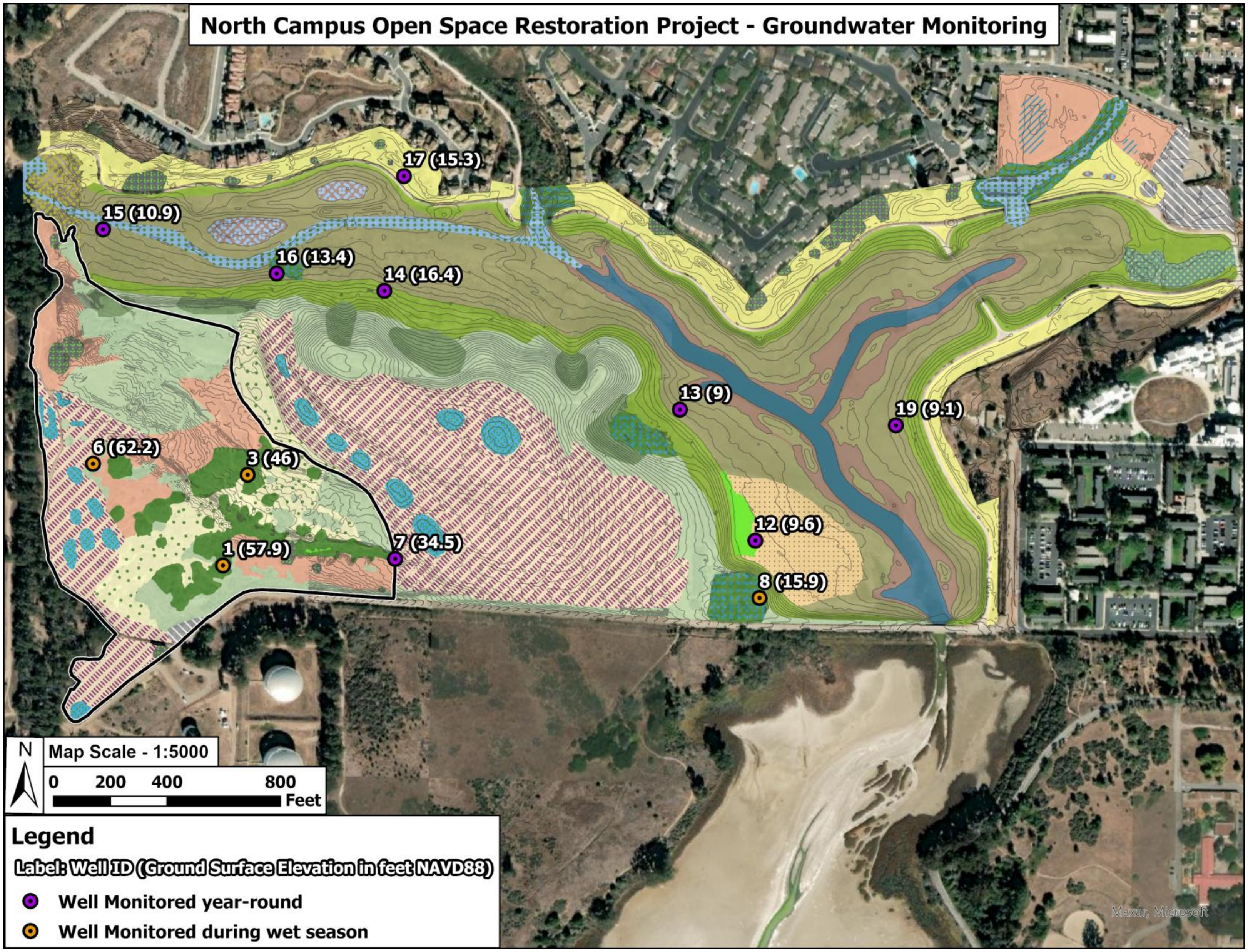

Figure 38. Map of the groundwater monitoring wells at North Campus Open Space, labeled with the well ID number and ground surface elevation in feet (NAVD88).

Groundwater Hydrology Data & Trends

At the upper wells that have remained in place since installation in 2011, there has been a significant rise of groundwater closer to the surface at wells 3 and 7 following the deposition and grading of soil on the NCOS mesa. Groundwater was rarely detected in these wells prior to the restoration project and not at all for the entire 2016 water year. After grading of the site was completed and monitoring resumed, we began to detect groundwater in well 3 in June 2019 at four feet below the surface and continued to detect water at an average depth of five feet below the surface until September 2020 when no water was detected (Appendix 6). In the 2021 water year the water level at well 3 was measured to be between 6.5 feet and 7 feet below ground from February until May and it was dry the rest of the year.

For well 7 in the 2020 water year, groundwater has consistently been recorded at an average depth of 3 to 4 feet below the surface (Appendix 6). In the 2021 water year the ground water level rose briefly to just 17 inches below the surface on February 2, 2021- a few days after a large rain event. Well 7 proceeded to become nearly dry in the end of July 2021, with only enough water to barely detect (Figure 36). In September 2021 well 7 appeared to fill with 23 inches of sediment- determined because the depth to the bottom of the well was consistently 23 inches less than it was previously recorded. This could have been caused by vandalism of the well with someone putting soil in the well.

During the relatively wet 2019 water year, well 7 was completely submerged for 11 weeks (Appendix 6) This well is in a ditch that, prior to grading, ran down to the former sediment basin under the riparian woodland adjacent to Venoco road. The grading of the project site filled this ditch just east of well 7 for the creation of the mesa, which evidently blocked the flow of water past the well, therefore resulting in groundwater becoming perched much closer to the surface than before. This does not appear to have affected the groundwater level at well 8, which is in the former sediment basin that was previously the end of the drainage ditch in which well 7 lies. At well 8, groundwater rises close to or above the surface following heavy rain and then recedes quickly over a few weeks, and this pattern does not appear to have changed since the grading of the site.

While most wells are responsive to rainfall events (7,12,13,15,16,17,19) some stay rather stable despite rainfall events (3,6,14) (Figure 37). In general, wells show that groundwater tends to rise closer to the surface following rainfall in the winter and spring months, and then it gradually recedes through the dry summer and fall months each year. Exceptions include wells 3, 6 and 14. Well 3 show a slight increase starting at rain events but is not nearly as responsive as other wells. At well 6, groundwater consistently was measured at eight feet below the surface in 2016, 2019 and 2020 water years. In the 2021 water year well 6 was measured at a ten-foot depth or dry for the entire water year. Well 14 was responsive to rain events in 2016 before restoration, but post restoration (2019-2021 water years) the well was much less responsive to rainfall events.

The primary factors that influence the amount of change in depth to groundwater throughout the year are the location of the monitoring well and how much rain falls during the winter and spring. The wells that are closest to the wetland (wells 13, 15, and 19) tend to show the greatest frequency of fluctuation in depth to groundwater, which may also be affected by periods of tidal activity in Devereux Slough. For example, the slough was tidal for most of the winter of the 2019 water year, and the depth to groundwater at well 19 along the eastern side of the wetland fluctuated by as much as two feet during this period (Appendix 6). In contrast, groundwater at well 19 rose from a depth of 4 feet to near or at the surface for most of the winter of the 2020 water year, during which the slough retained a high level of water until breaching in mid-March (Appendix 6).

Groundwater Salinity Data & Trends

After grading, groundwater salinity increased and has stayed between 20 and 80 ppt in the 2019-2021 water years with the lowest salinity readings typically between February and May. Salinity is highest and most responsive to rain events (showing decreased salinity after large rain events) along the eastern and southern margins of the salt marsh (well 19 and well 13). Salinity remains very low at all other wells indicating brackish to near freshwater measurements (Table 7 and Figure 41). Salinity at all the upper wells remains between 0 to 2 parts per thousand (ppt) on average.

Throughout the year, groundwater salinity generally decreases in the wells that are closest to the wetland during periods of rainfall in the winter and early spring months, sometimes by as much as 70 ppt. During the 2021 water year, the salinity recorded at wells 13 and 19 dropped significantly following each major rainfall somewhat proportional to the size of the rainfall event and stayed high during the dry summer months (Figure 39). In contrast, during the extended period of tidal activity of the slough in the 2019 water year, the salinity at wells 13 and 19 fluctuated less and remained relatively high (Appendix 6), perhaps because there was less time for freshwater from rainfall to percolate through the soil than in the 2021 water year.

Groundwater Data at Well 12

Data recorded with the Levelogger at monitoring well 12 shows that groundwater in the area remains at a baseline depth of approximately 3-4 feet below the surface during the dry months of each year and quickly rises close to the surface during heavier periods of rainfall in the winter and spring (Figure 42). In the 2021 water year there was a clear rise and quick fall of water level. Unfortunately the groundwater levelogger did not record salinity from December 14th- March 19th and all data from March 19th - May 11th is missing. Despite its proximity to the wetland, groundwater salinity at well 12 (measured as electrical conductivity by the Levelogger) is consistently at or less than 1 S/m.

Table 7. Pre-project and post-grading ground surface elevation and means of three parameters (groundwater table elevation, depth to water from surface, and salinity) monitored every two weeks (except for well 12, which is monitored with a Solinst Levelogger) at eight piezometers (monitoring wells) at North Campus Open Space. Pre-project data is from the 2016 water year (WY) and post-grading data is from three water years since grading of the project site (2018, 2019, and 2020). Water years (WY) run from October 1st to September 30th. Elevation data is measured in feet using the North American Vertical Datum of 1988 (NAVD88). NA (Not Applicable) is entered for wells that were in a different location pre-project and cannot be compared with data from their post-grading locations. "dry" is entered for pre-project data for well 7, where groundwater was not detected for WY2016. Figure 35 contains a map of NCOS with the locations of the wells labeled with the well number and ground surface elevation.

Well Number	7	12	13	14	15	16	17	19
Pre-project Well Elevation (ft.)	34.5	NA	NA	15.7	13.8	NA	17.3	13.1
Post-grading Well Elevation (ft.)	34.5	9.6	9.0	16.4	10.9	13.4	15.3	9.1
Mean WY2016 Groundwater Table Elevation (ft.)	dry	NA	NA	10.1	6.7	NA	9.5	6.6
Mean WY2018 Groundwater Table Elevation (ft.)	30.0	7.4	7.6	12.8	8.2	10.1	9.1	5.2
Mean WY2019 Groundwater Table Elevation (ft.)	31.4	7.5	7.0	13.1	8.9	10.4	9.6	4.7

Mean WY2020 Groundwater Table Elevation (ft.)	30.8	7.5	6.4	13.8	7.6	10.1	9.3	7.0
Mean WY2021 Groundwater Table Elevation (ft.)	30.2	7.2	3.4	12.4	6.2	8.2	8.7	3.9
Mean WY2016 Depth to Water from Surface (ft.)	dry	NA	NA	4.1	5.4	NA	6.4	5.0
Mean WY2018 Depth to Water from Surface (ft.)	4.5	2.2	1.4	3.6	2.6	3.3	6.3	3.9
Mean WY2019 Depth to Water from Surface (ft.)	3.1	2.1	1.9	3.1	2.0	3.0	5.5	4.2
Mean WY2020 Depth to Water from Surface (ft.)	3.8	2.1	2.7	2.5	3.3	3.3	6.0	2.2
Mean WY2021 Depth to Water from Surface (ft.)	5.6	2.4	6.7	5.0	5.5	6.4	7.8	6.2
Mean WY2016 Salinity (ppt)	dry	NA	NA	4	29	NA	8	78
Mean WY2018 Salinity (ppt)	0	1	61	2	33	6	6	93
Mean WY2019 Salinity (ppt)	1	<1	74	3	38	6	5	92
Mean WY2020 Salinity (ppt)	2	<1	64	4	41	7	7	50
Mean WY2021 Salinity (ppt)	1	<1	67	2	43	4	5	66

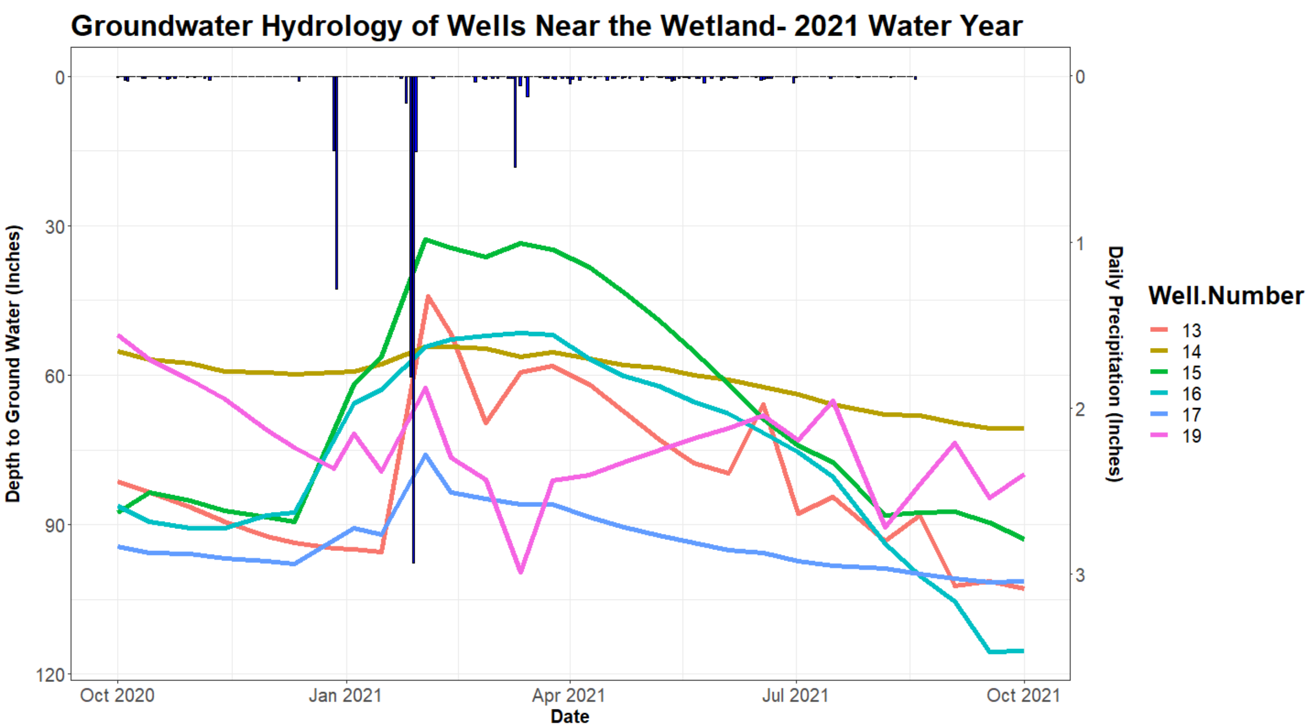

Figure 39. Depth to groundwater from surface (inches) measured every two weeks at six monitoring wells in salt marsh habitat near the North Campus Open Space wetland for water years 2021. Blue bars represent Daily precipitation (inches) recorded at a NOAA climate station on Coal Oil Point Reserve.

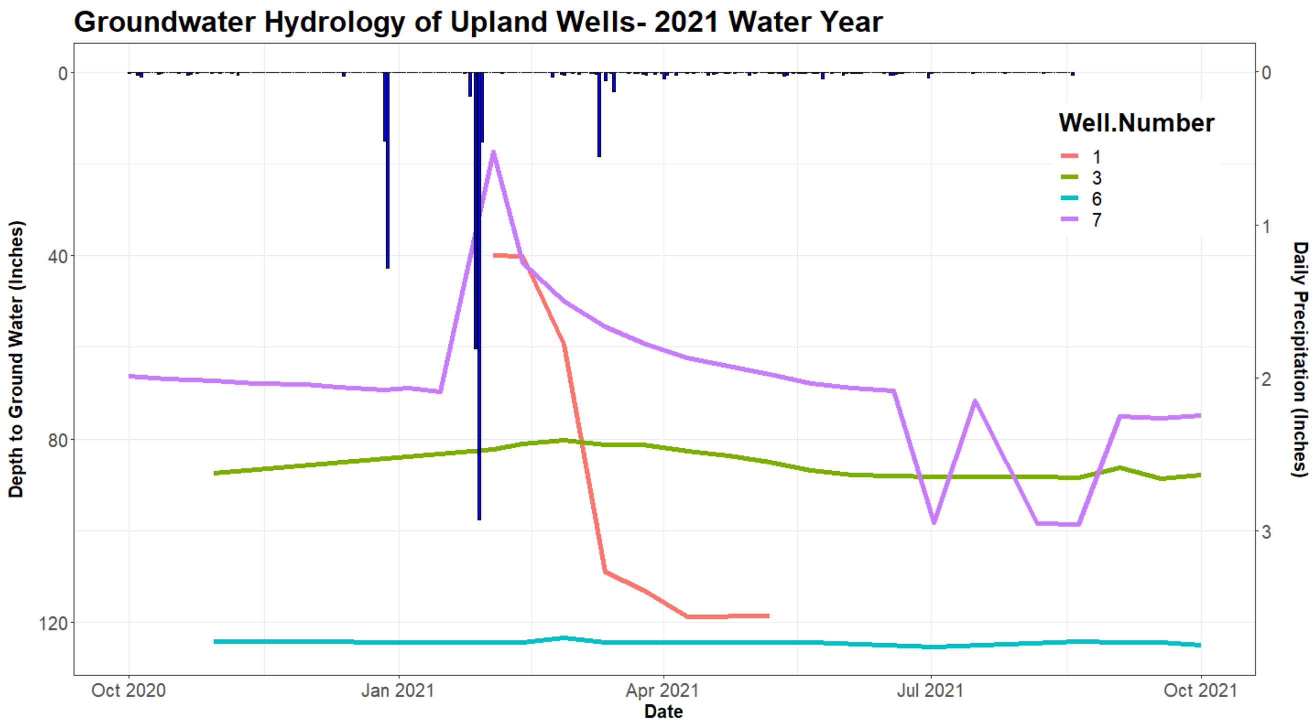

Figure 40. Depth to groundwater from surface (inches) measured every two weeks at four monitoring wells upland from the North Campus Open Space wetland on EEM/ South parcel land for water year 2021. Blue bars represent Daily precipitation (inches) recorded at a NOAA climate station on Coal Oil Point Reserve.

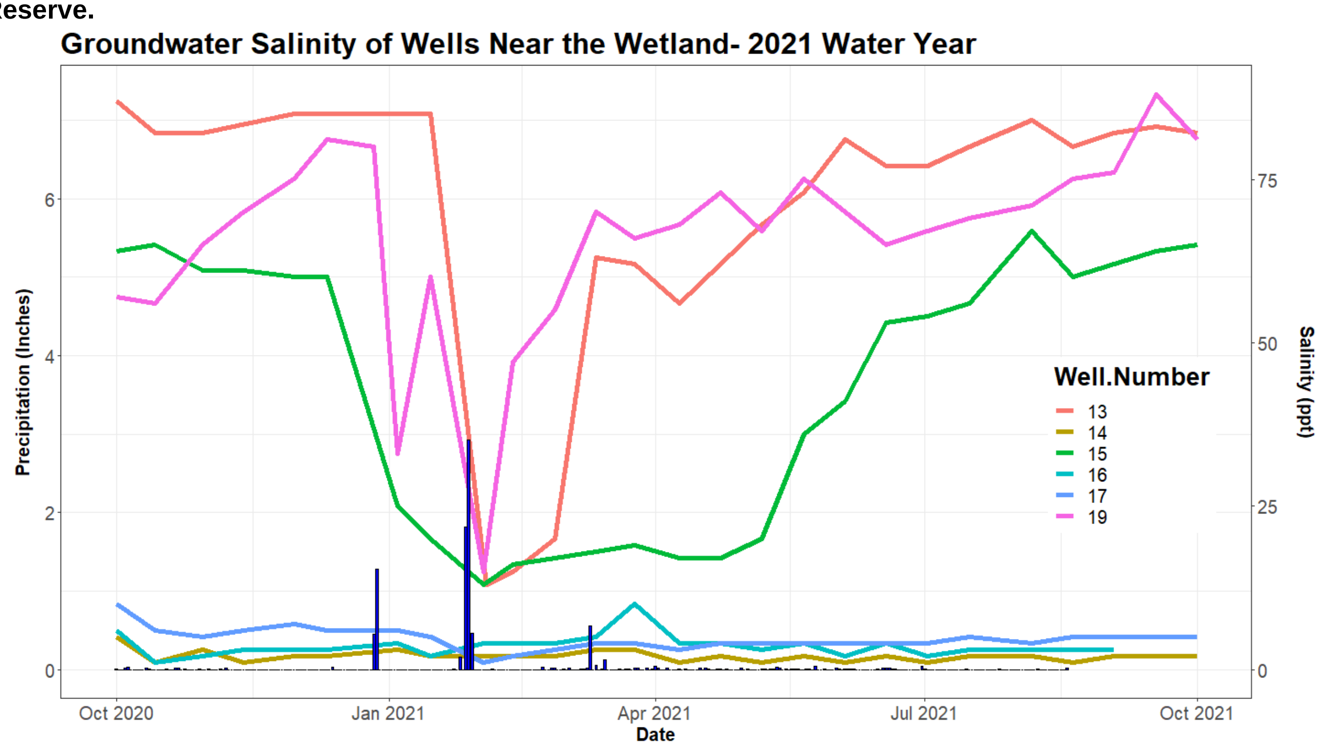

Figure 41. Groundwater salinity (in parts per thousand, ppt) measured every two weeks at six monitoring wells surrounding the North Campus Open Space wetland for water year 2021. Blue bars represent daily precipitation (inches) recorded at a NOAA climate station on Coal Oil Point Reserve.

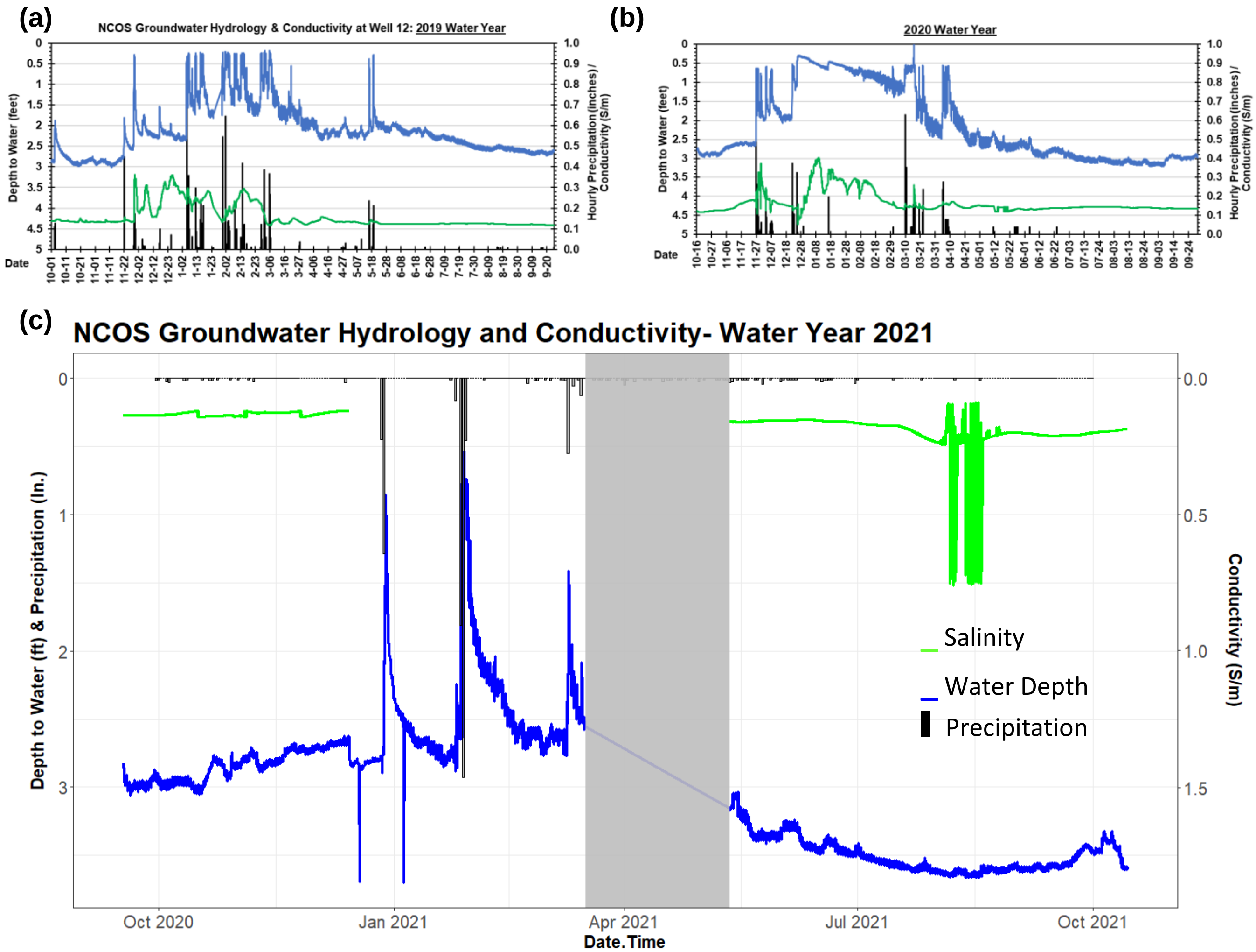

Figure 42. Plots of the depth to water from surface (feet) and conductivity (Siemens per meter, S/m) of groundwater recorded by a Solinst Levelogger every 15 minutes in piezometer monitoring well 12 in the (a) 2019, (b) 2020, and (c) 2021 water years (October 1 to September 30) at North Campus Open Space (NCOS). The left vertical axis representing Depth from Surface (feet) is in ascending order with 0 at the top representing the ground surface. Black bars represent hourly precipitation in inches recorded at a NOAA climate data station on the adjacent Coal Oil Point Reserve. The grey section in 2021 indicates a time at which data was unavailable. Figure 35 contains a map of the locations and elevations of groundwater monitoring wells.

Devereux Slough Water Quality

The enhancement of the ecological health and function of Devereux Slough is a key goal of the NCOS restoration project. CCBER monitors many aspects of water quality to track progress toward this goal. This monitoring consists of three components:

1. Automated collection of data on dissolved oxygen, conductivity, salinity, temperature, and chlorophyll and blue-green algae concentrations as well as water level using a multi-parameter sonde at a fixed location in the lower section of the slough in Coal Oil Point Reserve.
2. Weekly collection of data on dissolved oxygen, conductivity, salinity, and temperature at one foot depth intervals at three locations in the restored upper arms of the slough at NCOS using a handheld water quality sensor.
3. Periodic collection and analysis of storm water samples for concentrations of nutrients and suspended solids as well as other inputs from urban runoff that enters the wetland.

Lower Slough Water Quality Data - Methods

CCBER initiated the automated collection of water quality data in the lower section of Devereux Slough in 2014, three years before restoration at NCOS began. The objective of this monitoring is to develop a long-term, high-resolution data set of water quality parameters for detecting potential changes in the slough before and after restoration at NCOS. It can serve as a reference for comparison with water quality data collected in the restored upper slough. The data is collected with a multi-parameter YSI EXO1 sonde deployed in the main channel of the lower Devereux Slough (see map in Figure 34). The sonde is housed in a perforated two-inch diameter pvc pipe attached to a pier pylon, and it is set at a fixed depth that ensures the water quality sensors will remain submerged by at least 50 cm at low water levels. The sonde records dissolved oxygen (DO, in mg/L and percent saturation), conductivity/salinity (in µS/cm and psu), temperature (degrees Celsius), blue-green algae and chlorophyll (in relative fluorescence units or RFU and µg/L), and water depth (feet) every 15 minutes.

In this report, we present the daily average of the parameters recorded by the EXO1 sonde for the 2019, 2020 and 2021 water years, plotted in the three charts in Figure 40. These three water years differed greatly in the amount of precipitation received and the response of water quality measurements. Unfortunately, all three years experienced some extent of equipment malfunction. Each malfunction is represented by a blank or grey section in the figures. In the 2019 and 2020 water year the malfunction resulted in a total loss in data for certain time periods, however in the 2021 water year we were prepared and were able to replace the EXO1 sonde with one of our leveloggers to preserve partial data while the EXO sonde was out for maintenance. In the 2021 water year the EXO1 sonde was out between December 14, 2020, and March 04, 2021. The levelogger was able to capture water level, conductivity, and temperature, however DO, chlorophyll and BGA measurements were missing at that time.

Lower Slough Water Quality Data – Dissolved Oxygen and Conductivity/Salinity

The sonde is deployed at a fixed depth, but the hydrology of water in Devereux Slough typically becomes stratified and hypersaline (particularly in the late summer and fall). There are periods when the sonde's sensors may sit below the halocline where salinity is greater than at shallower depths. This at least partly explains the very low DO levels recorded by sonde during the first three months of the 2019 water year, and during the winter months of the 2020 water year.

In the 2019 water year, average DO concentrations were greatest from January until mid-April, which is when the most precipitation occurred, and the slough was tidal for several weeks. These two factors resulted in a significant decrease in conductivity and increase in DO. However, the DO concentrations during this time were abnormally high, indicating that there may have been a problem with the sensor. Late season rainfall in May of the 2019 water year led to a higher water level through summer that helped temper the gradual increase in conductivity and resulted in a higher water table throughout the summer months.

Conversely, in the 2020 water year, the water level in the slough remained at a depth of more than five feet above the sensors for more than three months following the first major rains of the winter season. This appears to have kept the EXO1 sensors below the halocline in higher density and hypersaline water with no mixing during this entire period, as indicated by the very low DO concentrations and a static conductivity of about 60,000 µS/cm (or 6 S/m), which is above the average seawater conductivity of 55,000 µS/cm (5.5 S/m) (Figure 43(b)). As soon as the slough breached the berm at the mouth and briefly became tidal in late March, the DO concentration quickly increased and then fluctuated within a normal range of 4 to 11 mg/L for the rest of the year.

Although the storms in the 2021 water year were much smaller than those in the 2020 water year, the water quality sensors were still quite responsive to rainfall events. The largest storm of the year seen in January 2021 resulted in a large decrease in conductivity and water level soon after. The intense January storm caused the berm to breach. Thereafter from March until October 2021 conductivity gradually increased as water depth gradually decreased. Since there is little to no flow in the slough for this part of the year- any decrease in water level is due to evaporation which results in increased salinity. Dissolved oxygen remains very low throughout the entire year, likely due to the very low amount of precipitation that occurred (Figure 39 (A)).

Lower Slough Water Quality Data – Chlorophyll and Blue-green Algae

Concentrations of chlorophyll and blue-green algae recorded by the EXO1 sonde tend to follow similar patterns each year. The concentrations are usually greatest in late summer and early fall when there is no influx of new water, and the existing water gradually evaporates and increases in salinity. The lowest concentrations occur primarily in the winter and spring, especially during and after periods of tidal fluctuation and filling of the slough with new water either from rainfall or from seawater brought in during tidal connectivity. There are usually brief spikes in concentrations following heavy rainfall, such as in mid-December and late March of the 2020 water year. Storms that produce a high amount of rainfall typically flush excess nutrients into the slough, which subsequently induces rapid growth of algae and phytoplankton. It is unclear what caused the high spikes in chlorophyll and blue-green algae in late November of the 2020 water year as this was not preceded by rain or any other influx of water. It did seem to coincide with a drop in temperature by an average of one degree Celsius as well as a brief drop in DO. These changes together suggest a shift or mixing of the layers or strata in the water column, possibly due to a large change in atmospheric pressure or a high wind event. The unusual spike in concentrations continued after all sensors were cleaned and calibrated on November 23rd, and only declined after the first major rains of the season fell at the end of November (see Figure 43). There was an unusual spike in chlorophyll in mid-November of the 2021 water year. Shortly after the YSI sonde was sent out for service, so we were unable to see the recovery after the high chlorophyll levels were seen. It followed more typical patterns for the rest of the year. There was a glitch in the YSI meter in 2021 resulting in very few blue green algae measurements. We decided to omit the blue green algae portion because it was lacking so many readings. The YSI meter is calibrated regularly, however we recently noticed that there is water level drift seen toward the end of the 2021 water year. Negative values should not be obtained from the Levelogger therefore the values measured September- October 2021 are due to a calibration malfunction, however the trend in decreasing water level is still correct.

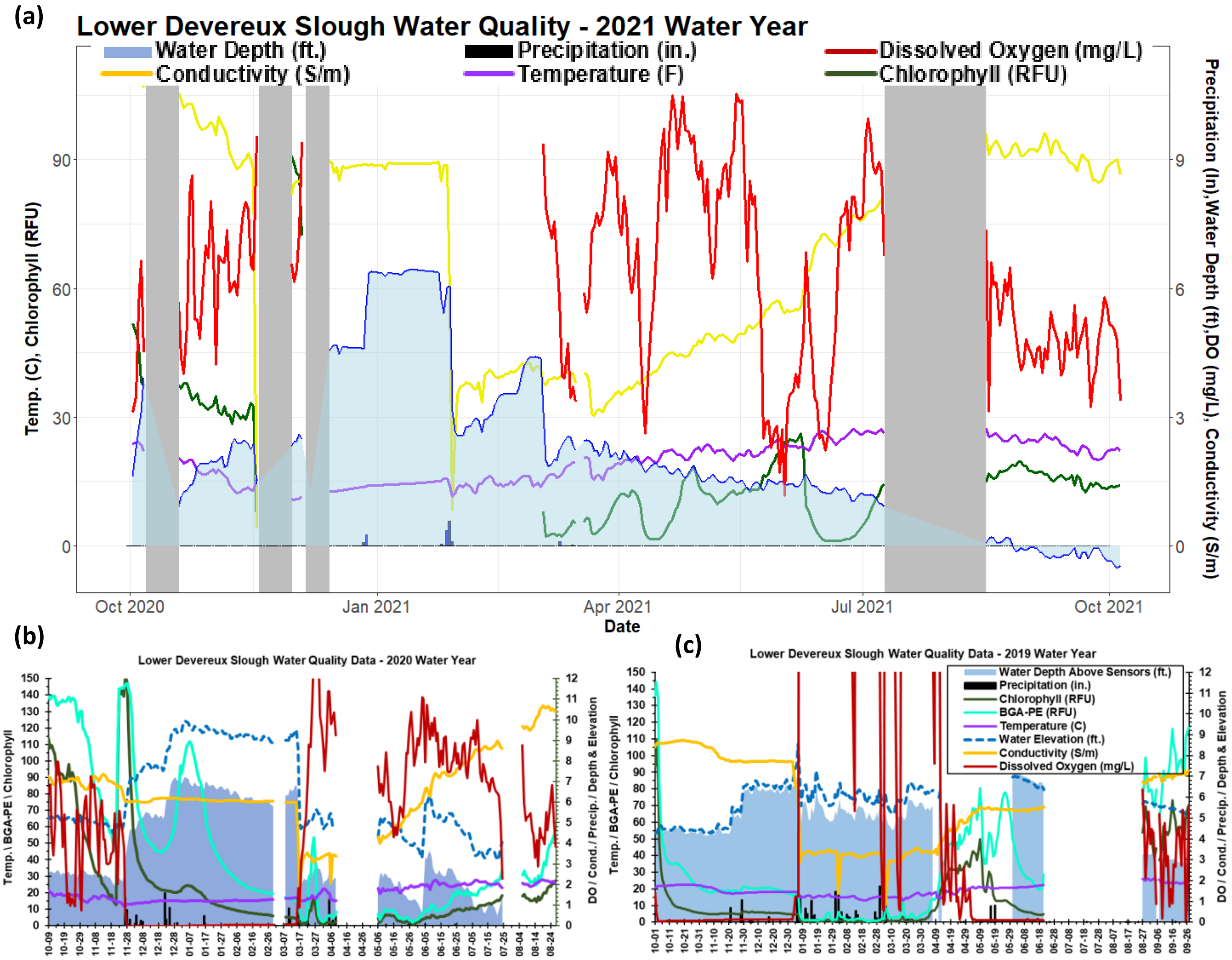

Figure 43. Daily average water quality and level data recorded in the (a) 2021 (b) 2020 and (c) 2019 water years (October 1st to September 30th) with a YSI EXO1 sonde in the lower portion of Devereux Slough (see map in Figure 27). A dashed blue line indicates the water surface elevation in feet (NAVD 88), determined from comparing staff gauge measurements with the sonde's depth measurements. In August 2019, the fixed position of the sonde was raised by approximately 2.25 ft, which decreased the depth of water above the sensors. RFU stands for Relative Fluorescence Units. For reference, seawater conductivity is approximately 5.5 Siemens/meter (32 – 37 ppt salinity) on average. Precipitation data was recorded at a NOAA climate station on Coal Oil Point Reserve. Gaps in the data or areas shaded in gray are periods when the sonde malfunctioned and/or was out for repairs.

Restored Upper Slough Water Quality Monitoring - Methods

In the restored upper arms of Devereux Slough, we have been collecting dissolved oxygen (DO, mg/L), conductivity/salinity (S/m), and temperature (C) data at three locations on a weekly basis (figures 44-49). This data is primarily collected by student interns using a portable YSI Pro2030 at the three bridges that cross the upper slough: the Marsh trail bridges over the Phelps Creek outlet and across the east channel, and the Venoco access road bridge (turquoise circles in Figure 31). From the bridges, the sensor is lowered to the water and data are recorded at the surface and at each foot of depth down to the bottom. The purpose of this monitoring is to detect and assess the stratification and variability of these water quality parameters at different locations in the wetland. This data provides environmental information for interpreting results from the monitoring of aquatic organisms such as arthropods and the tidewater goby, and it contributes to our understanding of the functionality of the wetland.

Restored Upper Slough Water Quality Monitoring – Data Summary & Main Observations

There are many factors that affect DO concentrations in water; one of the more prevalent factors is stratification. In stratified waters, the water's surface typically has more DO than the bottom for two reasons. First, water at the top typically has low salinity and can hold more O_2 than water at the bottom with high salinity. Second, plants such as duckweed that float on the water's surface produce O_2 while organisms at the bottom consume O_2. We see the most stratification at our sites in the winter when rainfall is most frequent and the water is the deepest. The winter also typically has higher DO than summer because low salinity and low temperatures result in a higher capacity for water to hold DO[3].

Our main observations from this monitoring are that there is vertical stratification of DO and conductivity at all locations in the wetland, but this varies in magnitude and duration depending on the depth of water and location. At the outlet of Phelps Creek, the water depth is usually at or below two feet and there is little to no stratification throughout most of the year. Conductivity at the Phelps Creek outlet remains at freshwater levels, with occasional brief increases likely caused by brackish water reaching the area when the slough is tidal, or during periods of high temperatures (Figure 45). The water at Phelps Creek did become stratified for a few weeks in the winter of the 2020 water year. During this period the water depth increased from two to five feet and the surface DO was greater than the bottom DO by as much as 8 mg/L. In the 2021 water, since it was so dry, Phelps creek never rose above 2 feet and there was little to no stratification seen. The low conductivity/salinity that prevails at the Phelps Creek outlet also plays a role in limiting the stratification of DO.

In contrast, surface DO tends to be higher than bottom DO for most of the year in the main slough channel by Venoco Bridge, where the water depth tends to remain well above two feet throughout the year (Figure 48). Stratification in conductivity is also most prevalent in the main slough channel by Venoco Bridge, where the conductivity at the bottom of the water column can be greater than the surface by as much as 10 Siemens per meter (Figure 49).

In the upper east arm of the restored slough, the degree of stratification sits roughly in-between the Phelps Creek and Venoco Bridge sites. Dissolved Oxygen is much more stratified than conductivity at

[3].Fondriest Environmental, Inc. "Dissolved Oxygen." Fundamentals of Environmental Measurements. 19 Nov. 2013. Web. < https://www.fondriest.com/environmental-measurements/parameters/water-quality/dissolved-oxygen/ >.

East Bridge, and conductivity/salinity levels at East Bridge are only slightly lower than the surface at Venoco Bridge.

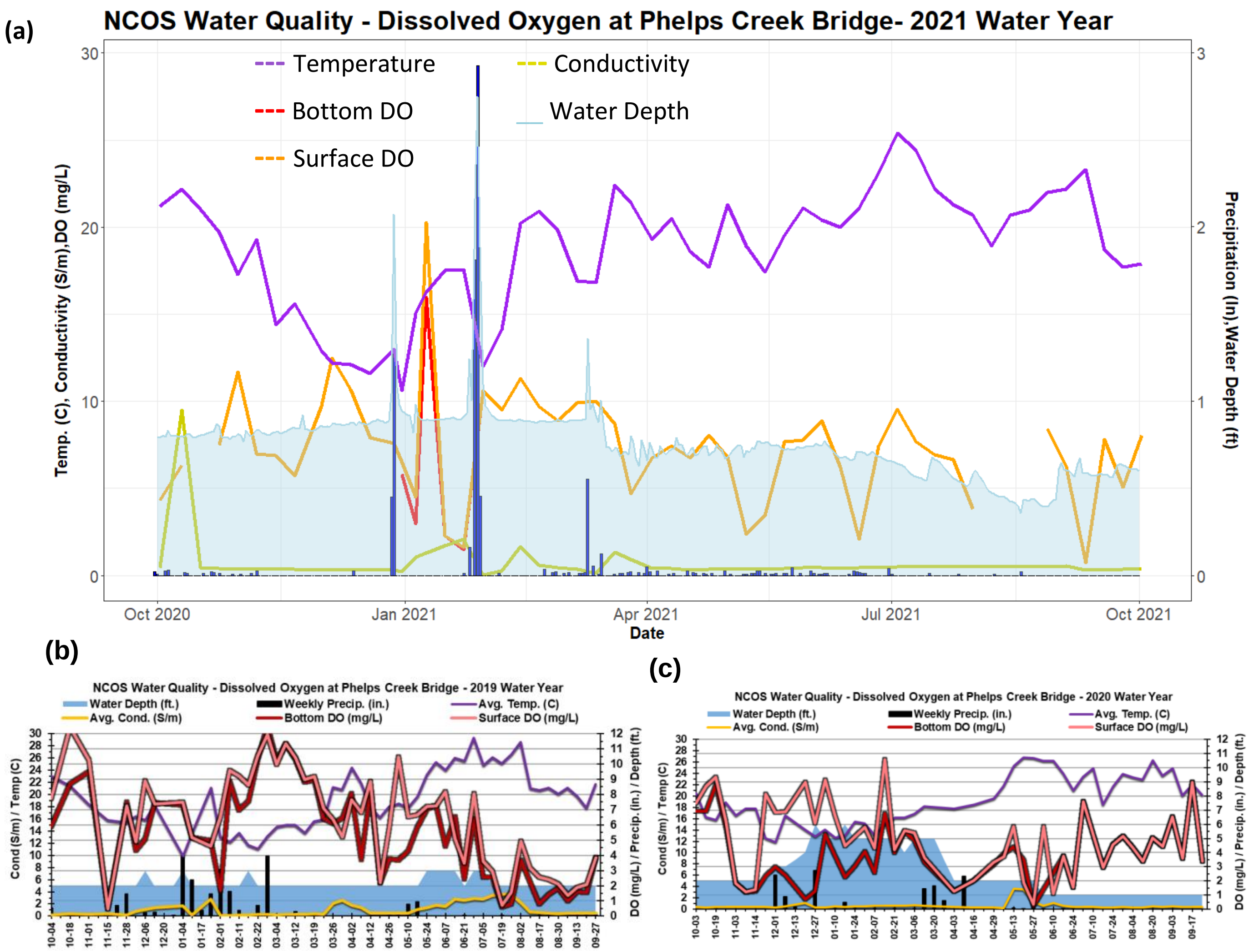

Figure 44. Dissolved oxygen (mg/L) at the surface (top 1-foot) and bottom of the water column recorded weekly in the (a) 2019 water year and (b) 2020 water year with a YSI Pro2030 at the Phelps Creek outlet into the upper Devereux Slough, North Campus Open Space. The temperature (Celsius – purple line) and conductivity (Siemens/meter – yellow line) are averaged across all depths. Water depth (feet) was approximated using markers on the YSI sensor cable. Precipitation data was obtained from a NOAA climate station on Coal Oil Point Reserve. The sampling locations are represented by turquoise circles in the map in Figure 27

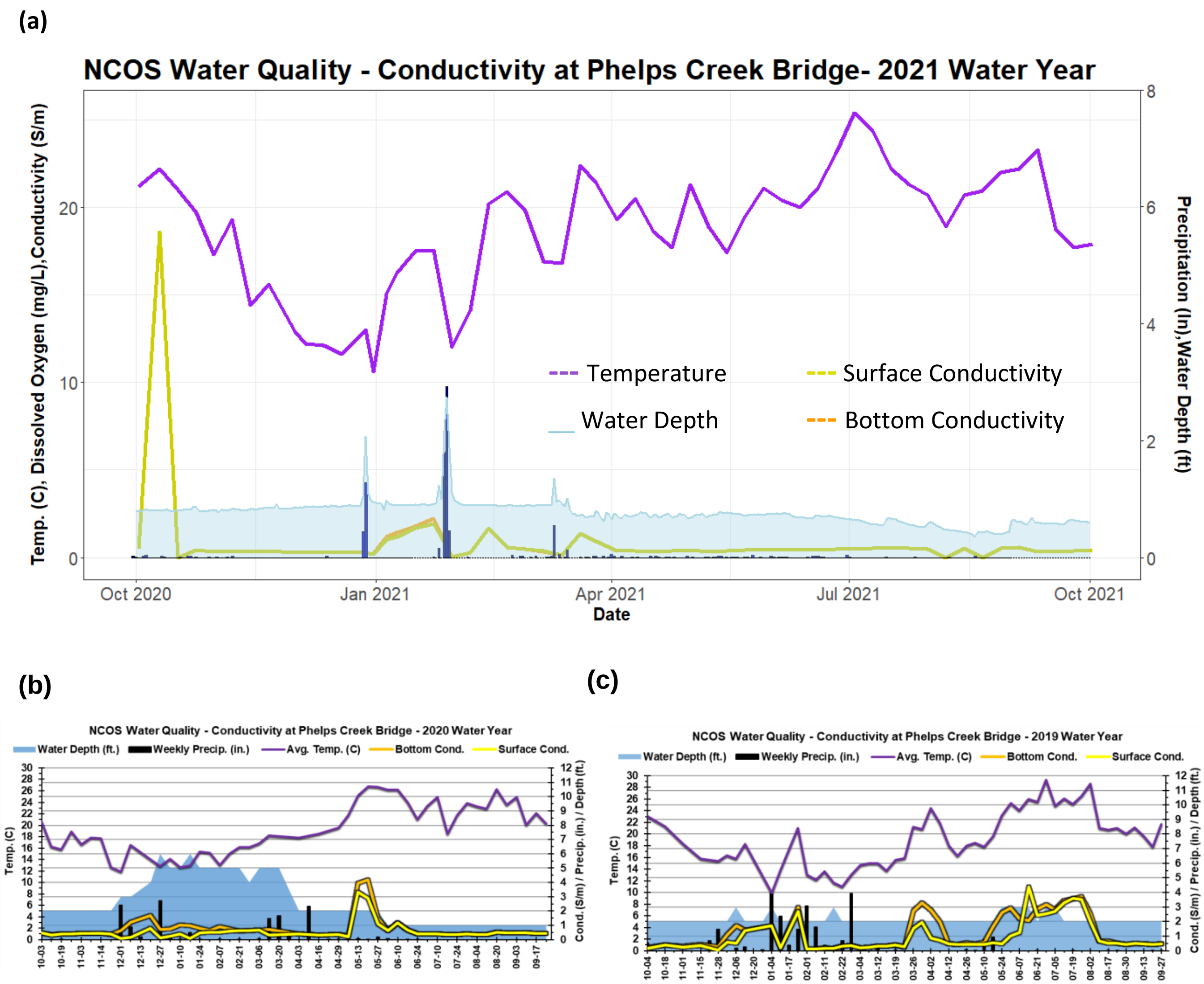

Figure 45. Conductivity (Siemens/meter) at the surface (top 1-foot of water column) and bottom of the water column recorded weekly in the (a) 2019 water year and (b) 2020 water year with a YSI Pro2030 at the Phelps Creek outlet into the upper Devereux Slough, North Campus Open Space. The temperature (Celsius – purple line) is averaged across all depths. Water depth (feet) was approximated using markers on the YSI sensor cable. Precipitation data was obtained from a NOAA climate station on Coal Oil Point Reserve. For reference, seawater conductivity is approximately 5.5 Siemens/meter (32 – 37 ppt salinity) on average. The sampling locations are represented by turquoise circles in the map in Figure 27.

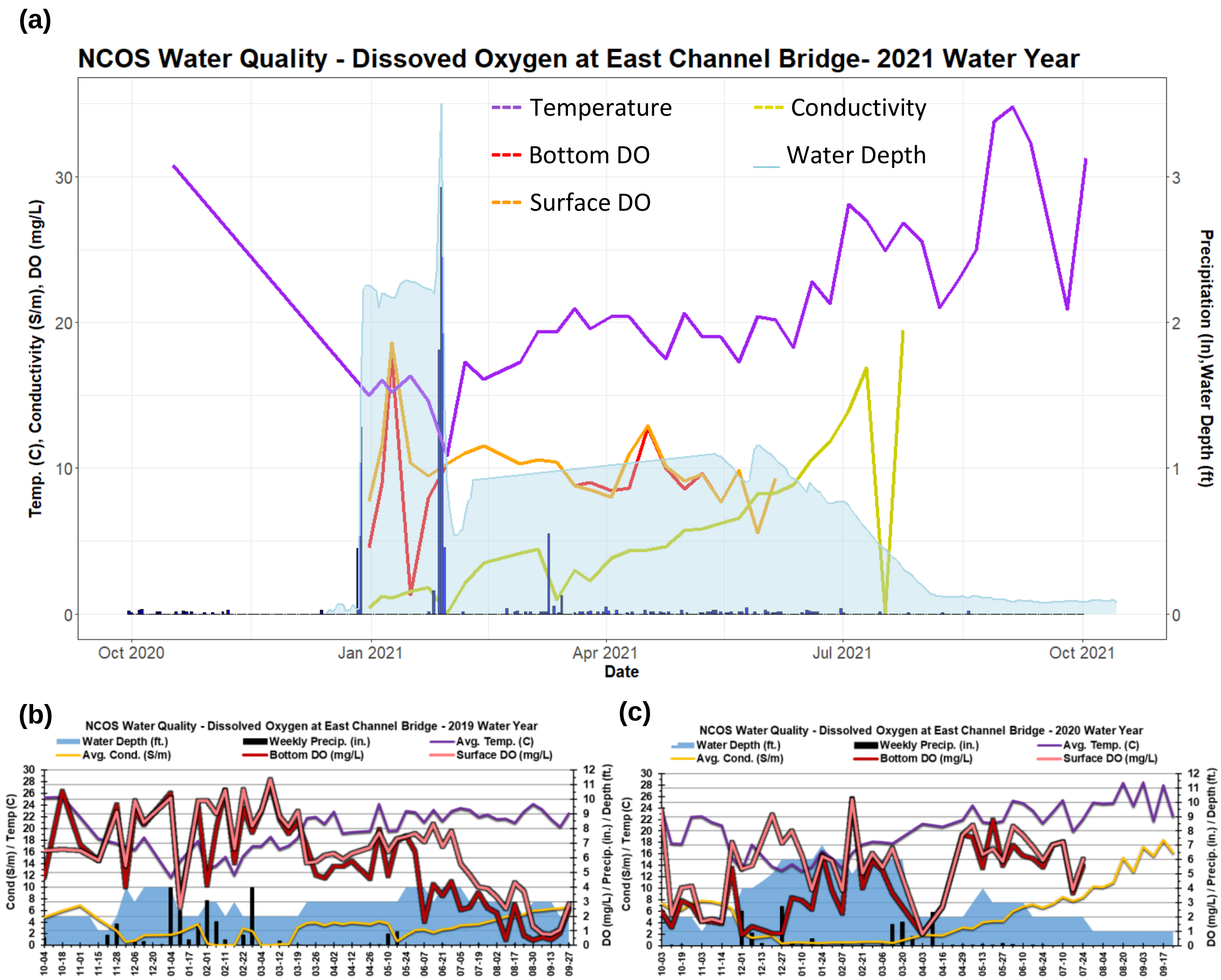

Figure 46. Dissolved oxygen (mg/L) at the surface (top 1-foot of water column) and bottom of the water column recorded weekly in the (a) 2019 water year and (b) 2020 water year with a YSI Pro2030 in the east channel of the upper Devereux Slough, North Campus Open Space. The temperature (Celsius – purple line) and conductivity (Siemens/meter – yellow line) are averaged across all depths. Water depth (feet) was approximated using markers on the YSI sensor cable. Precipitation data was obtained from a NOAA climate station on Coal Oil Point Reserve. For reference, seawater conductivity is approximately 5.5 Siemens/meter (32 – 37 ppt salinity) on average. The sampling locations are represented by turquoise circles in the map in Figure 27. Note that in August and September of the 2020 water year the YSI was unable to calculate DO in mg/L because salinity was above its detection limit.

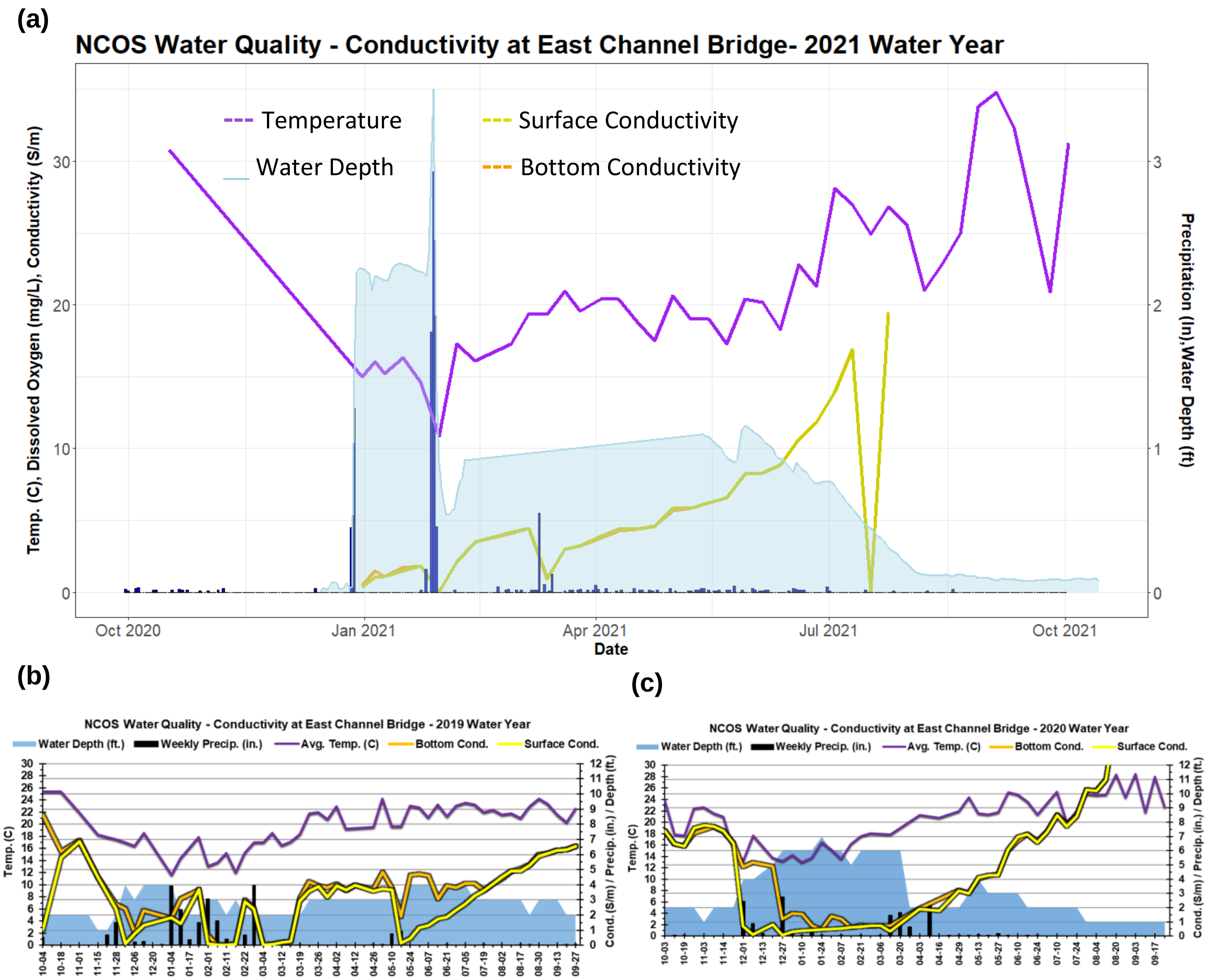

Figure 47. Conductivity (Siemens/meter) at the surface (top 1-foot of water column) and bottom of the water column recorded weekly in the (a) 2019 water year and (b) 2020 water year with a YSI Pro2030 in the east channel of the upper Devereux Slough, North Campus Open Space. The temperature (Celsius – purple line) is averaged across all depths. Water depth (feet) was approximated using markers on the YSI sensor cable. Precipitation data was obtained from a NOAA climate station on Coal Oil Point Reserve. For reference, seawater conductivity is approximately 5.5 Siemens/meter (32 – 37 ppt salinity) on average. The sampling locations are represented by turquoise circles in the map in Figure 27.

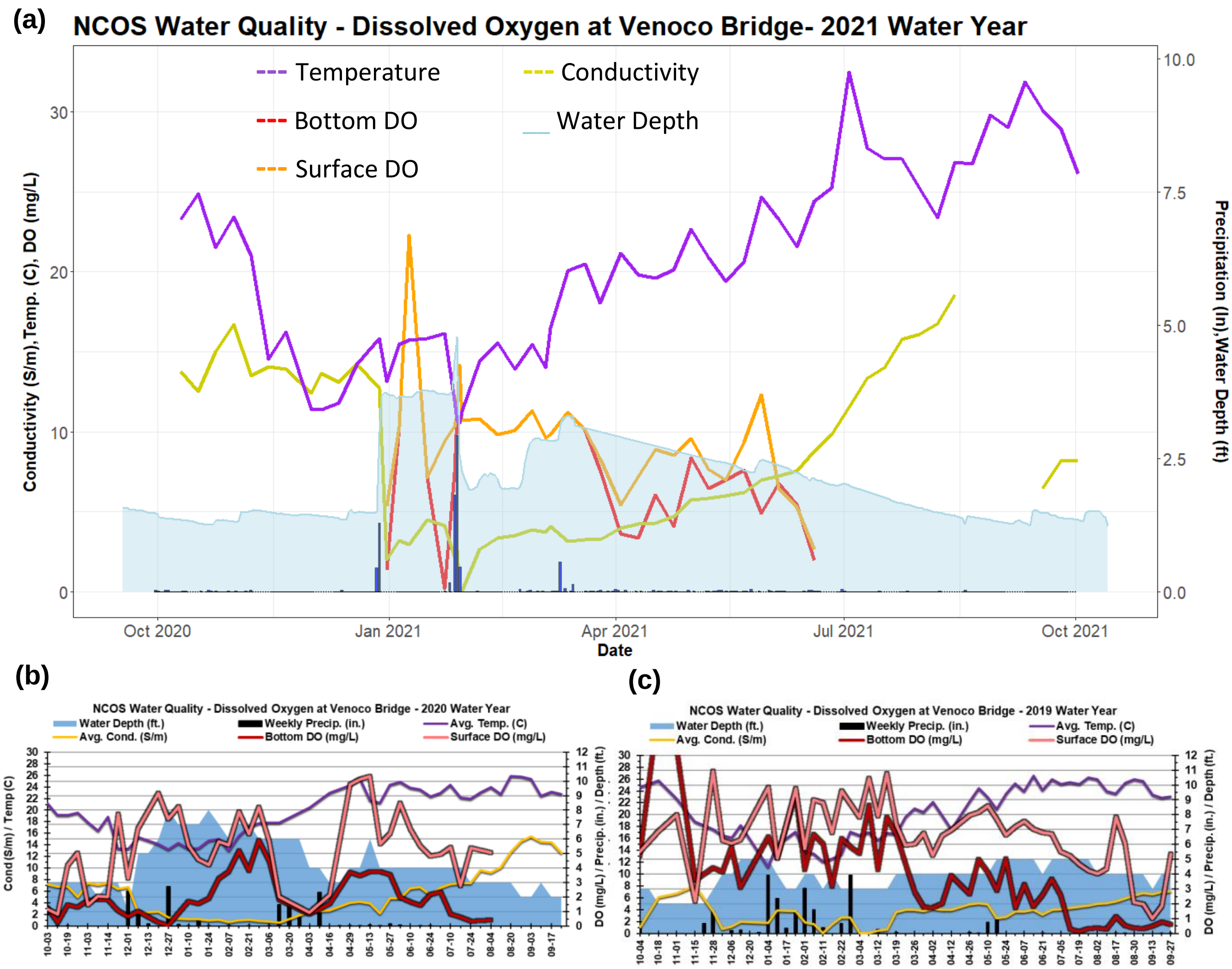

Figure 48. Dissolved oxygen (mg/L) recorded weekly in the (a) 2021 water year (b) 2020 water year and (c) 2019 water year with a YSI Pro2030 at the surface (top 1-foot of water column) and bottom of the water column in the main channel of the upper Devereux Slough at the Venoco access road bridge, North Campus Open Space. The temperature (Celsius – purple line) and conductivity (Siemens/meter – yellow line) are averaged across all depths. Water depth (feet) was approximated using markers on the YSI sensor cable. Precipitation data was obtained from a NOAA climate station on Coal Oil Point Reserve. For reference, seawater conductivity is approximately 5.5 Siemens/meter (32 – 37 ppt salinity) on average. The sampling locations are represented by turquoise circles in the map in Figure 27. Note that in August and September of the 2020 water year the YSI was unable to calculate DO in mg/L because salinity was above its detection limit.

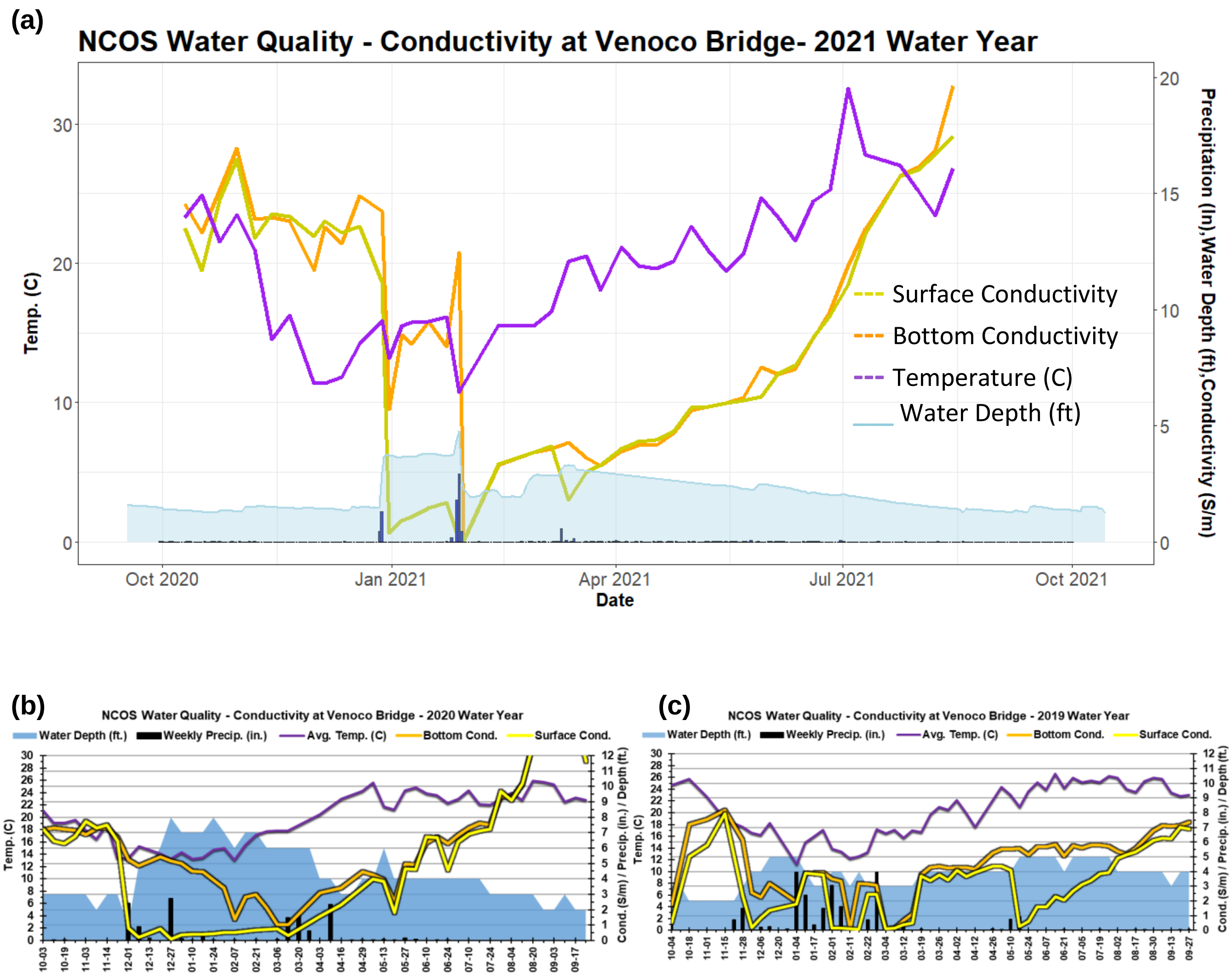

Figure 49. Conductivity (Siemens/meter) at the surface (top 1-foot of water column) and bottom of the water column recorded weekly in the (a) 2019 water year and (b) 2020 water year with a YSI Pro2030 in the main channel of the upper Devereux Slough at the Venoco access road bridge, North Campus Open Space. The temperature (Celsius – purple line) is averaged across all depths. Water depth (feet) was approximated using markers on the YSI sensor cable. Precipitation data was obtained from a NOAA climate station on Coal Oil Point Reserve. For reference, seawater conductivity is approximately 5.5 Siemens/meter (32 – 37 ppt salinity) on average. The sampling locations are represented by turquoise circles in the map in Figure 27.

Regular DO levels above 2 mg/L indicates that the wetland can functionally support aquatic wildlife year-round. Overall, except for a few brief dips to low levels, DO concentrations at all three sites remain above the critical threshold of 2 mg/L throughout the year in 2019 and 2020. DO was above this critical threshold throughout the most months in the 2021 water year, however DO dropped below 2 mg/L in January. The low DO measurements could have been caused by equipment malfunction.

Storm Water Sampling - Methods
In 2016, grab samples of pre-project storm water and baseline flows were collected and analyzed for inorganic nutrients (Nitrite+Nitrate, Phosphate, and Ammonia). These samples demonstrated the likelihood of a flux of inorganic nutrients, particularly nitrogen and phosphate, in the tributaries that enter NCOS and Devereux Slough, especially during the first major storm of the season. This study along with other pre-project water quality data and analyses are discussed in the report, "Water Quality of North Campus Open Space & Devereux Slough: Fall 2015 – Spring 2016", available on eScholarship (escholarship.org/uc/item/2923f039).

Sampling frequency increased following the completion of the wetland grading and CCBER continues to analyze nutrients at a high frequency during storms. Grab samples were collected at four locations (the red triangles in the map in Figure 27) during two major storms in 2018 for the analysis of dissolved inorganic nutrients, total suspended solids and oil and grease concentrations. Results of these analyses demonstrated trends for inorganic nutrients similar to the pre-project study in 2016. Concentrations of these nutrients tended to decrease downstream, as suggested by the lower concentrations detected at the Venoco Bridge sampling site. Ammonia (N) and Oil and Grease concentrations in the samples collected were below levels of concern. The concentration of Suspended solids ranged from the lowest amounts of 150 and 240 mg/L in Devereux Creek, increasing downstream to the highest levels of 700 and 1260 mg/L at Venoco Bridge.

High Frequency Automated Sampling

Beginning with the winter rain season of the 2019 water year, CCBER partnered with the lab of UCSB professor John Melack, who provided three portable Teledyne-ISCO samplers that were installed at the Phelps Creek, Whittier Channel (near the storm drain outflow) and Venoco Bridge sampling locations. These ISCO samplers are programmed to automatically collect samples at a set interval (*e.g.*, once per hour) throughout a storm, which allows for more detailed analysis of the flux of nutrients and suspended solids that enter the wetland system during different storm events. Unlike grab samples, which are typically obtained from the water surface, ISCO samplers pump water through a hose line that is secured well below the water surface, usually within a few inches of the stream bed and as near as possible to the thalweg. At the Venoco Bridge site, the ISCO sampling line sits about two feet above the floor of the channel and a few inches off one side of the tunnel under the bridge. The storm water sampling results for the 2021 water year can be seen in appendix 5. The sampling and analysis of storm water conducted in the 2019 and 2020 water years can be seen in previous year's reports (2019 water year, 2020 water year).

We determine which ISCO samples to analyze by plotting sample collection times on hydrographs of water level data collected with Solinst Leveloggers deployed at the sampling sites. Samples were selected as consistently as possible for each storm event. For storms that last only a few hours, we analyze samples from each hour during the storm. For longer storms we try to distribute the samples to measure different aspects throughout the storm including the pre-storm-rising limb, peak, descending limb and post storm.

Sample Processing and Analysis Methods

Samples selected to be analyzed for nutrients were filtered within 48 hours of collection. This consisted of pouring 10 to 15 mL of raw sample through a 47mm Pall-Gelman fiberglass filter installed on a vacuum into a 20 mL scintillation vial. These vials were then stored in a freezer until the UCSB MARINE SCIENCE INSTITUTE's Analytics Lab could analyze them. The analysis of suspended solids concentration involved one of two methods depending on a visual assessment of the turbidity of a sample. Samples that appeared largely transparent with little to no visible particles were analyzed using the Total Suspended Solids (TSS) method, which involves pouring the entire volume of sample through a single 47-mm fiberglass filter and comparing the dried weight of the filter with its initial "clean" weight to obtain the milligrams of solids per liter (mg/L) of sample. The filters are dried in an oven at 105 degrees Celsius for a minimum of two hours and then cooled in a desiccator for 15 minutes before weighing. A loss correction factor that accounts for the average amount of mass naturally lost from a package of filters during use is applied to the calculation of mg/L of suspended solids. The method used for more turbid samples, called Suspended Solids Concentration (SSC), involves drying a portion of sample in a clean HDPE bottle and comparing the pre- and post-drying mass, excluding the mass of the bottle, to obtain the grams of solids per kilogram (g/kg) of sample. The HDPE bottles used for this analysis are dried in an oven, without caps, at 97 degrees Celsius for approximately 40 hours, followed by two hours at 105 degrees. For interpretation of the results, the SSC data are converted to mg/L to be plotted along with the TSS data.

Summary and Results of 2021 Water Year Efforts

We collected samples at the three sites with ISCO samplers set up as well as one additional site- Devereux creek- with grab samples during five storm events. We also collected "baseline" grab samples in-between storm events. A total of 45 grab samples were collected and analyzed for both nutrients and suspended solids. Of the ISCO samples collected, 85 were analyzed for nutrients and 89 were analyzed for suspended solids.

Generally, the 2021 water year data suggest a greater flux of nutrients, particularly Nitrite+Nitrate, during the first major storm of the season, than in later storms, though there is variation between sites and storm events. This trend is consistent with the data collected in previous years. The concentration of Nitrite+Nitrate is lower at Venoco Bridge than in the upstream inputs from Devereux Creek, Phelps Creek, and Whittier Storm drain, while it appears that the opposite trend may be occurring for Ammonia (N). There does not appear to be any difference in Phosphate concentration at each sampling site.

Our watershed showed the expected pattern of having the highest flux of nutrients during the first storm for ammonia, and phosphate concentrations. Measured Nitrogen however, had a higher concentration in the second storm in January than the first in December. This is likely because the second storm was more intense than the first (5.35 inches compared to 1.73 for the first storm). The likely reason that this pattern is seen in Nitrite-Nitrate levels and not phosphorus or ammonia is the rate of nitrification. Nitrification is the transformation of ammonia to nitrate. Nitrification requires an aerobic environment and since intense storms increase the rate of flow and therefore increase DO availability it is likely that there was a higher rate of nitrification during the second storm therefore increasing nitrate levels and decreasing ammonia levels.

Suspended sediment showed similar values in each storm with some variation throughout the storm. The January storm had one outlier recorded at 20,000 mg/L, nearly twice as high as the second highest recorded value for that storm. The March storm had an even more extreme outlier reading 60,000 mg/L which was at least 4 times greater than the next highest measurement of that storm. Both outliers were collected from Venoco Bridge. Outliers of similar values were seen in the 2020 water year at Venoco Bridge and were likely caused by hypersaline water.

The mean suspended solids concentrations were highest from Venoco Bridge ISCO samples. Appendix 5 contains several charts of the nutrient and suspended solids concentrations (SSC) of samples collected at each site and plotted by date and time along with water stage and hourly rainfall data. These charts are supplemented with box plots that compare all samples analyzed for each analyte at each site. Water stage data was obtained from Solinst Leveloggers installed at or near each sampling site (for Devereux Creek the logger is approx. 1,800 feet downstream of the sampling site, in the western arm of NCOS.

Venoco continues to show elevated suspended sediment concentrations compared to other sites, but similar or lower levels of all nutrients analyzed. This likely results from the adjacent ecosystems. Whittier, Phelps, and Devereux are all adjacent to urban environments, receiving the immediate runoff from the surrounding impervious surfaces. It could also indicate that NCOS is functioning as a nutrient removing wetland meaning that these nutrients have time to filter out before reaching Venoco Bridge. Wetlands that have anoxic conditions are known to reduce the amount of nitrate that is transported downstream by the process of denitrification. Full denitrification is the process in which microbes existing in anoxic conditions break down soluble nitrate (NO3-) into nitric oxide (N2O) which is then broken down into nitrogen gas (N2) which makes up 78% of the air we breathe.

Other observations show that grab samples typically have higher concentration than ISCO samples for Ammonia and Phosphorus. This is likely because grab samples are closer to the surface where the immediate runoff is collected, while ISCO samples are taken near the bottom of the stream bed and surface runoff has not reached this lower water level due to stratification.

Table 8. Number of samples analyzed and the mean, minimum, and maximum concentrations of Ammonia (mg/L) detected in baseline and storm water grab and ISCO samples collected during the rainy season of the 2021 water year at the three main tributaries of Devereux Slough and in the main slough channel where it passes under the Venoco access road bridge at North Campus Open Space. Samples of hypersaline water collected at the Venoco bridge site are excluded.

AMMONIA (mg/L)					
Sample Type & Site	**Samples Analyzed**	**Minimum Concentration**	**Mean Concentration**	**Max Concentration**	**Standard Dev.**
GRAB - Baseline	**2**	**0.05**	**0.10**	**0.15**	
Devereux Creek	0	NA	NA	NA	NA
Phelps Creek	1	0.15	0.15	0.15	NA
Whittier Storm drain	1	0.05	0.05	0.05	NA
Venoco Bridge	0	NA	NA	NA	NA
GRAB - Storm	**35**	**0.01**	**0.23**	**0.51**	
Devereux Creek	13	0.04	0.19	0.19	0.16
Phelps Creek	5	0.01	0.28	0.28	0.20
Whittier Storm drain	6	0.16	0.31	0.31	0.14
Venoco Bridge	11	0.05	0.16	0.51	0.14
ISCO - Storm Only	**83**	**0.00**	**0.09**	**0.70**	
Phelps Creek	39	0.00	0.15	0.70	0.19
Whittier Storm drain	24	0.00	0.09	0.28	0.08
Venoco Bridge	20	0.00	0.04	0.19	0.05
Grand Total	**120**				

Table 9. Number of samples analyzed and the mean, minimum, and maximum concentrations of Phosphate and Nitrite+Nitrate (mg/L) detected in baseline and storm water grab and ISCO samples collected during the rainy season of the 2021 water year at the three main tributaries of Devereux Slough and in the main slough channel where it passes under the Venoco access road bridge at North Campus Open Space. Samples of hypersaline water collected at the Venoco bridge site are excluded.

PHOSPHATE (mg/L)					
Sample Type & Site	**Samples Analyzed**	**Minimum Concentration**	**Mean Concentration**	**Max Concentration**	**Standard Dev.**
GRAB - Baseline	**2**	**0.28**	**0.52**	**0.76**	**NA**
Devereux Creek	0	NA	NA	NA	NA
Phelps Creek	1	0.76	0.76	0.76	NA
Whittier Storm drain	1	0.28	0.28	0.28	NA
Venoco Bridge	0	NA	NA	NA	NA
GRAB - Storm	**35**	**0.13**	**0.44**	**0.78**	
Devereux Creek	13	0.26	0.48	0.78	0.20
Phelps Creek	5	0.25	0.50	0.64	0.15
Whittier Storm drain	6	0.22	0.42	0.63	0.17
Venoco Bridge	11	0.13	0.37	0.64	0.16
ISCO - Storm Only	**83**	**0.09**	**0.32**	**0.70**	
Phelps Creek	39	0.16	0.40	0.70	0.15
Whittier Storm drain	24	0.12	0.31	0.31	0.15
Venoco Bridge	20	0.09	0.25	0.25	0.16
Grand Total	**120**				

NITRITE+NITRATE (mg/L)					
Sample Type & Site	**Samples Analyzed**	**Minimum Concentration**	**Mean Concentration**	**Max Concentration**	**Standard Dev.**
GRAB - Baseline	**2**	**0.009**	**0.624**	**6.229**	**NA**
Devereux Creek	0	NA	NA	NA	NA
Phelps Creek	1	0.00	0.00	0.00	NA
Whittier Storm drain	1	0.12	0.12	0.12	NA
Venoco Bridge	0	NA	NA	NA	NA
GRAB - Storm	**35**	**0.00**	**1.49**	**3.52**	
Devereux Creek	13	0.71	1.72	3.35	0.90
Phelps Creek	5	0.35	1.71	3.43	1.11
Whittier Storm drain	6	0.26	1.32	2.39	1.00
Venoco Bridge	11	0.00	1.19	3.52	0.99
ISCO - Storm Only	**83**	**0.00**	**2.47**	**3.80**	
Phelps Creek	39	0.01	1.22	3.80	0.90
Whittier Storm drain	24	0.13	0.91	1.80	0.45
Venoco Bridge	20	0.00	0.93	3.50	1.13
Grand Total	**120**				

Table 10. Number of samples analyzed and the mean, minimum, and maximum concentrations of suspended solids (mg/L) detected in storm water samples collected during the rainy season of the 2021 water year at the three main tributaries of Devereux Slough and in the main slough channel where it passes under the Venoco access road bridge at North Campus Open Space. Samples of hypersaline water collected at the Venoco bridge site are excluded from this table.

SUSPENDED SOLIDS (mg/L)					
Sample Type & Site	**Samples Analyzed**	**Minimum Concentration**	**Mean Concentration**	**Max Concentration**	**Standard Dev.**
GRAB - Baseline	**2**	**690**	**1755**	**2820**	
Devereux Creek	NA	NA	NA	NA	NA
Phelps Creek	1	2820	2820	2820	NA
Whittier Storm drain	1	690	690	690	NA
Venoco Bridge	NA	NA	NA	NA	NA
GRAB - Storm	**35**	**7.3**	**186.22**	**21576.40**	
Devereux Creek	13	25.74	193.81	506.35	146.02
Phelps Creek	5	7.3	470.47	904.77	325.06
Whittier Storm drain	6	7.8	80.61	180.84	73.86
Venoco Bridge	11	26.07	2807.57	21576.40	6610.62
ISCO - Storm Only	**91**	**4.04**	**1587.33**	**58880.14**	
Phelps Creek	46	7.89	538.24	1960.61	513.44
Whittier Storm drain	24	4.04	141.05	744.28	184.53
Venoco Bridge	20	25.50	4083.96	58880.14	13184.17
Grand Total	**128**				

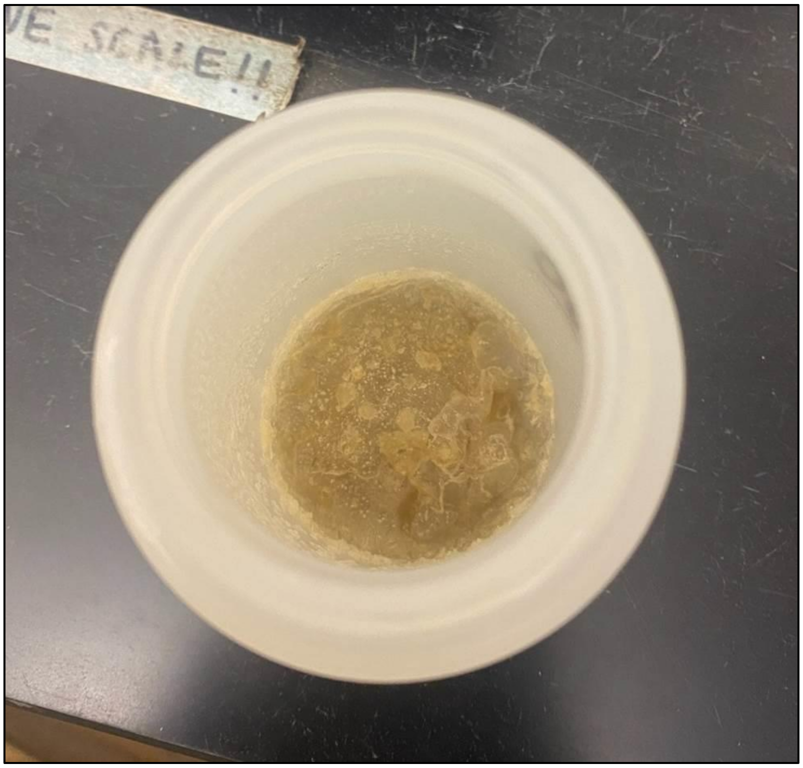

Figure 50. Photo of a suspended solids concentration sample after drying, with a high concentration of salts. The sample was collected at the Venoco Bridge site.

Future Storm water Plans

CCBER will follow this storm water sampling regime in the 2022 water year, and we are working on more detailed analyses of this data as well as flow rate data collected at the sampling sites to calculate the approximate volume and mass of nutrients and suspended solids that are flowing into and through the restored slough. Our intention is to produce a separate report focused on the hydrology and water quality of Devereux Slough.

6. CHARACTERIZATION OF PROJECT EFFORTS

When planting, maintenance, and monitoring began at the North Campus Open Space restoration project in the fall of 2017, we developed methods for workers to track the hours they spent on different tasks and at different zones of the project site using the app, Survey123. This includes recording the number of students and volunteers and the total hours they worked on tasks such as planting or weeding. The project effort data recorded for 2021, the fourth year of the project, is summarized below and compared with the 2020, 2019 and 2018 data to show changes in the proportion of effort by worker type, general task, and zone. Each year approximately 25,000 hours of work are recorded on average.

In 2020, safety restrictions related to the COVID-19 pandemic reduced the overall total hours contributed by all worker types, especially volunteers (Figure 51). Student hours increased in 2021. After asking many volunteers what interested them in volunteering, we found a trend that student volunteers felt that they missed out on hands on field and lab experience classes in 2020 due to pandemic restrictions and are more interested in in-person lab and field opportunities.

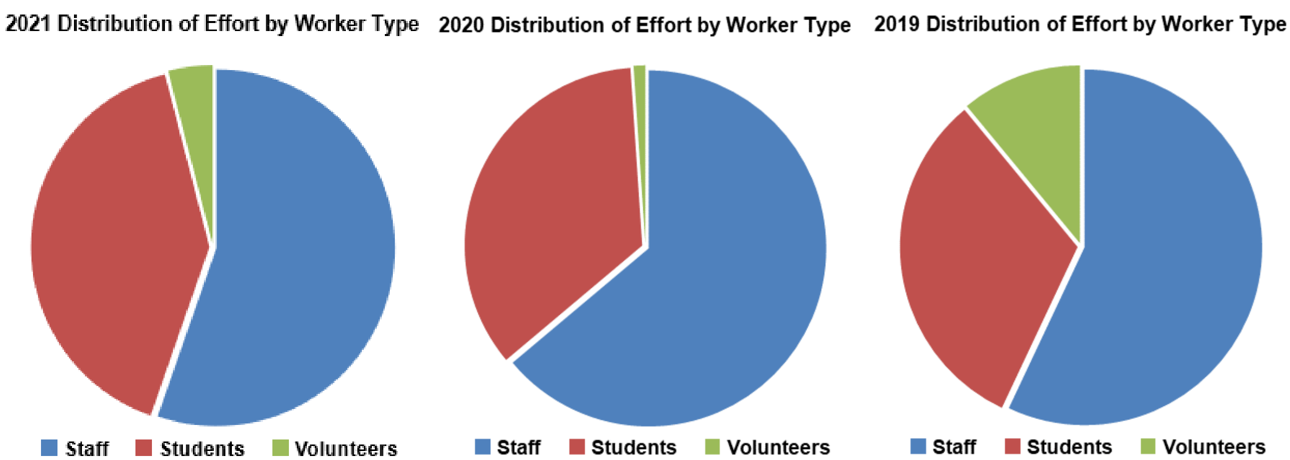

Figure 51. Pie charts of the proportion of effort (hours of work) at the North Campus Open Space restoration project by worker type in 2021, 2020 and 2019. The "Students" category includes paid workers and interns. Data for 2018 is not shown as it is nearly the same as 2019.

Looking at the distribution of work by task, we see that the proportion of effort allocated to planting has decreased by about 20 percent each year from 2018 until 2020 while other tasks have remained about the same, apart from slight increases in Monitoring/Research and Management/Reporting efforts (Figure 52). In 2021 planting efforts did not decrease, but rather stayed relatively the same as 2020 efforts. These trends reflect the emphasis on planting in the first two years of the project and the growth and expansion of monitoring and research at NCOS as the site develops.

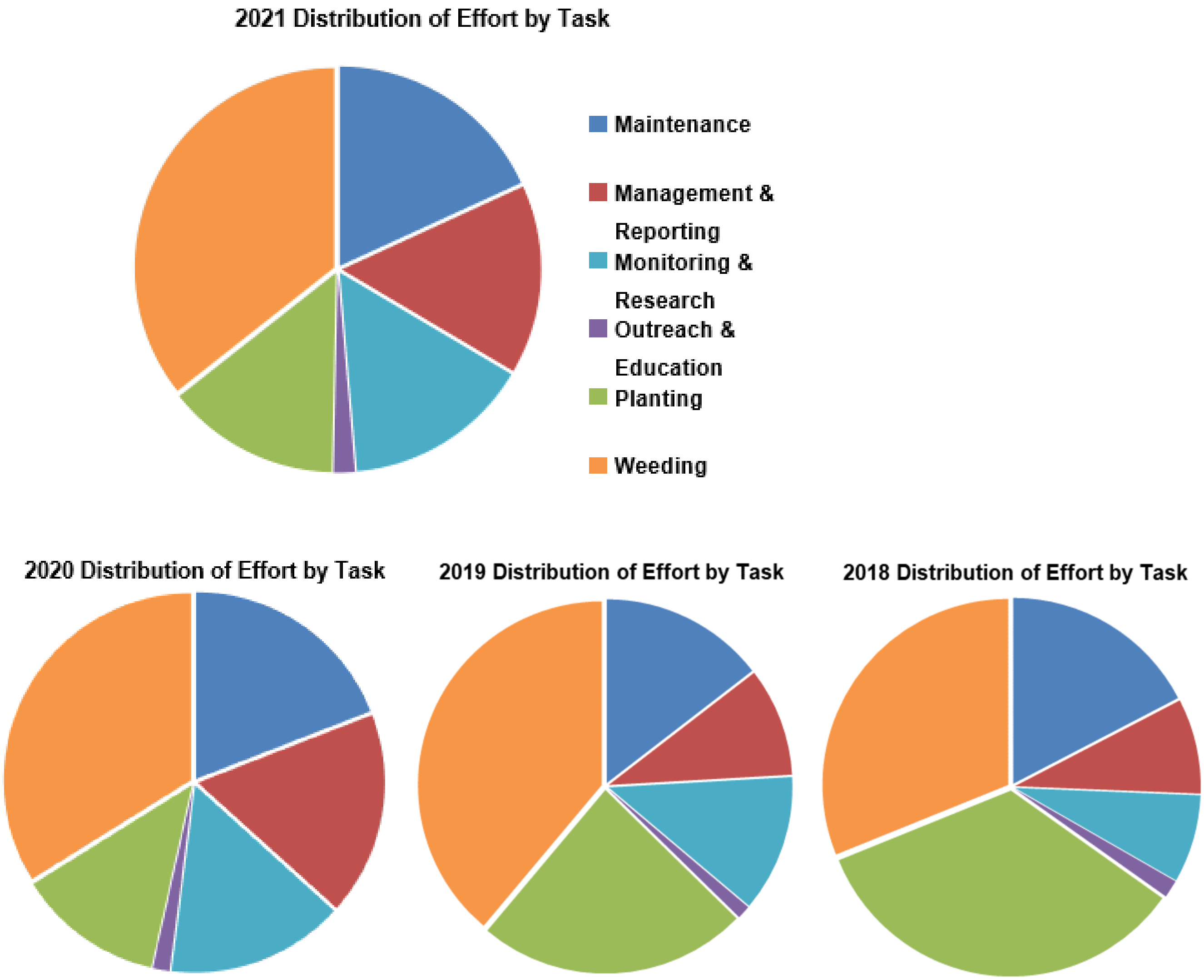

Figure 52. Pie charts of the proportion of effort (hours of work) at the North Campus Open Space restoration project by task in 2021, 2020, 2019, and 2018.

Lastly, the distribution of effort (primarily planting and weeding) across the five main zones of the NCOS project has changed significantly each year (Figure 53). For example, half of all work in 2018 was allocated to the Salt Marsh and Transition zone, which is the largest zone of the site and where planting was primarily focused in the first year of the project. Planting and weeding were more heavily focused on the Mesa zone in 2019, and in efforts in 2020 focused more on maintenance and weeding of the Mesa and Peripheral Uplands than in other zones. In 2021 there was even more emphasis put on planting and weeding on the mesa and saltmarsh transition. The construction and establishment of the visitor plaza, pollinator garden, and discovery trail in the "Whittier" zone explains the increase in project efforts there in 2020. The reduction of work in all areas other than the mesa zone reflects the well-established plantings that were carried out in the first two years of the project.

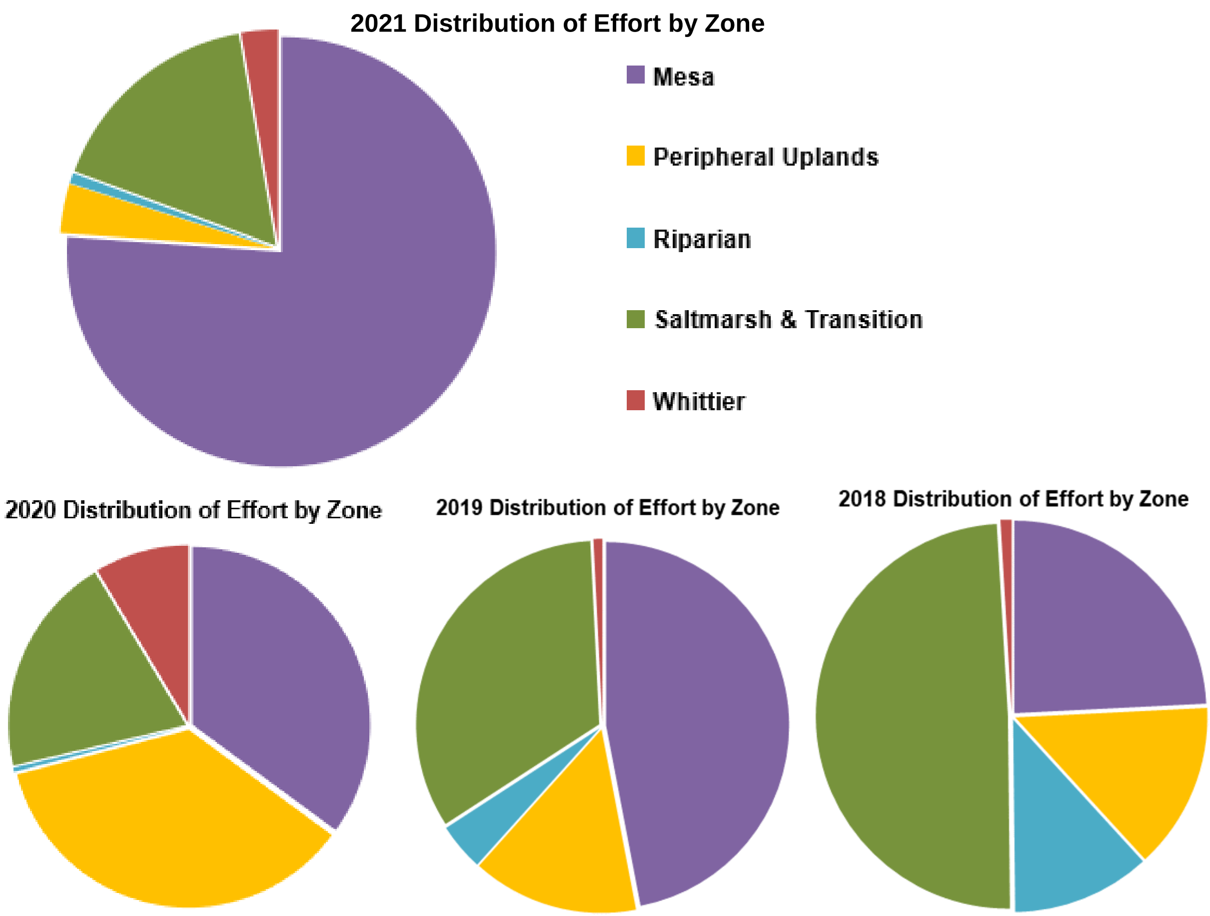

Figure 53. Pie charts of the proportion of effort (hours of work; primarily planting and weeding) at the North Campus Open Space restoration project by zone in 2021, 2020, 2019, and 2018. Refer to the map in Figure 1 for the location and extent of each zone.

APPENDIX 1 – PHOTO-DOCUMENTATION SAMPLES

The following photographs are samples from the photo-documentation monitoring of the North Campus Open Space restoration project taken from the five points circled in turquoise in the map below (14, 20, 31, 33a, and 41).

Map of photo monitoring points at the NCOS restoration project. See Figure 2 for a larger map with legend.

Photo point 14 – looking northwest over the Mesa from the east leg of the Mesa trail

Year 1 – July 2018

Photo point 14 – looking northwest over the Mesa from the east leg of the Mesa trail

Year 2 – July 2019

Photo point 14 – looking northwest over the Mesa from the east leg of the Mesa trail

Year 3 – July 2020

Photo point 14 – looking northwest over the Mesa from the east leg of the Mesa trail

Year 4- July 2021

Photo point 20 – looking northwest from the southeast corner of the NCOS project site

Baseline (post-grading) - October 2017

Photo point 20 – looking northwest from the southeast corner of the NCOS project site

Year 1 – October 2018

Photo point 20 – looking northwest from the southeast corner of the NCOS project site

Year 2 – October 2019

Photo point 20 – looking northwest from the southeast corner of the NCOS project site

Year 3 – October 2020

Photo point 20 – looking northwest from the southeast corner of the NCOS project site

Year 4 – July 2021

Photo point 31 – looking east from trail overlook on east side of Phelps Creek

Baseline (post-grading) - October 2017

Photo point 31 – looking east from trail overlook on east side of Phelps Creek

Year 1 – October 2018

Photo point 31 – looking east from trail overlook on east side of Phelps Creek

Year 2 – October 2019

Photo point 31 – looking east from trail overlook on east side of Phelps Creek

Year 3 – October 2020

Photo point 31 – looking east from trail overlook on east side of Phelps Creek

Year 4 – July 2021

Photo point 33a – looking southwest from upper end of east arm of restored wetland

Baseline (post-grading) - October 2017

Photo point 33a – looking southwest from upper end of east arm of restored wetland

Year 1 – October 2018

Photo point 33a – looking southwest from upper end of east arm of restored wetland

Year 2 – October 2019

Photo point 33a – looking southwest from upper end of east arm of restored wetland

Year 3 – October 2020

Photo point 33a – looking southwest from upper end of east arm of restored wetland

Year 4 – October 2021

Photo point 41 – looking south from trail along north side of east arm of restored wetland

Baseline (post-grading) - October 2017

Photo point 41 – looking south from trail along north side of east arm of restored wetland

Year 1 – October 2018

Photo point 41 – looking south from trail along north side of east arm of restored wetland

Year 2 – October 2019

Photo point 41 – looking south from trail along north side of east arm of restored wetland

Year 3 – October 2020

Photo point 41 – looking south from trail along north side of east arm of restored wetland

Year 4 – July 2021

APPENDIX 2 – VEGETATION MONITORING PLANT SPECIES LISTS

Table A2.1. Native plant species recorded during vegetation monitoring at the North Campus Open Space project. The numbers in each table cell represent the monitoring years in which each species was recorded in each habitat/plant community type (1 = 2018, 2 = 2019, 3 = 2020, 4 = 2021).

Native Species	Perennial Grassland	Peripheral Upland Mosaic	Remnant Salt Marsh	Restored Salt Marsh	Transition/High Salt Marsh	Remnant Brackish Marsh	Seasonal Fresh\Brackish Pond	Vernal Pools	Coastal Sage Scrub Mosaic	Riparian Woodland - New	Riparian Woodland - Pre-existing	Sandy Annuals	Sand Flat
Acmispon glaber								3					
Acmispon maritimus	2,4							3,4	2, 3				
Acmispon wrangelianus								4					
Alnus rhombifolia											2		
Alopecurus saccatus								3					
Ambrosia psilostachya	2, 3	1, 2, 3,4			2,4	3	3	2,4				2, 3,4	
Anemopsis californica										1			
Artemisia californica		1, 2, 3,4							3				
Arthrocnemum subterminale				1, 2, 3,4	3		3						
Atriplex lentiformis		1, 2		3	1, 2, 3,4		3			1,2,3,4			
Baccharis glutinosa										2			
Baccharis pilularis	1, 2, 3,4	1, 2, 3,4		2, 3,4	1, 2, 3,4			1, 2, 3,4	3,4	3	3,4		
Baccharis salicifolia								4					
Bolboschoenus maritimus		3		2, 3,4	3	1, 2, 3,4	1, 2, 3,4	2, 3,4		4			3

Native Species	Perennial Grassland	Peripheral Upland Mosaic	Remnant Salt Marsh	Restored Salt Marsh	Transition/High Salt Marsh	Remnant Brackish Marsh	Seasonal Fresh\Brackish Pond	Vernal Pools	Coastal Sage Scrub Mosaic	Riparian Woodland - New	Riparian Woodland - Pre-existing	Sandy Annuals	Sand Flat
Brickellia californica								2, 3,4					
Bromus carinatus		2, 3,							3	3			
Centromadia parryi australis		2, 3,4		3				3,4					
Cressa truxillensis	3,4	3	1, 2, 3,4	3	3								
Cyperus eragrostis	2, 3	2, 3,4		1, 3	1, 2, 3	2, 3,4		1, 2, 3,4					
Daucus pusillus		3											
Deinandra fasciculata	2, 3,4	2, 3,4		3	1, 2, 3,4	3		2, 3,4					
Distichlis littoralis	4		3,4	1, 2, 3,4	2, 3,4	3	1, 2, 3	4					
Distichlis spicata	2, 3,4	1, 2, 3,4	1, 2, 3,4	1, 2, 3,4	1, 2, 3,4	1, 2, 3,4	1, 3,4	4		3,4			3,4
Eleocharis acicularis	3	2		3	3		3	1, 2, 3,4					3
Eleocharis macrostachya	2,4	1, 2, 3,4	2	3	3	1, 2, 3,4		1, 2, 3,4					
Elymus condensatus		1, 2, 3,4							3,4				
Elymus glaucus		2						2,4	2,4	3			
Elymus triticoides		1, 2, 3,4		1, 2, 3	1, 2, 3,4	4	3		3,4	4			
Encelia californica		1,4			1, 2,4				3,4				
Epilobium brachycarpum	2, 3,4	2, 3,4		3	1, 2, 3,4	1, 2, 3,4		1, 2, 3,4	3,4	3		2, 3	
Epilobium canum		1, 2, 3,4											
Epilobium ciliatum		2, 3,4				4						2	
Erigeron canadensis	1, 2, 3,4	2, 3,4		2, 3,4	1, 2, 3,4	4	3	1, 2, 3,4	3,4	2	2, 3,4	2, 3,4	3

Native Species	Perennial Grassland	Peripheral Upland Mosaic	Remnant Salt Marsh	Restored Salt Marsh	Transition/High Salt Marsh	Remnant Brackish Marsh	Seasonal Fresh\Brackish Pond	Vernal Pools	Coastal Sage Scrub Mosaic	Riparian Woodland - New	Riparian Woodland - Pre-existing	Sandy Annuals	Sand Flat
Eriogonum parvifolium		2, 3,4											
Eriophyllum confertiflorum		3,4											
Eryngium vaseyi	4							1, 2, 3,4					
Euphorbia serpens		2, 3		3	2			2,4					
Euphorbia maculata		4											
Extriplex californica			3	1, 2, 3,4	1, 2, 3,4		3						3
Frankenia salina	1,4	4	1, 2, 3,4	1, 2, 3,4	1, 2, 3,4	4	3						3,4
Grindelia camporum								2, 3,4					
Hazardia squarrosa		4											
Heterotheca grandiflora	1, 2, 3,4	2, 3,4				3		1, 2, 3,4	3,4			1,2,3,4	
Hordeum brachyantherum	4		2	2, 3	3			2, 3,4					
Hordeum brachyantherum ssp.brachyantherum	2, 3	1, 2, 3	1, 3	1, 3	1, 3,4			1, 2, 3,4	4				
Isocoma menziesii	2	2, 3,4		3,4	2, 3,4								
Jaumea carnosa	4		3	1, 2, 3,4	3,4	3	1, 2, 3						3,4
Juncus bufonius	2, 3,4	1, 2, 3,4		3	2, 3		2,4	2, 3,4					
Juncus occidentalis		2, 3,4						3					
Juncus patens		4											
Juncus phaeocephalus	3,4	2, 3						3					
Laennecia coulteri	2, 3	2, 3		3	1, 2, 3,4	4		2, 3		3	3		

Native Species	Perennial Grassland	Peripheral Upland Mosaic	Remnant Salt Marsh	Restored Salt Marsh	Transition/High Salt Marsh	Remnant Brackish Marsh	Seasonal Fresh\Brackish Pond	Vernal Pools	Coastal Sage Scrub Mosaic	Riparian Woodland - New	Riparian Woodland - Pre-existing	Sandy Annuals	Sand Flat
Lepidium nitidum	4												
Limonium californicum				3									
Lonicera subspicata v. subsp.		4							3,4				
Lupinus bicolor												1, 2, 3	
Lupinus succulentus	1	2						1, 2, 3,4					
Malacothrix Saxatilisv. Tenu		4											
Mimulus aurantiacus									3,4				
Persicaria lapathafolia		2				2, 3,4							
Phalaris lemmonii								1, 2, 3,4					4
Plagiobothrys undulatus								1, 2, 3,4					
Plantago erecta	1, 3,4	2			1			2,4					
Platanus racemosa										1,2,4			
Populus trichocarpa											1,2, 3,4		
Pseudognaphalium californicum	3	1, 3											
Psilocarphus brevissimus	2	2						1, 2, 3,4					
Quercus agrifolia		3,4						4	2, 3,4		2,4		
Rosa californica										1			
Rubus ursinus										3			

Native Species	Perennial Grassland	Peripheral Upland Mosaic	Remnant Salt Marsh	Restored Salt Marsh	Transition/High Salt Marsh	Remnant Brackish Marsh	Seasonal Fresh\Brackish Pond	Vernal Pools	Coastal Sage Scrub Mosaic	Riparian Woodland - New	Riparian Woodland - Pre-existing	Sandy Annuals	Sand Flat
Salicornia pacifica	4		1, 2, 3,4	1, 2, 3,4	1, 2, 3,4	1, 2, 3,4	1, 2, 3,4			4			1, 2, 3,4
Salix exigua										1,2,3,4			
Salix lasiolepis		2, 3,4	3	3	3			2, 3	4	3,4	1,2, 3,4		1
Salvia leucophylla		2, 3,4							3,4				
Schoenoplectus californicus	3			2, 3	3		1, 2, 3,4	2, 3,4			1, 2		
Scrophularia californica		4											
Sidalcea malvifora	4												
Sisyrinchium bellum	4	2, 3.,4						1, 2, 3,4	4				
Solanum douglasii		2, 3			1, 2			3				2	
Spergularia macrotheca				4	4								
Stebbinsoseris heterocarpa	1, 2, 3,4							2,4					
Stipa pulchra	1, 2, 3,4	2, 3,4						1, 2, 3,4	3,4				
Suaeda taxifolia			3	3	1, 2, 3,4	3	3						3
Symphyotrichum chilense					2					3			
Symphyotrichum subulatum	2, 3,4	1, 2, 3,4	3	1, 2, 3,4	1, 2, 3,4	1, 2, 3,4	2, 3	1, 2, 3,4	3,4	2, 3			2, 3,4
Typha latifolia								1, 2, 3,4					
Vulpia microstachys	3												
Xanthium strumarium			1, 2	2	3	1, 2,4	3						

Table A2.2. Non-native plant species recorded during vegetation monitoring at the North Campus Open Space project. The numbers in each table cell represent the monitoring years in which each species was recorded in each habitat/plant community type (1 = 2018, 2 = 2019, 3 = 2020). The California Invasive Plant Council's rating for each species is indicated as follows: **(H)** – High, **(L)** – Limited, **(M)** – Moderate, and **(W)** – Watch.

Non-Native Species	**Perennial Grassland**	**Peripheral Upland Mosaic**	**Remnant Salt Marsh**	**Restored Salt Marsh**	**Transition/High Salt Marsh**	**Remnant Brackish Marsh**	**Seasonal Fresh\Brackish Pond**	**Vernal Pools**	**Coastal Sage Scrub Mosaic**	**Riparian Woodland – New**	**Riparian Woodland - Pre-existing**	**Sandy Annuals**	**Sand Flat**
Aegilops cylindrical **(W)**	1, 2, 3	2, 3		2	2			3					
Aloe maculata		3											
Amaranthus albus				3,4	3,4								
Araujia sericifera **(W)**	2					3							
Atriplex prostrata		2,4		1, 2, 3	1, 2, 3	1, 2,4	2, 3						2, 3,4
Atriplex rosea					3								
Atriplex semibaccata **(M)**	1	1, 2, 3,4		2	1, 3,4								
Avena barbata **(M)**	4	3,4			4			4	4			3,4	
Avena fatua **(M)**	1, 2, 3,4	1, 2, 3,4			1, 2, 3,4	4		1, 2, 3,4	2, 3,4	4		2	
Bassia hyssopifolia **(L)**		2											
Beta vulgaris **(L)**	1				4								
Brachypodium distachyon **(M)**	1, 2, 3,4	2, 3,4			1, 2, 3,4			1, 2, 3,4	3,4			1, 2	
Brassica nigra **(M)**	1,4	3,4		4	1				1, 3			1,4	
Bromus catharticus	2, 3,4	1, 2, 3,4		1, 2, 3	1, 2, 3,4	3,4		2					
Bromus diandrus **(M)**	1, 2, 3,4	1, 2, 3,4			1, 2, 3,4	2,4		1, 2, 3,4	2, 3,			1, 2, 3,4	
Bromus hordeaceus **(L)**	1, 2, 3,4	1, 2, 3,4			1, 2, 3,4	4		2, 3,4		4			

Non-Native Species	**Perennial Grassland**	**Peripheral Upland Mosaic**	**Remnant Salt Marsh**	**Restored Salt Marsh**	**Transition/High Salt Marsh**	**Remnant Brackish Marsh**	**Seasonal Fresh\Brackish Pond**	**Vernal Pools**	**Coastal Sage Scrub Mosaic**	**Riparian Woodland – New**	**Riparian Woodland - Pre-existing**	**Sandy Annuals**	**Sand Flat**
Bromus madritensis		4							4				
Capsella bursa-pastoris		1, 2, 3		2									
Carduus pycnocephalus **(M)**	1, 3,4												
Centaurium sp.	4	4			3	4				4			
Centaurium tenuiflorum	2, 3	2, 3						1, 2, 3					
Chenopodium album		2				3							3,4
Chenopodium murale		3		1, 3			2						2
Convolvulus arvensis		2, 3,4		1				1, 3,4					
Cortaderia selloana **(H)**	4										1, 2, 3		
Cotula coronopifolia **(L)**		4		2, 3,4	3,4	2,4		2, 3,4		3			4
Crypsis schoenoides				2, 3,4		1	2, 3,4	1, 2, 3,4					3
Cyclospermum sp.		3											
Cynodon dactylon **(M)**		1, 2, 3,4		1, 2, 3,4	1, 2, 3,4	1, 2, 3,4							
Dichondra micrantha	2, 3	2			1								
Dysphania ambrosioides		2											
Erharta erecta **(M)**		3											
Erigeron bonariensis	3,4	2, 3,4		2	2, 3,4					2, 3			
Erigeron sumatrensis		3											
Erodium botrys	1, 2	3,4	2		1,4			2,4				2,4	
Erodium cicutarium **(L)**	1, 2, 3	2,4			1			4	3,4			1, 2, 3	

Non-Native Species	Perennial Grassland	Peripheral Upland Mosaic	Remnant Salt Marsh	Restored Salt Marsh	Transition/High Salt Marsh	Remnant Brackish Marsh	Seasonal Fresh\Brackish Pond	Vernal Pools	Coastal Sage Scrub Mosaic	Riparian Woodland – New	Riparian Woodland - Pre-existing	Sandy Annuals	Sand Flat
Eucalyptus globulus **(L)**		2											
Eucalyptus sp.		3											
Euphorbia maculata		3			3								
Festuca bromoides		1, 2, 3			3,4			2					
Festuca myuros **(M)**	1, 2, 3,4	1, 2, 3,4	1	1, 2	1, 2, 3,4	4		1, 2, 3,4				1, 2, 3,4	
Festuca perennis **(M)**	1, 2, 3,4	1, 2, 3,4	1, 2, 3,4	1, 2, 3,4	1, 2, 3,4	2, 3,4		1, 2, 3,4	1, 3,4	3,4		1, 3	
Foeniculum vulgare **(M)**	1				1, 3,4								
Geranium dissectum **(L)**	1, 2, 3,4	2, 3,4	3,4		3			1, 2, 3,4	4			2	
Helminthotheca echioides **(L)**	1, 2, 3,4	1, 2, 3,4	1, 2	2, 3,4	1, 2, 3	1, 2, 3,4		2, 3,4	4	2, 3			
Hirschfeldia incana **(M)**	2												
Hordeum marinum **(M)**	1, 3,4	1, 3,4		1, 2, 3,4	1, 2, 3,4	3,4		2,4				4	
Hordeum murinum **(M)**	2, 3,4	1, 2, 3,4		1, 2,4	1, 2, 3,4								
Hypochaeris glabra **(L)**	2,4							2, 3,4				2, 3,4	
Lactuca serriola	1, 3	1, 2, 3,4	3		1, 2, 3,4			1, 2,4					
Lepidium didymum	1	1, 2, 3,4		1	1,4								
Logfia gallica	3,4	2						3				2	
Lotus corniculatus					2								
Lysimachia arvensis	1, 2, 3,4	1, 2, 3,4		2	1, 2, 3,4			1, 2, 3,4	4		2, 3,4	2, 3,4	
Lythrum hyssopifolia **(M)**	2, 3,4	1, 2, 3,4			1, 3	4		1, 2, 3,4					
Malva parviflora	1, 2, 3,4	1, 2, 3,4			1, 2, 3,4			2	3,4				

Non-Native Species	Perennial Grassland	Peripheral Upland Mosaic	Remnant Salt Marsh	Restored Salt Marsh	Transition/High Salt Marsh	Remnant Brackish Marsh	Seasonal Fresh\Brackish Pond	Vernal Pools	Coastal Sage Scrub Mosaic	Riparian Woodland – New	Riparian Woodland - Pre-existing	Sandy Annuals	Sand Flat
Matricaria discoidea					1								
Medicago lupulina	1, 3,4	2, 3						2, 3,4	3,4				
Medicago polymorpha **(L)**	1, 2, 3,4	1, 2, 3,4	1	1, 3,4	1, 2, 3,4	4		1, 2, 3,4	1, 2, 3,4	2		1, 2, 3,4	
Melilotus albus	1,4				3								2, 3
Melilotus indicus	1, 2, 3,4	1, 2, 3,4		1, 2, 3,4	1, 2, 3,4			1, 2, 3,4	1, 2, 3,4	2		2, 3	2,4
Oxalis pes-caprae **(M)**								2					
Parapholis incurva	1, 2, 3,4	1, 2, 3,4		1, 2, 3,4	1, 2, 3,4			2, 3,4					2,4
Paspalum dilatatum		1, 2, 3,4			1, 2								
Pennisetum clandestinum **(L)**		2		1	1, 2								
Phalaris aquatic **(M)**								1					
Pinus halepensis		3											
Pinus pinea		2,4									1, 2		
Pinus sp.											1		
Plantago coronopus	1, 2, 3,4	1, 2, 3,4		1, 2, 3,4	1, 2, 3,4	2, 3,4	2	2, 3,4		4			4
Plantago lanceolata **(L)**	1, 2, 3,4	1, 2, 3.4			1, 2, 3,4			1, 2, 3,4				1	
Plantago major		2											
Poa annua		1, 2, 3			1, 3,4			4		3			
Polycarpon tetraphyllum		3									3		
Polygonum aviculare depressum	2, 3	1, 2, 3,4		1, 2, 3,4	1, 2, 3,4	2, 3		2, 3,4		2			2
Polypogon interruptus	3	3,4		3	3,4			1, 2, 3,4					

Non-Native Species	**Perennial Grassland**	**Peripheral Upland Mosaic**	**Remnant Salt Marsh**	**Restored Salt Marsh**	**Transition/High Salt Marsh**	**Remnant Brackish Marsh**	**Seasonal Fresh\Brackish Pond**	**Vernal Pools**	**Coastal Sage Scrub Mosaic**	**Riparian Woodland – New**	**Riparian Woodland - Pre-existing**	**Sandy Annuals**	**Sand Flat**
Polypogon monspeliensis **(L)**	1, 3,4	2, 3,4		2, 3,4	2, 3,4	2, 3,4		1, 2, 3,4		4			3,4
Polypogon viridis	4	4			3			2,4	4	4			
Portulaca oleracea		3											
Pseudognaphalium luteoalbum	2, 3,4	2, 3,4			2, 3,4	2, 3,4		3,4					
Raphanus sativus **(L)**			1, 2, 3,4										
Rumex crispus **(L)**	2	1, 2, 3,4	2, 3		1, 3	1, 3,4		1, 2,4	2				
Salsola tragus **(L)**	2	1, 2,4		2,4	1,4								
Senecio vulgaris		2											
Silene gallica								2					
Sonchus asper	1, 2	1,4		1	1,4	3		1, 2,4					
Sonchus oleraceus	1, 2,4	1, 2, 3,4	4	1	1			2, 3,4		3			
Sonchus sp.	2, 3,4	2, 3,4		2,4	2, 3,4	4		2, 3,4	3,4			4	
Sorghum sp.								2					
Spergula arvensis				3,4	3			3					
Spergularia bocconi		2											
Spergularia rubra	1												
Spergularia sp.	2, 3,4	1, 2, 3,4	2, 3	1, 2, 3,4	1, 2, 3,4	1, 2, 3,4	2, 3	3,4		3			2, 3,4
Stipa miliacea		2,4						2					
Tamarix ramosissima **(H)**								2					
Taraxacum officinale		2, 3											

Non-Native Species	Perennial Grassland	Peripheral Upland Mosaic	Remnant Salt Marsh	Restored Salt Marsh	Transition/High Salt Marsh	Remnant Brackish Marsh	Seasonal Fresh\Brackish Pond	Vernal Pools	Coastal Sage Scrub Mosaic	Riparian Woodland – New	Riparian Woodland - Pre-existing	Sandy Annuals	Sand Flat
Trifolium hirtum **(L)**	3,4	2, 3,4		2	1, 2	4		1, 2,4					
Trifolium repens		2											
Trifolium tomentosum	3												
Triticale	1, 2, 3			2	1				1				
Vicia sativa	1, 2	1, 2,4	1, 3,4		1			2,4				2	
Vicia sp.			1										
Vicia villosa	1		4					1					
Washingtonia robusta **(M)**		2,4											

APPENDIX 3 – BIRD SURVEY SPECIES LISTS

Table A3.1. List of all bird species and the total number of individuals of each species observed in each of the first four years of monthly bird surveys at the North Campus Open Space restoration project. Each "Survey Year" begins in September and ends in August. The species are grouped by guild, with more detailed categories defined by eBird Clements v2018 integrated checklist (August 2018).

	Survey Year 1		Survey Year 2		Survey Year 3		Survey Year 4	
Guild & Common Name	**# of Obs**	**Avg. Count/ Survey**	**# of Obs**	**Avg. Count/ Survey**	**# of Obs**	**Avg. Count/ Survey**	**# of Obs.**	**Avg. Count/ Survey**
Cormorants and Anhingas	**1**	**0.08**	**3**	**0.33**	**5**	**1.33**	**8**	**2.08**
Double-crested Cormorant	1	0.08	3	0.33	5	1.33	8	2.08
Gulls, Terns, and Skimmers	**13**	**8.25**	**28**	**13.42**	**27**	**8.83**	**13**	**2.33**
California Gull	2	1.00	4	1.33	5	1.08	1	0.08
Caspian Tern		0.00		0.00	2	0.42		
Mew Gull		0.00	3	1.83	1	1.33		
Ring-billed Gull	3	3.00	6	1.33	4	1.08	4	1.25
Western Gull	8	4.25	15	8.92	15	4.92	8	1.00
Herons, Egrets, and Ibis	**34**	**9.17**	**43**	**3.83**	**78**	**22.58**	**45**	**5.00**
Black-crowned Night-Heron	2	0.33	2	0.17	15	1.58	20	2.75
Great Blue Heron	14	1.33	5	0.42	17	2.25	6	0.50
Great Egret	6	3.58	13	1.08	20	7.17	11	1.00
Green Heron	7	0.58	3	0.25	2	0.17	1	0.17
Snowy Egret	4	3.25	19	1.83	24	11.42	7	0.58
White-faced Ibis	1	0.08	1	0.08		0.00		
Hummingbirds	**88**	**10.17**	**84**	**8.83**	**104**	**10.42**	**135**	**14.67**
Allen's Hummingbird	5	0.58	5	0.42	9	0.92	13	1.17
Anna's Hummingbird	81	9.33	78	8.33	94	9.42	117	13.08
Black-chinned Hummingbird		0.00		0.00	1	0.08	1	0.08
Rufous Hummingbird	2	0.25	1	0.08		0.00		
Selasphorus sp							4	0.33
Insectivores	**429**	**117.58**	**670**	**172.33**	**765**	**211.00**	**815**	**183.83**
Blackbirds	***37***	***21.42***	***50***	***19.33***	***35***	***16.42***	***33***	***16.25***
Bullock's Oriole	1	0.08		0.00	1	0.08		
Great-tailed Grackle	1	0.17		0.00	3	0.25	1	0.08
Hooded Oriole	4	0.50	7	0.58	10	0.92	4	0.33

	Survey Year 1		Survey Year 2		Survey Year 3		Survey Year 4	
Guild & Common Name	**# of Obs.**	**Avg. Count per Survey**	**# of Obs.**	**Avg. Count per Survey**	**# of Obs.**	**Avg. Count per Survey**	**# of Obs.**	**Avg. Count per Survey**
Red-winged Blackbird	12	2.67	22	9.17	7	1.50	12	2.33
Western Meadowlark	19	18.00	20	9.50	13	13.58	15	13.42
Yellow-headed Blackbird		0.00	1	0.08	1	0.08	1	0.17
Cardinals, Grosbeaks, and Allies		***0.00***	***2***	***0.17***		***0.00***	***1***	***0.08***
Western Tanager		0.00	2	0.17		0.00	1	0.08
Catbirds, Mockingbirds, and Thrashers	***2***	***0.17***		***0.00***	***3***	***0.25***	***1***	***0.08***
California Thrasher	2	0.17		0.00	3	0.25	1	0.08
Gnatcatchers	***8***	***0.75***	***25***	***2.42***	***48***	***5.75***	***66***	***0.08***
Blue-gray Gnatcatcher	8	0.75	25	2.42	48	5.75	66	9.33
Kinglets	***5***	***0.42***	***15***	***1.25***	***16***	***1.42***	***32***	***3.00***
Ruby-crowned Kinglet	5	0.42	15	1.25	16	1.42	32	3.00
Martins and Swallows	***46***	***32.42***	***39***	***44.58***	***40***	***66.17***	***31***	***37.92***
Barn Swallow	6	0.83	8	1.25	6	1.67	2	0.25
Cliff Swallow	26	28.92	25	40.92	27	60.08	22	36.50
Northern Rough-winged Swallow	10	1.75	3	0.50	2	1.83	3	0.58
Tree Swallow	4	0.92	2	1.25	4	2.42	4	0.58
Violet-green Swallow		0.00	1	0.67	1	0.17		
New World Sparrows	***117***	***22.92***	***212***	***49.50***	***271***	***64.00***	***292***	***59.08***
Fox Sparrow	1	0.08		0.00		0.00		
Golden-crowned Sparrow	1	0.17		0.00	1	0.08		
Lincoln's Sparrow		0.00	5	0.42	9	0.83	17	1.58
Savannah Sparrow	1	0.25	10	2.08	17	4.42	9	1.75
Savannah Sparrow (Belding's)	8	1.17	8	1.50	5	0.58	8	0.75
Song Sparrow	69	8.67	121	15.42	154	18.00	183	22.75
White-crowned Sparrow	37	12.58	68	30.08	85	40.08	75	32.25

	Survey Year 1		Survey Year 2		Survey Year 3		Survey Year 4	
Guild & Common Name	**# of Obs .**	**Avg. Count per Survey**	**# of Obs.**	**Avg. Count per Survey**	**# of Obs.**	**Avg. Count per Survey**	**# of Obs.**	**Avg. Count per Survey**
Nuthatches		***0.00***	***3***	***0.25***	***8***	***0.75***	***7***	***0.67***
Red-breasted Nuthatch		0.00		0.00	8	0.75	5	0.50
White-breasted Nuthatch		0.00	3	0.25		0.00	2	0.17
Parrotbills, Wrentit, and Allies		***0.00***	***3***	***0.25***	***3***	***0.25***	***5***	***0.58***
Wrentit		0.00	3	0.25	3	0.25	5	0.58
Penduline-Tits and Long-tailed Tits	***9***	***5.00***	***21***	***10.67***	***31***	***15.25***	***24***	***19.92***
Bushtit	9	5.00	21	10.67	31	15.25	24	19.92
Starlings and Mynas	***6***	***1.67***	***11***	***4.67***	***14***	***6.17***	***7***	***1.58***
European Starling	6	1.67	11	4.67	14	6.17	7	1.58
Swifts	***1***	***0.17***	***1***	***1.08***		***0.00***		
Vaux's Swift	1	0.17	1	1.08		0.00		
Thrushes	***28***	***4.42***	***31***	***5.00***	***32***	***5.00***	***38***	***4.92***
Hermit Thrush		0.00	1	0.08	1	0.08	1	0.08
Western Bluebird	28	4.42	30	4.92	31	4.92	37	4.83
Tits, Chickadees, and Titmice		***0.00***	***5***	***0.42***	***4***	***0.42***	***11***	***1.25***
Oak Titmouse		0.00	5	0.42	4	0.42	11	1.25
Tyrant Flycatchers: Pewees, Kingbirds, and Allies	***121***	***11.58***	***193***	***18.25***	***184***	***18.08***	***173***	***16.42***
Ash-throated Flycatcher		0.00	3	0.25		0.00		
Black Phoebe	65	6.00	112	10.42	89	8.08	86	7.75
Cassin's Kingbird	11	1.50	28	3.17	30	3.75	20	1.83
Pacific-slope Flycatcher	1	0.08	1	0.08	3	0.25		
Say's Phoebe	42	3.83	47	4.17	51	4.67	59	5.92
Tropical Kingbird		0.00	1	0.08	3	0.33	2	0.17
Western Kingbird	1	0.08		0.00	7	0.92	6	0.75
Western Wood-Pewee	1	0.08	1	0.08		0.00		
Willow Flycatcher		0.00		0.00	1	0.08		
Wagtails and Pipits	***24***	***14.33***	***19***	***10.67***	***8***	***5.00***	***9***	***5.25***
American Pipit	24	14.33	19	10.67	8	5.00	9	5.25

	Survey Year 1		Survey Year 2		Survey Year 3		Survey Year 4	
Guild & Common Name	**# of Obs.**	**Avg. Count per Survey**	**# of Obs.**	**Avg. Count per Survey**	**# of Obs.**	**Avg. Count per Survey**	**# of Obs.**	**Avg. Count per Survey**
Woodpeckers	***6***	***0.67***	***11***	***0.92***	***15***	***1.33***	***12***	***1.00***
Acorn Woodpecker	2	0.33		0.00	1	0.08		
Downy Woodpecker	2	0.17	2	0.17	6	0.50	5	0.42
Hairy Woodpecker	2	0.17		0.00	6	0.58	1	0.08
Northern Flicker		0.00	3	0.25	1	0.08	2	0.17
Nuttall's Woodpecker		0.00	6	0.50	1	0.08	4	0.33
Wrens	***19***	***1.67***	***29***	***2.92***	***53***	***4.75***	***73***	***6.42***
Bewick's Wren	13	1.17	14	1.67	17	1.58	21	1.75
House Wren	4	0.33	9	0.75	26	2.17	33	3.00
Marsh Wren		0.00	3	0.25	10	1.00	19	1.67
Rock Wren	2	0.17	3	0.25		0.00		
Kingfishers		**0.00**	**5**	**0.42**	**4**	**0.33**	**1**	**0.08**
Belted Kingfisher		0.00	5	0.42	4	0.33	1	0.08
Omnivores	**152**	**35.08**	**140**	**22.17**	**144**	**24.25**	**156**	**34.92**
Blackbirds		***0.00***	***1***	***0.17***		***0.00***		
Brewer's Blackbird		0.00	1	0.17		0.00		
Catbirds, Mockingbirds, and Thrashers	***6***	***0.67***	***18***	***1.92***	***15***	***1.42***	***7***	***0.67***
Northern Mockingbird	6	0.67	18	1.92	15	1.42	7	0.67
Jays, Magpies, Crows, and Ravens	***53***	***20.92***	***47***	***9.58***	***72***	***14.92***	***77***	***24.00***
American Crow	53	20.92	46	9.50	72	14.92	75	23.83
Common Raven							1	0.08
California Scrub-Jay		0.00	1	0.08		0.00	1	0.08
New World Sparrows	***79***	***9.50***	***57***	***7.25***	***47***	***4.92***	***62***	***7.17***
California Towhee	78	9.42	56	7.17	47	4.92	57	6.75
Spotted Towhee	1	0.08	1	0.08		0.00	5	0.42
Old World Sparrows	***14***	***4.00***	***17***	***3.25***	***10***	***3.00***	***13***	***3.08***
House Sparrow	14	4.00	17	3.25	10	3.00	13	3.08
Raptors	**64**	**6.00**	**79**	**7.50**	**86**	**8.33**	**98**	**9.25**
Falcons and Caracaras	***5***	***0.50***	***6***	***0.50***	***5***	***0.42***	***8***	***0.67***
American Kestrel	5	0.50	5	0.42	4	0.33	7	0.58

	Survey Year 1		Survey Year 2		Survey Year 3		Survey Year 4	
Guild & Common Name	**# of Obs.**	**Avg. Count per Survey**	**# of Obs.**	**Avg. Count per Survey**	**# of Obs.**	**Avg. Count per Survey**	**# of Obs.**	**Avg. Count per Survey**
Peregrine Falcon							1	0.08
Merlin		0.00	1	0.08	1	0.08	1	0.08
Owls		***0.00***	***7***	***0.58***	***6***	***0.83***	***10***	***0.83***
Burrowing Owl		0.00	6	0.50	3	0.25	9	0.75
Great Horned Owl		0.00	1	0.08	3	0.58	1	0.08
Shrikes	***9***	***0.75***	***9***	***0.75***	***11***	***1.08***	***5***	***0.42***
Loggerhead Shrike	9	0.75	9	0.75	11	1.08	5	0.42
Vultures, Hawks, and Allies	***50***	***4.75***	***57***	***5.67***	***64***	***6.00***	***74***	***7.25***
Cooper's Hawk	11	0.92	16	1.42	19	1.83	23	2.08
Accipiter sp.							1	0.08
Northern Harrier		0.00		0.00	2	0.17	4	0.33
Osprey		0.00	1	0.08		0.00	1	0.08
Red-shouldered Hawk	8	0.83	8	0.75	15	1.33	8	0.83
Red-tailed Hawk	17	1.50	19	1.92	15	1.42	16	1.42
Turkey Vulture	7	0.75	7	0.67	9	0.75	12	1.42
White-tailed Kite	7	0.75	6	0.83	4	0.50	9	1.00
Seed & Fruit Eaters	**174**	**65.83**	**205**	**87.08**	**201**	**67.17**	**245**	**66.33**
Blackbirds	***1***	***0.08***	***1***	***0.08***	***2***	***0.58***	***1***	***0.17***
Brown-headed Cowbird	1	0.08	1	0.08	2	0.58	1	0.17
Cardinals, Grosbeaks, and Allies	***1***	***0.08***	***1***	***0.08***	***1***	***0.17***		
Black-headed Grosbeak		0.00		0.00	1	0.17		
Blue Grosbeak	1	0.08	1	0.08		0.00		
Estrildids	***23***	***11.50***	***33***	***20.92***	***28***	***14.17***	***27***	***10.50***
Scaly-breasted Munia	23	11.50	33	20.92	28	14.17	27	10.50
Finches, Euphonias, and Allies	***85***	***20.92***	***99***	***28.17***	***95***	***23.75***	***61***	***38.33***
House Finch	72	19.08	76	24.08	73	21.00	16	29.42
Lesser Goldfinch	13	1.83	22	4.00	20	2.50	43	8.75
American Goldfinch							1	0.08
Purple Finch		0.00	1	0.08	2	0.25	1	0.08

	Survey Year 1		Survey Year 2		Survey Year 3		Survey Year 4	
Guild & Common Name	**# of Obs.**	**Avg. Count per Survey**	**# of Obs.**	**Avg. Count per Survey**	**# of Obs.**	**Avg. Count per Survey**	**# of Obs.**	**Avg. Count per Survey**
Grouse, Quail, and Allies		***0.00***	***1***	***0.17***		***0.00***		
California Quail		0.00	1	0.17		0.00		
New World Sparrows	***3***	***0.75***	***16***	***2.33***	***20***	***2.42***	***10***	***2.00***
Chipping Sparrow		0.00	2	0.17	1	0.17		
Clay-colored Sparrow		0.00	1	0.08		0.00		
Dark-eyed Junco	1	0.08		0.00		0.00	1	0.08
Lark Sparrow	2	0.67	13	2.08	19	2.25	9	1.92
Pigeons and Doves	***61***	***32.50***	***54***	***35.33***	***55***	***26.08***	***46***	***15.33***
Eurasian Collared-Dove	9	1.17	2	0.33	5	0.58	5	0.58
Mourning Dove	23	7.83	19	4.25	18	2.33	13	1.92
Rock Pigeon (Feral Pigeon)	29	23.50	33	30.75	32	23.17	28	12.83
Shorebirds	**224**	**95.25**	**189**	**86.67**	**175**	**69.25**	**99**	**40.50**
American Avocet		0.00		0.00	2	0.17		
Black-necked Stilt	5	0.83	11	1.50	23	3.17	4	0.50
Dunlin	1	0.08	1	0.08		0.00		
Greater Yellowlegs	18	1.83	14	1.50	18	1.83	12	1.25
Killdeer	94	38.25	93	34.00	71	32.00	45	16.75
Least Sandpiper	45	14.08	30	23.33	17	6.92	18	6.42
Lesser Yellowlegs		0.00		0.00	1	0.17	1	0.08
Long-billed Curlew	2	0.17	3	0.83	2	0.25		
Long-billed Dowitcher		0.00	2	0.42	5	1.83	1	0.42
Pectoral Sandpiper		0.00	1	0.08	1	0.17		
Red-necked Phalarope	2	0.33	3	0.33	5	1.50		
Sanderling		0.00	1	0.17		0.00		
Semipalmated Plover	16	29.33	7	13.92	7	15.25	4	0.83
Solitary Sandpiper		0.00	1	0.08		0.00		
Spotted Sandpiper	1	0.08	1	0.08	5	0.42		
Western Sandpiper	36	9.67	17	9.58	11	4.00	10	11.83
Western Snowy Plover	1	0.08	2	0.50	4	1.00		
Whimbrel		0.00	1	0.17		0.00		

	Survey Year 1		Survey Year 2		Survey Year 3		Survey Year 4	
Guild & Common Name	**# of Obs.**	**Avg. Count per Survey**	**# of Obs.**	**Avg. Count per Survey**	**# of Obs.**	**Avg. Count per Survey**	**# of Obs.**	**Avg. Count per Survey**
Willet	1	0.08		0.00		0.00		
peep sp.							1	1.92
Wilson's Snipe	2	0.42	1	0.08	3	0.58	3	0.50
Warblers	**56**	**9.17**	**114**	**20.42**	**193**	**60.75**	**185**	**40.00**
Common Yellowthroat	16	1.58	41	4.17	77	7.83	107	10.58
Orange-crowned Warbler	3	0.33	3	0.25	11	1.08	6	0.50
Yellow Warbler	1	0.08	4	0.58	4	0.42		
Yellow-rumped Warbler	36	7.17	66	15.42	101	51.42	72	28.92
Waterfowl & ALLIES	**104**	**43.17**	**202**	**98.33**	**262**	**192.92**	**136**	**48.17**
Grebes	***2***	***0.25***	***10***	***1.25***	***21***	***2.42***	***8***	***0.75***
Clark's Grebe		0.00		0.00	5	0.42		
Eared Grebe	2	0.25	6	0.83	4	0.67		
Pied-billed Grebe		0.00	2	0.25	11	1.25	8	0.75
Western Grebe		0.00	2	0.17	1	0.08		
Rails, Gallinules, and Allies	***7***	***0.67***	***59***	***34.92***	***48***	***42.58***	***23***	***11.58***
American Coot	5	0.50	45	33.67	39	41.75	16	10.83
Sora	2	0.17	14	1.25	7	0.58	4	0.50
Virginia Rail		0.00		0.00	2	0.25	3	0.25
Waterfowl	***95***	***42.25***	***133***	***62.17***	***193***	***147.92***	***105***	***35.83***
American Wigeon	3	0.58		0.00	8	2.67	10	3.83
Blue-winged Teal	1	0.08	2	0.25	2	0.25		
Bufflehead	2	0.17	4	0.42	2	0.33		
Cackling Goose (Aleutian)	5	1.25	1	0.08		0.00	1	0.58
Canada Goose	16	13.83	22	20.25	21	45.17	17	9.33
Canvasback		0.00		0.00	1	0.33		
Cinnamon Teal	7	2.00	8	1.50	17	4.33	5	1.42
Cinnamon Teal x Northern Shoveler (hybrid)		0.00	1	0.08		0.00		
Gadwall	7	1.58	10	3.50	21	8.58	11	3.75
Greater White-fronted Goose	7	4.67	2	0.33	4	0.83	2	0.17
Green-winged Teal		0.00	3	1.17	5	1.08	1	0.17

	Survey Year 1		Survey Year 2		Survey Year 3		Survey Year 4	
Guild & Common Name	**# of Obs.**	**Avg. Count per Survey**	**# of Obs.**	**Avg. Count per Survey**	**# of Obs.**	**Avg. Count per Survey**	**# of Obs.**	**Avg. Count per Survey**
Hooded Merganser	1	0.08	2	0.25	1	0.08	2	0.33
Mallard	35	16.08	53	27.42	62	52.83	40	13.25
Mute Swan		0.00	1	0.08		0.00		
Northern Pintail	2	0.25		0.00	6	1.08		
Northern Shoveler	3	0.75	14	4.08	17	17.67	6	0.92
Redhead	1	0.08	2	1.58	8	5.67	4	0.75
Ring-necked Duck		0.00		0.00	1	0.33		
Ross's Goose		0.00	2	0.33	1	0.08	1	0.42
Ruddy Duck	5	0.83	4	0.50	15	6.42	3	0.42
Snow Goose		0.00	2	0.33	1	0.17	2	0.50
Grand Total	**1339**	**399.75**	**1763**	**521.42**	**2044**	**677.17**	**1936**	**447.17**

Table A3.2. List of species and number of observations of breeding behavior recorded during monthly bird surveys at North Campus Open Space and reported to the Santa Barbara Audubon Society's Breeding Bird Study in 2018, 2019 and 2020. Note that some of the NCOS bird survey observations are also reported to the Breeding Bird Study.

	NCOS Monthly Bird Survey Observations				Breeding Bird Study Observations			
Species Common Name	**2018**	**2019**	**2020**	**2021**	**2018**	**2019**	**2020**	**2021**
American Crow			2				3	1
Anna's Hummingbird		1						
Barn Swallow							1	1
Bewick's Wren							1	
Black Phoebe	3	2	1			1	3	2
Bushtit	1							1
California Towhee	2		1	1	1		2	1
Canada Goose		2	2	3		1	1	
Cassin's Kingbird						1		

Cliff Swallow	5	4	1	3	3	3	3	2
Cooper's Hawk	1		2				1	
Dark-eyed Junco								1
European Starling						1	1	
Gadwall		2				3	1	2
Great Egret						1		
Great Horned Owl					1		1	1
House Finch	2	3	3	3	2	4	3	5
House Sparrow	2				2	1		
Killdeer	4	3	2		5	6	2	2
Lark Sparrow		2	1				1	2
Lesser Goldfinch		1	1			1	1	1
Mallard	1	2	2		2	2	2	2
Mourning Dove								1
Northern Mockingbird				1				1
Northern Rough-winged Swallow								1
Nuttall’s Woodpecker								1
Red-shouldered Hawk	1						1	1
Red-tailed Hawk		1						
Rock Pigeon (Feral Pigeon)	1				1			
Savannah Sparrow (Belding's)			3	1			4	2
Say's Phoebe				2	1	1		1
Song Sparrow		2	1	4		7	1	2
Western Bluebird	1				1			1

Western Kingbird				1				1
Western Sandpiper	1							
Western Snowy Plover			1		2	1	1	
White-tailed Kite				2				
White-breasted Nuthatch								1
Wrentit			1					
Grand Total	**25**	**25**	**24**	**21**	**21**	**34**	**34**	**37**

Cardno

Memorandum

Cardno, Inc.

201 N. Calle Cesar Chavez
Suite 203
Santa Barbara, CA 93103
USA

Phone 805 962 7679
Toll-free 800 368 7511
Fax 805 963 0412
www.cardno.com

Date To: August 25, 2021

From: Lisa Stratton, UCSB; Chris Kofron, USFWS; Justin Garcia & Jennifer Pareti, CDFW

RE: Hannah Donaghe

Devereux Slough and UCSB North Campus Open Space July 2021 PostConstruction Aquatic Species Survey Report

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Introduction

The Cheadle Center for Biodiversity and Ecological Restoration (CCBER) at The University of California, Santa Barbara (UCSB) is in the process of restoring the former Ocean Meadows Golf Course to native upland and wetland/marsh habitats in Santa Barbara County. This area is called the North Campus Open Space (NCOS) and includes the downstream end of Devereux Creek from the west, Phelps Creek from the north, and stormwater inflows from the northeast via East Channel that converge and drain into Devereux Slough (Figure 1). Prior to restoration, Devereux Creek flowed into Devereux Slough at a weir on the north side of the Venoco Access Road. The weir has been removed, and grading has restored portions of the upper channels of Devereux Creek, allowing tidal influence upstream to near the Phelps Creek confluence and into the eastern channel. Preconstruction surveys of Devereux Creek and Phelps Creek by Dr. Rosemary Thompson and CCBER staff in 2016, and post-construction surveys in the fall of 2017, 2018, and 2020 found no tidewater gobies to be present. The 2019 post-construction tidewater goby survey conducted on October 17, 2019 by Dr. Rosemary Thompson found tidewater gobies in Devereux Slough downstream of Venoco Road. The 2018-2021 surveys also found no southwestern pond turtles or California red-legged frogs.

A post-construction survey was conducted on July 29, 2021, in in Devereux Slough, the restored channels, and lower Phelps Creek by Hannah Donaghe (federal permit TE14532C-1, state permit S-201000002-20167-001) with assistance from Evan Davies (Cardno biologist) and CCBER staff (Lisa Stratton, Beau Tindall, and Darwin Richardson). The methods used and results of the surveys are described below.

Methods

Tidewater goby and other fish. Sampling sites were selected in the field based on access, water depth, density of *Ruppia* (an aquatic plant), and approximate location sampled in previous years (Figure 2). Sample locations include three locations in Devereux Slough plus four locations in the restored channels, one near Venoco Road, one in the East Channel, one in the Main

Channel, and one in the West Arm. Two of these sites were not sampled, the Main Channel and West Arm, due to low water depth and dense aquatic vegetation. Sampling was conducted between 8:00 AM and 12:00 PM. A minnow seine 18 feet long by 4 feet high with 3 millimeter (mm) mesh was used for the sampling in lower Devereux Slough. However, a minnow seine 3 meters (m) long by 1 m high with 3 mm mesh was used for the sampling at all other sites due to the amount of aquatic vegetation present that could entangle and damage fish. Seine hauls varied in length from about 20 to 100 feet. At the lower Devereux Slough site, one 100-foot seine haul was conducted across the entire channel, followed by two 50-foot seine hauls that covered approximately half the width of the channel, to reduce the amount of time fish were out of the water during identification. The seine was pulled across the channel in NCOS and in Devereux Slough and then swept into the shoreline, lifted, and placed on the shore. Fish captured were identified and counted. The fish were then returned to the water. Substrate was too rocky at the upper slough site to conduct an effective seine haul, and dip net sweeps were made in this area. Water depth at the estuary sites was generally 2 to 3 feet, and other sites were shallower, ranging from 6 inches to 2 feet. Phelps Creek was sampled using dip nets with 3 mm or smaller mesh. Many sweeps were made wherever open water occurred with minimal obstructions. Organisms captured were identified and released.

Water quality. Water quality parameters (temperature in °C, dissolved oxygen in mg/l, and salinity in ppt) were measured by CCBER staff with a YSI Pro 2030 at each sampling location.

Results and Discussion

Table 1 summarizes the fish and crayfish captured. All fish captured are native to the area, except mosquitofish which were captured in Phelps Creek, and can tolerate a wide range of salinities. The crayfish are also not native. No tidewater gobies were captured at any sample sites. Tidewater goby has been reported in Phelps Creek in the past. Tidewater gobies remaining upstream or those in Devereux Slough could expand into NCOS aquatic habitats in the future. Tidewater gobies generally only live one year (Swift et al. 1989, Moyle 2002).

The only fish species collected in the restored estuarine channels on NCOS (Main Channel – lower) was California killifish, which was also found in Devereux Slough. Removal of the weir at the Venoco Road crossing has allowed them access to upstream areas. Abundance of species is expected to fluctuate over time in response to changes in habitat conditions and may stabilize as the restored area reaches a dynamic equilibrium. No fish were captured in the East Channel, likely due to low water levels and high temperatures.

The non-native red swamp crayfish continues to occur in Phelps Creek, although fewer were found than in previous surveys, including the 2020 survey. Crayfish were only observed at the lower end of Phelps Creek in 2021. Its spread into the restored channels will likely be limited by its intolerance of high salinity.

Table 1 Fish Captured during 2021 Survey

Site	Common Name	Scientific Name	Number	Method
PC	No fish captured	N/A	0	Dipnet
	Red swamp crayfish	*Procambarus clarkii*	several	
PC mouth	California killifish	*Fundulus parvipinnis*	55	Dipnet
	Mosquitofish	*Gambusia affinis*	3	
	Red swamp crayfish	*Procambarus clarkii*	2	
DS-L	California killifish	*Fundulus parvipinnis*	1,259	Seine (3 hauls)
	Longjaw mudsucker	*Gillichthys mirabilis*	31	
	Topsmelt	*Atherinops affinis*	634	

DS-M	California killifish	*Fundulus parvipinnis*	80	Seine (2 hauls)[1]
	Longjaw mudsucker	*Gillichthys mirabilis*	36	
DS-U	California killifish	*Fundulus parvipinnis*	100	Dipnet[2]
Site	**Common Name**	**Scientific Name**	**Number**	**Method**
MC-L	California killifish	*Fundulus parvipinnis*	287	Seine (1 haul)
MC	Not sampled[3]	N/A	N/A	N/A
MC-WA	Not sampled[3]	N/A	N/A	N/A
EC	No fish captured	N/A	0	Seine (1 haul)

Table Notes:

PC = Phelps Creek

DS = Devereux Slough; L= lower, M = middle, U = upper

MC = Main Channel (central NCOS); L = lower; WA = West Arm; EC = East Channel

[1] Due to silty substrate and water depth, access and effectiveness of seining was limited and only short seine hauls (less than 20 feet) were able to be conducted parallel to the shore.

[2] Substrate was too rocky to conduct an effective seine haul and water level was low. Dipnet sweeps were performed and only killifish were captured at this site and many dead killifish were observed along shoreline.

[3] This site was not sampled due to very low water level (<6 inches) and dense aquatic vegetation. Conditions at East Channel site considered representative of this site.

Water quality measured at the sample sites is presented in Table 2.

Table 2 Water Quality at Fish Sample Sites

Location	Lat	Long	DO (mg/L)	Salinity (ppt)	Temperature (C)
Phelps Creek	34.422963	-110.879851	1.09	2.3	17.9
Phelps Bridge	34.421244	-119.878893	2.38	3.2	19.9
West Arm	34.420759	-119.878412	Not sampled	Not sampled	Not sampled
Central NCOS	34.420057	-119.876934	Not sampled	Not sampled	Not sampled
East Channel	34.420628	-119.874310	N/A[4]	N/A[5]	26.1
Main Channel – lower (North of Venoco Bridge)	34.417846	-119.874249	N/A[1]	N/A[3]	23.9
Devereux Slough – upper (South of Venoco Bridge)	34.416734	-119.874077	N/A[1]	N/A[3]	23.9

[4] Meter readout was "over"

[5] Meter readout for ppt was "over"; conductivity readout was 197,000 uS/cm [3] Meter readout for ppt was "over"; conductivity readout was 157,000 uS/cm

Devereux Slough - mid	34.412124	-119.876542	3.09	66.0	24.0
Devereux Slough - lower	34.409813	-119.879393	0.8*	62.9	22.1

Table Notes:

Figure 1 **Creeks and channels at NCOS.**


Phelps Creek
Devereux Creek
Phelps Bridge
West Arm
East Channel
East Bridge NCOS
Central NCOS
Main Channel
North Venoco Bridge
Venoco Road
South Venoco Bridge
Devereux
Slough
Devereux Pier
Devereux Mouth
N
2000 ft

References

Moyle, P. B. 2002. Inland Fishes of California. University of California Press, Berkeley and Los Angeles. Pp 431-434.

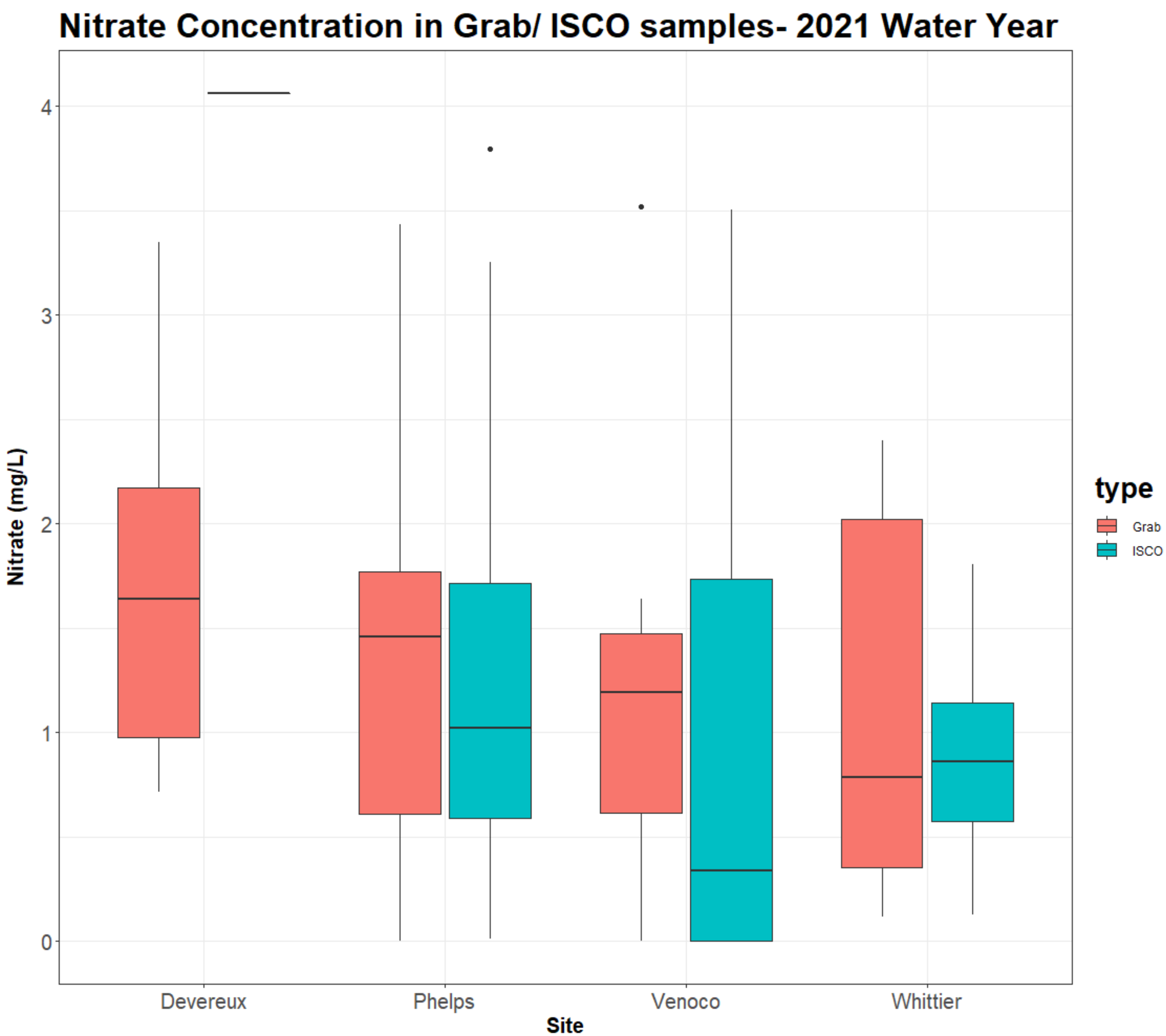
Swift, C., J. L. Nelson, C. Maslow, and T. Stein. 1989. Natural History Museum of Los Angeles County, Contributions in Science, Number 404:1-19.

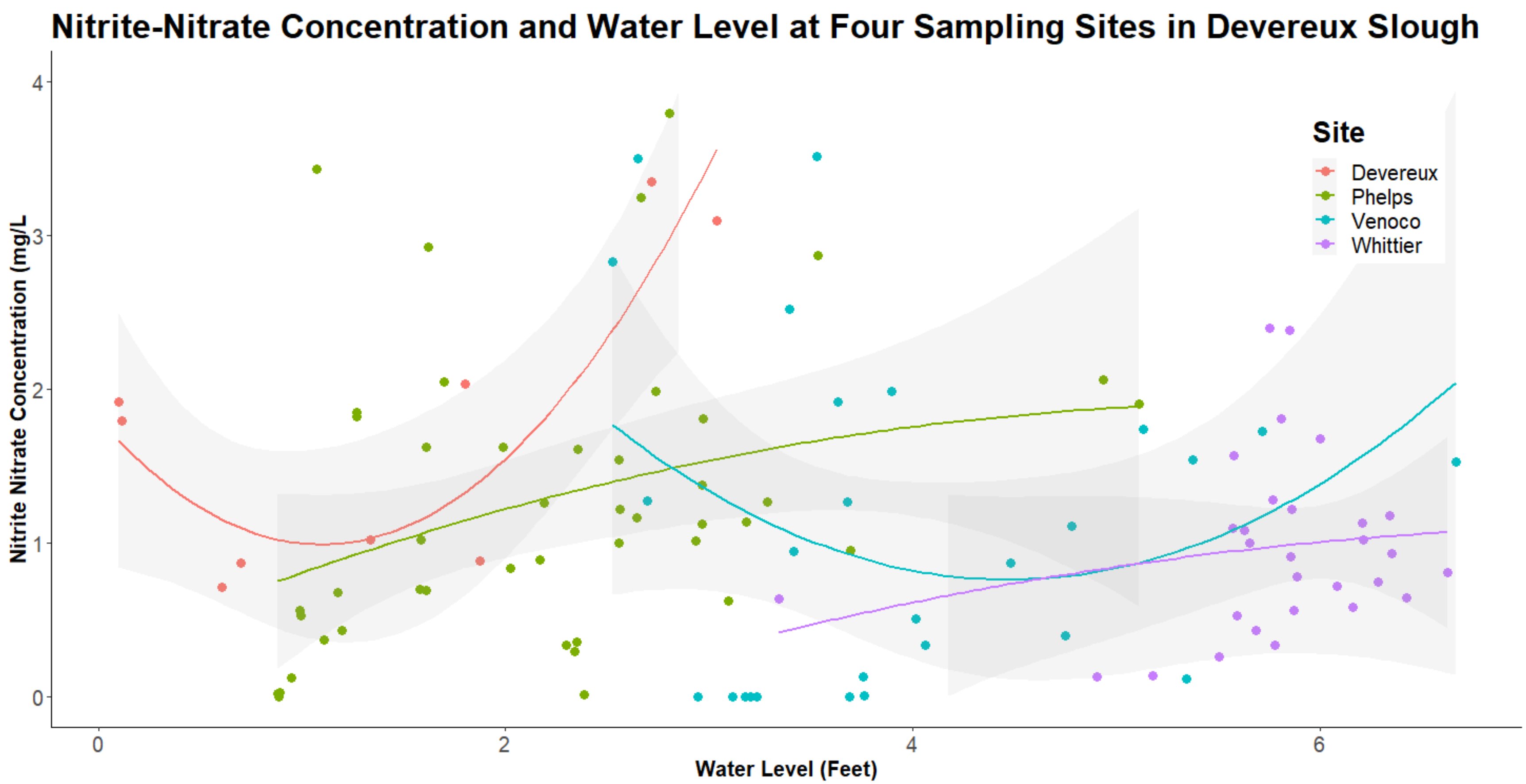
APPENDIX 5 – 2020 WATER YEAR STORM WATER DATA

Table A5.1. Grab and ISCO samples analyzed for nutrients (N) and suspended solids concentrations (SSC) at each sampling site for each storm and baseline event in the 2020 Water Year (October 1, 2019, to September 30, 2020) at North Campus Open Space. At Devereux Creek, only Grab samples were collected and analyzed.

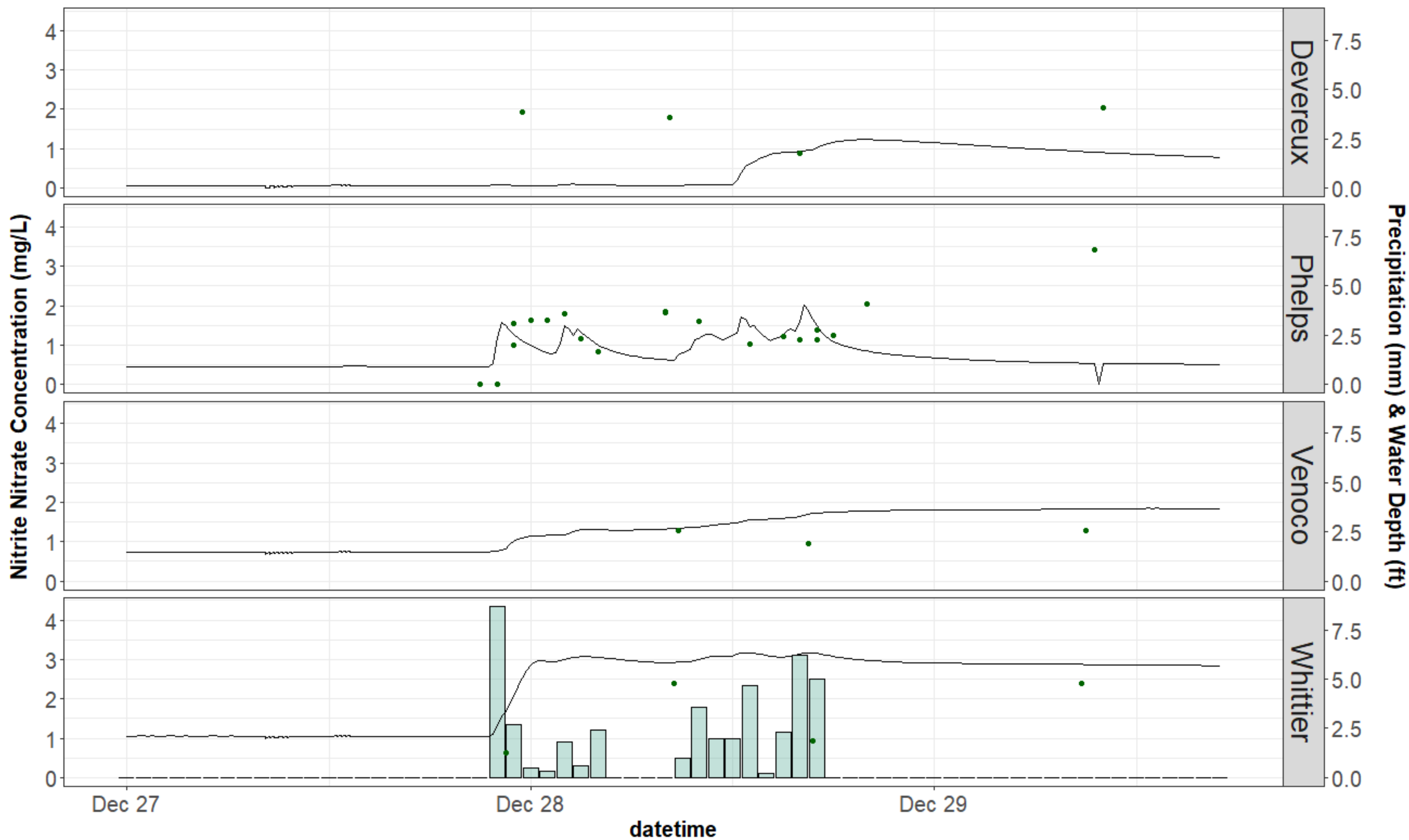
		Devereux Creek	Phelps Creek		Whittier Storm drain Outfall		Venoco Bridge	
Date	**Event Type**	**Grab**	**Grab**	**ISCO**	**Grab**	**ISCO**	**Grab**	**ISCO**
12/27-12/29/2020	Storm	4	4	16	4	0	3	0
01/25-01/29/2021	Storm	6	1	12	1	12	7	13
03/03/2021	Baseline	0	1	0	0	12	0	0
03/09/-03/11/2021	Storm	3	0	11	1	0	0	8

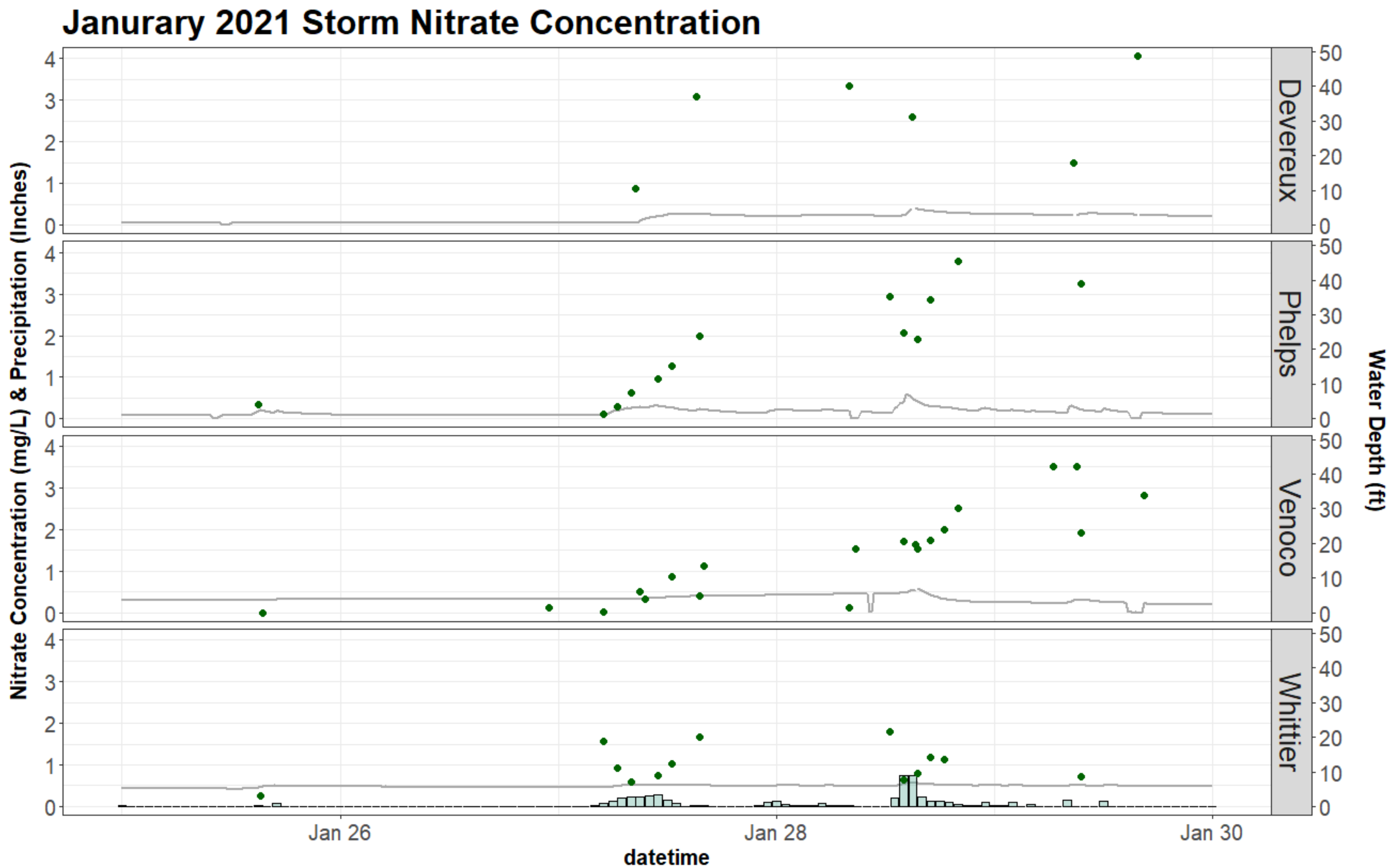
NUTRIENT CONCENTRATIONS DATA: Nitrite+Nitrate – Site Comparisons

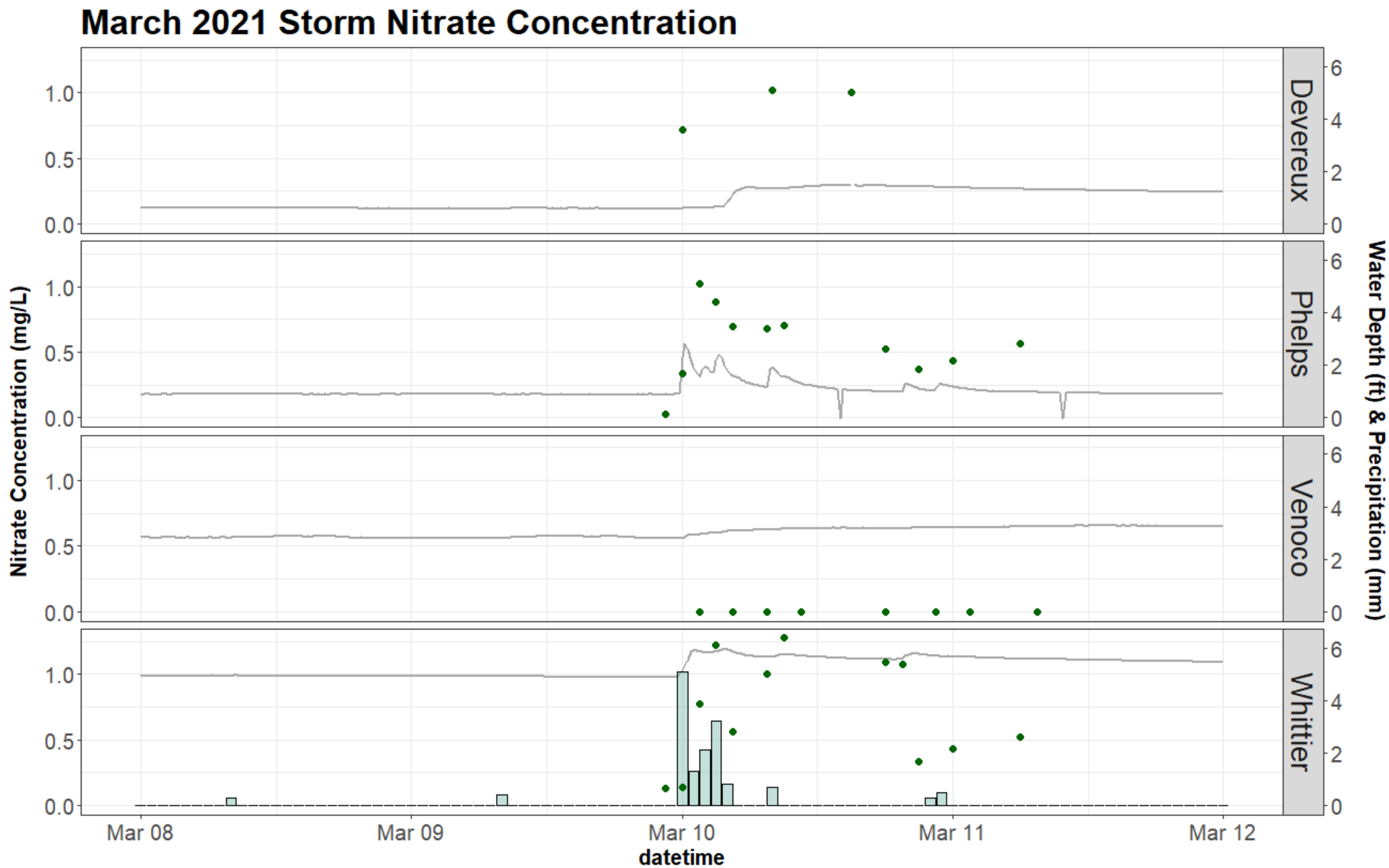

Nitrate Concentration in Grab/ ISCO samples- 2021 Water Year
Nitrate (mg/L)
0
1
2
3
4
Devereux
Phelps
Venoco
Whittier
Site
type
Grab
ISCO


Nitrite-Nitrate Concentration and Water Level at Four Sampling Sites in Devereux Slough
Nitrite Nitrate Concentration (mg/L
Water Level (Feet)
Site
Devereux
Phelps
Venoco
Whittier
0
1
2
3
4
0
2
4
6

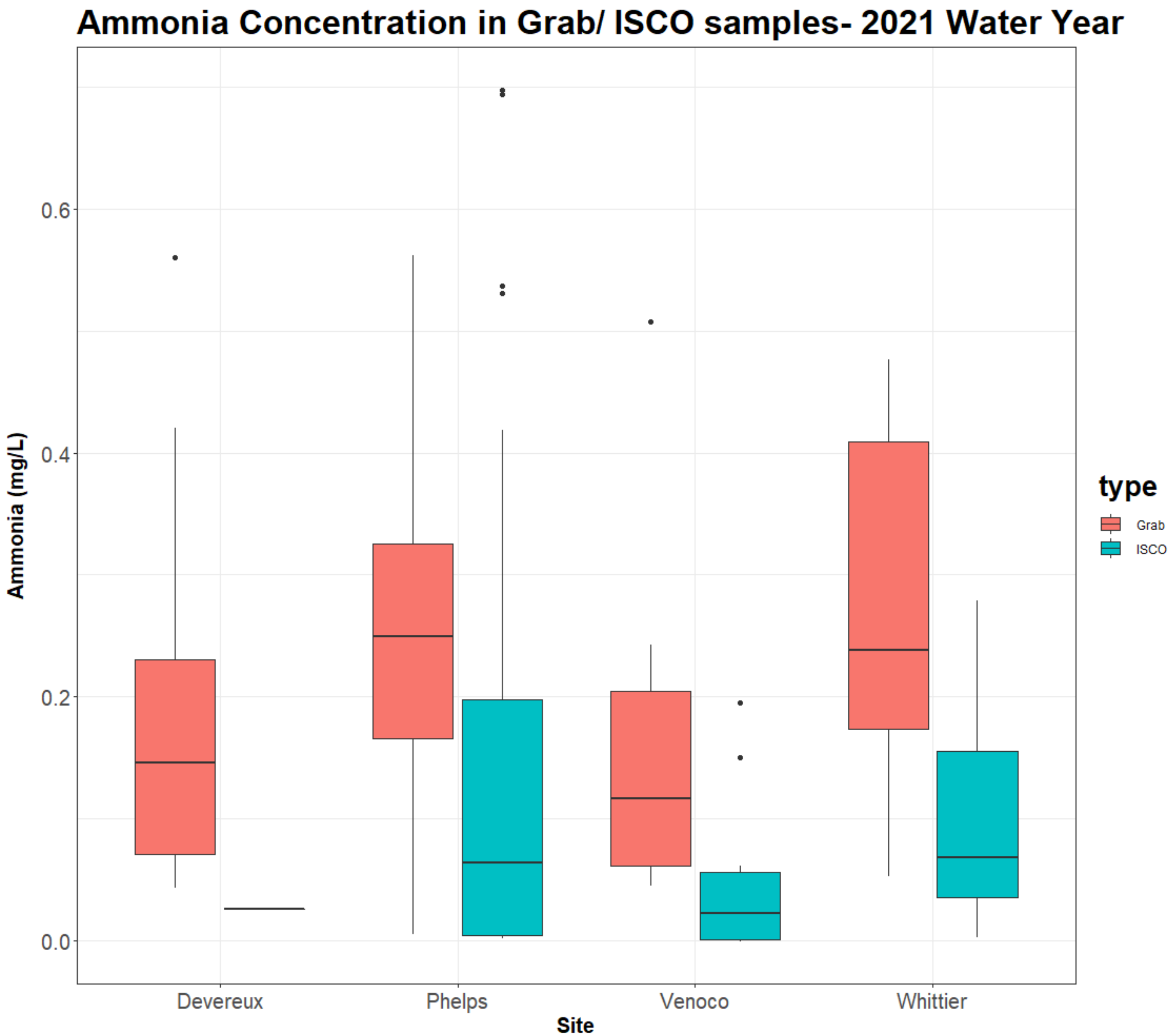
December 2020 Storm Nitrate Concentration

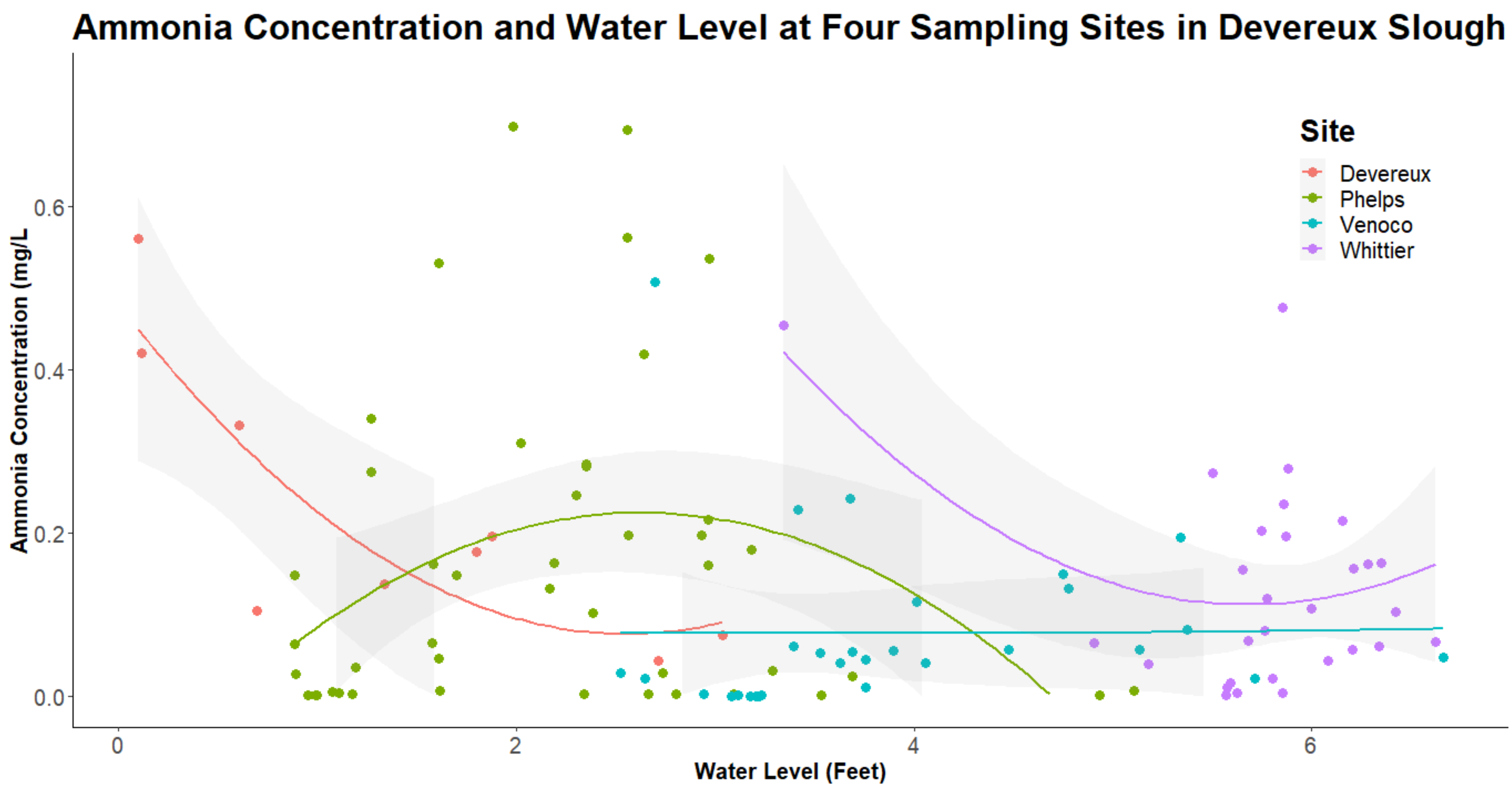


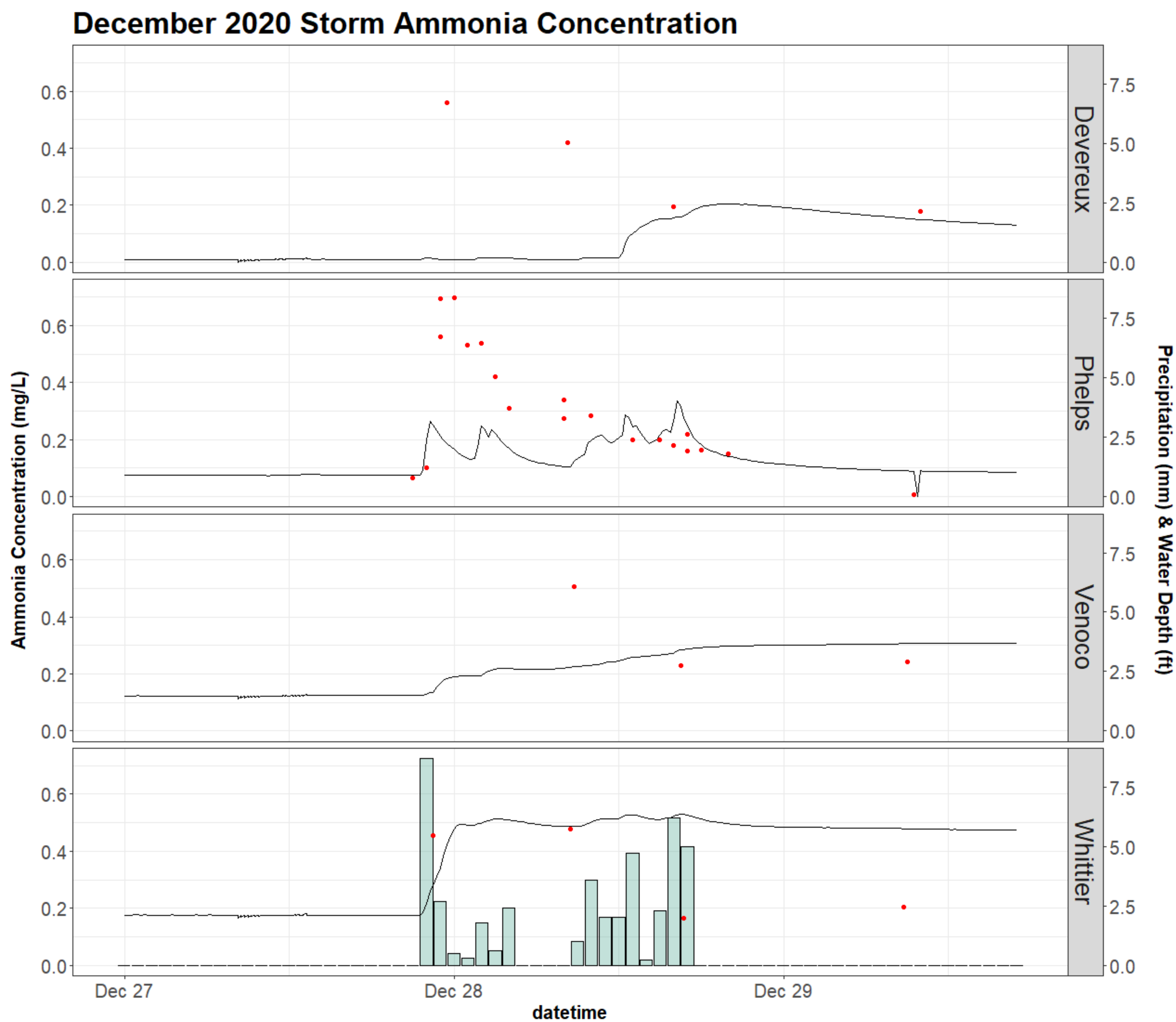

Janurary 2021 Storm Nitrate Concentration
Nitrate Concentration (mg/L) & Precipitation (Inches)
Water Depth (ft)
Devereux
Phelps
Venoco
Whittier
0
1
2
3
4
0
10
20
30
40
50
Jan 26
Jan 28
Jan 30
datetime


March 2021 Storm Nitrate Concentration
Nitrate Concentration (mg/L)
Water Depth (ft) & Precipitation (mm)
Devereux
Phelps
Venoco
Whittier
0.0
0.5
1.0
0
2
4
6
Mar 08
Mar 09
Mar 10
Mar 11
Mar 12
datetime

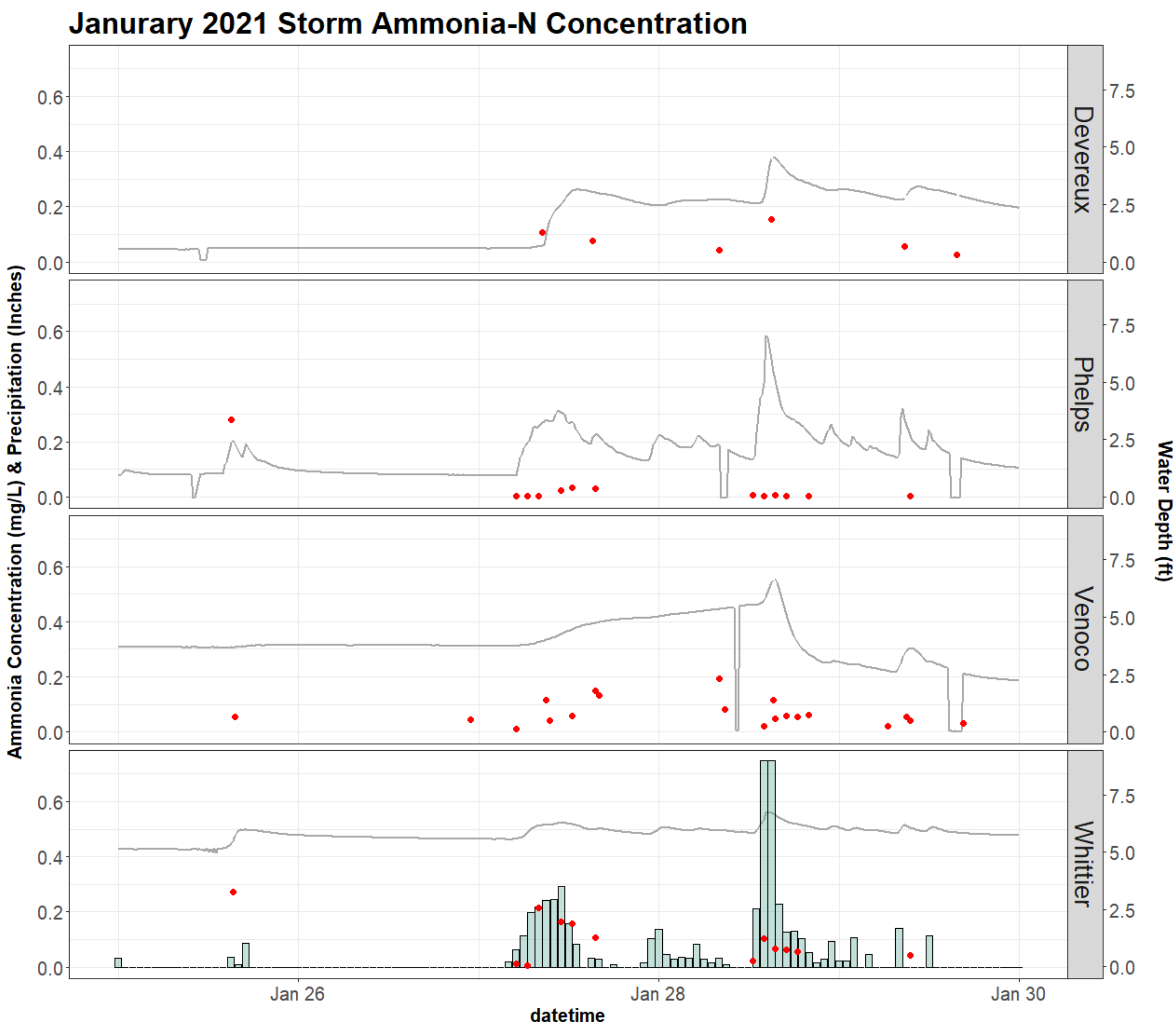
NUTRIENT CONCENTRATIONS DATA: Ammonia – Site Comparisons

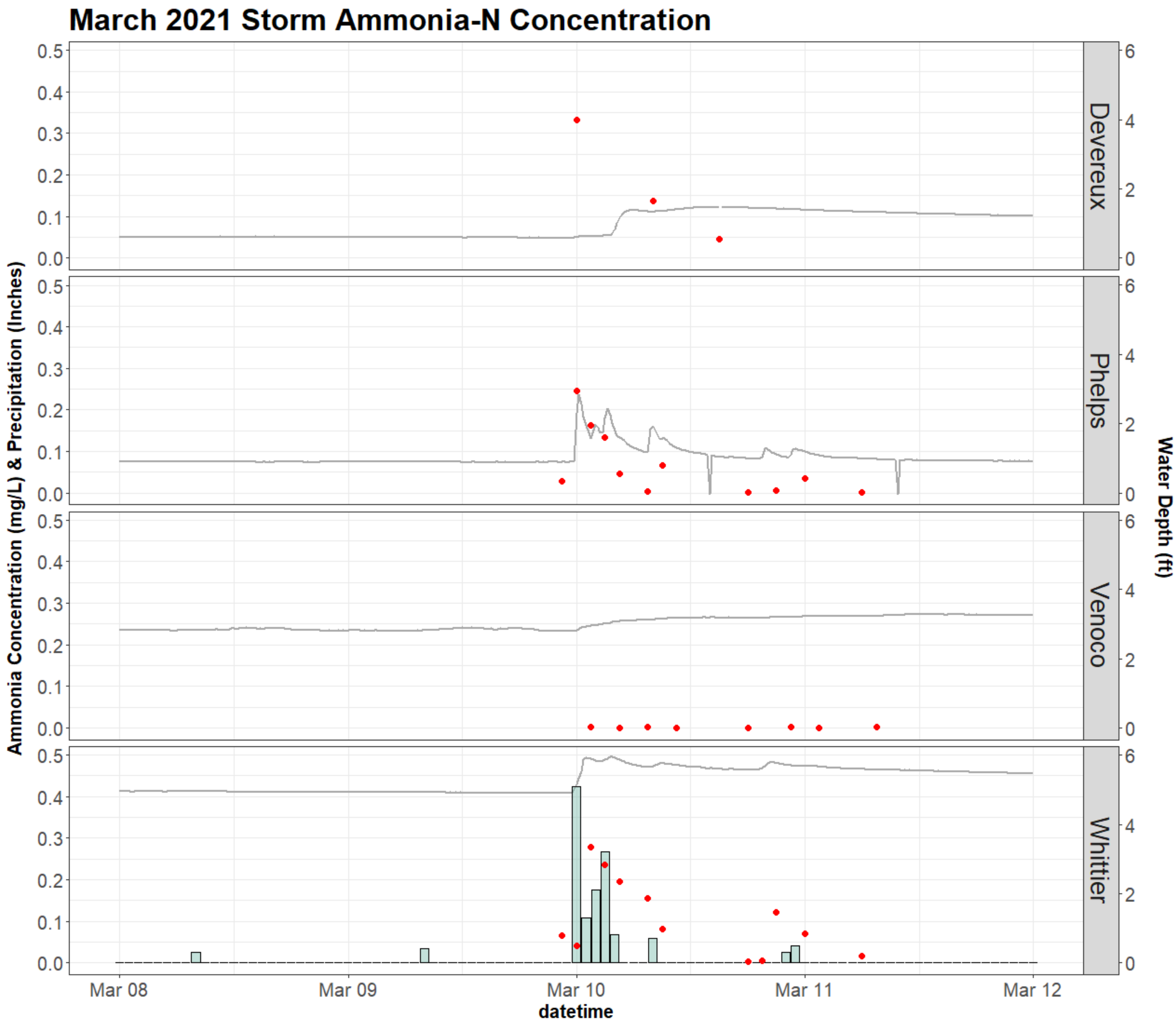

Ammonia Concentration in Grab/ ISCO samples- 2021 Water Year
Ammonia (mg/L)
0.6
0.4
0.2
0.0
Devereux
Phelps
Venoco
Whittier
Site
type
Grab
ISCO


Ammonia Concentration and Water Level at Four Sampling Sites in Devereux Slough
Site
Devereux
Phelps
Venoco
Whittier
Ammonia Concentration (mg/L
0.0
0.2
0.4
0.6
0
2
4
6
Water Level (Feet)

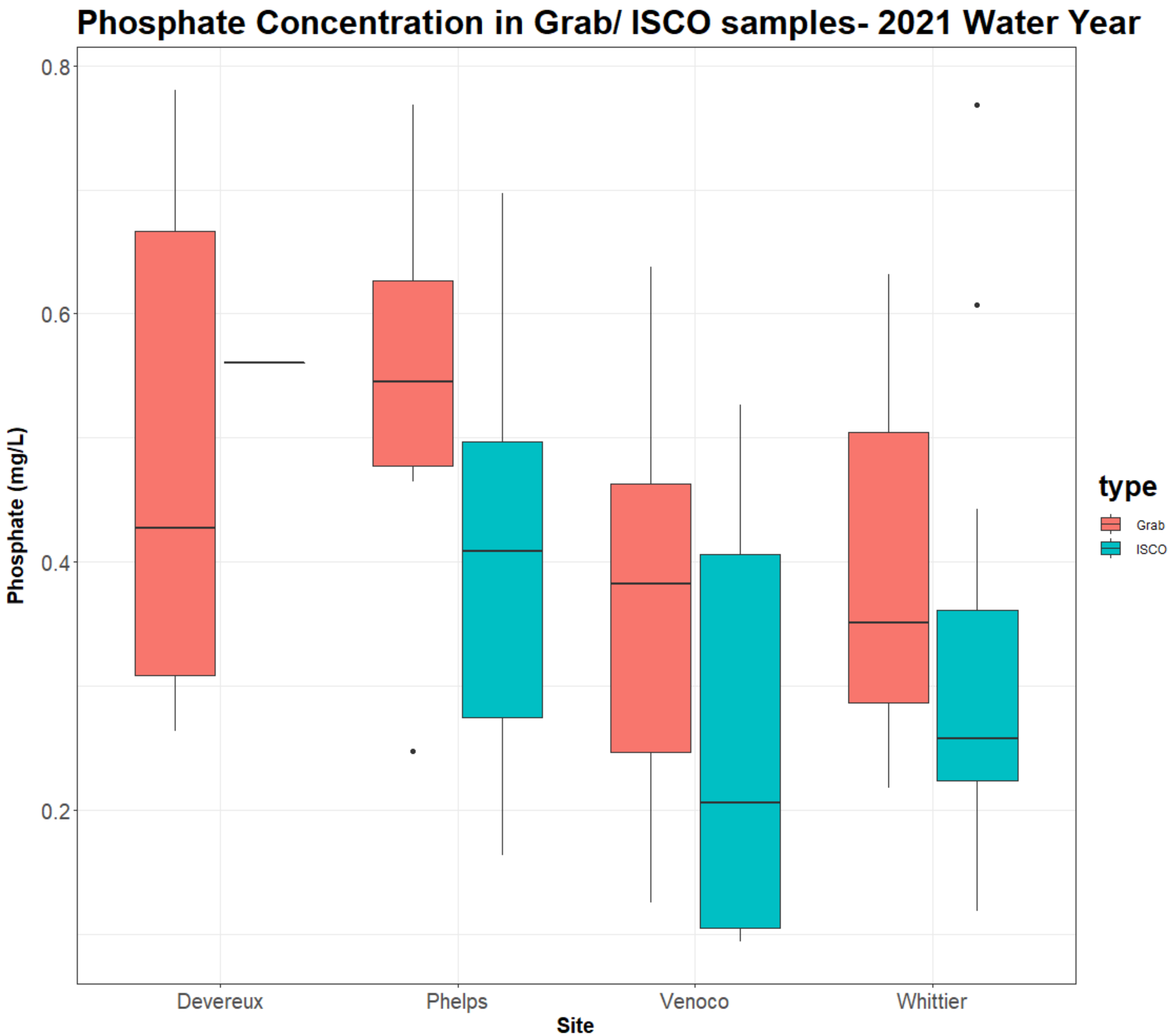


December 2020 Storm Ammonia Concentration
Ammonia Concentration (mg/L)
Precipitation (mm) & Water Depth (ft)
Devereux
Phelps
Venoco
Whittier
0.0
0.2
0.4
0.6
0.0
2.5
5.0
7.5
Dec 27
Dec 28
Dec 29
datetime

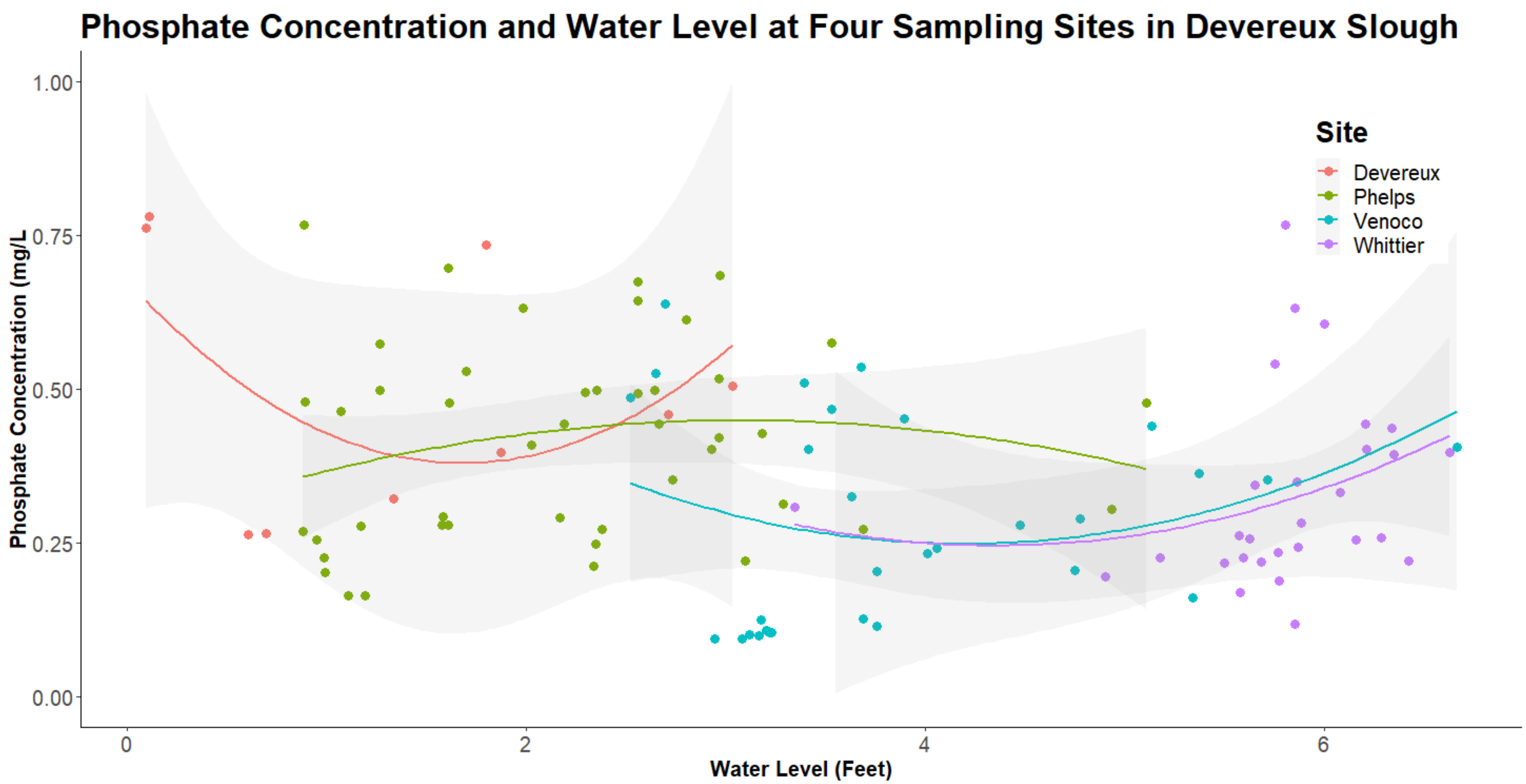

Janurary 2021 Storm Ammonia-N Concentration
Ammonia Concentration (mg/L) & Precipitation (Inches)
Water Depth (ft)
Devereux
Phelps
Venoco
Whittier
0.0
0.2
0.4
0.6
0.0
2.5
5.0
7.5
Jan 26
Jan 28
Jan 30
datetime

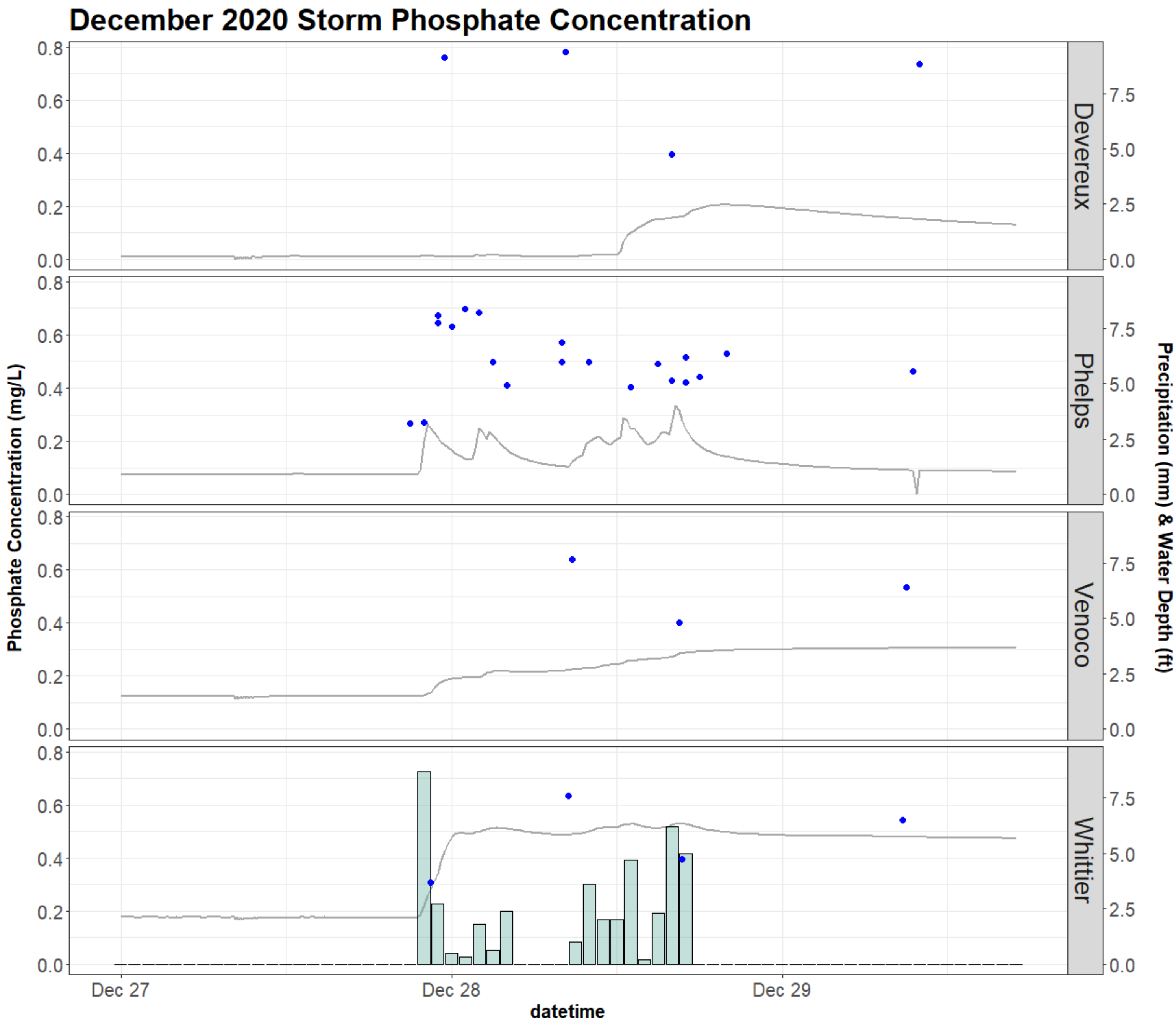

March 2021 Storm Ammonia-N Concentration
Ammonia Concentration (mg/L) & Precipitation (Inches)
Water Depth (ft)
Devereux
Phelps
Venoco
Whittier
0.5
0.4
0.3
0.2
0.1
0.0
6
4
2
0
Mar 08
Mar 09
Mar 10
Mar 11
Mar 12
datetime

NUTRIENT CONCENTRATIONS DATA: Phosphate – Site Comparisons

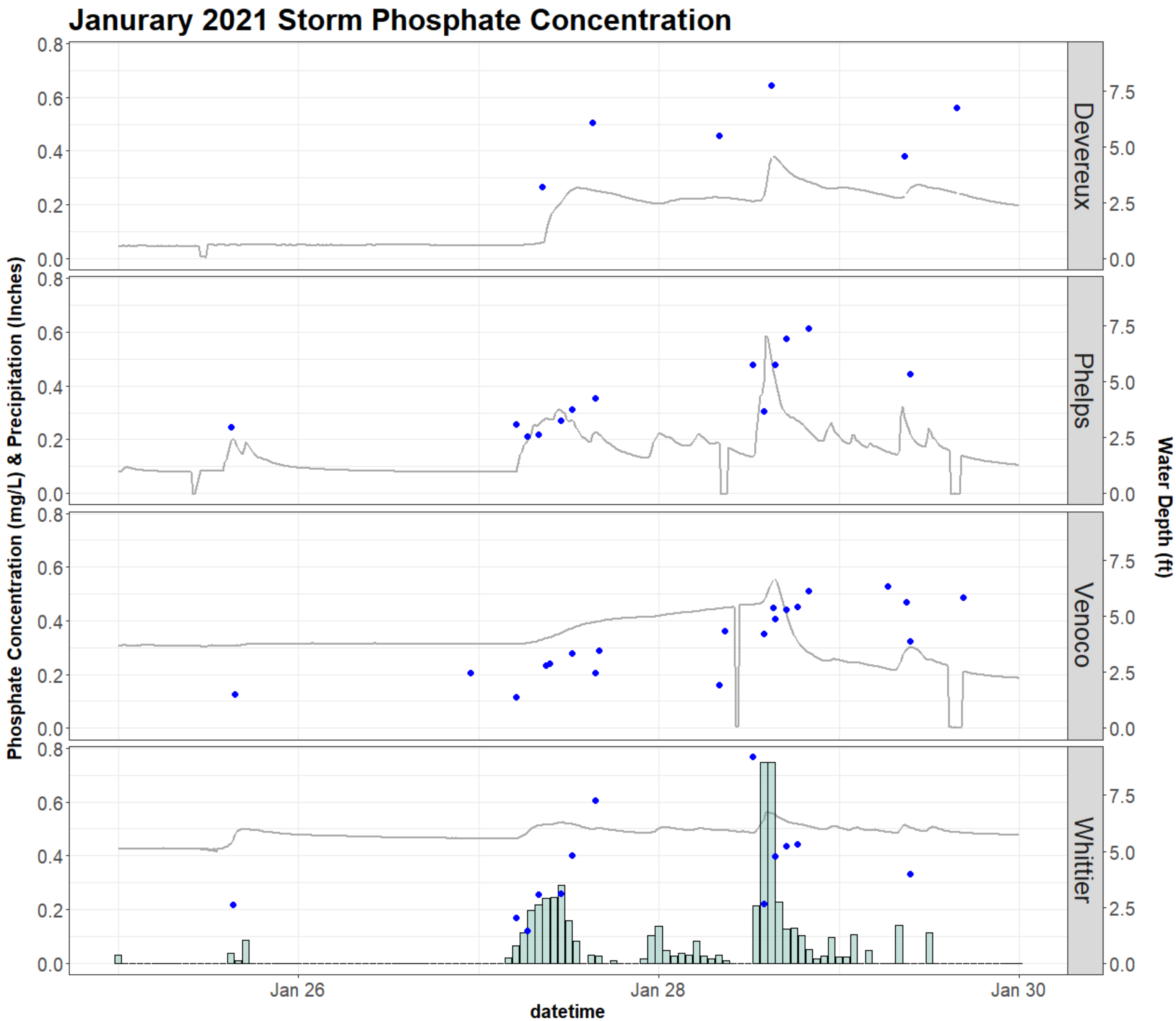


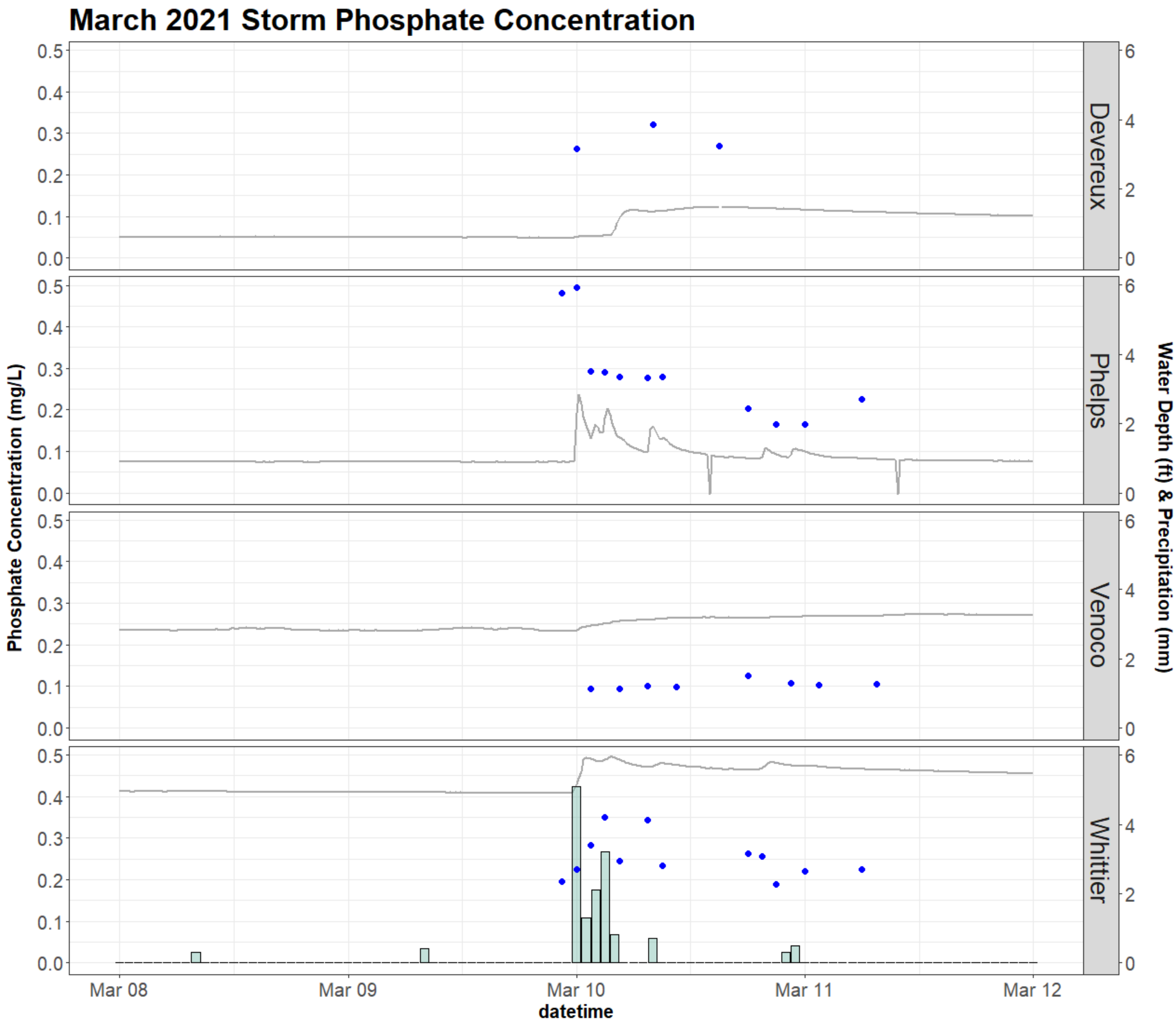
Phosphate Concentration in Grab/ ISCO samples- 2021 Water Year
Phosphate (mg/L)
0.8
0.6
0.4
0.2
Devereux
Phelps
Venoco
Whittier
Site
type
Grab
ISCO


Phosphate Concentration and Water Level at Four Sampling Sites in Devereux Slough
1.00
0.75
0.50
0.25
0.00
Phosphate Concentration (mg/L
0
2
4
6
Water Level (Feet)
Site
Devereux
Phelps
Venoco
Whittier



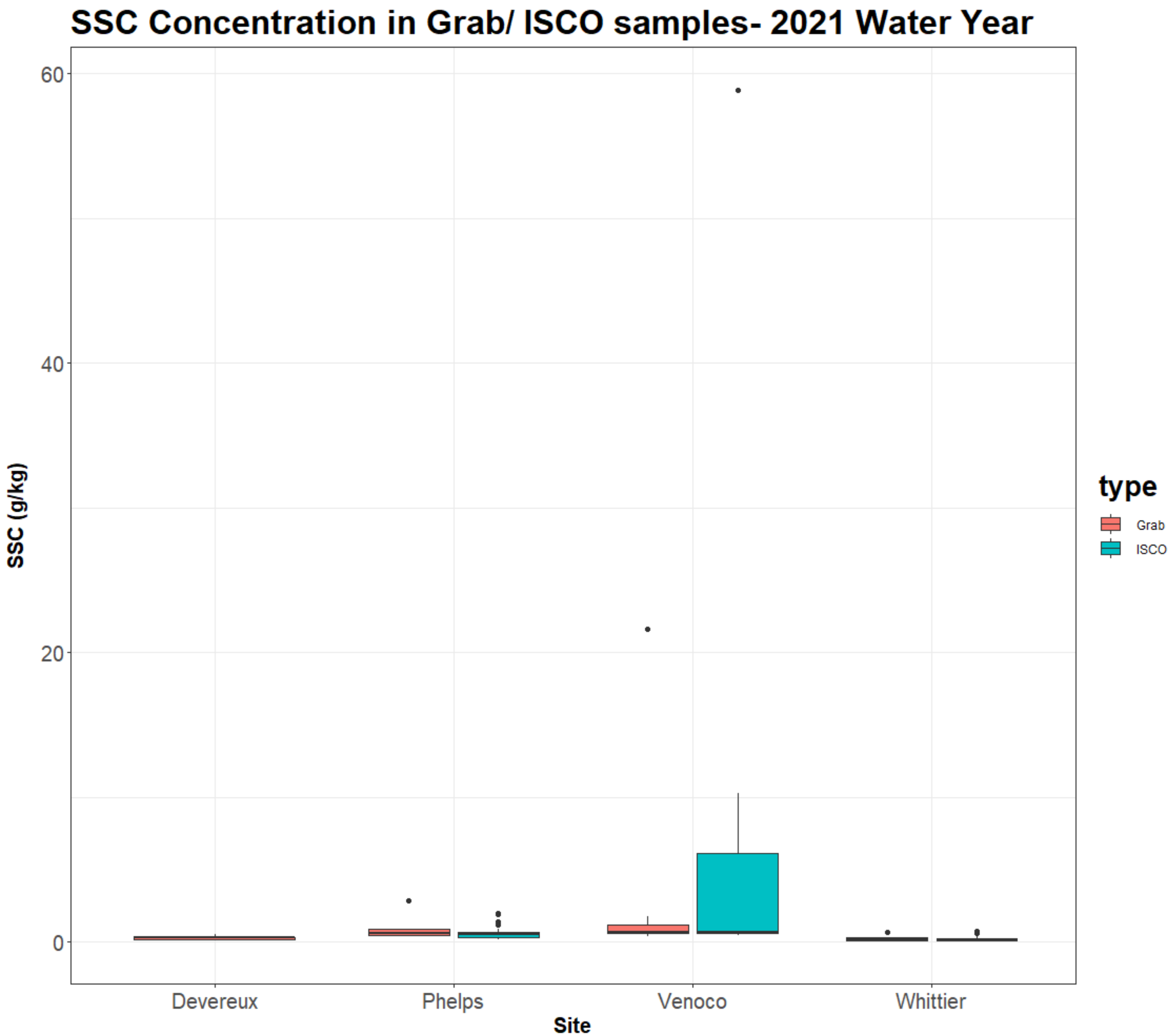
December 2020 Storm Phosphate Concentration
Phosphate Concentration (mg/L)
Precipitation (mm) & Water Depth (ft)
Devereux
Phelps
Venoco
Whittier
0.0
0.2
0.4
0.6
0.8
0.0
2.5
5.0
7.5
Dec 27
Dec 28
Dec 29
datetime

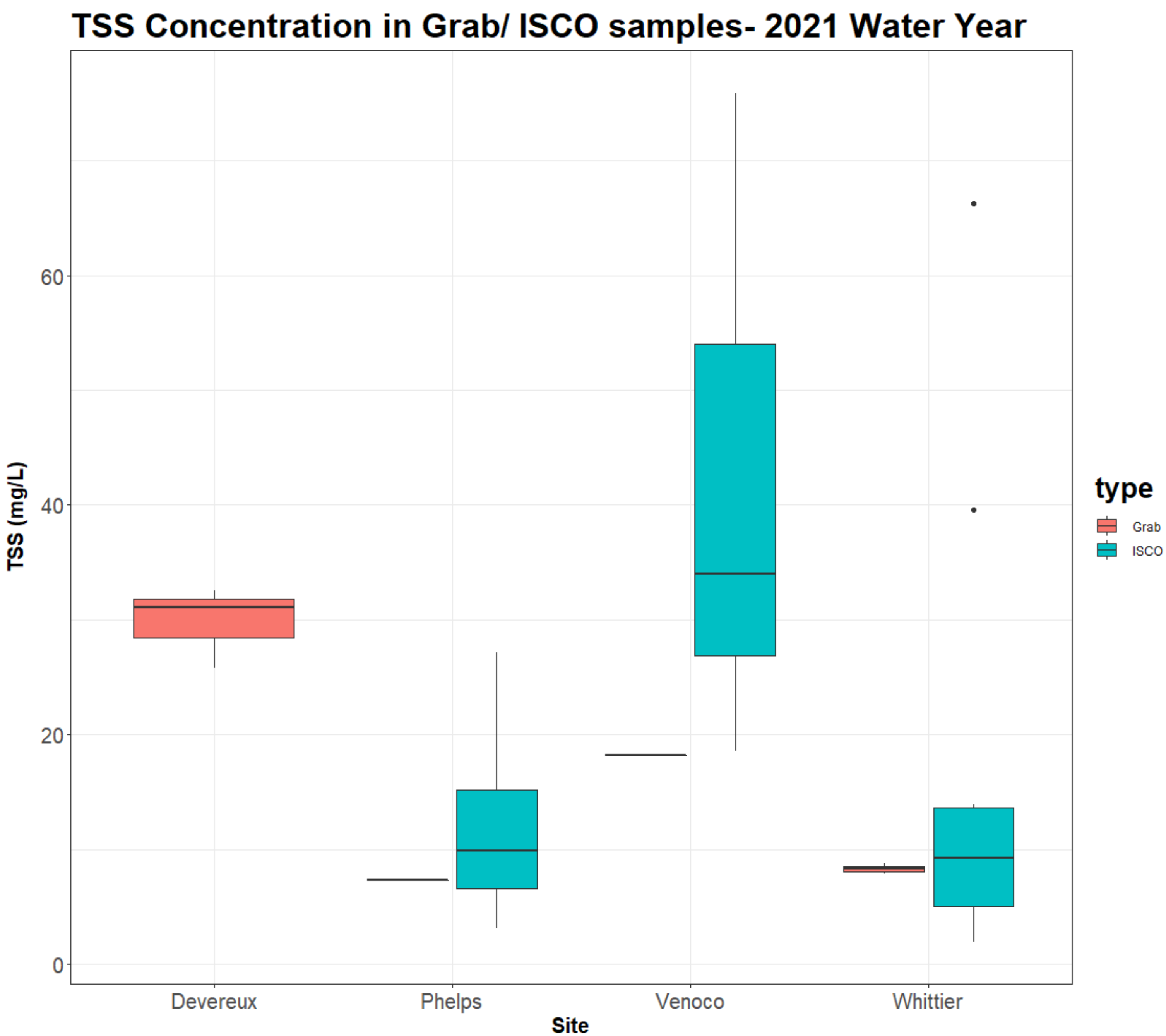

Janurary 2021 Storm Phosphate Concentration
Phosphate Concentration (mg/L) & Precipitation (Inches)
Water Depth (ft)
Devereux
Phelps
Venoco
Whittier
0.0
0.2
0.4
0.6
0.8
0.0
2.5
5.0
7.5
Jan 26
Jan 28
Jan 30
datetime

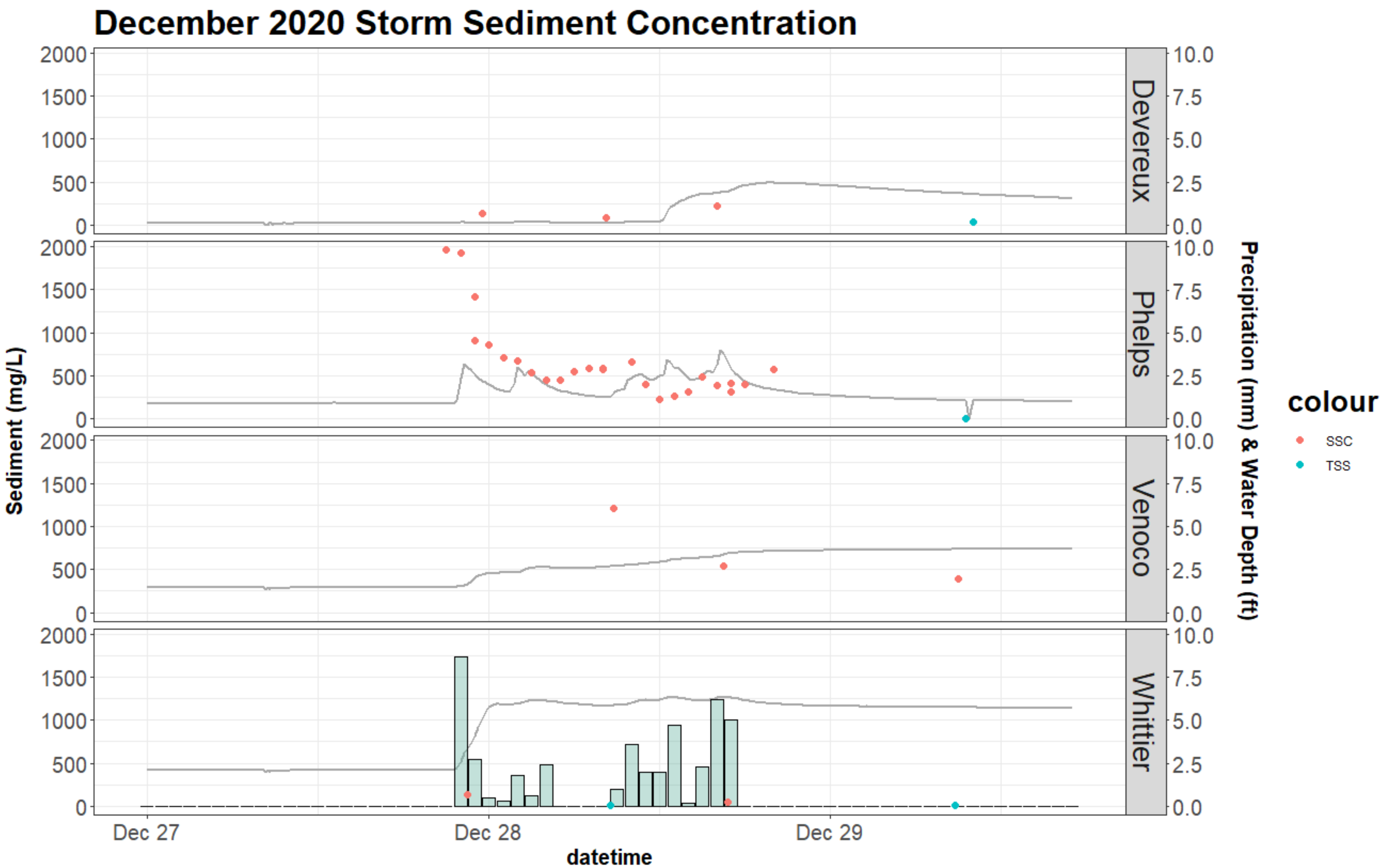


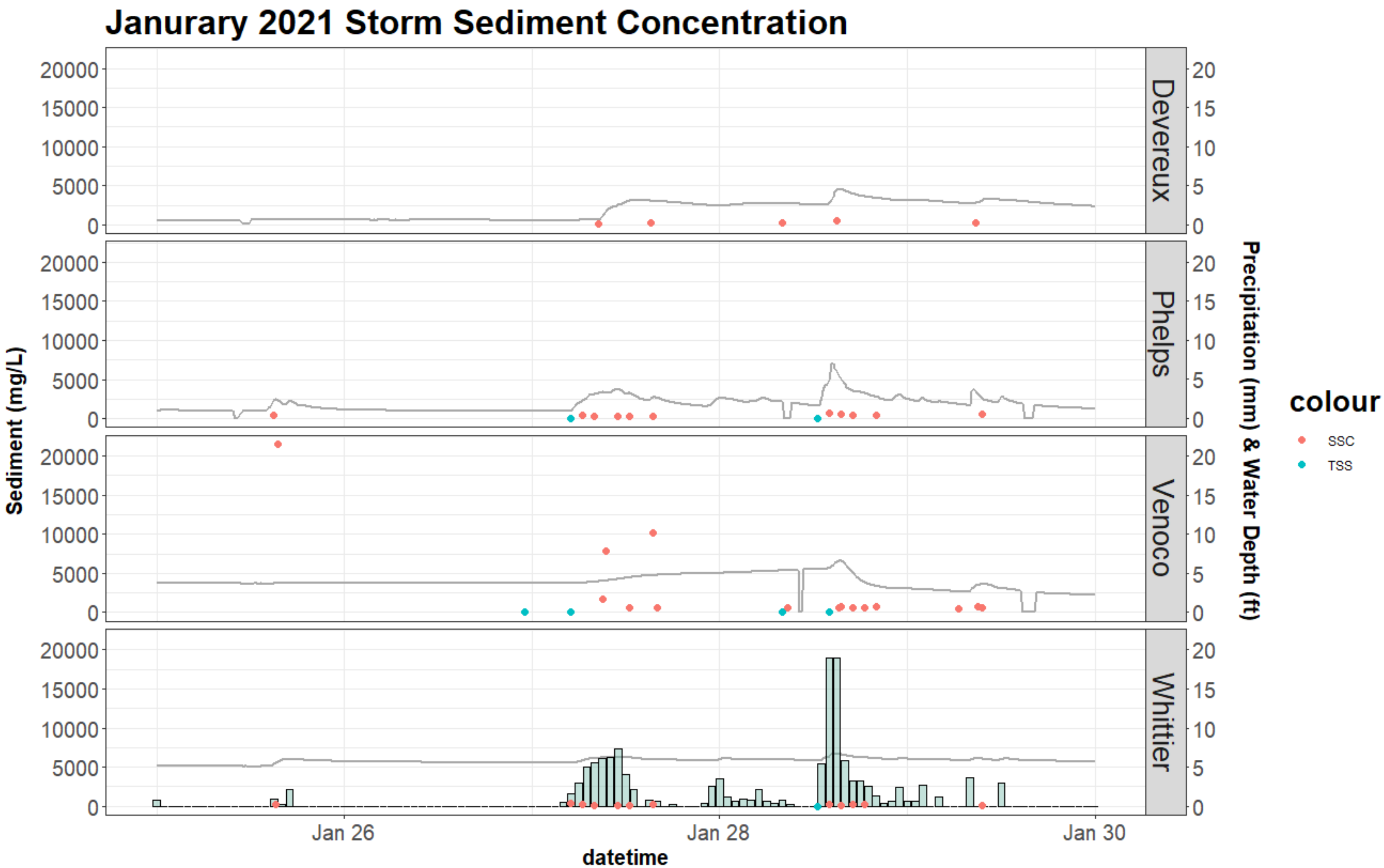
March 2021 Storm Phosphate Concentration
Phosphate Concentration (mg/L)
Water Depth (ft) & Precipitation (mm)
Devereux
Phelps
Venoco
Whittier
0.0
0.1
0.2
0.3
0.4
0.5
0
2
4
6
Mar 08
Mar 09
Mar 10
Mar 11
Mar 12
datetime

Suspended solid concentrations- WY 2021: TSS & SSC – Site Comparisons

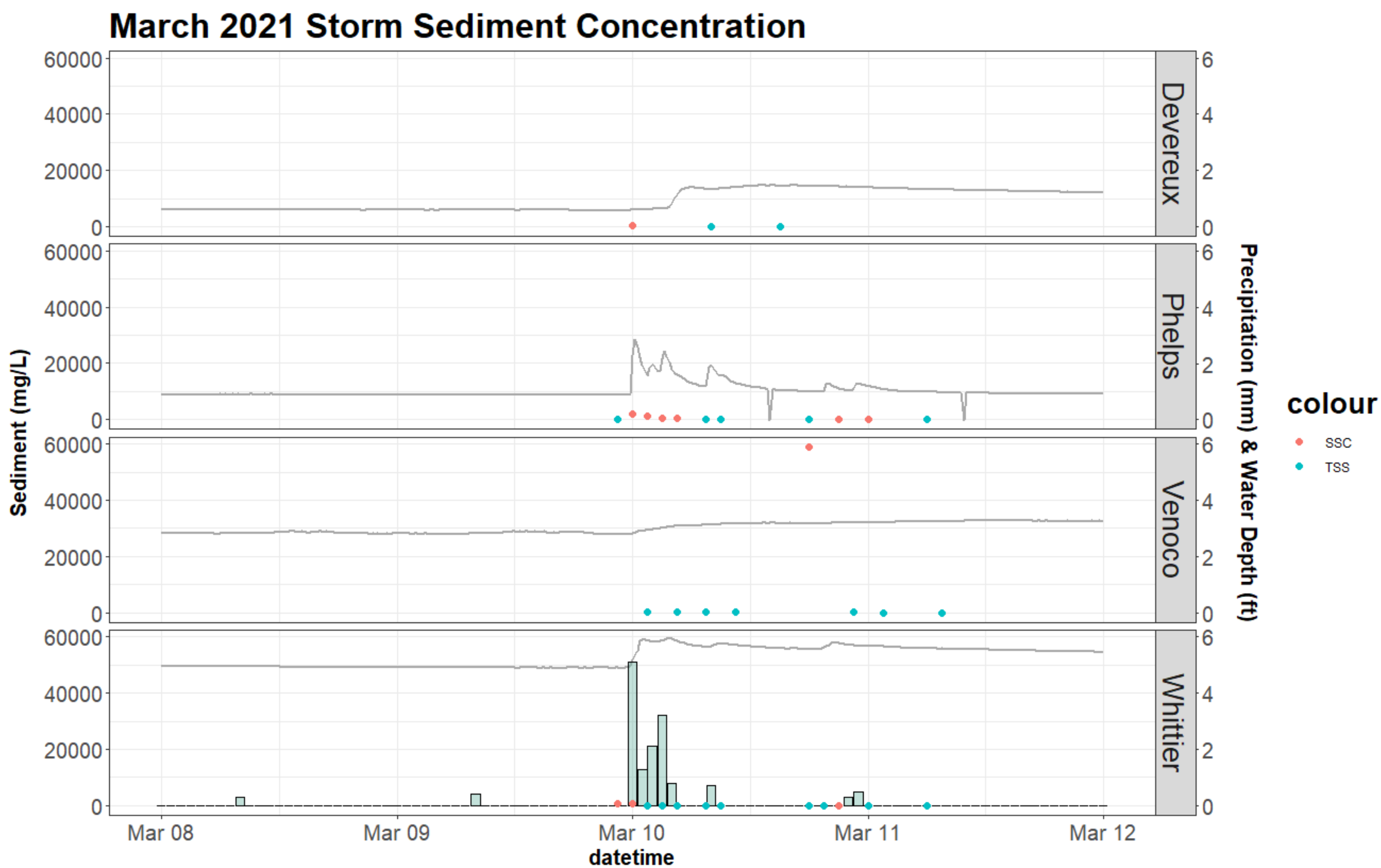

SSC Concentration in Grab/ ISCO samples- 2021 Water Year
SSC (g/kg)
60
40
20
0
Devereux
Phelps
Venoco
Whittier
Site
type
Grab
ISCO


TSS Concentration in Grab/ ISCO samples- 2021 Water Year
TSS (mg/L)
60
40
20
0
Devereux
Phelps
Venoco
Whittier
Site
type
Grab
ISCO


December 2020 Storm Sediment Concentration
Sediment (mg/L)
Precipitation (mm) & Water Depth (ft)
Devereux
Phelps
Venoco
Whittier
datetime
Dec 27
Dec 28
Dec 29
0
500
1000
1500
2000
0.0
2.5
5.0
7.5
10.0
colour
SSC
TSS



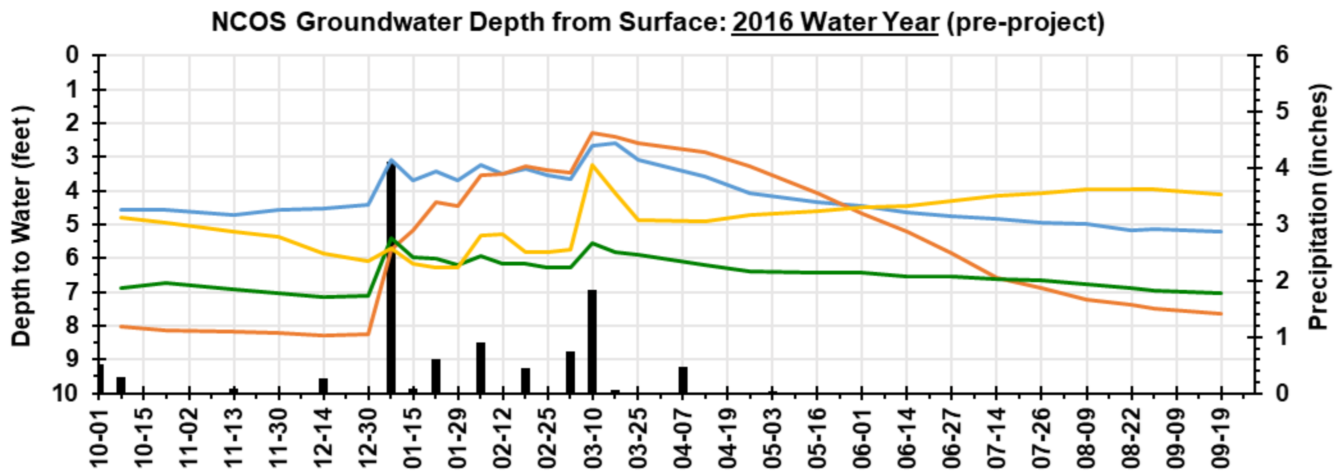
Janurary 2021 Storm Sediment Concentration
Devereux
Phelps
Venoco
Whittier
Sediment (mg/L)
Precipitation (mm) & Water Depth (ft)
datetime
Jan 26
Jan 28
Jan 30
colour
SSC
TSS

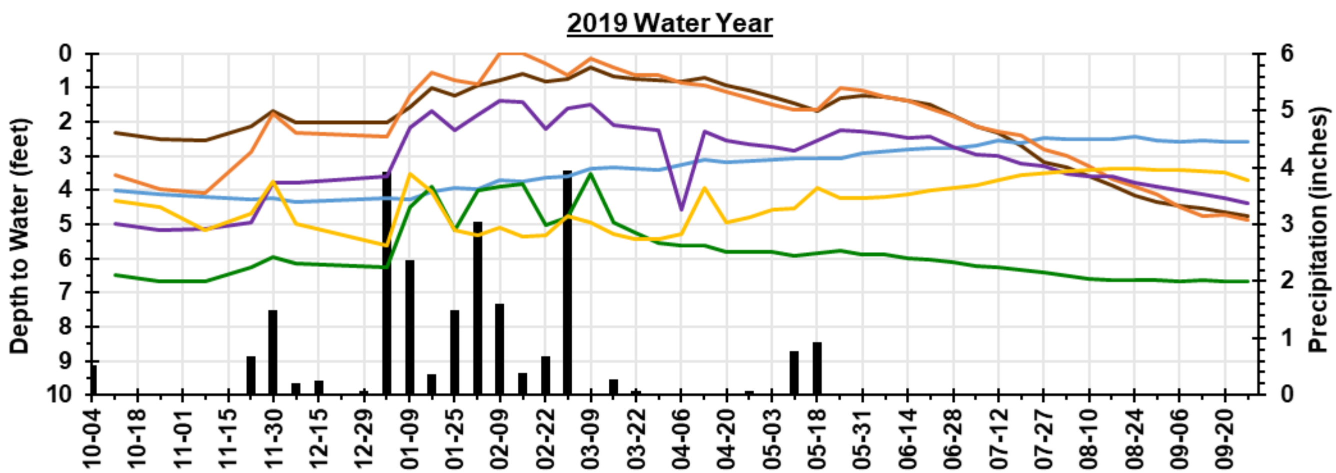


March 2021 Storm Sediment Concentration
Sediment (mg/L)
Precipitation (mm) & Water Depth (ft)
datetime
Devereux
Phelps
Venoco
Whittier
60000
40000
20000
0
6
4
2
0
Mar 08
Mar 09
Mar 10
Mar 11
Mar 12
colour
SSC
TSS

APPENDIX 6 – Previous years groundwater data

Legend: Precipitation — Well 13 — Well 14 — Well 15 — Well 16 — Well 17 — Well 19





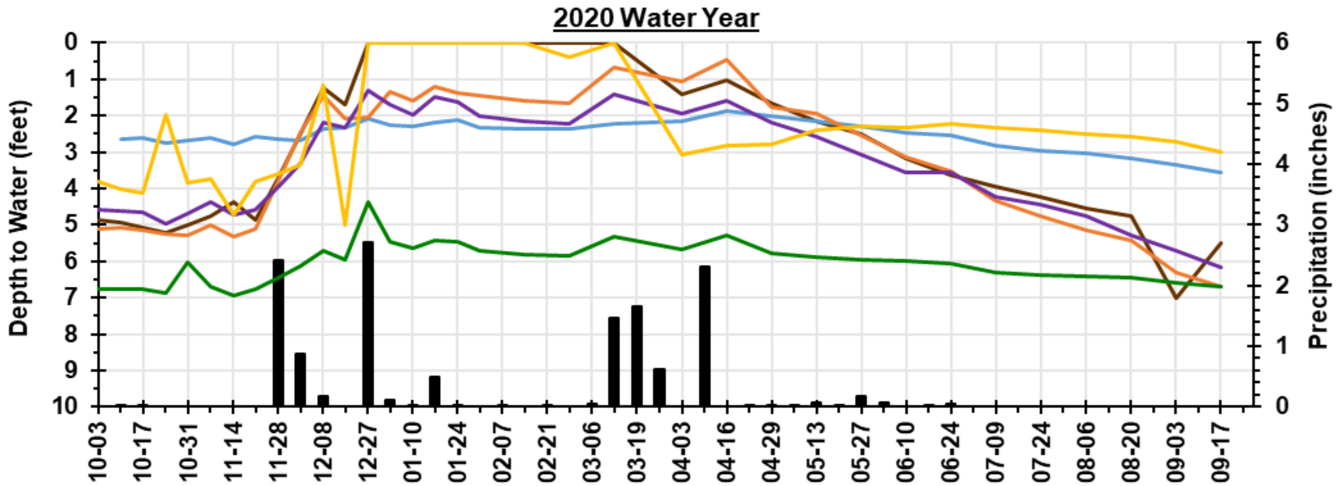
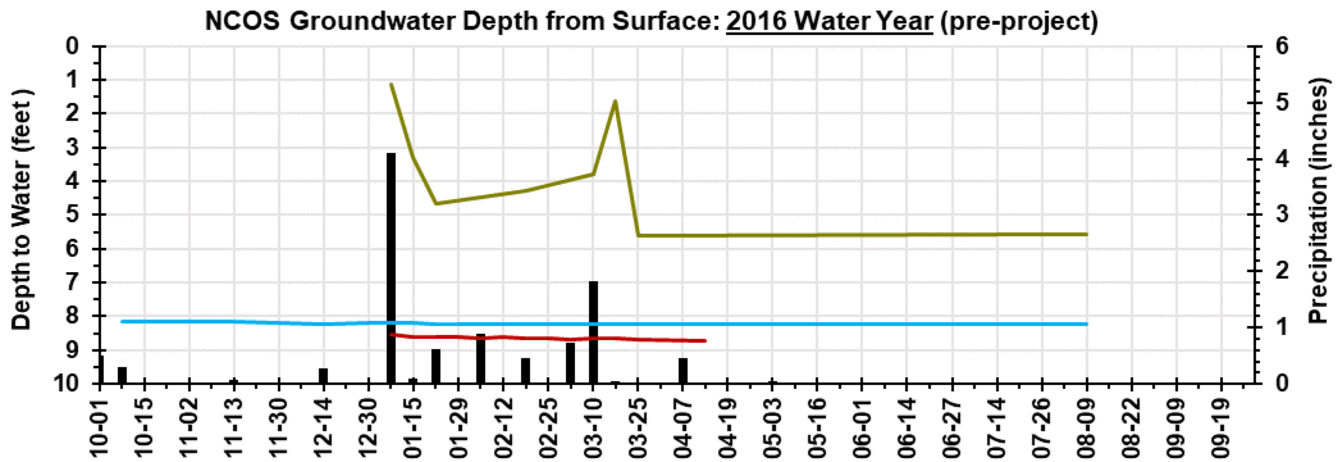


Figure 36. Plots of the depth to groundwater from surface (feet) measured every two weeks at six piezometers (monitoring wells) surrounding the North Campus Open Space wetland. Chart (a) is pre-project data collected in the 2016 water year at four wells installed in the same location after grading. Charts (b) and (c) are data collected in the post-grading water years of 2019 and 2020, respectively. The horizontal axis is the week of the water year with a date shown for every other week. Black bars represent weekly precipitation (inches) recorded at a NOAA climate station on Coal Oil Point Reserve.

Legend: Precipitation Well 1 Well 3 Well 6 Well 7 Well 8



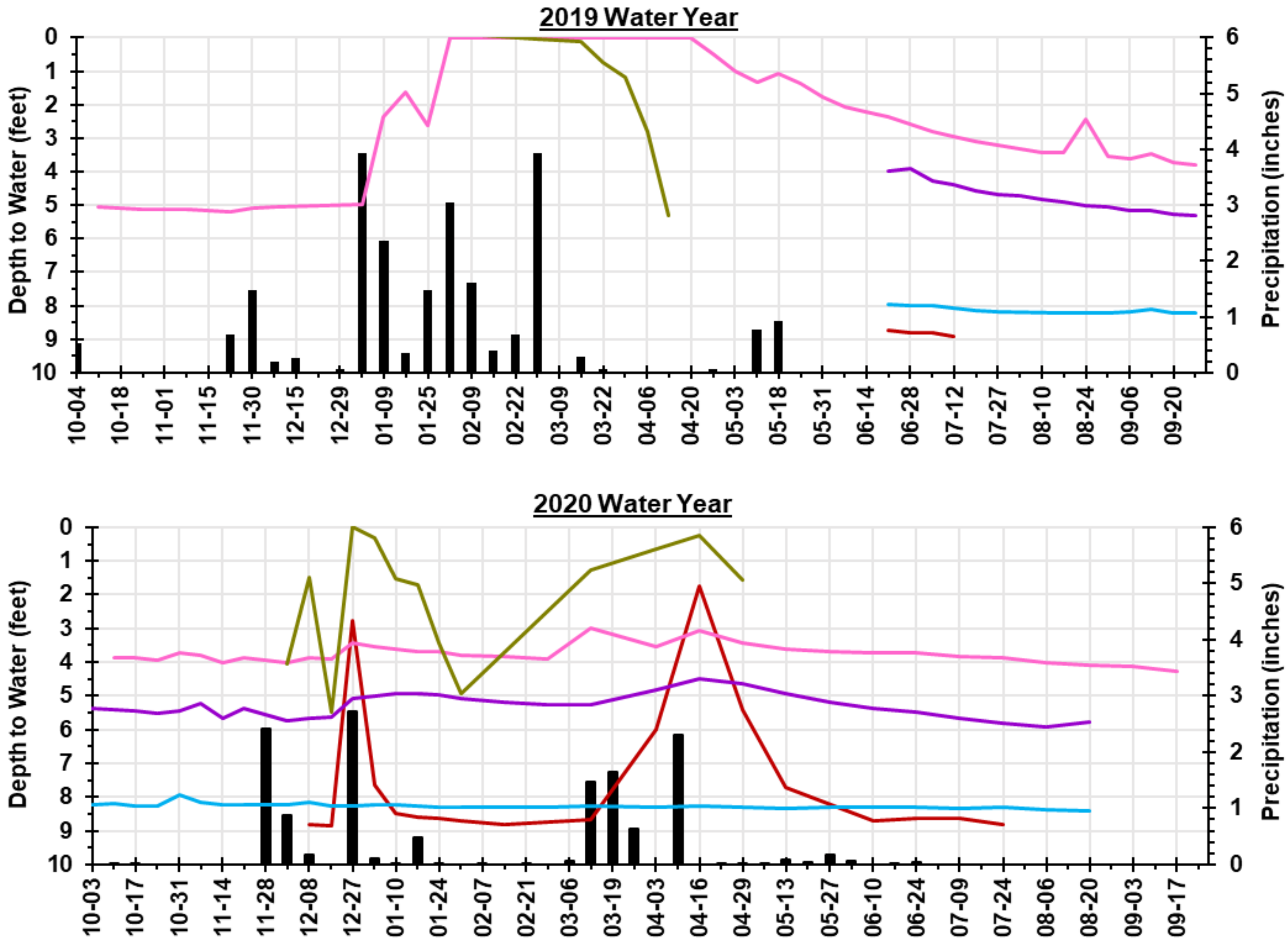
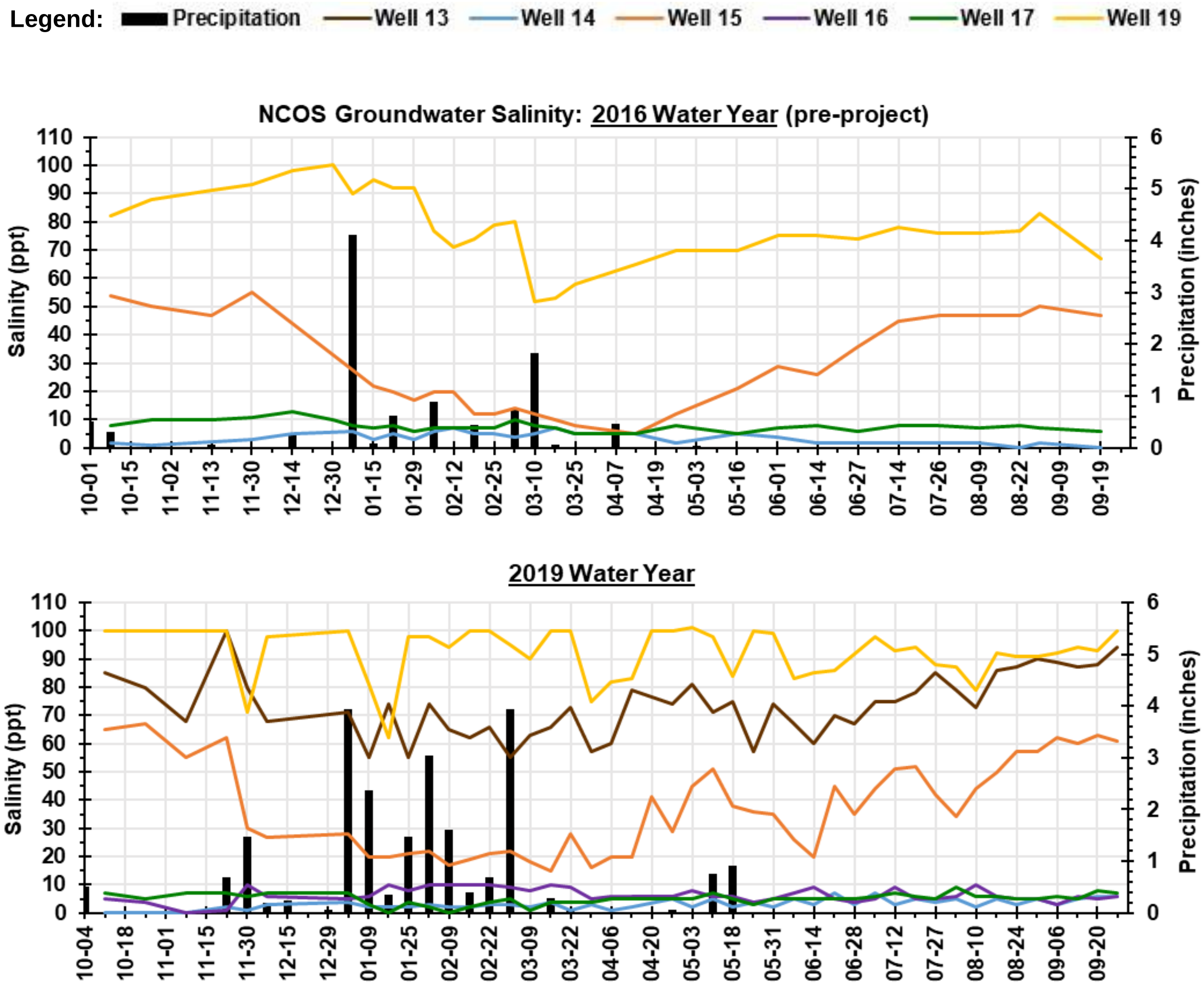


Figure 37. Plots of the depth to groundwater from surface (feet) measured periodically at five piezometers (monitoring wells) on the upper areas of North Campus Open Space. Chart (a) is pre-project data collected in the 2016 water year (no water detected in wells 3 and 7). Charts (b) and (c) are data collected in the post-grading water years of 2019 and 2020, respectively. The horizontal axis is the week of the water year with a date shown for every other week. Black bars represent weekly precipitation (inches) recorded at a NOAA climate station on Coal Oil Point Reserve.


Legend: Precipitation Well 13 Well 14 Well 15 Well 16 Well 17 Well 19
NCOS Groundwater Salinity: 2016 Water Year (pre-project)
Salinity (ppt)
Precipitation (inches)
10-01 10-15 11-02 11-13 11-30 12-14 12-30 01-15 01-29 02-12 02-25 03-10 03-25 04-07 04-19 05-03 05-16 06-01 06-14 06-27 07-14 07-26 08-09 08-22 09-09 09-19
2019 Water Year
Salinity (ppt)
Precipitation (inches)
10-04 10-18 11-01 11-15 11-30 12-15 12-29 01-09 01-25 02-09 02-22 03-09 03-22 04-06 04-20 05-03 05-18 05-31 06-14 06-28 07-12 07-27 08-10 08-24 09-06 09-20

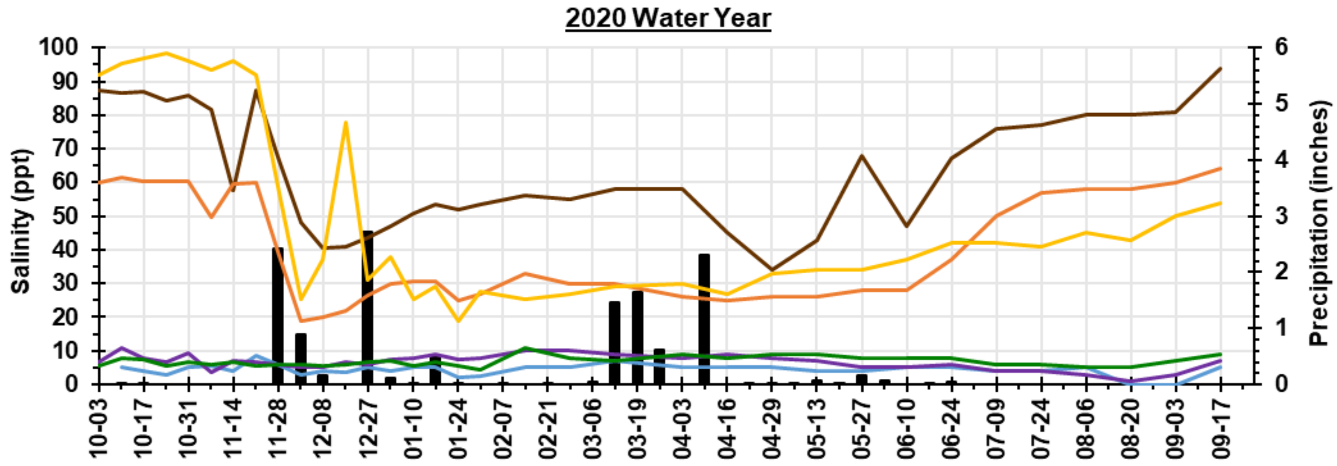


Figure 38. Plots of groundwater salinity (in parts per thousand, ppt) measured every two weeks at six piezometers (monitoring wells) surrounding the North Campus Open Space wetland. Chart (a) is pre-project data collected in the 2016 water year at four wells installed in the same location after grading. Charts (b) and (c) are data collected in the post-grading water years of 2019 and 2020, respectively. The horizontal axis is the week of the water year with a date shown for every other week. Black bars represent weekly precipitation (inches) recorded at a NOAA climate station on Coal Oil Point Reserve.

Bats

In 2020, CCBER performed a pilot study on conducting quarterly surveys of bats in four areas of NCOS using a Wildlife Acoustics sensor and app on a tablet. These surveys showed seasonal variation in the overall number of detections, a proxy for abundance and bat activity on site, as well as the number of species. Overall, up to eight bat species were detected, though the certainty of three of these species is low as they were detected only one to three times and are considered rare (Table 3). Details about this pilot study, including comparisons with a baseline survey of bats at NCOS in 2017, are further described in an article on the CCBER website. After consultation with Paul Collins of the Santa Barbara Natural History Museum, we determined that our method was only capturing bat species that prefer to stay close to the ground. In 2021 we worked to revise our collection methods and hope to stort bat monitoring again in 2022.

Table A7.1 Number of bat calls per species recorded during dawn (AM) and dusk (PM) acoustic surveys conducted once per quarter at four regions of North Campus Open Space in 2020. The counts do not indicate the number of bats present. Bat calls are detected, recorded and initially identified with a Wildlife Acoustics Echo Meter Touch 2 Pro. Recordings and initial identifications are inspected and compared with keys using Wildlife Acoustics Kaliedoscope software to improve accuracy and confidence as much as possible. Confidence is low for the identification of the species preceded with an asterisk (*).

	WINTER 2020			SPRING 2020			SUMMER 2020			FALL 2020			GRAND
Common Name	**AM**	**PM**	**TOTAL**	**AM**	**PM**	**TOTAL**	**AM**	**PM**	**TOTAL**	**AM**	**PM**	**TOTAL**	**TOTAL**
MESA													
Big Brown Bat				4		*4*							**4**
Hoary Bat				1	5	*6*					19	*19*	**25**
Mexican Free-tailed Bat	3	35	*38*	3	32	*35*		2	*2*		42	*42*	**117**
Silver-haired Bat		3	*3*	1	4	*5*					1	*1*	**9**
NORTH													
Big Brown Bat								2	*2*		4	*4*	**6**
California Myotis		1	*1*										**1**
Hoary Bat	6	7	*13*	6	2	*8*					2	*2*	**23**
Mexican Free-tailed Bat	32	58	*90*	29	8	*37*				10	28	*38*	**165**
Silver-haired Bat		5	*5*	11	3	*14*					3	*3*	**22**
* Western Red Bat								1	*1*				**1**
* Yuma Myotis							2		*2*				**2**
NORTHEAST													
Big Brown Bat					2	*2*		1	*1*				**3**
California Myotis								1	*1*				**1**

Hoary Bat		5	*5*		5	*5*				4	15	*19*	**29**
Mexican Free-tailed Bat		43	*43*	5	79	*84*				50	49	*99*	**226**
Silver-haired Bat		6	*6*	1	25	*26*		2	*2*				**34**
* Western Red Bat										1		*1*	**1**
* Western Yellow Bat					1	*1*							**1**
SOUTH PARCEL													
Big Brown Bat	1		*1*		8	*8*		2	*2*				**11**
California Myotis				4		*4*		1	*1*				**5**
Hoary Bat	3	2	*5*		2	*2*					26	*26*	**33**
Mexican Free-tailed Bat	58	9	*67*	4	5	*9*					12	*12*	**88**
Pocketed Free-tailed Bat											1	*1*	**1**
Silver-haired Bat					2	*2*		1	*1*		1	*1*	**4**
* Yuma Myotis				1		*1*							**1**

Soils

In 2019 soil samples were taken to analyze total carbon, organic carbon, and inorganic carbon components to interpret carbon sequestration. While most of the soil cores have been analyzed, this project has been put on hold due to malfunctions of the elemental analyzer. We intend to take soil cores in 2023 to compare pre and post restoration efforts.

There are also 3, large experimental plots testing the effects of biochar and compost layering versus biochar addition only and compost only. The results are still being analyzed. Another part of this study that has recently developed in 2021 is the collection of soil samples for E-DNA analysis. Samples were collected in November 2021, and we still await the lab results.

Birds

Aside from the bird monitoring efforts mentioned earlier in this paper there are two other projects to monitor and provide bird habitat. The first is a UCSB student is dissecting owl pellets to understand the owl's diet. The project also involves an E-DNA sample of the owl pellets that is still awaiting results. Three trial samples of shorebird guano will also be sent in for E-DNA analysis as part of this E-DNA trial.