North Campus Open Space Restoration Project

Monitoring Report: Year 5, December 2022

UC SANTA BARBARA
Cheadle Center for Biodiversity & Ecological Restoration

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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 (Cheadle Center), 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 fifth year of implementation and with planting of the project site complete, project efforts are now focused primarily on research projects, and supporting 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 five years of the project, with a primary focus on the fifth year (2021-22). This work documents the progress of the project and supports longer-term research and monitoring programs. Results from the fifth year of monitoring show this project to have been successful and exceeded our expectations thanks to the dedication of staff, students and contracted organizations. Though the project has been extremely successful a few challenges that are worth mentioning include: unpredictable drought period which affects both the flora and fauna, as well as the covid 19 pandemic interrupting some of the expected work effort. 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. 2022 photos show the addition of the outdoor classroom.

Vegetation

All habitats/plant communities have 0% cover of high-risk invasive species in the sampled quadrats as determined by the California Invasive Plant Council (Cal IPC). All habitats met the year 5 success criteria for total vegetation cover relative percent native cover and native biodiversity when interpreted within the context of the site. Peripheral uplands, which border the residential areas, had a mean of 50% total cover instead of the 70% criteria level for year 5, however this is the result of the multiple plots located within the mulched buffer adjacent to the homes which is there to provide fire protection, thus the vegetated portion more than exceeded the total cover goal. Three habitats, grassland, Sandy annual area, and salt marsh had year 5 total cover goals of 80,80 and 90% respectively and year five values of 77, 75 and 88% respectively. Not only are the total cover goals unrealistically high for these habitats given the goal of interstitial space for wildflowers in the grassland and sandy annual site and wildlife foraging in the saltmarsh, but the observed levels were ecologically similar to the targets. Graduated success criteria (by year) for these habitats also got much stricter in the fifth year. So, while they do not all meet the official success criteria, we would argue that our initial target covers were not ecologically appropriate in the 5th year and that the habitats themselves are thriving.

Overall, the results from year 5 monitoring are significantly improved from the year 4 results which had been impacted by the pandemic interruption of work during the peak weed season. There have been 89 native species identified in the quadrat transect monitoring over the past five 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 2022 monitoring year, the Ventura marsh milk-vetch habitat continued to reproduce prolifically at the primary site and 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)*.

Wildlife

In the fifth year of wildlife monitoring at the NCOS project we documented a single burrowing owl visiting in October 2021. We also had at least two pairs of western snowy plovers who successfully fledged young in the mudflats rather than the sandy area. The western snowy plover had a successful breeding season on the beach at Coal Oil Point, which is their preferred habitat, so we do not expect a large population of these shorebirds to choose to nest in the estuary where resources are not as abundant as on the beach. Belding's savannah sparrows have been spotted on site for the last 5 years with evidence of breeding that includes nests with eggs.

Monthly bird surveys in year five had an increase from year four in 8 of the 13 general bird species groups. Year 5 had the most terrestrial insectivores of any year with a 500 count increase. Omnivores were also the highest of any other monitoring year. 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. 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 2020-22. A synthesis of weekly coverboard monitoring documented an increase in most herp species compared to pre-project monitoring.

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 five 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.

The 2022 water year, although still below the average threshold, had more rainfall than the 2021 water year. There were 4 storms including one in late October. Typically, October only has 4% of yearly rainfall in Santa Barbara County, but in 2021 October accounted for 13% of rainfall- starting the wet season off earlier than normal. We had an especially wet December 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 2022 water year had only 64% (10.1 inches) of the typical rainfall in the area which is an increase from the 49% (9 inches) of 2020[1]. These factors resulted in very high salinity levels in the estuary late in the water year.

Table 1. Total rainfall of 2022 and average distribution of rainfall throughout the year in Santa Barbara County. Average values are retrieved from Santa Barbara County Water Resources. (n.d.). Historical Monthly Rainfall Trends – Countywide. https://www.countyofsb.org/2322/Monthly-Yearly-Rainfall. Values in red are more than 10% lower than average, values in green are more than 10% higher than the average.

Month	% of 2022 rainfall	Santa Barbara County average % of rainfall by month
October	13 %	4 %
November	0 %	10 %
December	71 %	15 %
January	1 %	20 %
February	0 %	21 %
March	11 %	18 %
April	2 %	7 %
May	0 %	2 %
June	0 %	0 %
July	0 %	0 %
August	0 %	0 %
September	1 %	1 %

[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 (Cheadle Center), 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 4 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. Nearly 7,000 plants comprised of 13 CSS-associated species 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. 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.

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. 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).

Year 4 Planting Summary

There were over 20,000 plants and 29 species planted in year 4 bringing the overall total to over 342,000 seedlings planted. Of all the seedlings planted, 80% were planted in the Mesa area focusing on the vernal pool habitat and 17% were on the salt marsh transition. The federally endangered Ventura marsh milk-vetch (*Astragalus pycnostachys* var*. lanosissimus*) continues to thrive and has expanded its boundaries through natural seeding.

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.

Year 5 Planting Summary

The Duttenhaver outdoor classroom and refurbished parking lot project construction concluded in March 2022 and supports environmental education at all levels. There were an estimated 15,000 plants from 25 different species planted in 2022 bringing the total to over 365,000 plants and 71 species. Of all the seedlings planted 70% were on the mesa with a continued concentration on the vernal pool habitat and 20% were planted at Whittier in association with the outdoor classroom planting. Throughout the whole project about 30% of all seedlings were planted on the mesa.

Report Structure and Content

This report describes the NCOS monitoring program, methods and protocols, and includes data primarily from the fifth year of monitoring (October 2021 to October 2022) along with some data from year 1 through 4 for comparison.

Monitoring and research efforts as well as data presented in previous reports that are not included in this year 5 report include the development of the bathymetry of the wetland, studies on sediment accretion, carbon sequestration, trail use surveys, tick presence, bird recording, bat species surveys and greenhouse gas fluxes of the wetland. Past reports and independent research projects completed by students and staff can be found at our escholarship website. If funding is secured, we plan to re-measure the elevation cross-sections of the wetland again in 2023 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.

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, water quality and nutrient flux 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 Cheadle Center'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 five 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 Cheadle Center 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 2. 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 every 3 meters. 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 2. 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	8/ 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	7/217 points, ~ 105 trees
Riparian Woodland – Pre-existing	1.5	PIT	June/July	2/62 points, 9 trees
Riparian Woodland – New (Phelps Creek and Whittier Channel)	1.7	PIT, Individual Trees	June/July	2/62 points, ~ 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 increased from year four to year five in every habitat except remnant brackish marsh where multiple dry years led to a build-up of thatch. The overall vegetation cover also increased in more than half of the habitats despite the drought. The presence of non-native vegetation is significantly under 50% relative to natives for all habitats. Non-native vegetation was either reduced or stayed the same in all habitats except the perennial grass land and vernal pool habitats in which non-native vegetation increased 10% or less reflecting the impact of the drought. The results of year five vegetation monitoring shows that sites with an initial low presence of non-natives remained consistently low, which indicates that once non-natives are eradicated, and natives establish there is the potential to have a stable ecosystem. Overall, there were 78 native species identified site wide in quadrat monitoring in 2022.

Both the new and previously established riparian woodland canopy and sub canopy is 100% native based on the 2022 survey. All salt marsh habitats continued to be dominated by natives as they were in year four, with only slight fluctuations of native and non-native distribution. The average absolute cover of native species in newly restored habitats site-wide increased from a mean of 7% to 59%.

Pickleweed, *Salicornia pacifica*, was recorded the most frequently in 2022. This species appeared in 211 of 528 quadrats or 40%. *Distichlis spicata* was the second most common and *Spergularia marina* is the third most common species. Late in the 2021 monitoring season an expert botanist identified the native species *Spergularia marina* 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 in earlier years. After gaining this knowledge for the 2022 monitoring season it was found that most of the Spergularia on site is in fact the native species. 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 a reduction in the absolute and relative percent of non-native vegetation cover in year five. Vernal Pools are the only habitat that had a noticeable increase in relative non-native abundance (by 10%) from year 4 to year 5. This increase in vernal pool non-natives is mostly due to the sharp increase in *Polypogon monspeliensis* and *Melilotus indicus*, but nearly all prominent non-natives increased in vernal pools in year 5 reflecting the impact of multiple dry years in a row. *Medicago polymorpha* is one species that did see a 3-fold decrease from year 4 to year 5 in the vernal pool habitat. Overall, there were 70 non-native species identified site wide in quadrat monitoring in 2022.Total non-native diversity has not fluctuated much over the year- remaining between 70-78 species identified site wide. The percent cover of non-native species across all plots has increased from 4% to 7%, because of the spread to bare ground areas.

Peripheral upland mosaic had the largest decrease in non-native abundance followed by the sandy annual site. Most of the other habitats had similar or slightly lower non-native species cover. The Sandy annual site typically has the most fluctuation from year to year because there is only one transect to reflect a large area with annually changing vegetation cover.

Cortaderia selloana, ranked as “High” on the Cal-IPC inventory was successful eradicated from all habitats with no instances in 2022 vegetation monitoring. It covered 4.3 percent of the Pre-existing Riparian Woodland habitat in 2021. Other species on the Cal-IPC inventory included 15 ranked as “Moderate” and 14 as “Limited”.

Italian rye grass, *Festuca perennis* (ranked “Moderate” by Cal-IPC), was the most frequently recorded invasive species in 2022 and was found in 48% of quadrats. *Festuca perennis* 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, 233 quadrats in the fourth year and 251 in year 5. Two other non-natives recorded frequently include *Polypogon monspeliensis* and *Bromus hordeaceus*. Non-native *Spegularia* species reduced dramatically in year 5 after the new discovery of the native *Spergularia*. 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 all monitoring years, the relative cover of bare ground decreased and continues to stay below 50 percent in all restored habitats, except the Sand Flat (70%). This habitat is expected to retain between 30% and 40% bare ground in the form of mud flats or salt flats

The relative cover of thatch, which we define as dead vegetation from the previous year’s growth (some of which was mowed or trimmed), fluctuates from year to year in most habitats. 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 five include remnant salt marsh (10% increase) and remnant brackish marsh (15% increase). The Sandy annual site had a large amount of thatch last year, and it was much reduced in 2022 monitoring because mowing was implemented to increase the expression of annual flowering plants.

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 year, there was nearly no other cover recorded in the fresh brackish pond (reduced 30% from last year). Other cover increased by 20% in the peripheral upland mosaic due to mulching along the border with the residences to reduce fire risk.

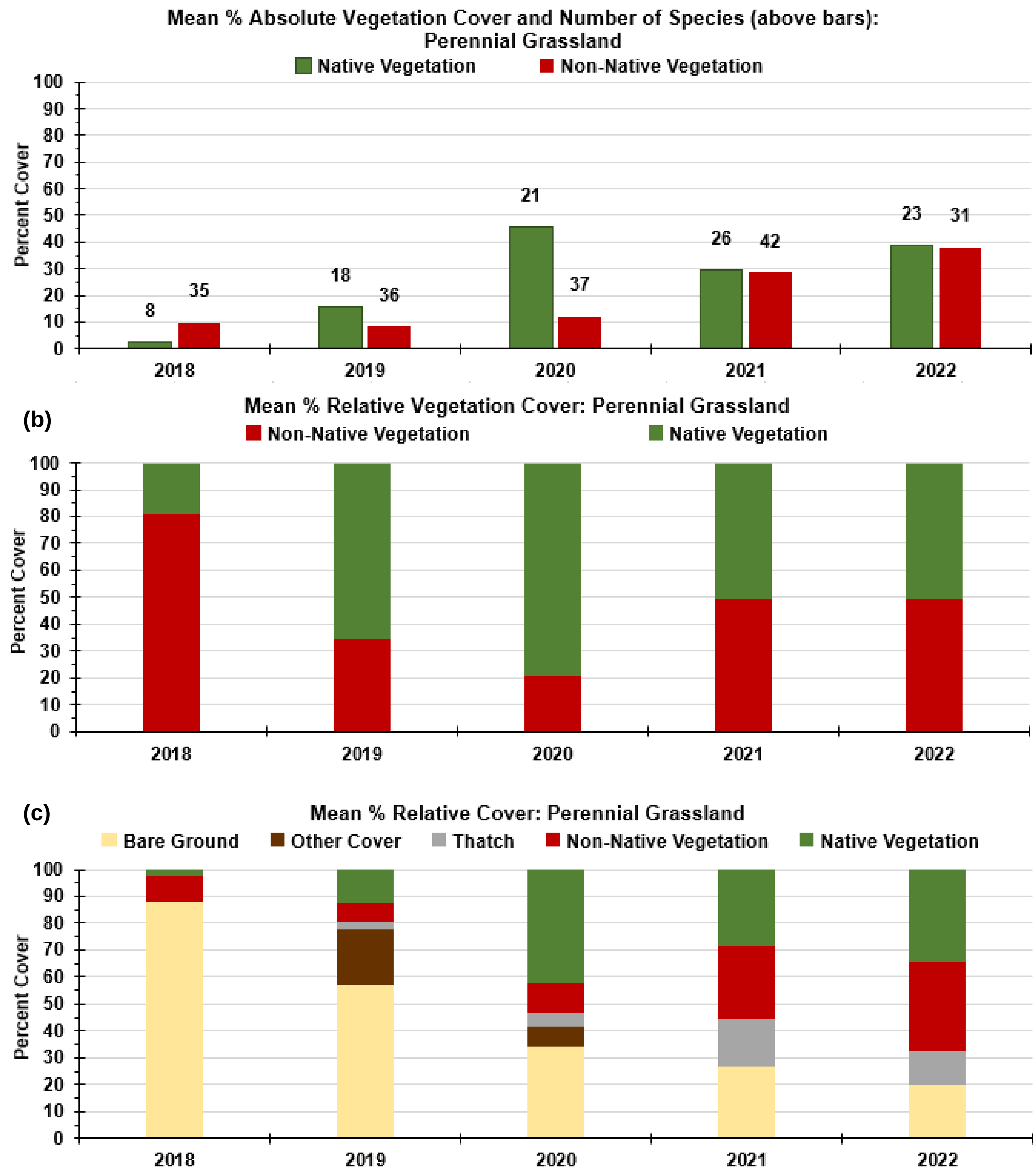


Figure 4. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the Native Perennial Grassland habitat at the North Campus Open Space restoration project. In plot (a), the numbers above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

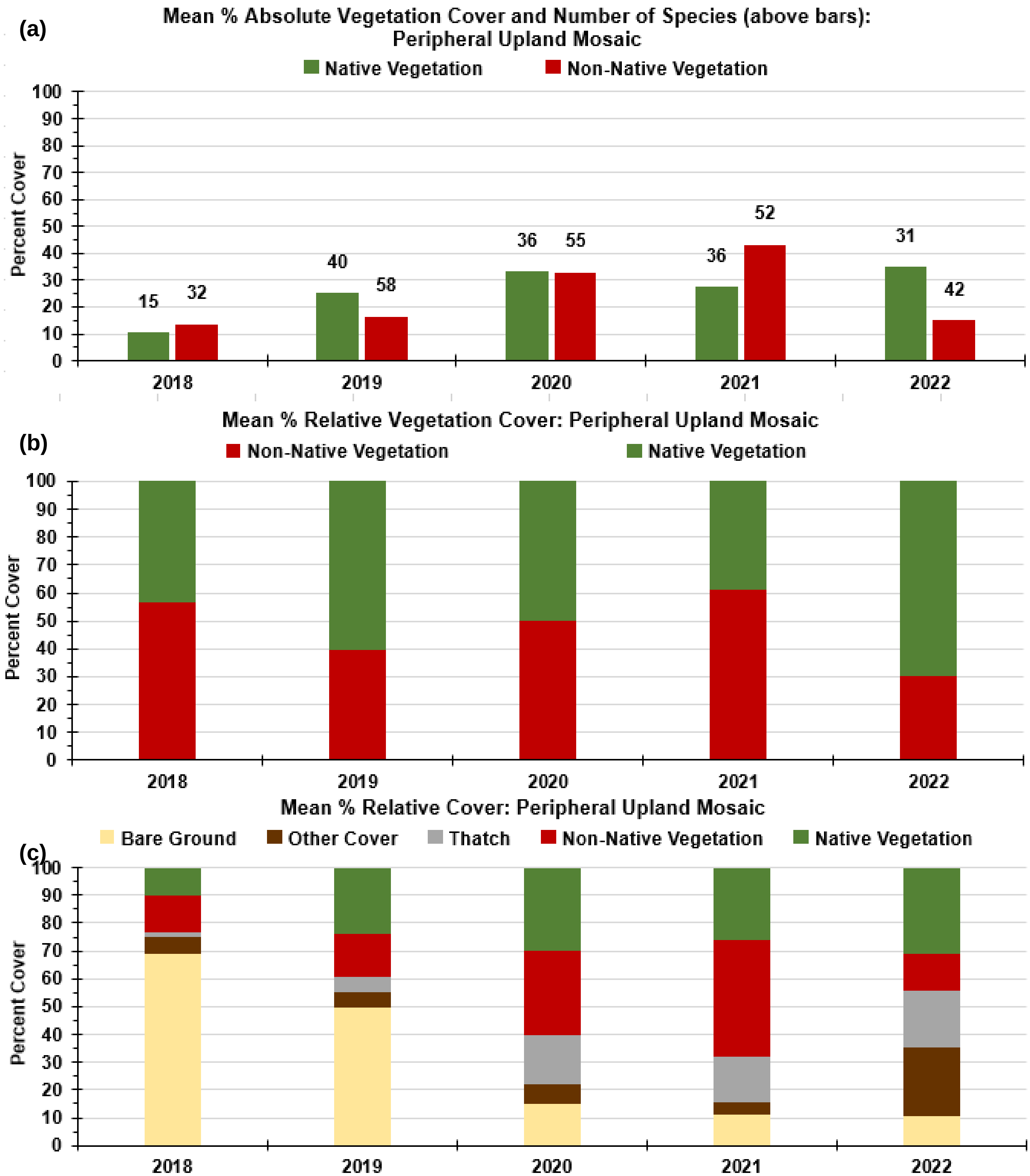


Figure 5. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the Peripheral Upland Mosaic habitat at the North Campus Open Space restoration project. In plot (a), the numbers above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

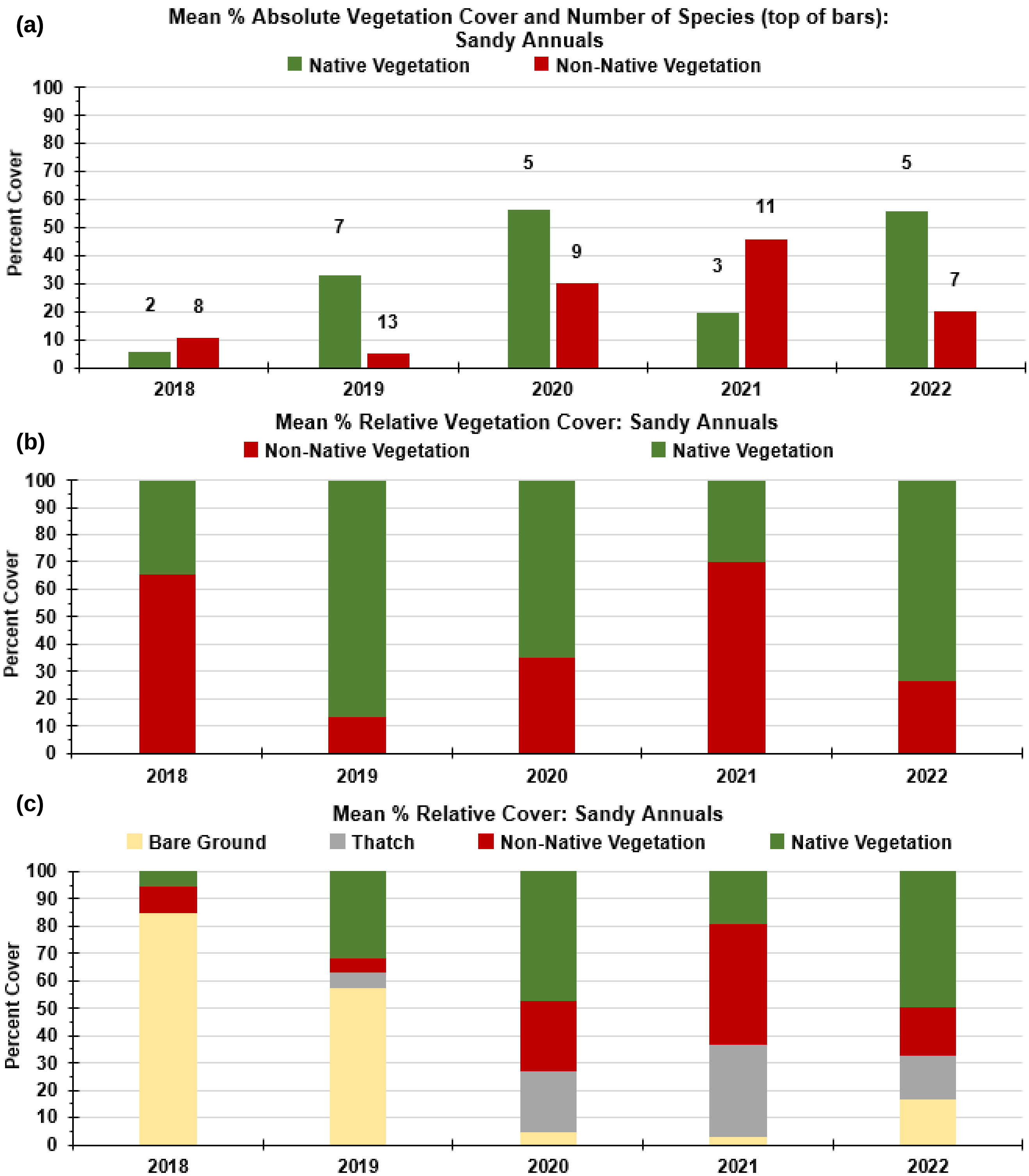


Figure 6. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the Sandy Dune Annuals habitat at the North Campus Open Space restoration project. In plot (a), the numbers above the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

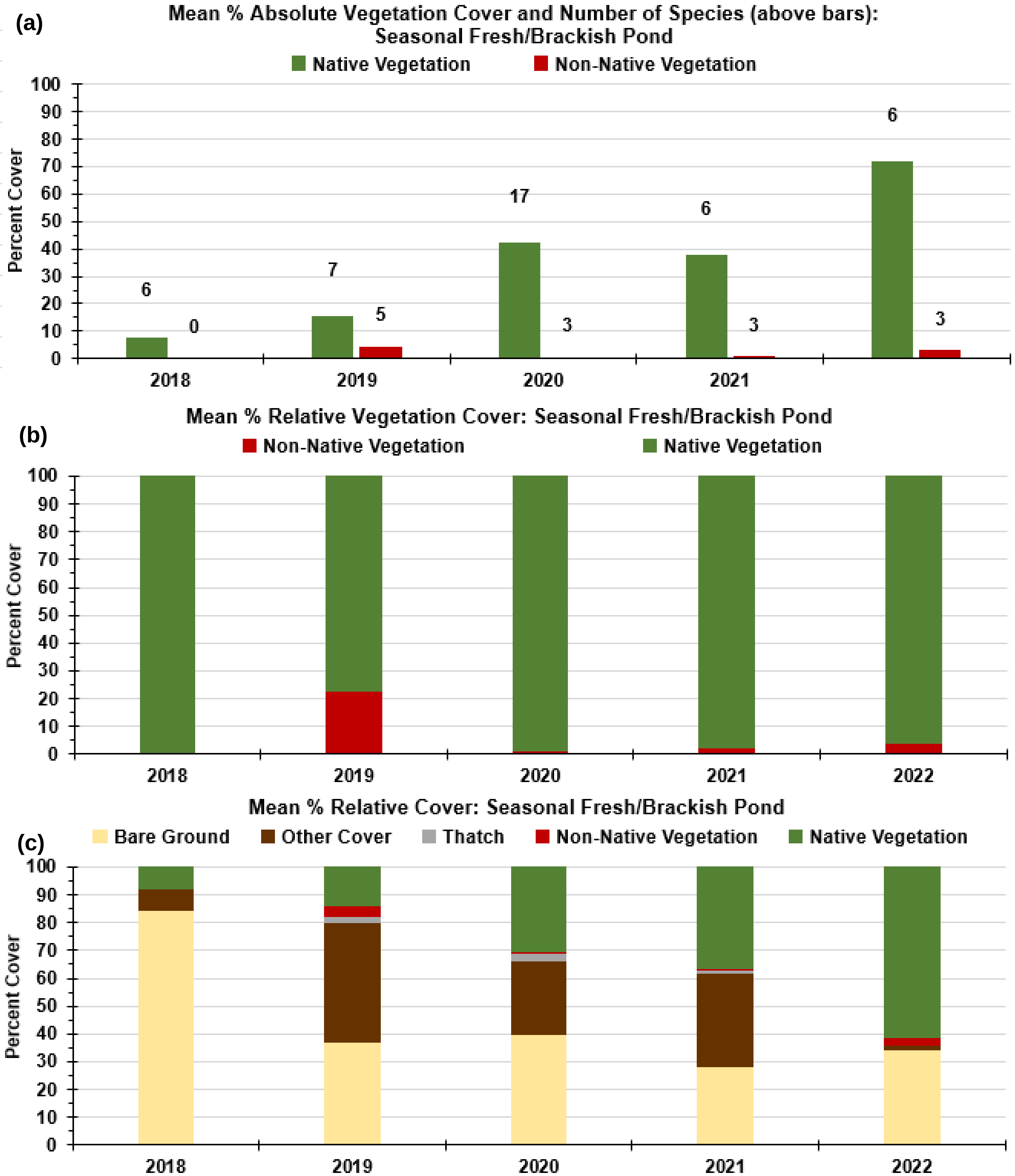


Figure 7. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the Seasonal Fresh/Brackish Pond habitat at the North Campus Open Space restoration project. In plot (a), the numbers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

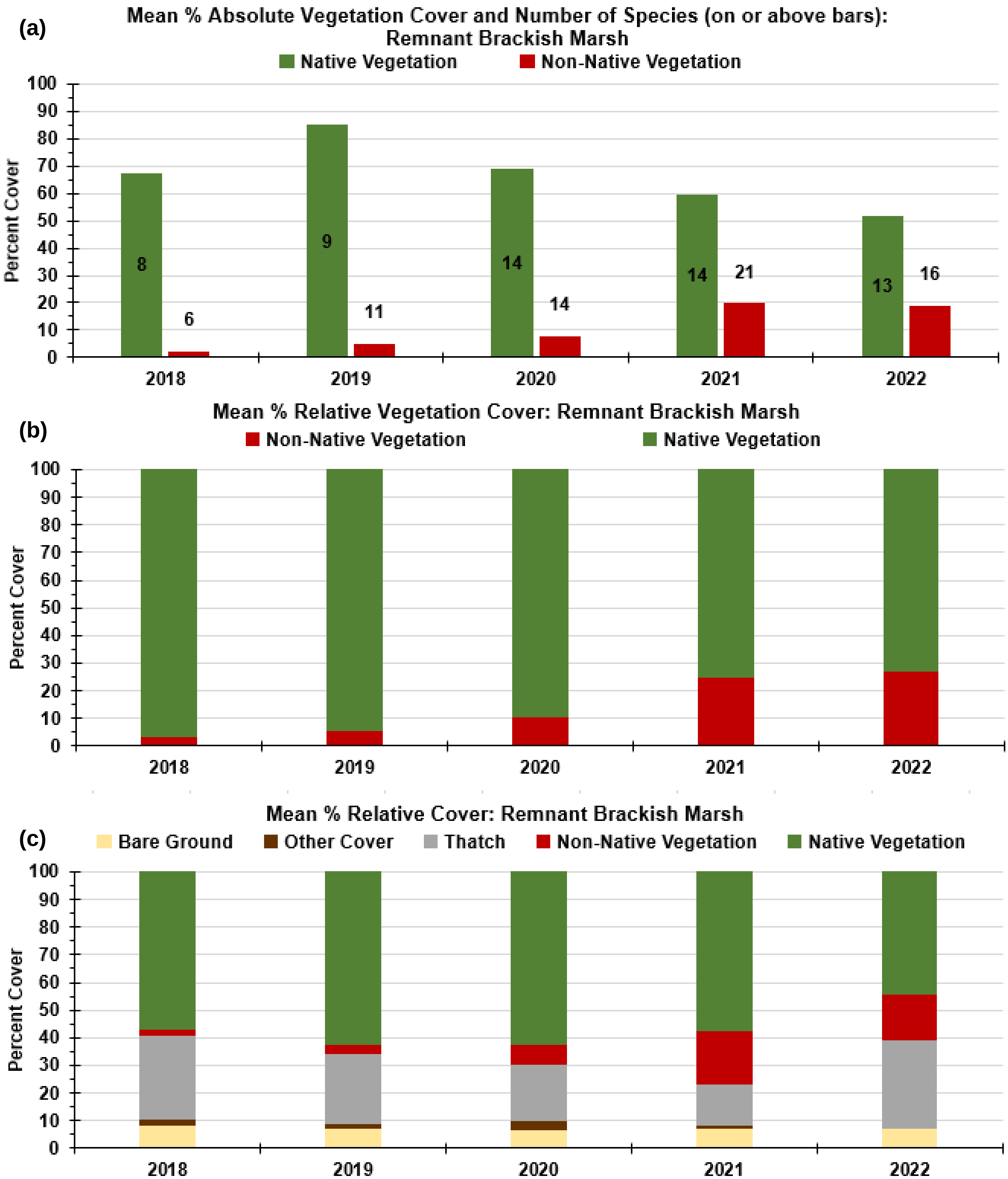


Figure 8. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the Remnant Brackish Marsh habitat at the North Campus Open Space restoration project. In plot (a), the numbers above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

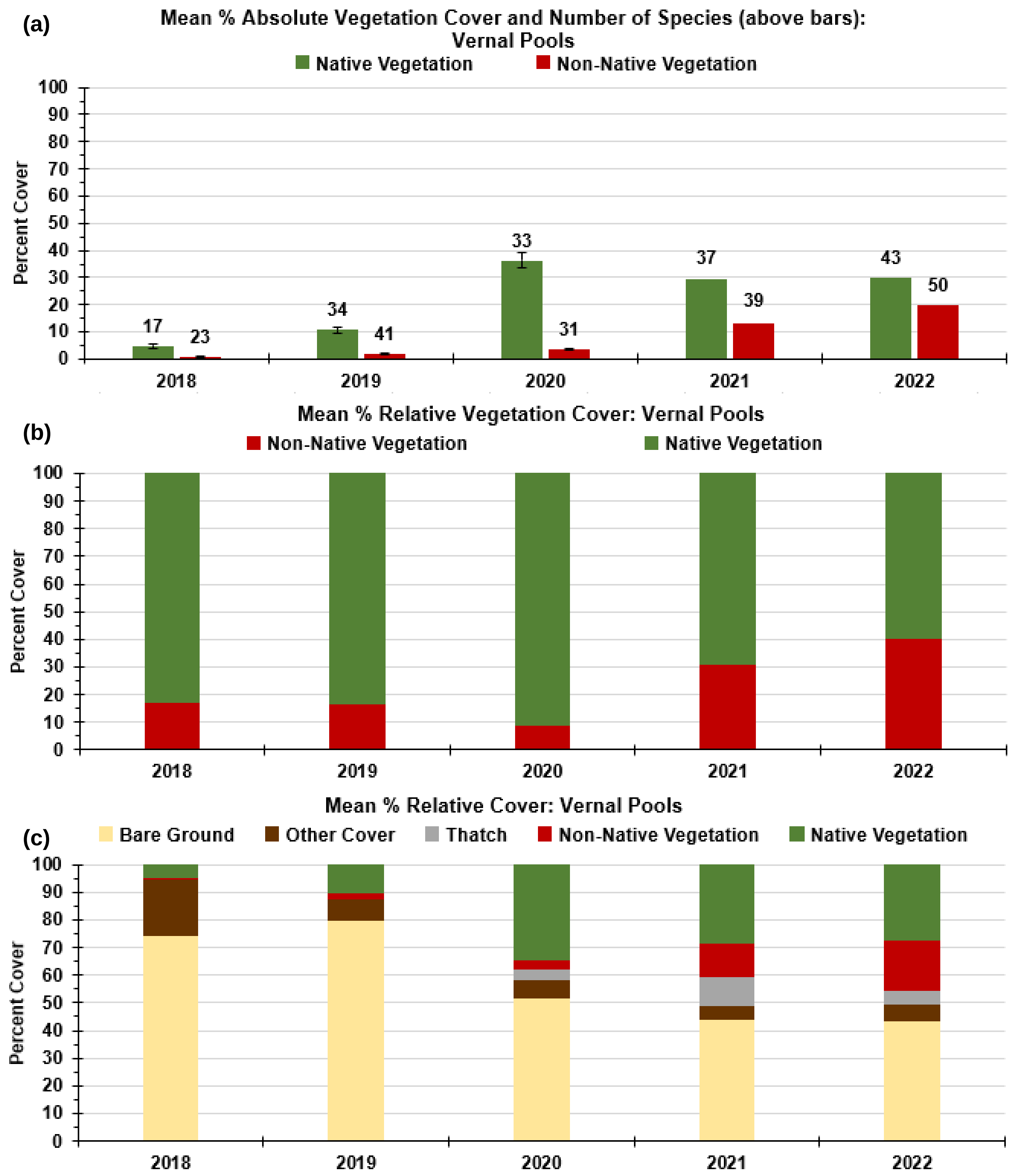


Figure 9. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the eight vernal pools on the mesa of the North Campus Open Space restoration project. In plot (a), the numbers above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

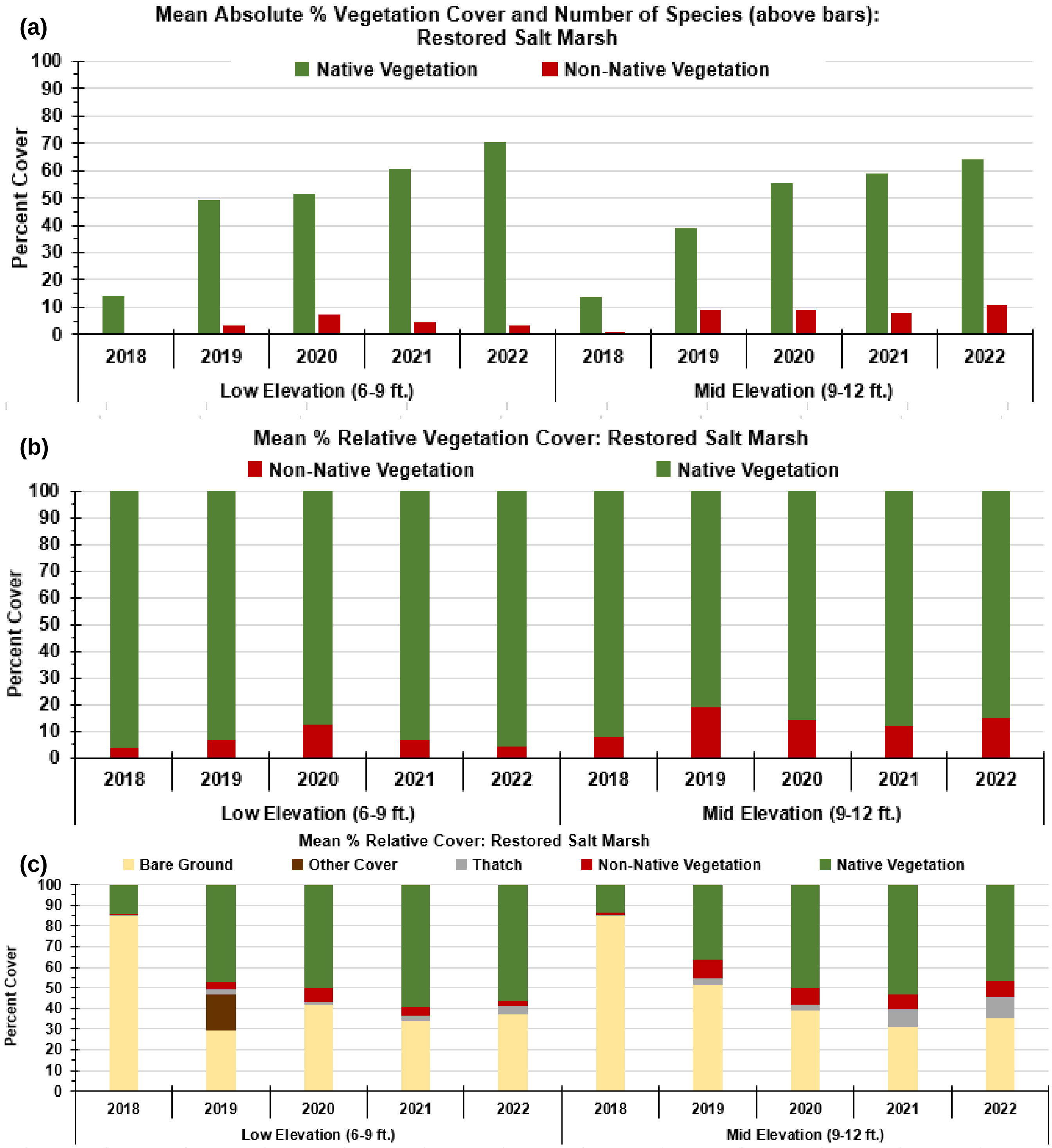


Figure 10. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the Low and Mid Elevation Restored Salt Marsh habitats at the North Campus Open Space restoration project. In plot (a),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

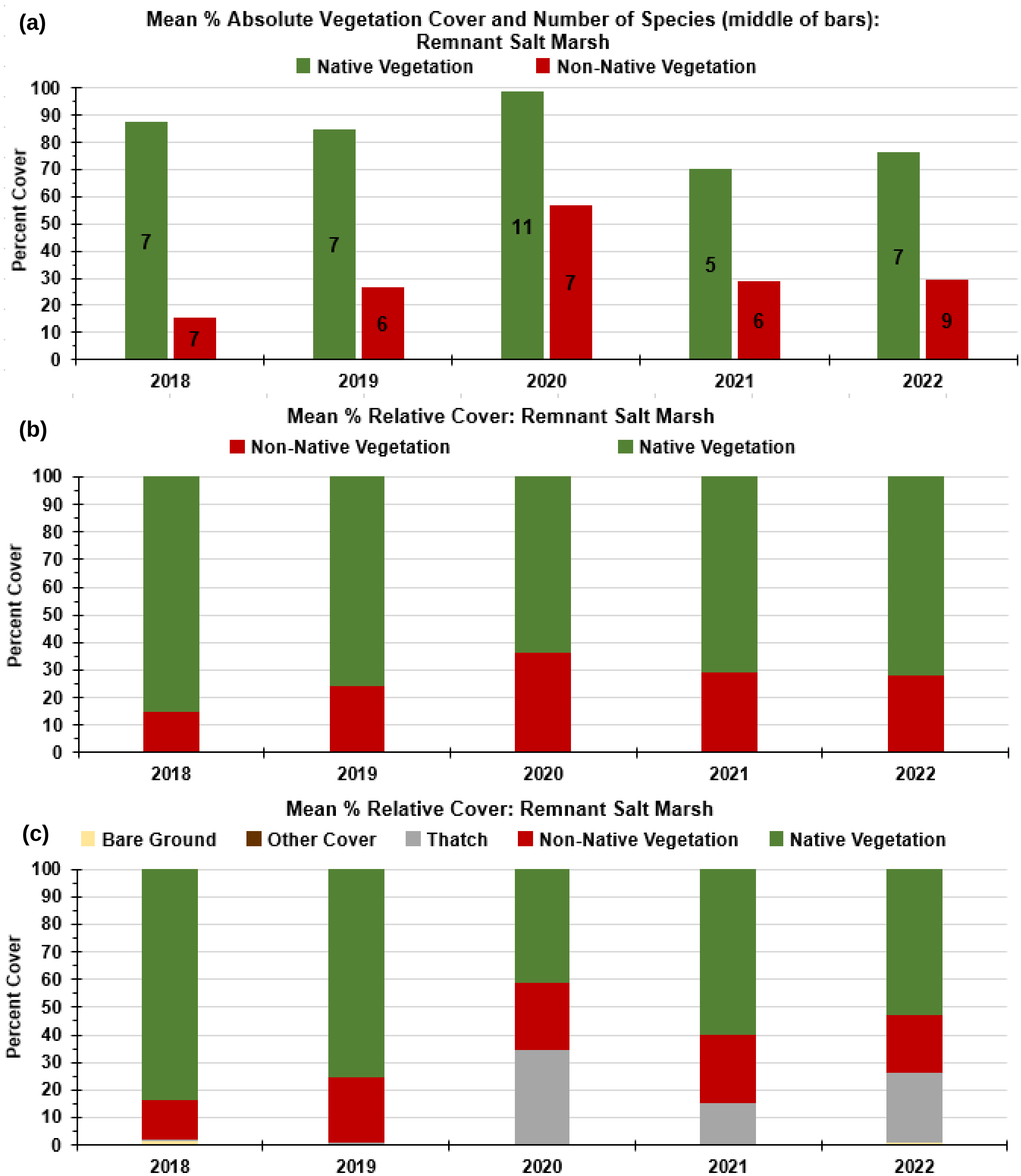


Figure 11. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the Remnant Salt Marsh at the North Campus Open Space restoration project. In plot (a), the numbers above the bars are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

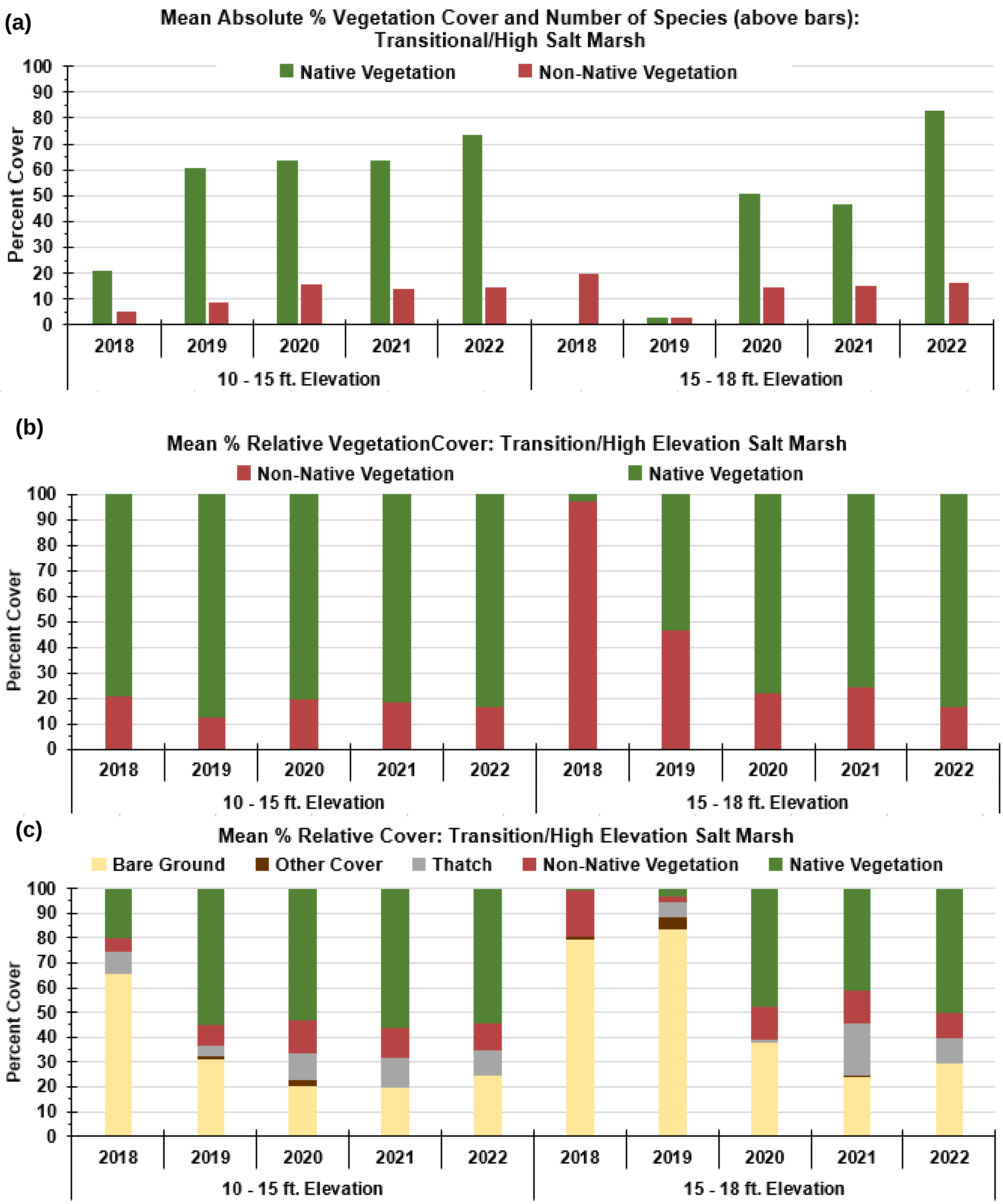


Figure 12. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the two elevation bands of Transition/ High Salt Marsh habitat at the North Campus Open Space restoration project. In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

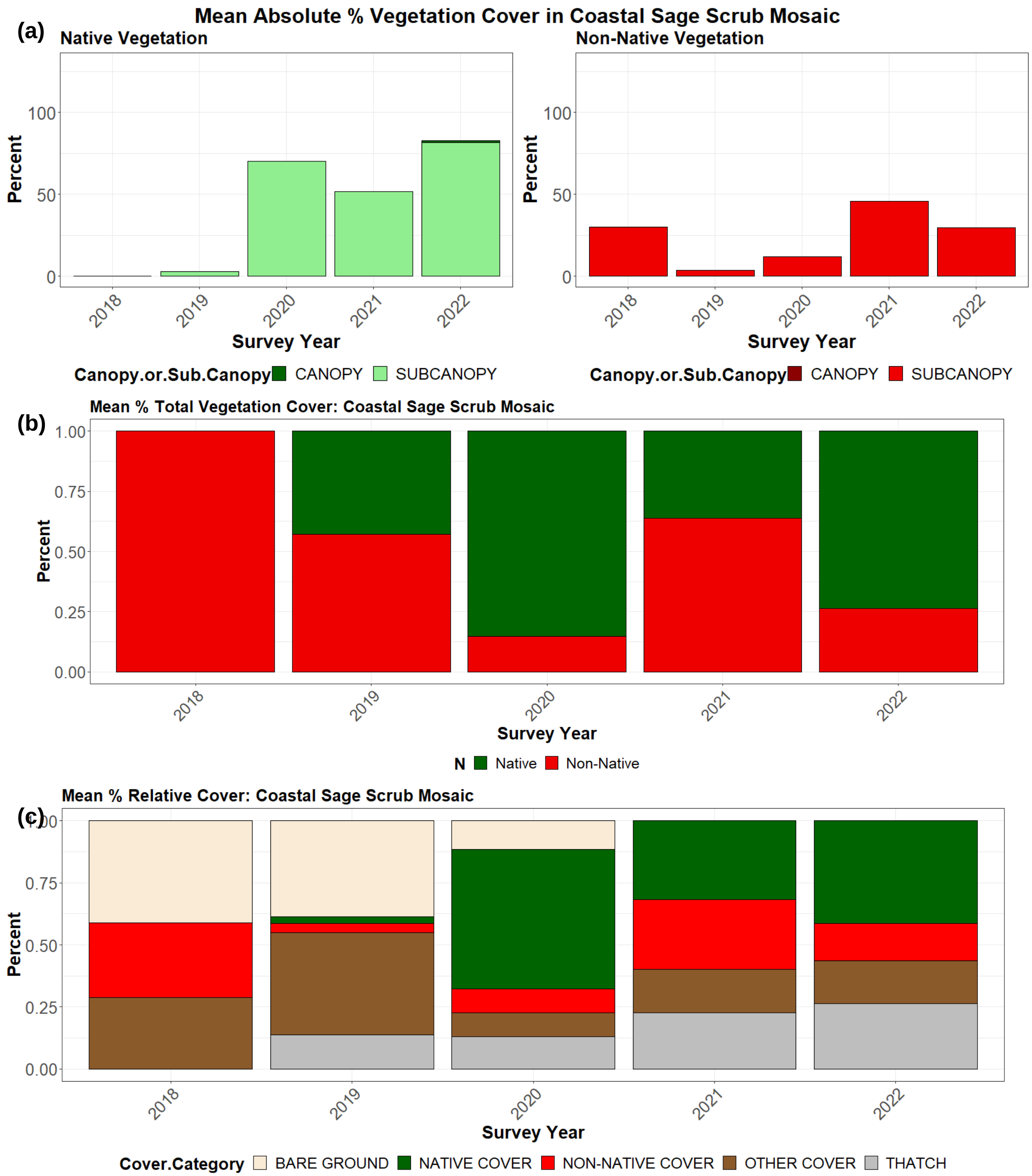


Figure 13. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the Coastal Sage Scrub.

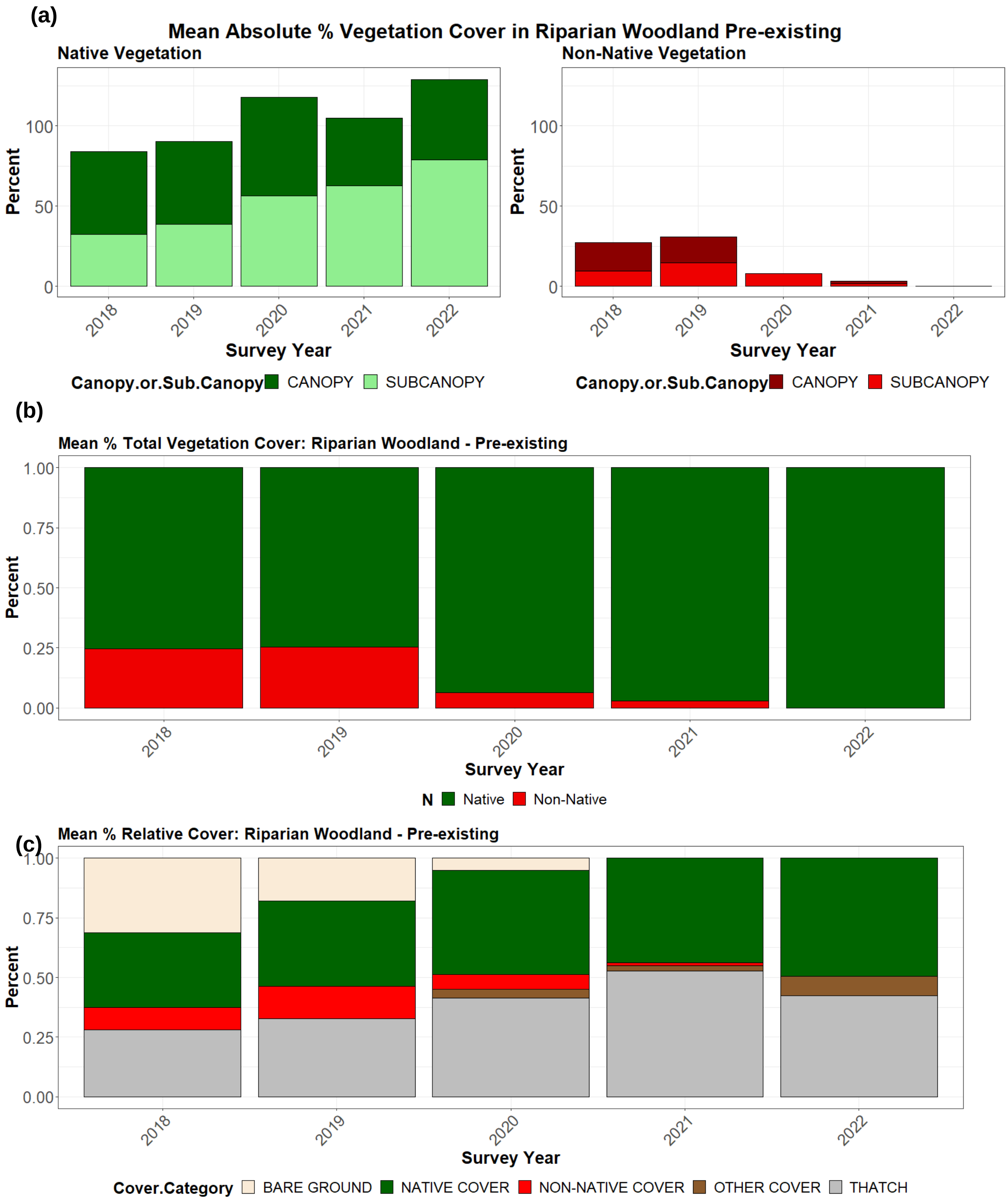


Figure 14. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the new Riparian Woodland habitats (sampled using point of intercept transect) at the North Campus Open Space restoration project.

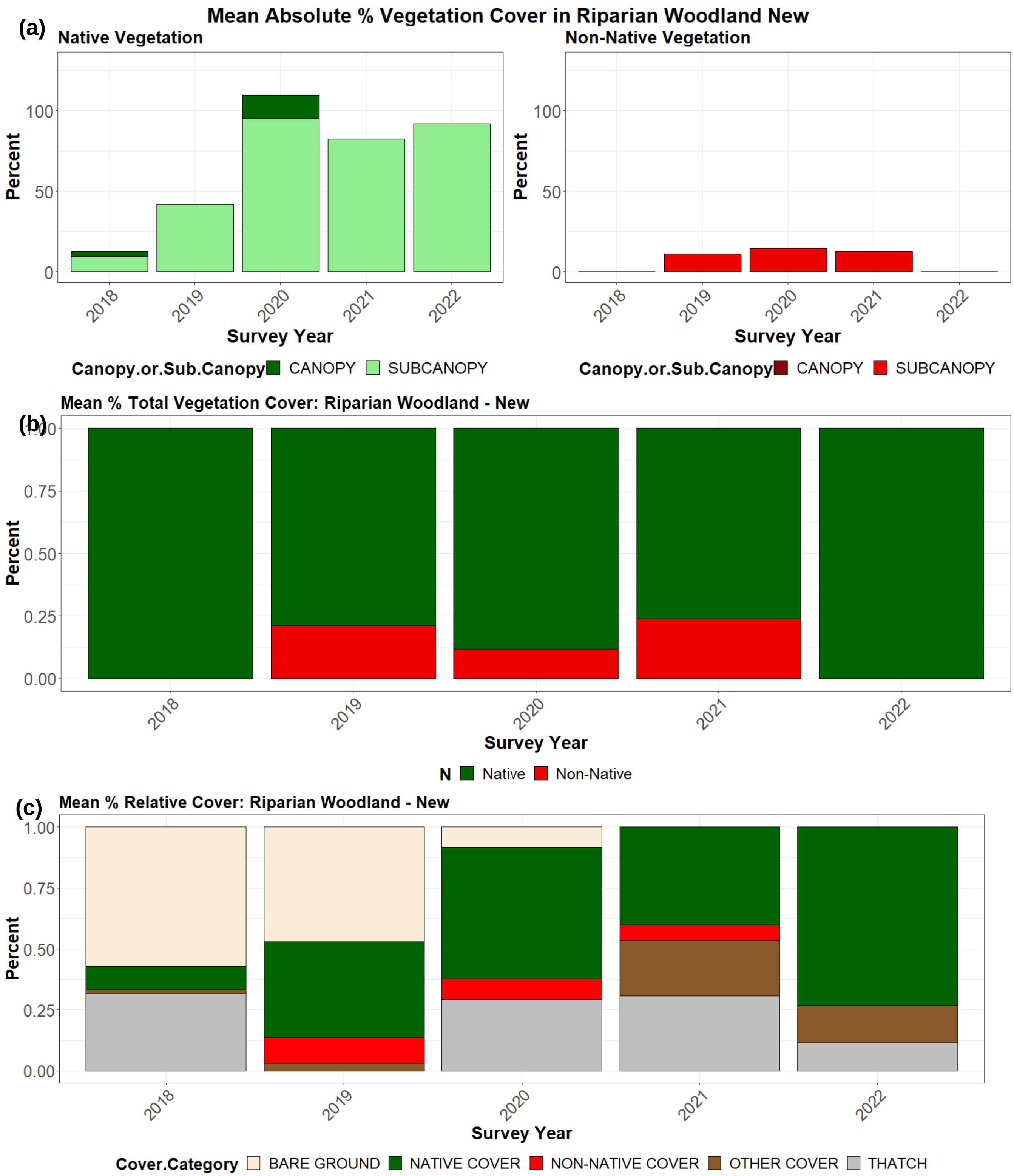


Figure 15. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the pre-existing Riparian Woodland habitats at the North Campus Open Space restoration project

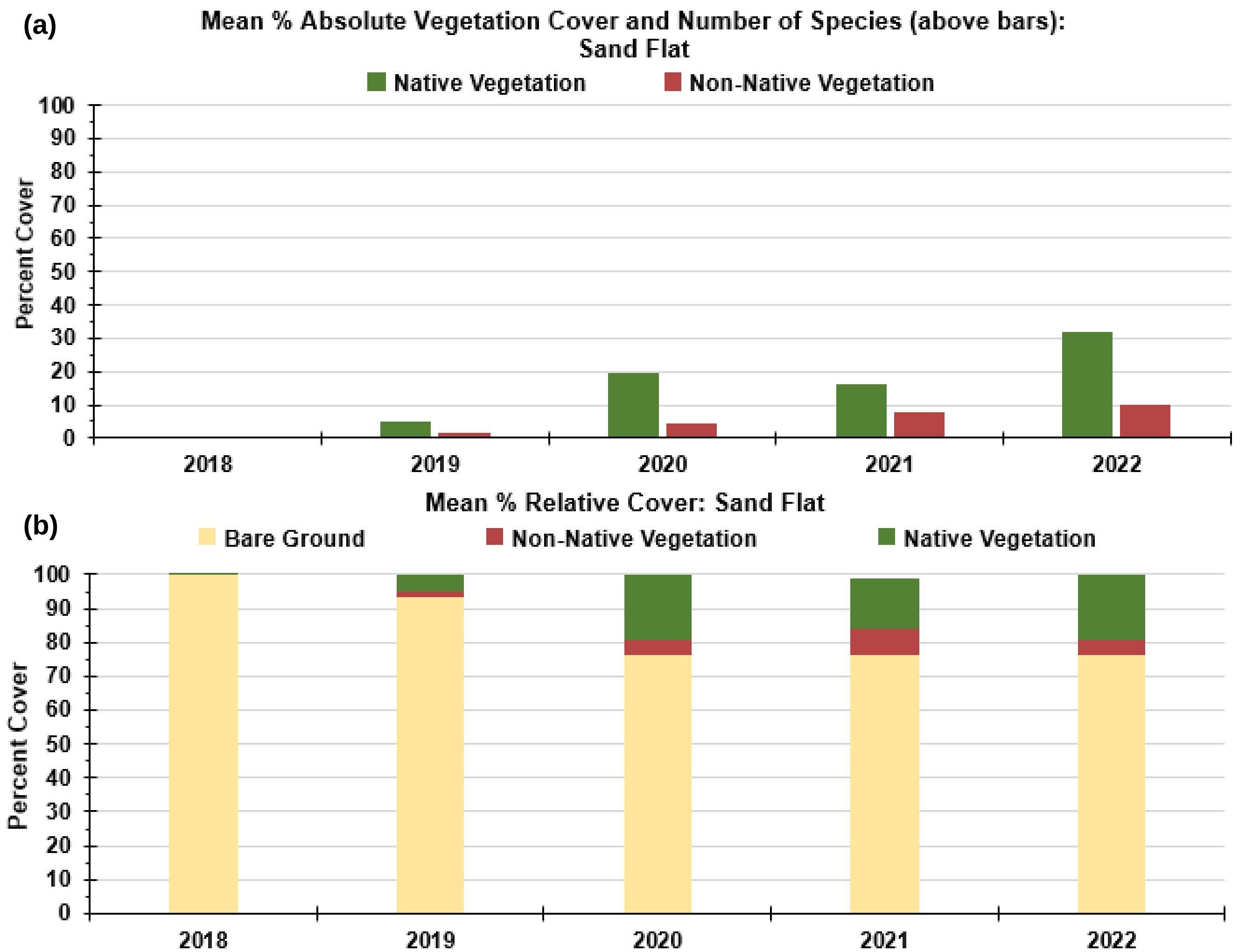


Figure 16. Mean percent of (a) absolute cover of native and non-native vegetation, and (b) relative cover of vegetation, thatch, other cover types, and bare ground in the Sand Flat habitat at the North Campus Open Space restoration project. In plot (a), the numbers above the bars are the number of native 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 3 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 2022 shows that most habitats met four out of four success criteria except in perennial grassland (2), peripheral upland (3), salt marsh (3), vernal pool (3) and sandy annuals(3) where year 5 criteria may have been too stringent for the particular habitats. Namely, as discussed in the introduction, the perennial grassland total cover and % relative native cover success criteria for year five of 80 and 70% respectively does not reflect the goal of having open ground for bird and lizard foraging and wildflower expression between bunch grasses. A total cover goal of 60% would be a more appropriate ecological goal. The relative percent native goal of 70% also does not adequately reflect the naturalization of Mediterranean annual grasses into this community; 50% would be more realistic. The peripheral upland goal of 80% total cover is appropriate for the plant portion of the community, however the transects include multiple plots immediately adjacent to the homes where we have established a mulch fire-break which skews the total vegetation cover data results inappropriately. The salt marsh relative native goal of 90% was nearly met with 88% cover and has therefore been essentially met. The vernal pool relative native cover goal of 80% is aspirational, but several very dry years have allowed invasive plants to become established where they might be excluded in typical rainfall years.

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*) 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 has always been less than 5%, and all species rated as high by Cal-IPC were eradicated before 2022.

Table 3. 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	77
% Native Relative	*50*	***60***	***70***	*70*	*70*	19	**65**	**79**	51	51
% Invasive Relative	***<5***	***<5***	***<5***	***<5***	***<5***	**0**	**0**	**0**	**0**	**0**
Diversity (Native Species)	***3***	***4***	***6***	***7***	***7***	**8**	**18**	**21**	**25**	**23**
Peripheral Upland (Mixed Grassland/Shrubland)										
% Total cover	*35*	*45*	***60***	***70***	*80*	24	42	**66**	**71**	50
% Native Relative	*50*	***60***	*70*	*70*	***70***	43	**61**	50	39	**70**
% Invasive Relative	***<5***	***<5***	***<5***	***<5***	*<5*	**0**	**0**	**0**	**0**	**0**
Diversity (Native Species)	***3***	***4***	***6***	***7***	***7***	**15**	**40**	**36**	**35**	**31**
Salt Marsh										
% Total cover	*30*	***40***	***60***	*70*	***70***	15	**50**	**62**	68	**73**
% Native Relative	***70***	***80***	***80***	***80***	*90*	**94**	**88**	**87**	**91**	88
% Invasive Relative	***<5***	***<5***	***<5***	***<5***	***<5***	**0**	**0**	**0**	**0**	**0**
Diversity (Native Species)	***4***	***6***	***7***	***7***	***8***	**11**	**15**	**30**	**14**	**17**
Transitional/High Salt Marsh										
% Total cover	*30*	***40***	***50***	***60***	***65***	24	**46**	**74**	**72**	**92**
% Native Relative	***50***	***60***	***65***	***70***	***80***	**55**	**86**	**79**	**80**	**77**
% Invasive Relative	***<5***	***<5***	***<5***	***<5***	***<5***	**0**	**0**	**0**	**0**	**0**
Diversity (Native Species)	***8***	***8***	***10***	***12***	***15***	**20**	**22**	**28**	**20**	**25**
Fresh/Brackish Marsh (Seasonal Pond)										
% Total cover	*50*	*50*	*60*	*70*	***80***	8	20	43	39	**96**
% Native Relative	***70***	***70***	***70***	***80***	***80***	**99**	**78**	**99**	**98**	**91**
% Invasive Relative	***<5***	***<5***	***<5***	***<5***	***<5***	**0**	**0**	**0**	**0**	**0**
Diversity (Native Species)	*7*	***7***	***10***	***12***	***14***	6	**7**	**17**	**16**	**16**

	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	**50**
% Native Relative	***70***	***70***	***70***	*80*	*80*	**83**	**84**	**91**	69	60
% Invasive Relative	***<5***	***<5***	***<5***	***<5***	*<5*	**0**	**0**	**0**	**0**	**0**
Diversity (Native Species)	***7***	***7***	***10***	***12***	***15***	**17**	**28**	**33**	**37**	**43**
Sandy Dune Annuals										
% Total cover (variable by season)	*20*	***25***	***30***	***35***	***40***	16	**38**	**86**	**56**	**44**
% Native Relative	*50*	***60***	*70*	*70*	*80*	35	**87**	65	17	75
% Invasive Relative	***<5***	***<5***	***<5***	***<5***	***<5***	**0**	**0**	**0**	**0**	**0**
Diversity (Native Species)	*3*	***3***	***4***	*5*	***5***	2	**7**	**5**	3	**6**
Coastal Sage Scrub/Chaparral Mosaic										
% Total cover	*30*	*40*	***50***	*60*	***65***	30	7	**66**	**79**	**77**
% Native Relative	*50*	*60*	***65***	*70*	***80***	0	43	**83**	59	**74**
% Invasive Relative	***<5***	***<5***	***<5***	***<5***	***<5***	**0**	**0**	**0**	**0**	**0**
Diversity (Native Species)	*8*	*8*	***10***	***12***	***15***	0	3	**16**	**16**	**24**
Riparian										
% Total cover	*50*	***50***	***60***	***70***	***80***	13	**53**	**90**	**88**	**81**
% Native Relative	***70***	***70***	***70***	***80***	***80***	**100**	**81**	**88**	**85**	**100**
% Invasive Relative	***<5***	***<5***	***<5***	***<5***	***<5***	**0**	**0**	**0**	**0**	**0**
Diversity (Native Species)	*7*	*7*	***10***	***12***	***14***	4	6	**12**	**12**	**12**

Tree Monitoring Data

12 Coast live oak and 3 Western Sycamore were planted in 2022 around the new Outdoor classroom and parking lot area. Monitoring the height, diameter at breast height (DBH), and vigor of the 243 trees that were planted in years 1-4 of the restoration project continued. Fifteen narrowleaf willows (*Salix exigua*) originally planted in the first year of the project were excluded from this study beginning in 2021 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.

No trees were found to be dead in year 5 monitoring (vigor rating of 4). Five trees were found to be dead in year 4. Three trees were found to be dead in year 3 monitoring: 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 trees were found dead in year 2 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. This brings our overall success rate of tree survival for the 4 years of monitoring to 97.5%.

Overall, every year of monitoring had an increase in growth for all six species. A comparison of the year four and year five data for trees planted shows an increase in overall mean height by 18 inches-from an average of 97 to 115 inches. There was also an increase in mean DBH from 1 to 2 inches. The mean overall vigor rating stayed relatively the same. The species that exhibited the greatest increase in mean height in year five is the white alder (*Alnus rhombifolia*) (Figure 18) which had a mean height increase from year four to year five of 34 inches. The greatest average tree diameter increase was seen in Coast Live oak which increased an average of 1.3 inches from year four to year five. Similar growth patterns were observed in every year of monitoring.

The vigor of trees planted at the Whittier location is the most robust (1.02). The vigor at all sites is quite good with the highest being an average of 1.13 at the mesa location. White alder at Whittier grows at an astonishing rate compared to other species and locations with an average height of 24 feet. The white alder are significantly taller than other species and also have one of the largest diameters compared to other tree species (Figure 19).

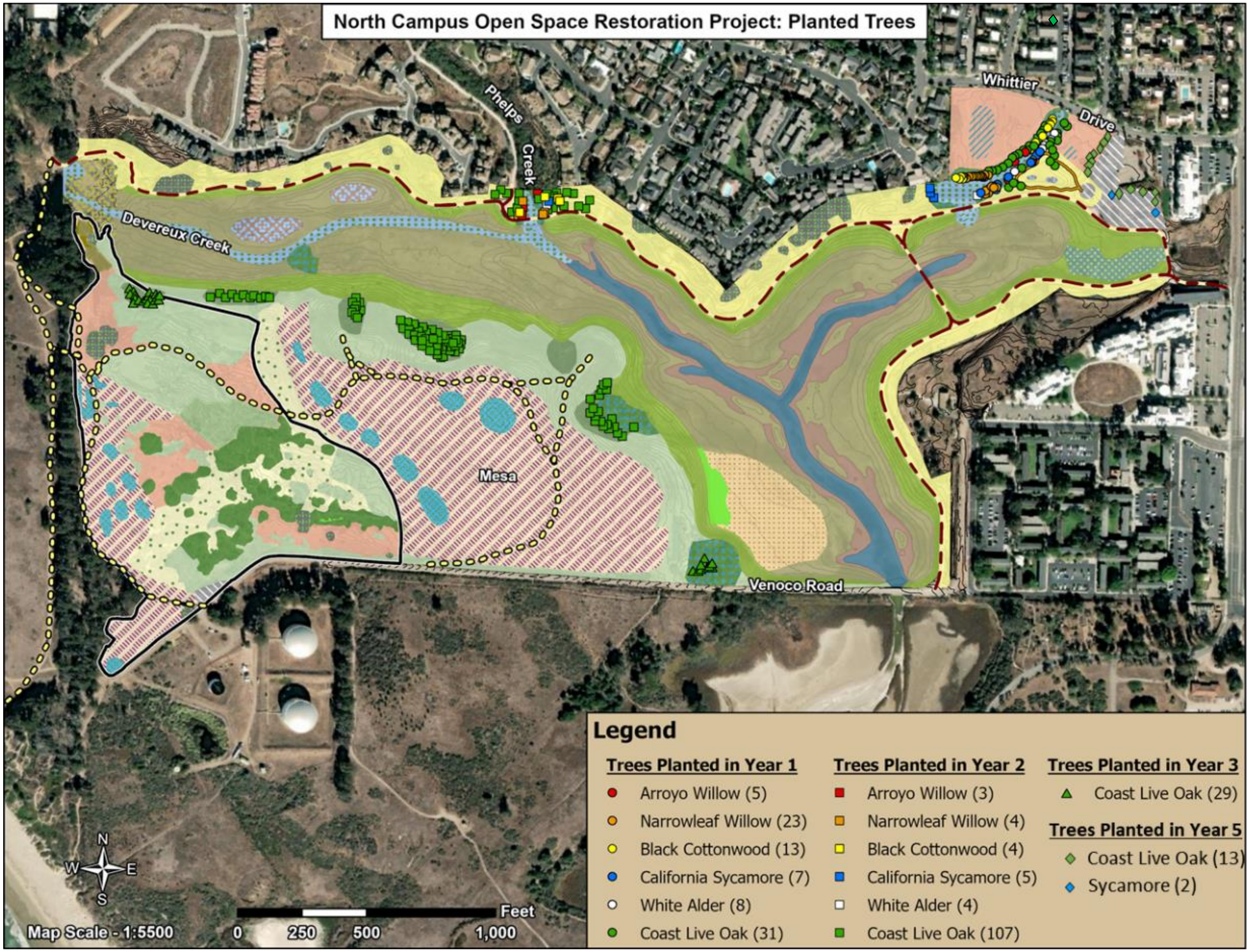


Figure 17. Map of trees planted during the first three years of the North Campus Open Space restoration project. See Figure 1 for a legend of the habitats/plant communities and trails.

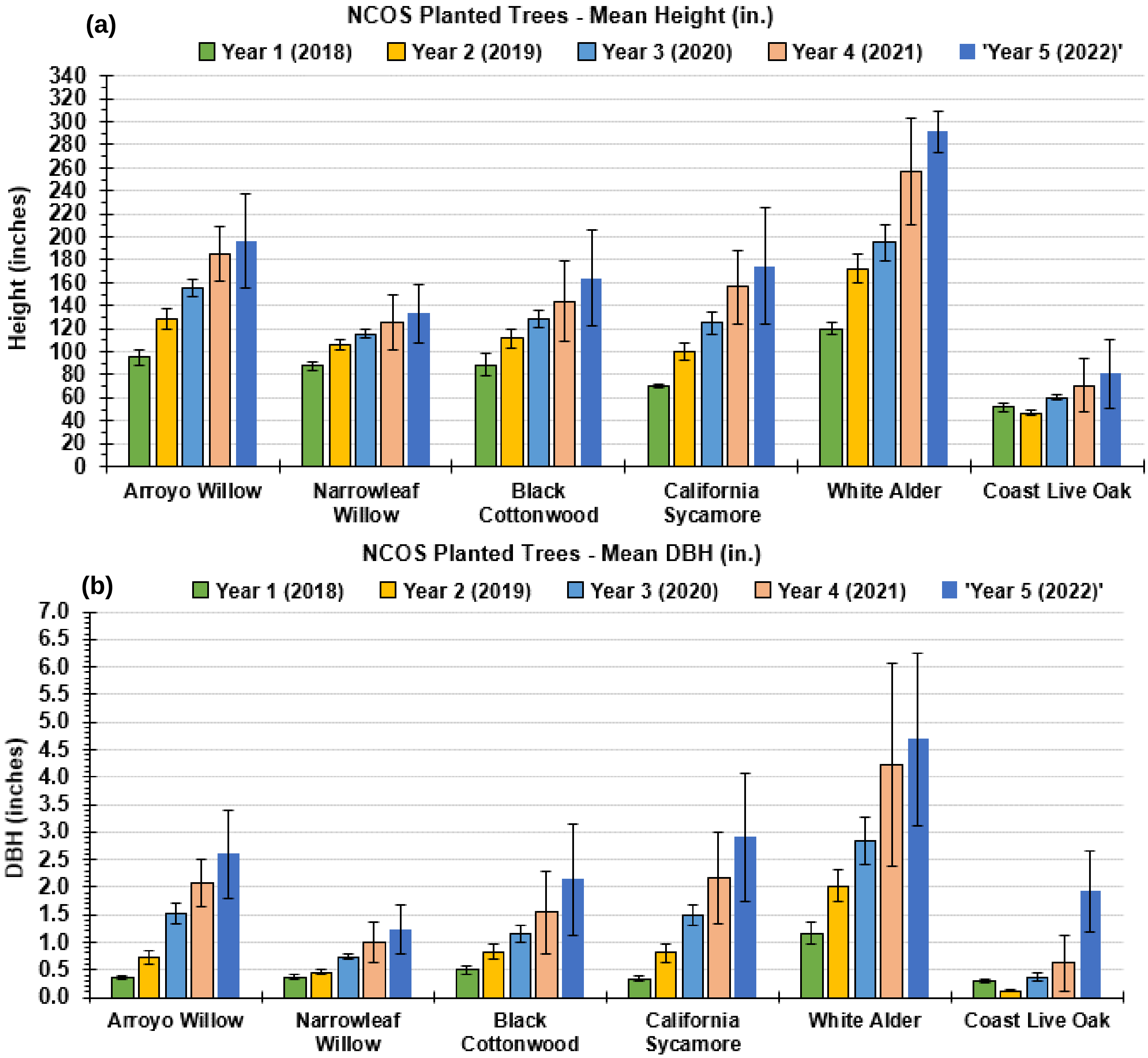


Figure 18. Bar charts of (a) the mean height (inches) and (b) mean diameter at breast height (inches) of six tree species planted during the first and second years of the North Campus Open Space restoration project. Error bars are +/- one standard deviation of the mean.

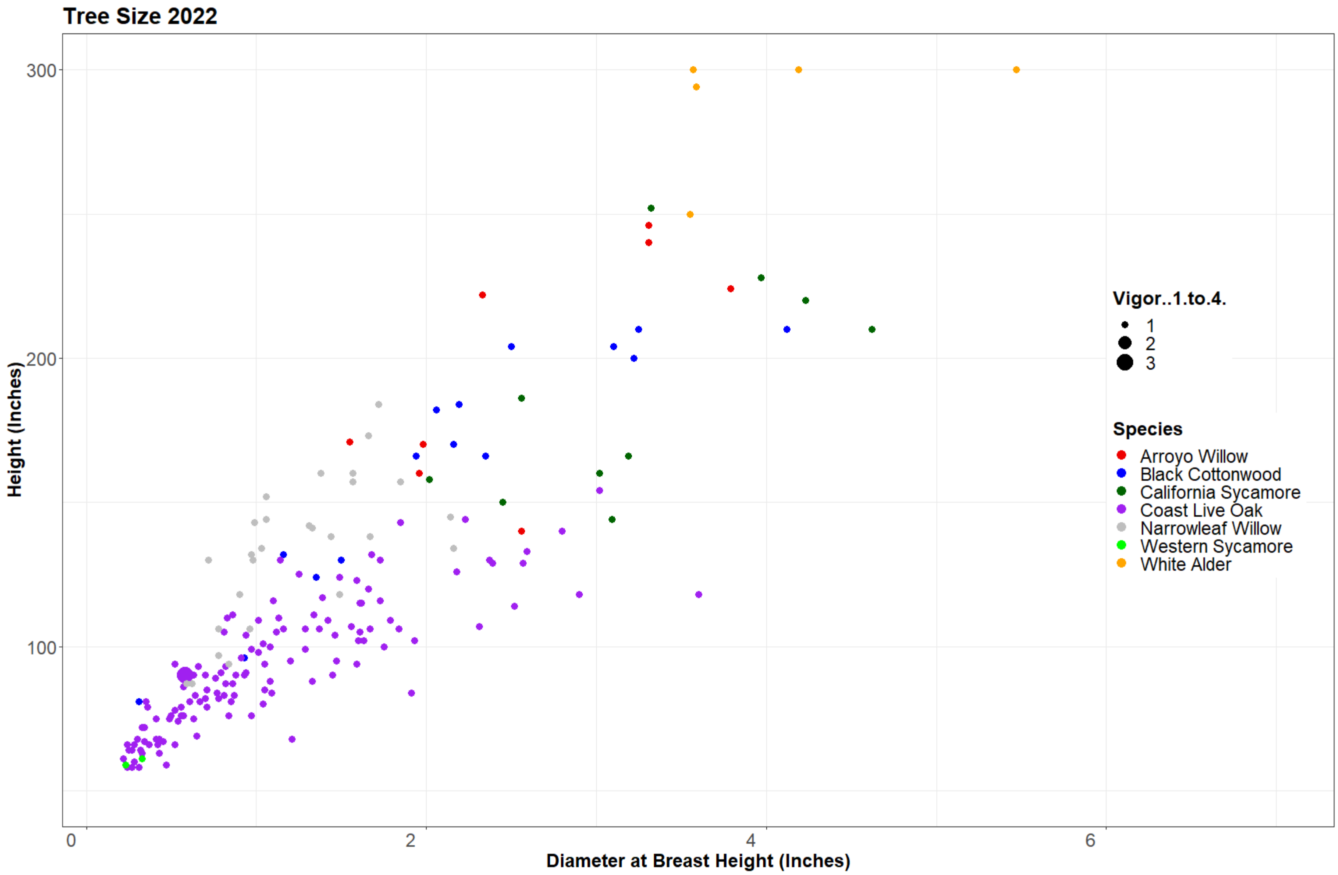


Figure 19. Scatter plot of tree height and diameter. This figure represents all living planted trees that are part of the study within the NCOS property in year 5. The size of point represents the vigor or health of the tree, 1 represents the healthiest tree.

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

The Cheadle Center 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.

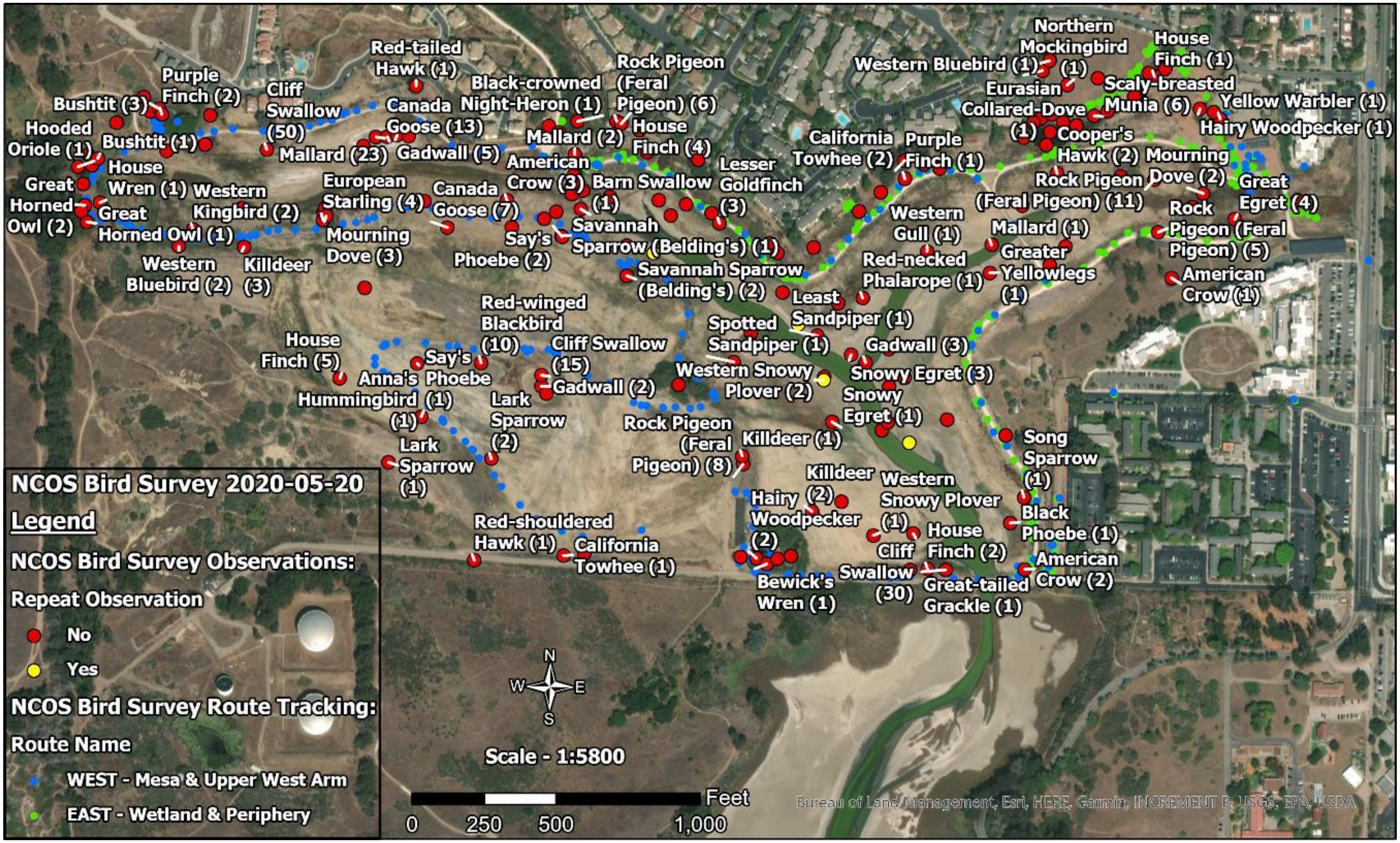


Figure 20. Map of observation data and routes from a bird survey of NCOS conducted on May 20, 2020. Using the ESRI ArcGIS Collector app on tablets, the observation data is manually entered by a member of each team and the route tracking is automatically recorded every 30 seconds. Many, but not all of 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 addition, we report the total number of species observed and the percent of total count by guild for each of the five years of survey data collected from September 2017 through August 2022.

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. Figure 22, represents changes in the percent of total count 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 431 in year one to 570 in year two, and then to 731 in year three (September 2019 – August 2020) but dropped to 470 in year 4 and rose back up to 563 in year 5. The increasing trend is primarily driven by large annual increase in the mean counts of insectivore guilds (Figure 21). The number of bird sightings increased in every group from year 4 to year 5 monitoring. There was a particularly high increase in terrestrial insectivores. There were overall more than 300 more insectivores recorded in 2022 than in 2021. There was not one specific species that caused this increase, but rather a slight increase in many insectivore species. Other species that had a notable increase include Anna's hummingbird and the California Towhee.

The total number of species observed increased from 104 in year one to 129 in year two, 128 species in year three, 115 species in year four and 122 in year 5. We did not observe any new species in year 5. Collectively, 169 species have been recorded over the five years of surveys. This covers 71 percent of the 239 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 Bobolinks. Trends in the total number of species and the percent of total observations per guild are similar to the mean monthly counts, though they show a smaller degree of change between years (Figures 21 and 22).

Discussion of Slough Water Level Influence on Bird Trends

The year 5 estuary water level was higher than year 4 in all months except January due to the December breach in year 5. 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 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 Shovelers.

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 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. 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). Year 5 returned to a mid-range water level- with an early breach in December the slough was the lowest of all survey years in January, but it did fill back up before the summer season. The bird count was also mid-range compared to other survey years. 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. We 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 Cheadle Center website (www.ccber.ucsb.edu/news-events/2nd-annual-ncos-vs-copr-bird-survey-roundup).

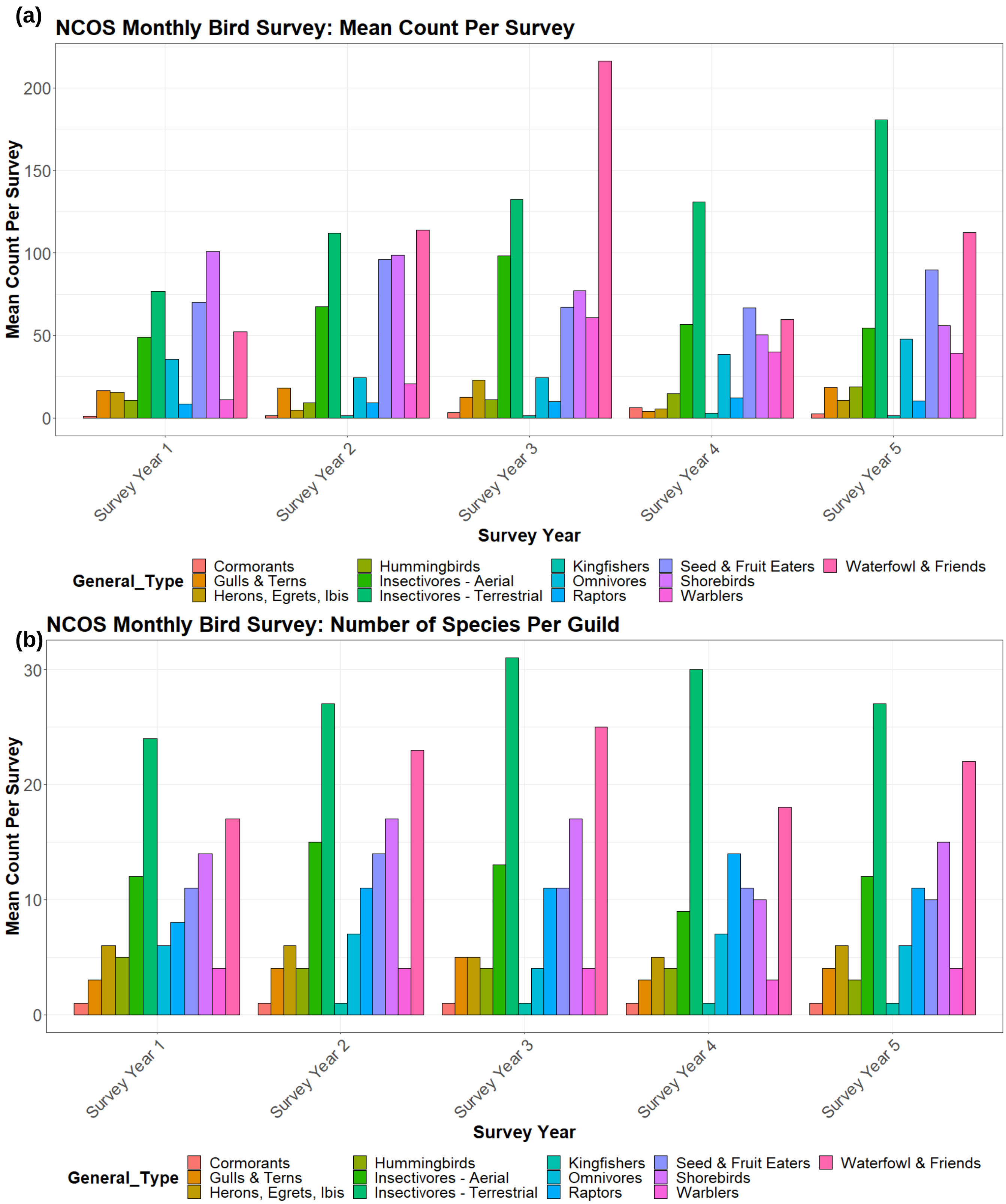


Figure 21. (a) Mean of counts per survey of birds in 13 guilds observed in each year (September through August) of monthly surveys at NCOS (2017 – 2022). (b) Total number of species observed in 13 guilds in each year of monthly bird surveys at NCOS.

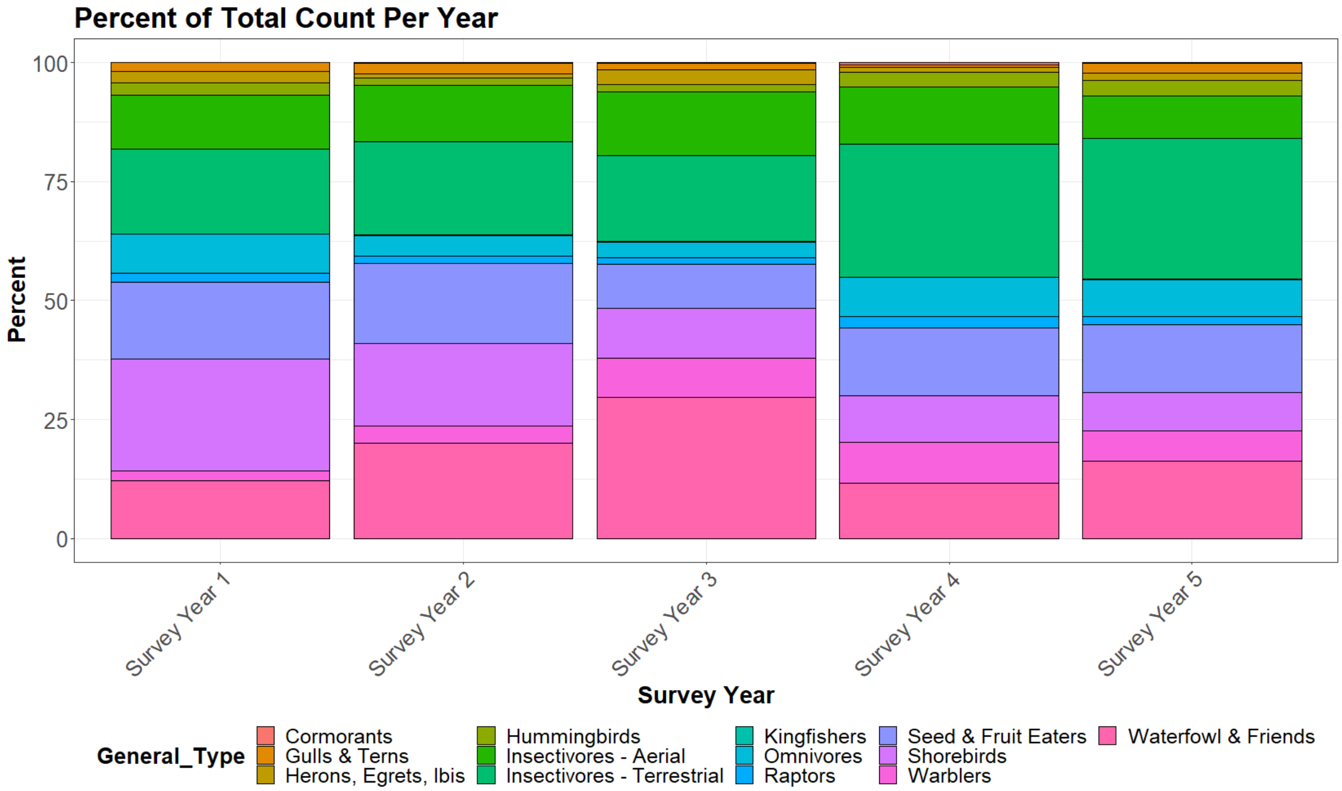


Figure 22. Percent of total yearly count by guild (September through August) of monthly bird surveys at NCOS (2017-2022).

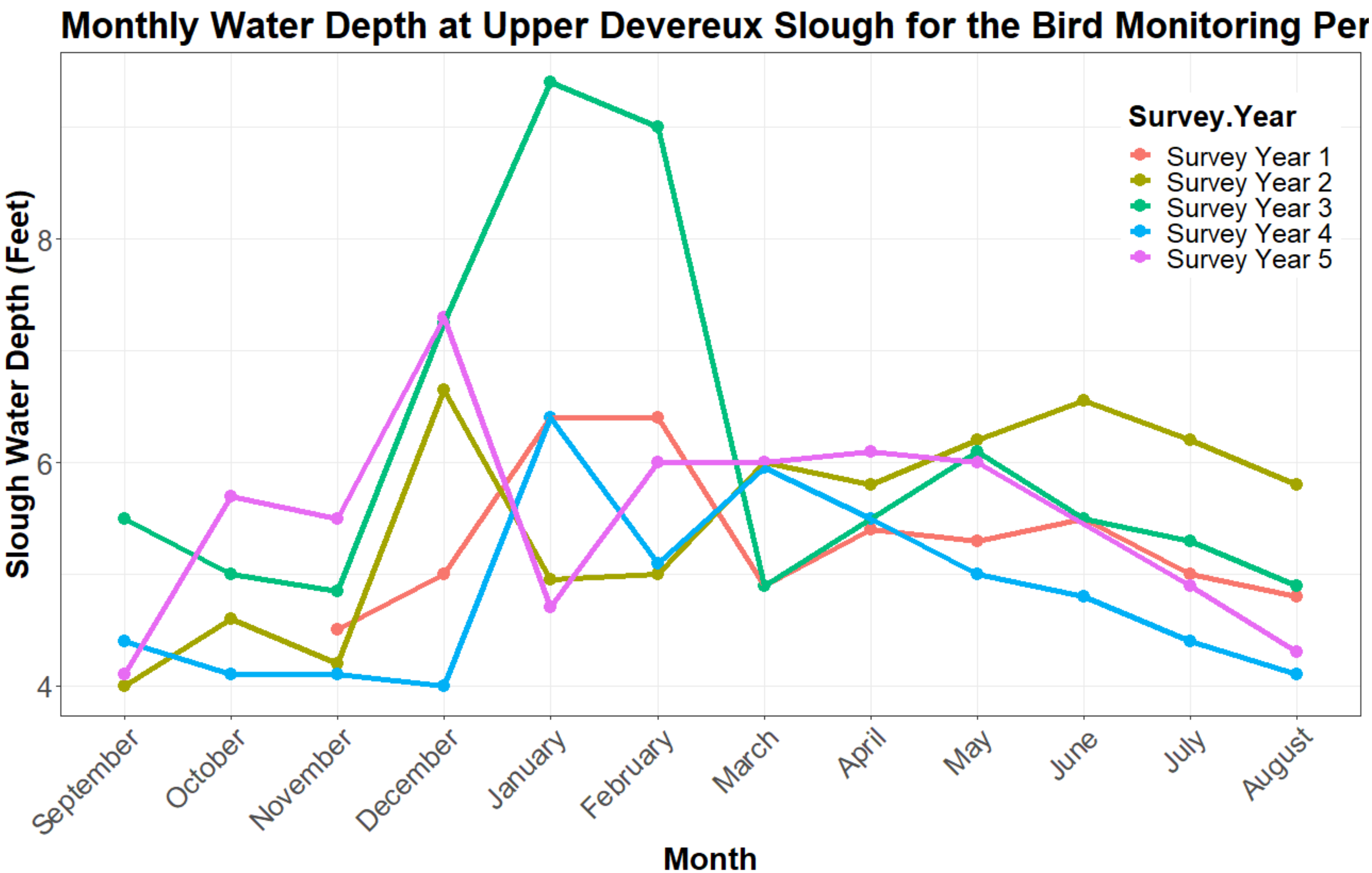


Figure 23. Line graph comparing the water surface elevation (in feet) of the upper Devereux Slough for each year (September through August) of monthly bird surveys at NCOS. Year 1 (2017-18), Year 2 (2018-19), Year 3 (2019-20), Year 4 (2020-21) and Year 5 (2021-22).

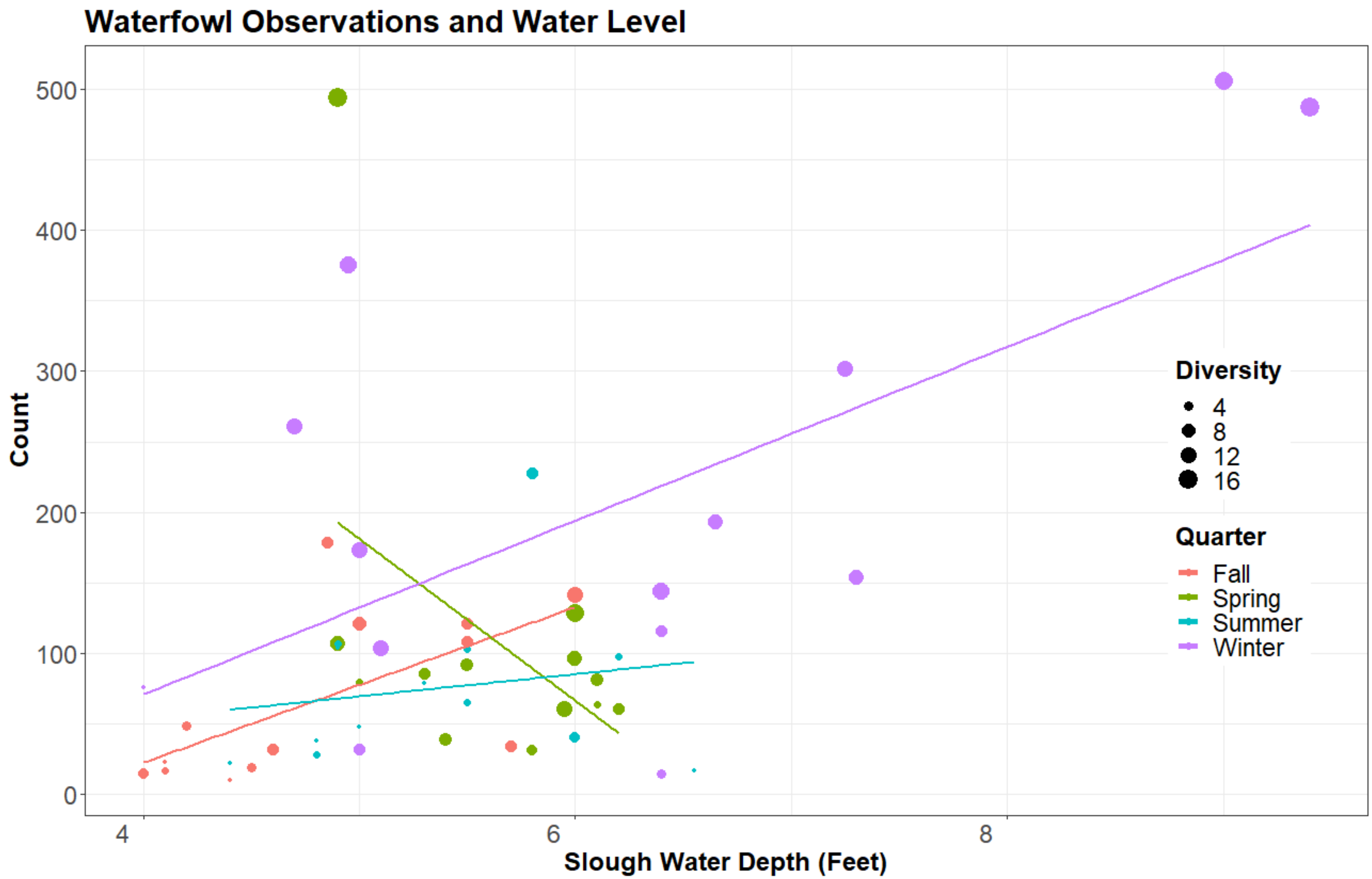


Figure 24. Number of waterfowl observed in monthly surveys from 2017-2022 and a linear trend line for each season. The size of each point represents the number of species seen in that survey. Season has a strong effect on observations because of migration patterns.

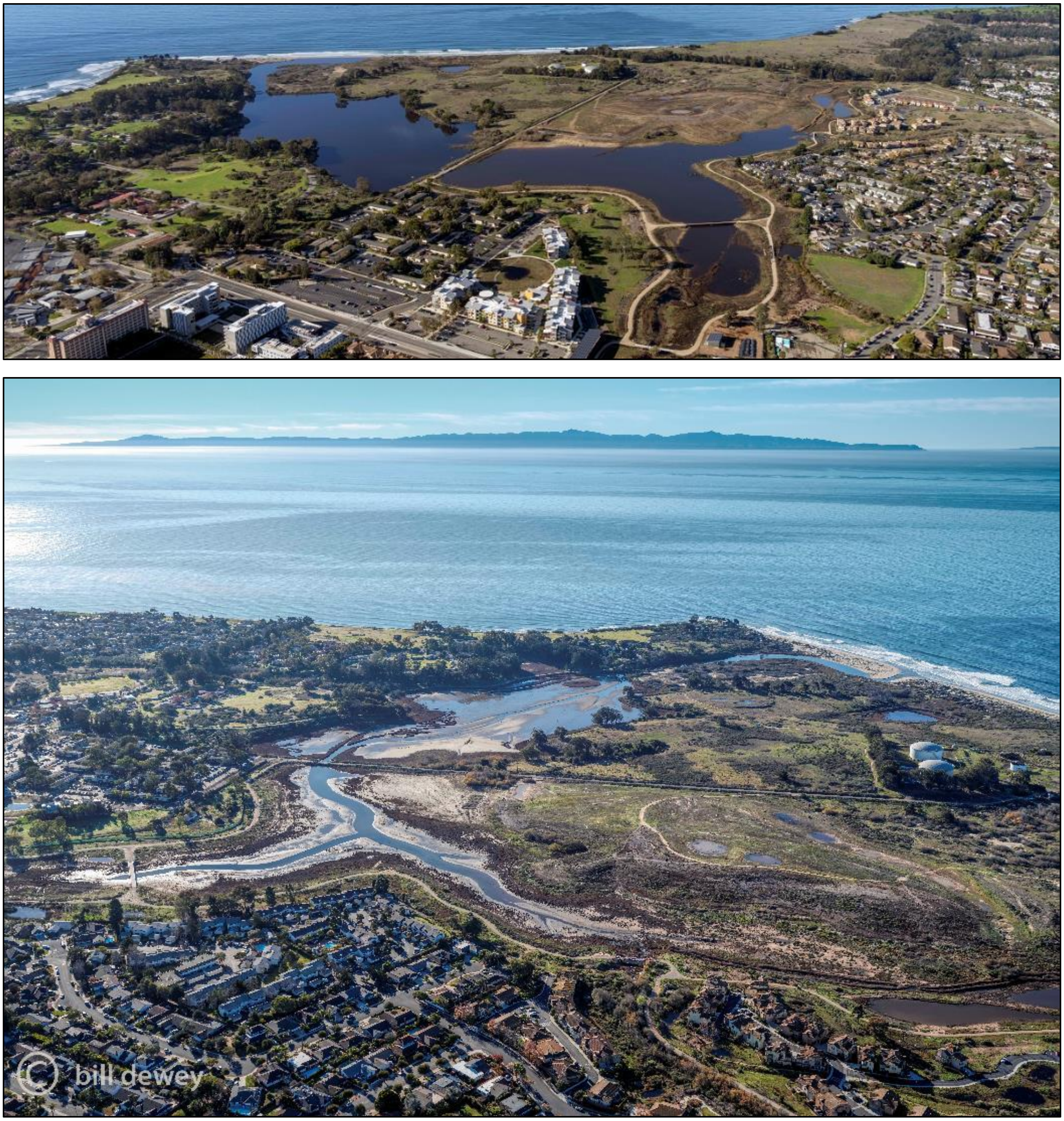


Figure 25. Aerial photos of North Campus Open Space by Bill Dewey. Top: December 2019 showing the high-water level when the Slough is full; Bottom: January 2022 showing the low water level after the slough has opened, Credit: Bill Dewey

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 and intertidal mudflats 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 in the perennial grassland.

Western Snowy Plovers 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 in 2021 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. In 2022 North Campus open space had its first observed successful breeding by two pairs with 2 chicks apiece that fledged. The full news article on snowy plover can be found here.

Belding's Savannah Sparrow have been recorded in each year of surveys, particularly in the spring and summer breeding seasons. 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 cryptic species.

50 habitat features called 'hibernaculum' 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. Burrowing owls have been observed on site for most of the overwintering period (October – March) in all years, however in year 5, 2021-22, the newly arrived burrowing owl was harassed by a peregrine falcon and disappeared soon after that. In October of 2020, six artificial burrows were installed specifically for burrowing owl on the mesa, and two owls were documented regularly using these features in the year three survey and three owls in the fourth year of surveying.

A UCSB undergraduate student dissected owl pellets, and documented that burrowing owls at NCOS mainly consume insects such as earwigs, ground beetles, woodlice, and wasps while literature shows that burrowing owls at other locations consume more small vertebrates such as mice. Our small mammal study shows that there is not a large population of mice at NCOS. A full list of species found in NCOS burrowing owl pellets can be seen in Table 4.

Table 4. Total number of individuals found in 32 burrowing owl pellets collected between 2020 and 2021, by number found across all pellets and by number of pellets containing this species. (Kyra Sullivan, 2022)

Species	Common Name	Total Number of Individuals Across All Pellets	Number of Pellets Present
Reithrodontomys megalotis (Baird, 1857)	Western harvest mouse	16	10
Mus musculus (Linmaeus, 1758)	House mouse	4	4
Thomomys bottae (Eydoux and Gervais, 1836)	Botta's pocket gopher	1	1
Peromyscus sp. (Gloger, 1841) (unconfirmed)	Deer mouse	1	1
Forficula auricularia (Linnaeus, 1758)	European earwig	436	32
Vespuls sp. (Panzer, 1799)	Social wasp	32	4
Armadillidium sp. (Brandt, 1833)	Woodlouse	329	11
nr. Calathus sp. (Boneellt, 1810)	Ground beetle	317	27

Figure 26. Top Left image: Western snowy plover chick on the slough shore at NCOS in July 2022 (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 five years of data, we now have observations of breeding behavior recorded for 30 species, including observations of breeding behavior of 2 new species in 2022. There is an average of 12 species and 22 breeding behavior observations per year with a total of 112 breeding behavior observation during surveys (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 similar to the monthly bird survey data, with a total of 39 species exhibiting breeding behavior at the site since 2017 at an average of 15 species and 30 observations per year. 2022 observations show 17 species and 29 observations of breeding at NCOS. This database does include some of the records from our monthly bird surveys (Table A3.2 in Appendix 3). Overall, 160 observations of bird breeding have been recorded at North Campus open space since 2017

Special Status Aquatic Species

To fulfill project grant and permit monitoring requirements, and for general interest, the Cheadle Center 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 and 2022 the survey was led by permitted biologist Hannah Donaghe (federal permit TE14532C-1, state permit S-201000002-20167-001), with the assistance of Cheadle Center 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, 2020-22) 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 2022 survey is provided in Appendix 4 of this report. A parallel EDNA survey from 2021-22 also found no evidence of tidewater goby in the slough system (Lafferty, K. pers com 2022).

Outside of the surveys described above, Cheadle Center 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 Cheadle Center managed areas. This list is available on the Cheadle Center Symbiota database here.

Aquatic Macroinvertebrate and Zooplankton Study

A study comparing the aquatic macroinvertebrate species diversity and abundance 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. This is a long-term project and is expected to be continued at least until 2023. Several undergraduate interns, volunteers and student leaders 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. Water samples were collected for E-DNA analysis in 2022 to compare with hand sorted samples. All E-DNA is processed by Jonah Ventures. We found that macroinvertebrates shed much less DNA than other organisms so few replicates of invertebrate eDNA came back from the lab to compare to hand sorted samples. We did get interesting results from algae and fish DNA that can be seen here.

The hand sampling conducted in 2018 found up to 13 taxa at NCOS dominated by four types overall (Copepoda, Corixidae, Ostracoda, and Cladocera); these species have the ability to adapt to changes in salinity and dissolved oxygen. In addition, four taxa have 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. Students found that salinity has a greater impact on species than site does (Figure 28.). A detailed report on the analysis of aquatic invertebrates collected in 2018/2019 is available on eScholarship (escholarship.org/uc/item/59c872mm). A poster presentation on the findings can be found at https://escholarship.org/uc/item/64f0w6hx.

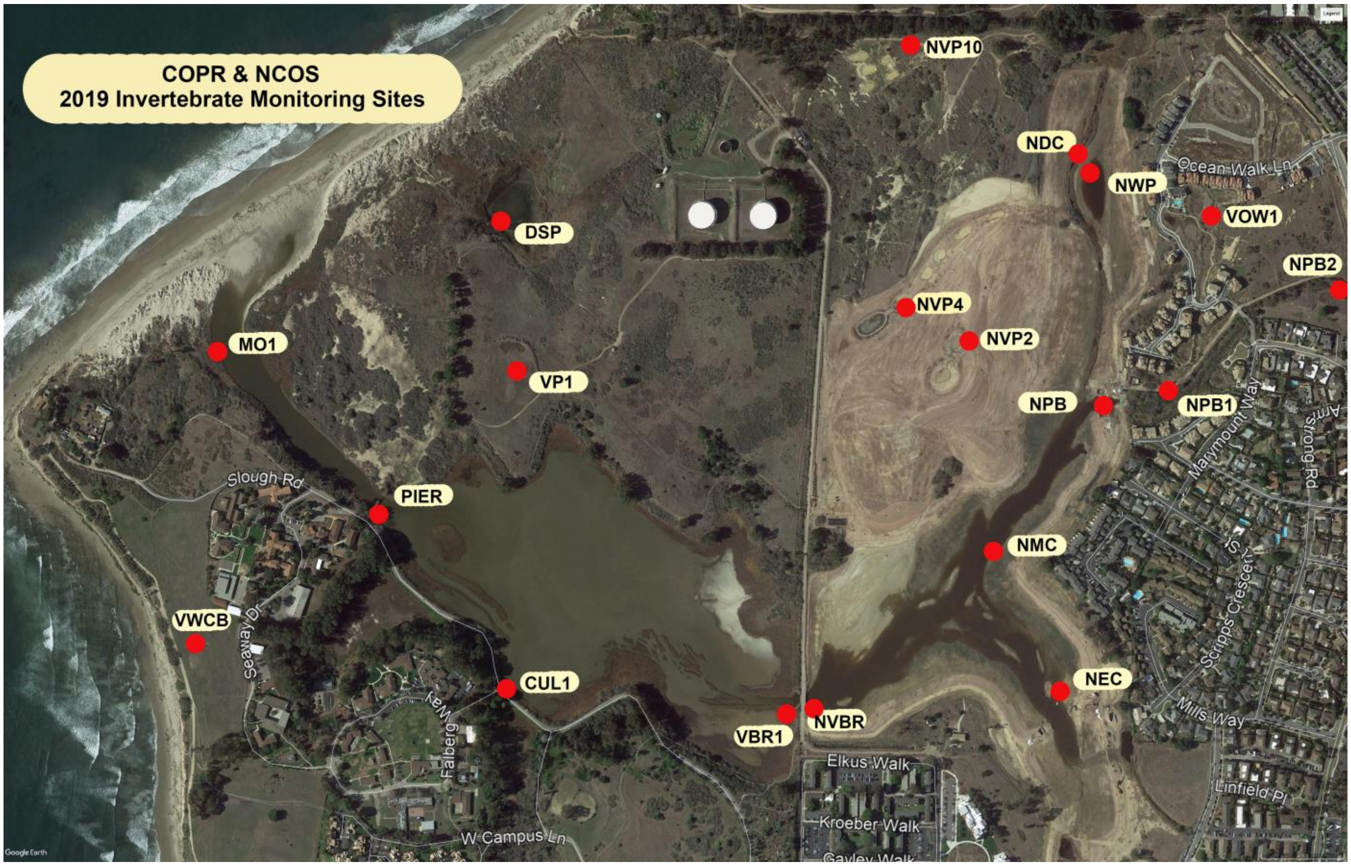


Figure 28. Map of Aquatic Invertebrate Sampling Locations

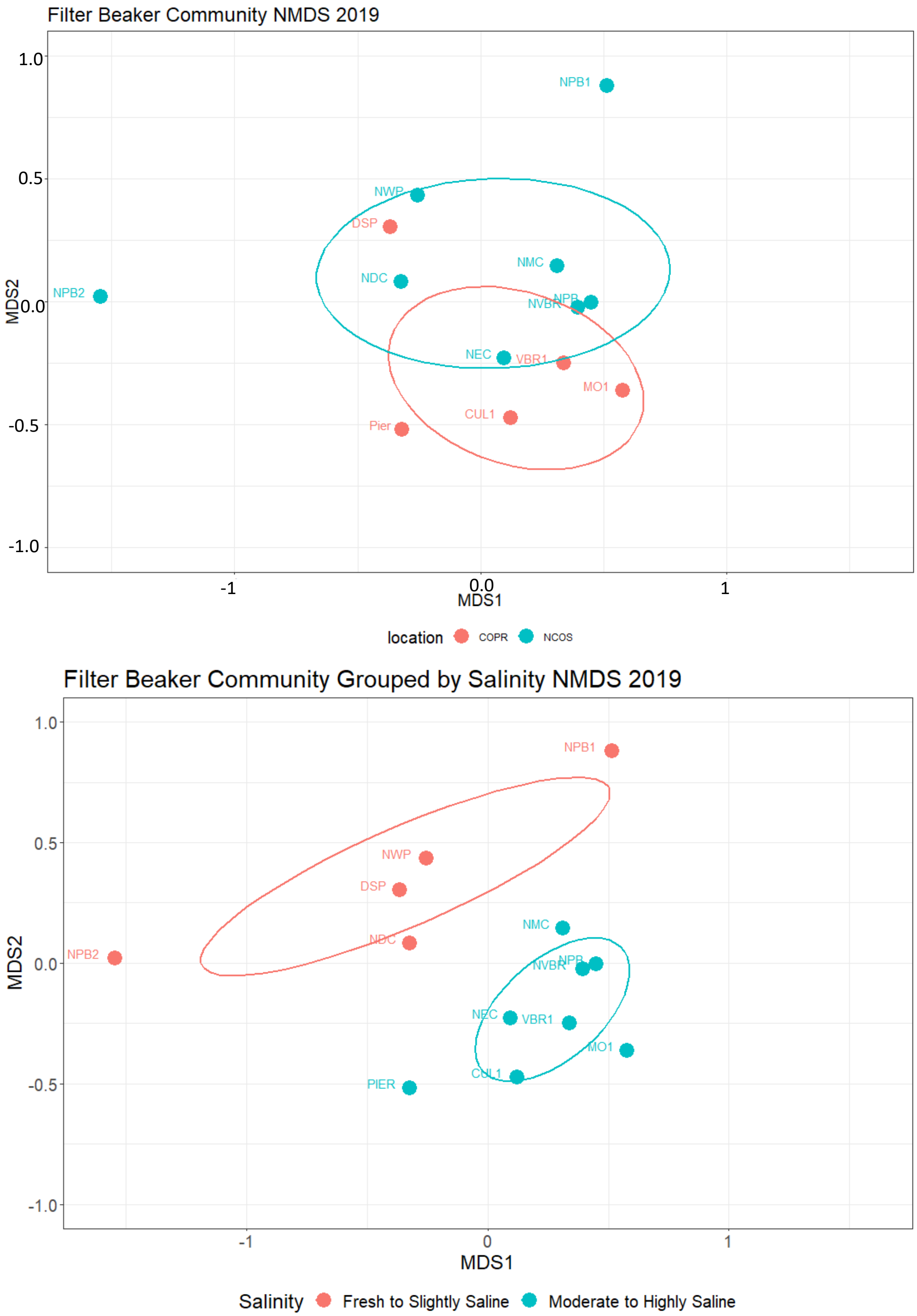


Figure 29. Statistical analysis (NMDS) on aquatic invertebrate species based on site location and salinity (see location map- Figure 28).

We hope to expand on this study in the 2022 academic year by comparing substrate types such as algae, leaf litter, clay soils and sandy soils.

Small Rodents, and Reptiles

Beginning in November 2019, the Cheadle Center 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 2022 survey indicate that the same mice species are appearing in the traps. In one week of trapping 12 deer mice and 3 harvest mice were captured.

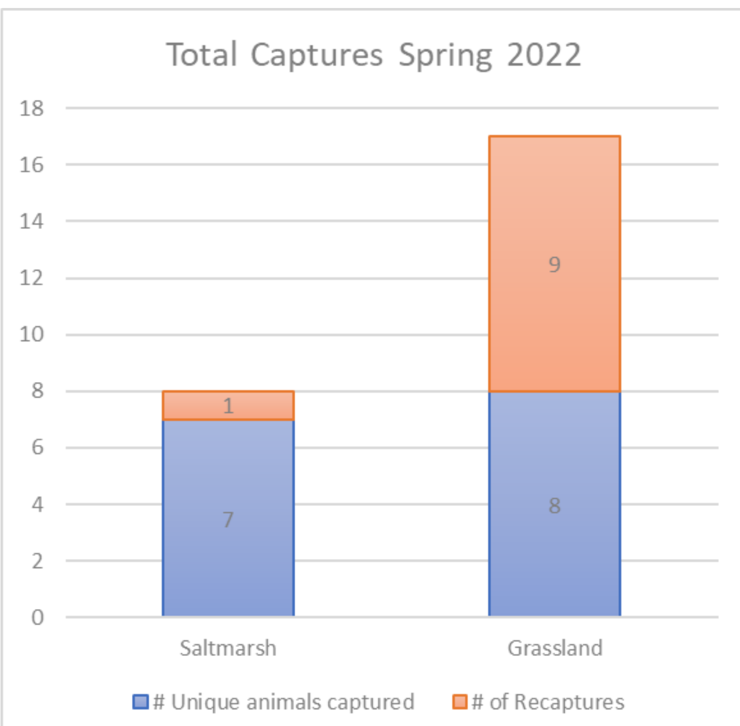


Figure 30. Small Rodent captures in three grids of 20 Sherman Live traps for four nights in a row in each habitat for 2022 monitoring.

In October 2020, we established and have continued 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 on a weekly basis. 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 presence in a variety of habitats with different histories of disturbance and restoration. The student leader of this project presented the results at the Joint Meeting of Ichthyologists and Herpetologists in July 2022. The poster can be found here. Results, shown in figure 28 reflect an increase in the frequency of finding snakes and frogs and alligator lizards but a decrease in salamanders and skinks and little change in the abundance western fence lizards.

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.

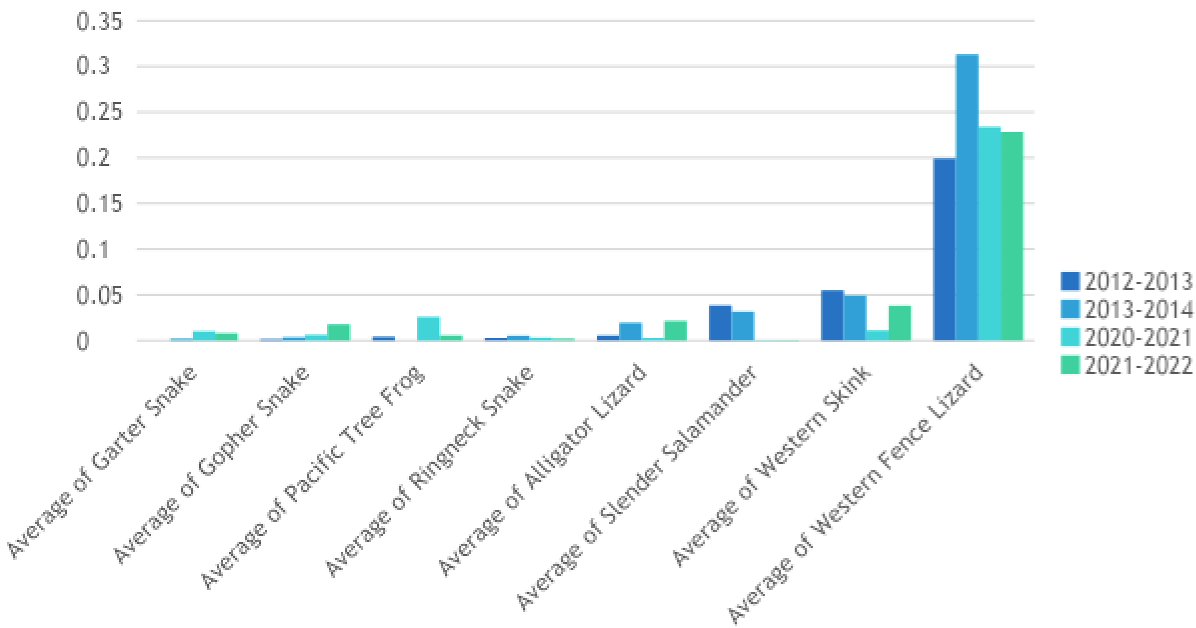


Figure 31. (a) Herp populations before and after Restoration.
(b) Herp populations vary between restoration sites. Source: Alistair Dobson Full Poster:
https://escholarship.org/uc/item/869559br

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. Water quantity and quality is also correlated with our other monitoring efforts as well such as bird observations, vegetation success and small mammal counts.

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,
- Nutrient and suspended solid concentration and flux in storm water entering and flowing out of Devereux Slough.

The hydrology of Devereux slough has varied each year. 2019 was a wet year with many scattered small storms, 2020 was an average year in terms of rainfall quantity with mostly medium sized storms. 2021 was very dry- producing less than half of the average rainfall and one large storm was responsible for more than 60% of the year’s water. In 2021 the slough breached in January and there was no subsequent water to fill the slough. 2022 was also dry, but not as extreme as 2021. The majority of rainfall occurred early in the season with many scattered storms in December resulting in an early breach. There was enough late season rain that the slough did not dry up until mid-summer.

Vernal pool overview
The vernal pools at NCOS held water for more time in 2019 and 2020 than in 2021 and 2022. This pattern is partially, if not fully, due to the rainfall patterns, the vernal pools could also be experiencing increased drainage. Vernal pools 1 and 2 at NCOS have continued to hold water for approximately 100 days or more. The 100 day threshold is often used to mark the success of a vernal pool. Other vernal pools on site dry out much faster, possibly due to more permeable soils or rodent activity. Vernal pools need compact clay-like soils along with sufficient rain to prevent water from soaking into the ground. Although some vernal pools dried out more quickly, we have documented a large population of aquatic invertebrates and native vernal pool plants in the pools.

Ground water overview
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. Depth to ground water and salinity increase slowly after the last major rainfall event of the water year (Figures 43-45). This is similar to patterns seen in surface water.

Surface water overview
The hydrology data is important for documenting the increased water holding capacity of Devereux

Slough, and the timing, frequency, and duration of tidal flux. There is a sand berm at the mouth of the slough that typically breaches once a year causing Devereux slough to become tidal. In the 2022 water year the persistent rain in December caused the berm to breach and Devereux Slough remained tidal for about 17 days. The tidal patterns seen in 2022 were similar to that of 2021. 2019 and 2020 were different; once the slough broke and became tidal it remained tidal for about 5 days during high tide and then no longer showed 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 addition to monitoring water levels, the Cheadle Center is collecting flow rates and nutrient concentrations 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 be able to predict nutrient exports for a known storm intensity. The surface water level and flow rate monitoring methods and data are described in the following two sections.

Surface Water - Methods

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

- Devereux Creek
- Phelps Creeks
- Whittier Channel Stormdrain
- Whittier Pond
- Eastern arm of the restored slough
- Venoco Road bridge
- Lower Slough 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.

Table 5. 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 32.

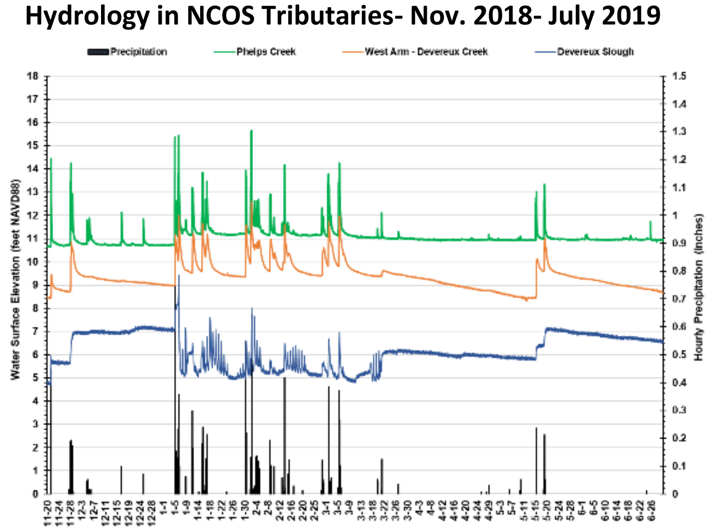
Deployment Location	Logger Elevation (ft. NAVD88)
Devereux Slough Pier (YSI EXO1 sonde)	Water quality sensors: 2.25, depth sensor: 3.4
East Arm Trail Bridge	4.51
Phelps Creek - Marymount Bridge	9.99
Venoco Bridge - north side	2.96
West Arm - Devereux Creek	8.41
Whittier Storm drain	10.41
Whittier Pond	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). Some of our older leveloggers had issues in recording data due to age and technical difficulties. If there is a gap in the figures below it is due to errors in the device.

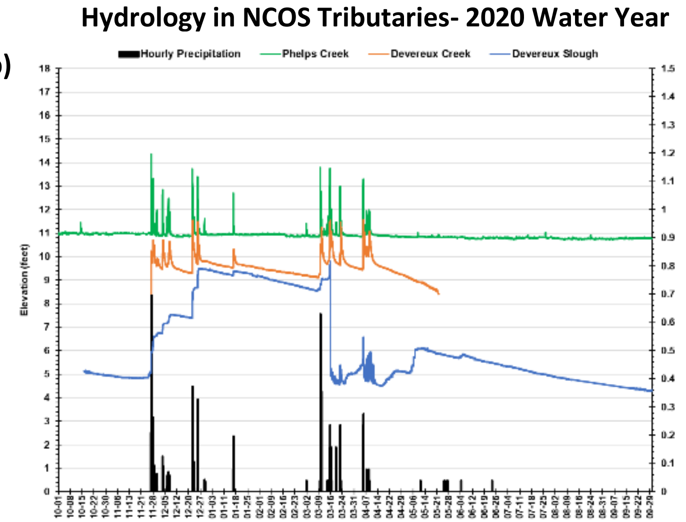
Elevation profiles of the beach berm at the mouth of the slough are measured at least twice per year. This contributes to the development of a long-term database that documents how the wetland functions under wet and dry conditions and improves our understanding of breaching and tidal patterns as well 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 32. 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.

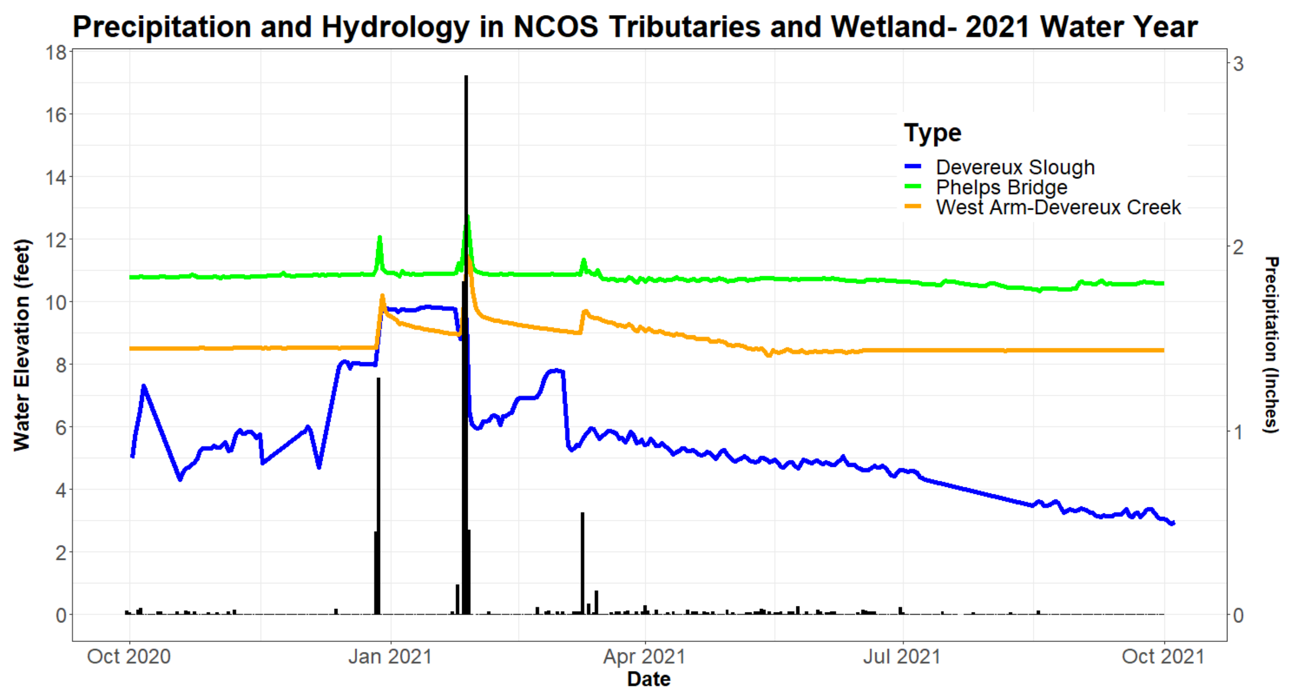
(a)


Hydrology in NCOS Tributaries- Nov. 2018- July 2019
Precipitation
Phelps Creek
West Arm - Devereux Creek
Devereux Slough
Water Surface Elevation (feet NAVD88)
Hourly Precipitation (inches)

(b)


Hydrology in NCOS Tributaries- 2020 Water Year
Hourly Precipitation
Phelps Creek
Devereux Creek
Devereux Slough
Elevation (feet)
Precipitation (inches)

(c)


Precipitation and Hydrology in NCOS Tributaries and Wetland- 2021 Water Year
Type
Devereux Slough
Phelps Bridge
West Arm-Devereux Creek
Water Elevation (feet)
Precipitation (Inches)
Oct 2020
Jan 2021
Apr 2021
Jul 2021
Oct 2021
Date

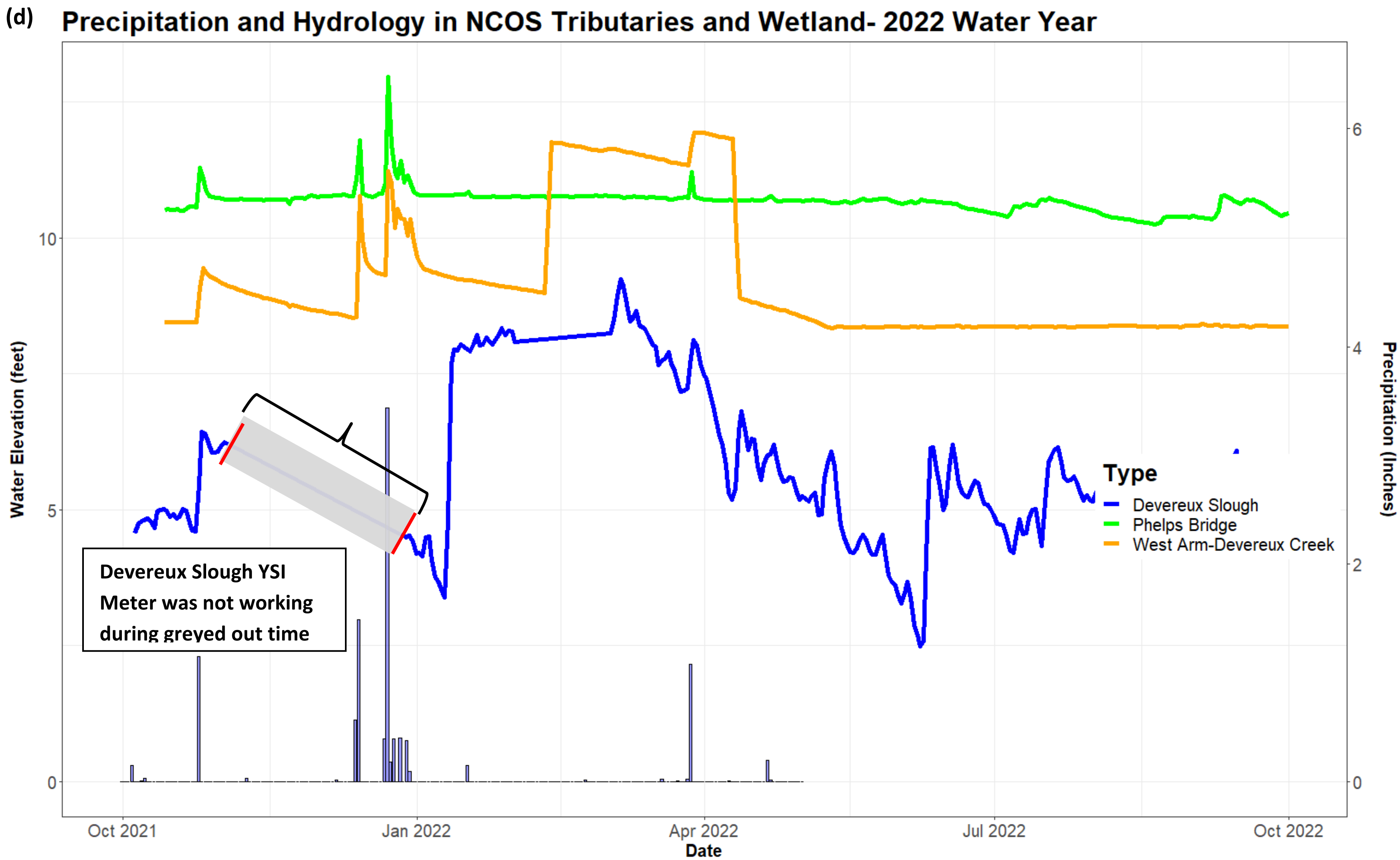
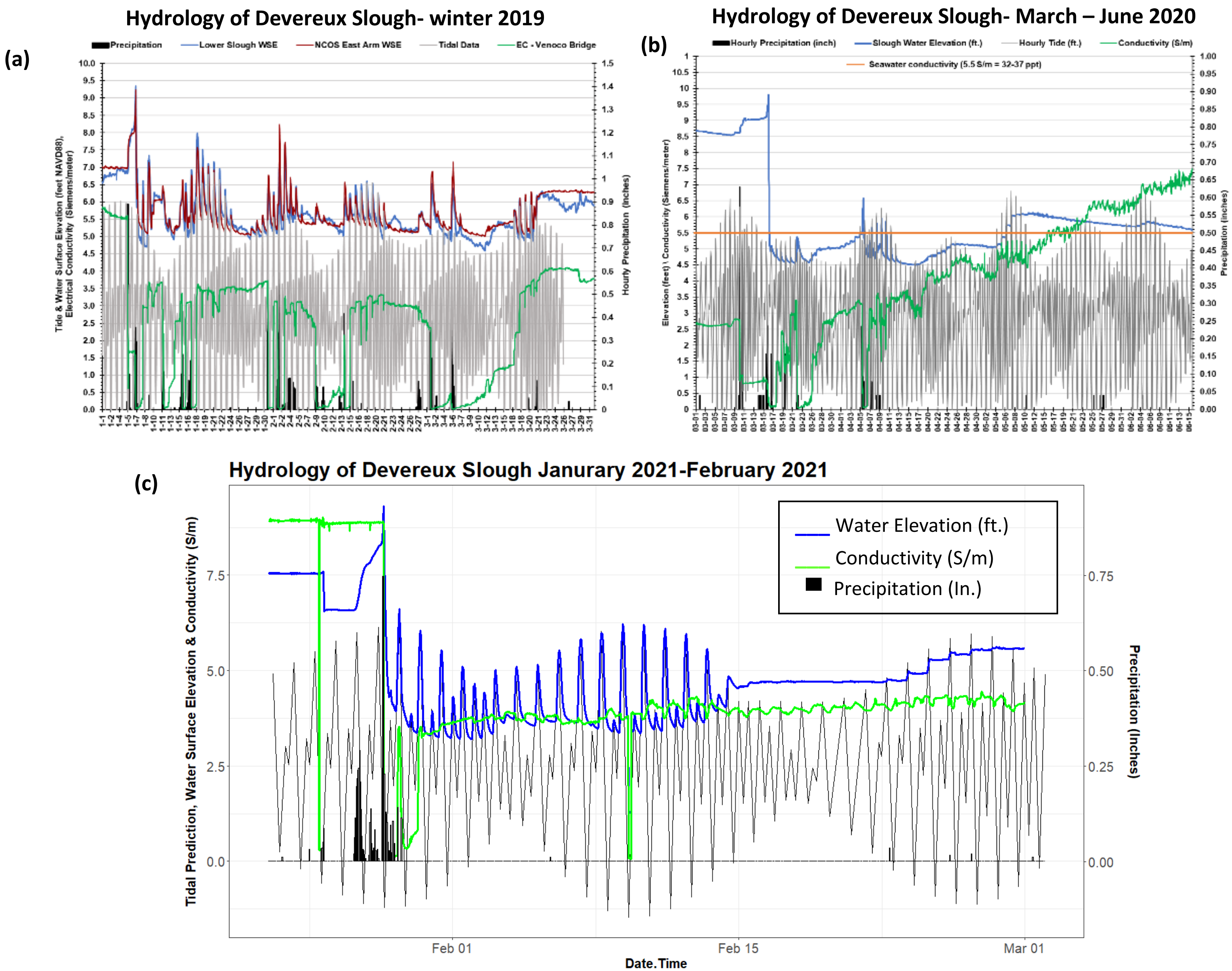


Figure 33. Water elevation collected from leveloggers located at 2 NCOS tributaries and the Wetland (Devereux Slough). Rainfall from NOAA for Water year (a) 2019 (b) 2020 (c) 2021 and (d) 2022.



(a)
Hydrology of Devereux Slough- winter 2019
Precipitation
Lower Slough WSE
NCOS East Arm WSE
Tidal Data
EC - Venoco Bridge
Tide & Water Surface Elevation (feet NAVD88), Electrical Conductivity (Siemens/meter)
Hourly Precipitation (inches)
(b)
Hydrology of Devereux Slough- March – June 2020
Hourly Precipitation (inch)
Slough Water Elevation (ft.)
Hourly Tide (ft.)
Conductivity (S/m)
Seawater conductivity (5.5 S/m = 32-37 ppt)
Elevation (feet) \ Conductivity (Siemens/meter)
Precipitation (inches)
(c)
Hydrology of Devereux Slough Janurary 2021-February 2021
Water Elevation (ft.)
Conductivity (S/m)
Precipitation (In.)
Tidal Prediction, Water Surface Elevation & Conductivity (S/m)
Precipitation (Inches)
Feb 01
Feb 15
Mar 01
Date.Time

(d)

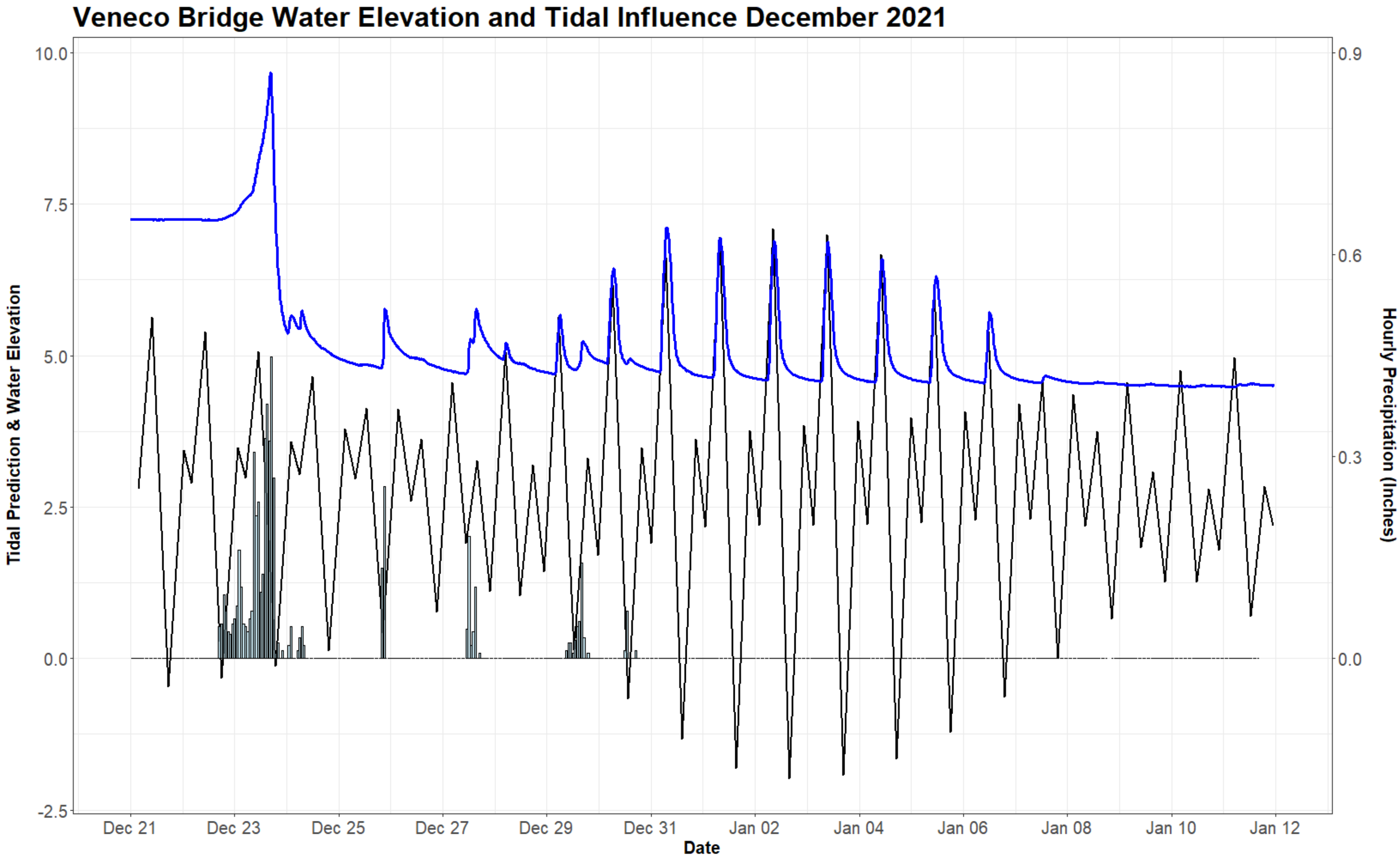


Figure 34. Water elevation collected from Solinst levelogger at Venoco Bridge. Tidal predictions and rainfall from NOAA for Water year (a) 2019 (b) 2020 (c) 2021 and (d) 2022.

Surface Water Levels

Prior to the NCOS restoration project, half of the larger 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 during storm events. 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.

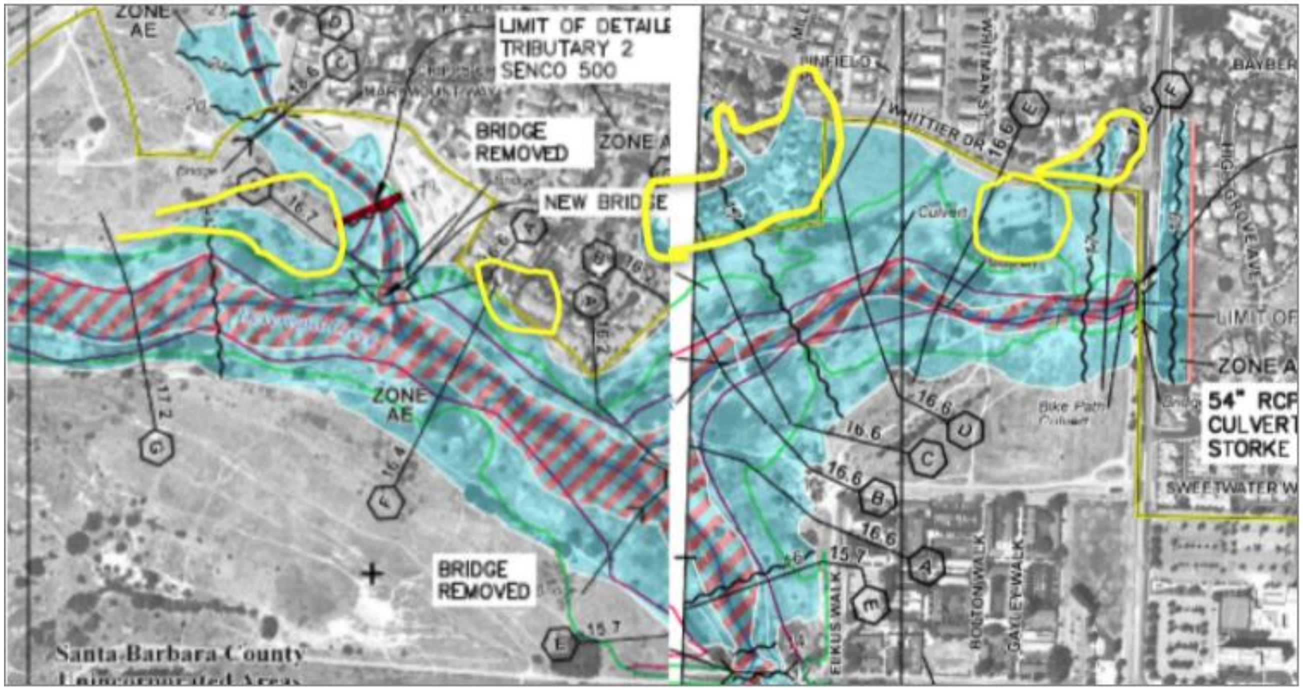


Figure 35. Pre-project flood hazard map that shows the proposed revision as a faint green line and residential areas to be removed from the flood hazard zone with the yellow highlighting.

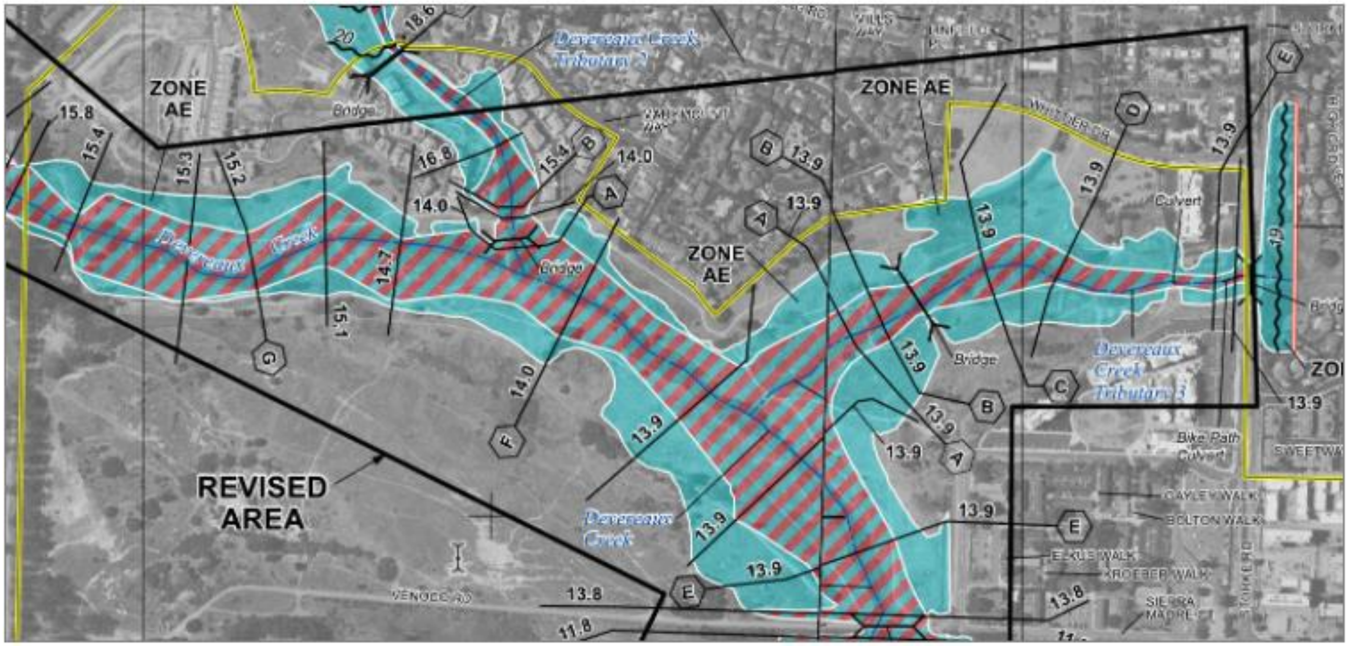


Figure 36. Revised flood hazard map illustrating the flood reduction benefits of the NCOS project.

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 provide information for calculating the velocity and volume of water entering the system during storms or other runoff 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 wading rod is used to record water velocity in 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 velocity measurement 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 feet per second (cfs) for the stream. To calculate a rating curve for use in water quality analyses, we are collecting velocity measurements during different flow rates and different water stage levels. This monitoring is conducted by two Cheadle Center 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 lower 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, once in 2021, four times in 2022. Phelps creek is the most easily accessible site making it easy to make many measurements. Phelps Creek at Marymount bridge is also ideal for flow measurements because it has a uniform geometry with little erosion. We plan to continue taking frequent flow measurements of Phelps creek in the 2023 water year. We will continue to collect flow measurements as opportunities arise to increase the robustness of rating curve and estimates of runoff velocity, volume and fluxes during different storm events.

We focused on increasing the amount of flow measurements at Phelps creek in the 2022 water year because this site has the most regular and measurable flow. Many of the larger storms occurred during holiday (Christmas and New Year's) when staff and students were unavailable, but we were able to capture four flow measurements at Phelps in the 2022 water year.

Table 6. Surface water velocity and flow rates measured in Phelps Creek, Devereux Creek and in the main wetland channel flowing into 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	Segments are 1 foot wide.
12/13/2021	1:15-3:00	3.35	24	0.78	1.31	0.0	0.087	0.05	Segments are 1 foot wide.
12/13/2021	1:15-3:00	3.29	24	0.78	1.36	0.0	0.043	0.03	Segments are 1 foot wide.
12/14/2021	11:00-11:45	3.75	55	1.81	2.58	0.01	1.85	1.09	Segments are 1 foot wide.
12/28/2021	2:45-3:00	2.77	30	0.98	1.47	0.0	0.28	0.16	Segments are 1 foot wide.
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 7. 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.

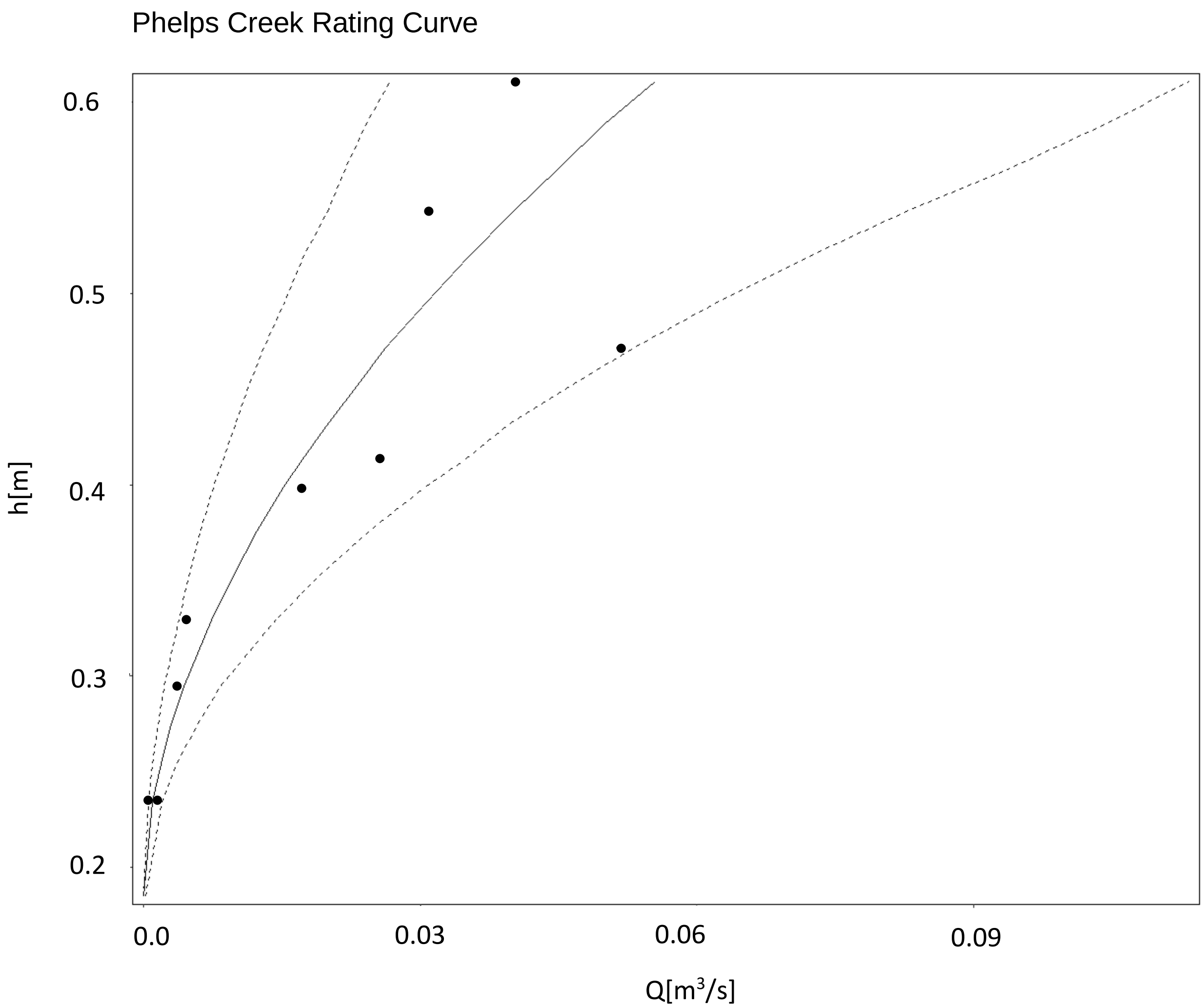


Fig 37. The points represent points in which the flow was measured. The solid line represents the mean flow rate at a given water height and the dotted lines represent the upper and lower limits of stream flow based on a generalized power-law model with variance that varies with stage in the bdrc package of R statistical software. The generalized power-law is introduced in Hrafnkelsson et al. (2020).

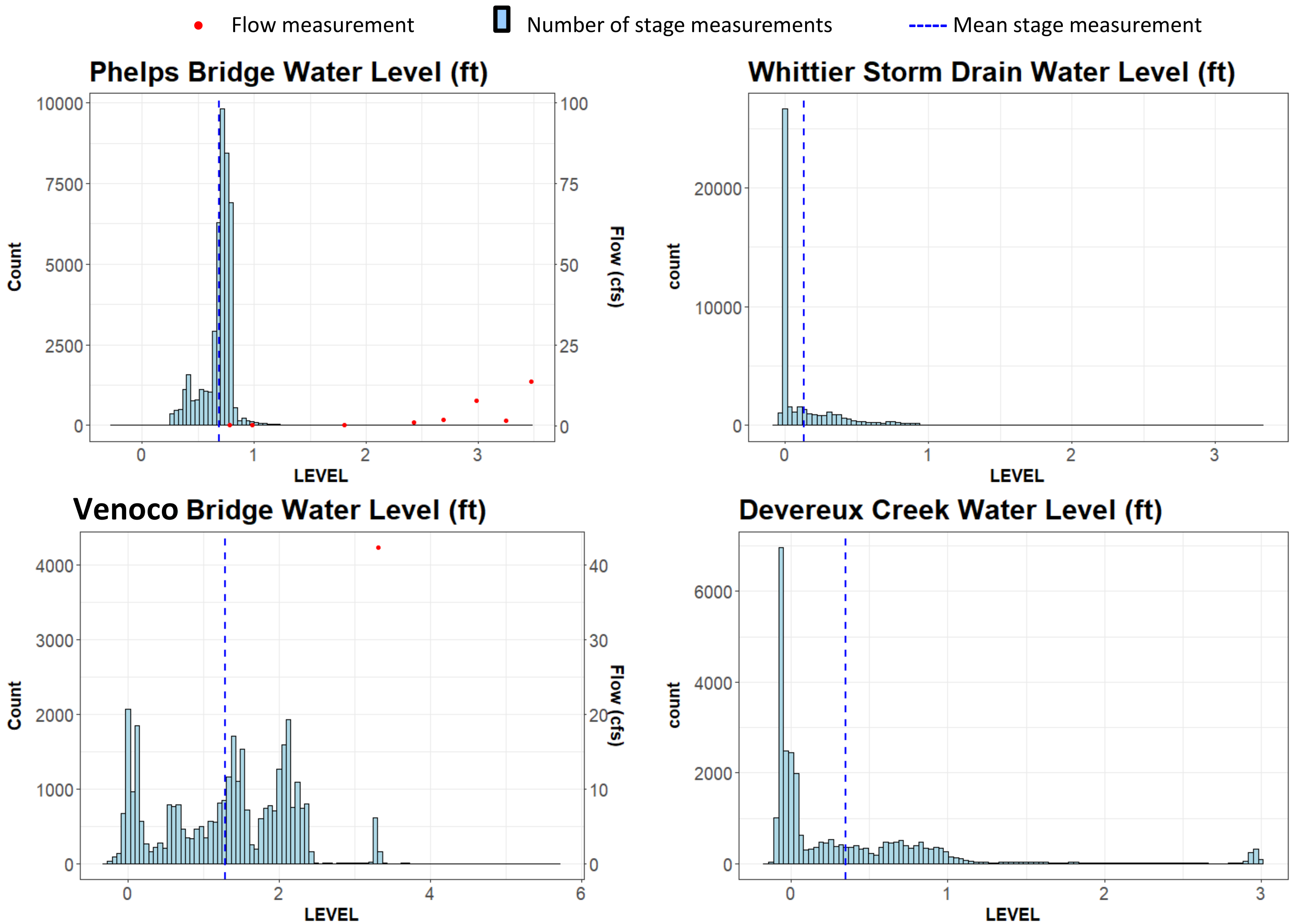


Figure 38. Frequency of water level and four locations taken from Sonlist leveloggers every 15 minutes in the 2022 water year. The dark blue line represents the mean water level at each location. The red point's represent the level at which flow rate has been collected.

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 36) 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 Cheadle Center staff and student interns.

The fifth year of vernal pool hydrology monitoring (water year 2022) began on December 15th, 2021 when vernal pools 2-8 were inundated by 1-16 inches of water. 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. Vernal pools are considered functional when they hold a minimum of a few inches of water for at least 100 days.

Figure 39. 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.

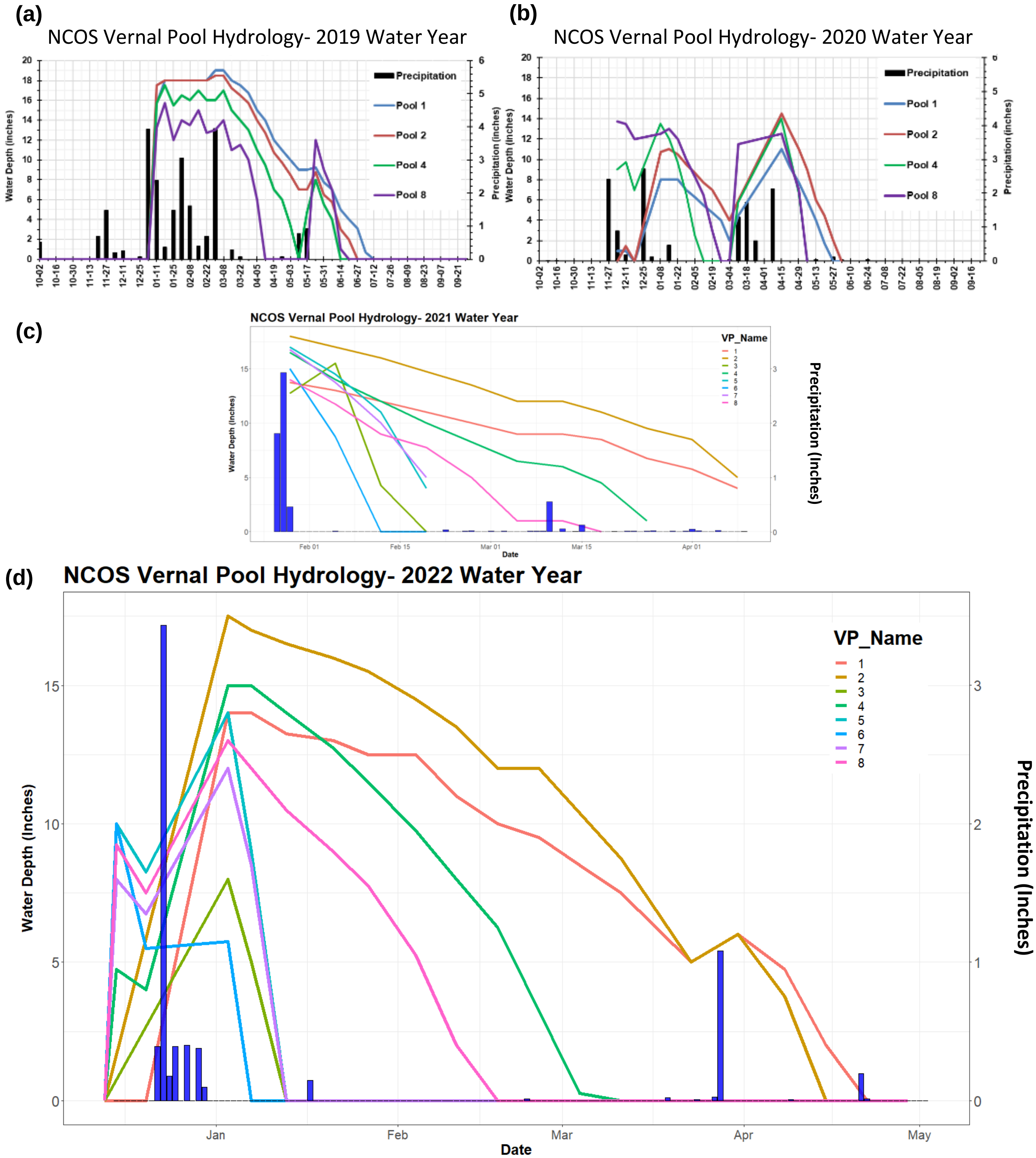


Figure 40. (a) Hydrograph of weekly water depth (inches) in four of the restored vernal pools on the North Campus Open Space (NCOS) mesa in the 2019 water year (b) 2020 water year (c) 2021 water year (d) 2022 water year. Precipitation in inches is recorded at a NOAA climate station on Coal Oil Point Reserve. Vernal pools are measured weekly at the deepest point.

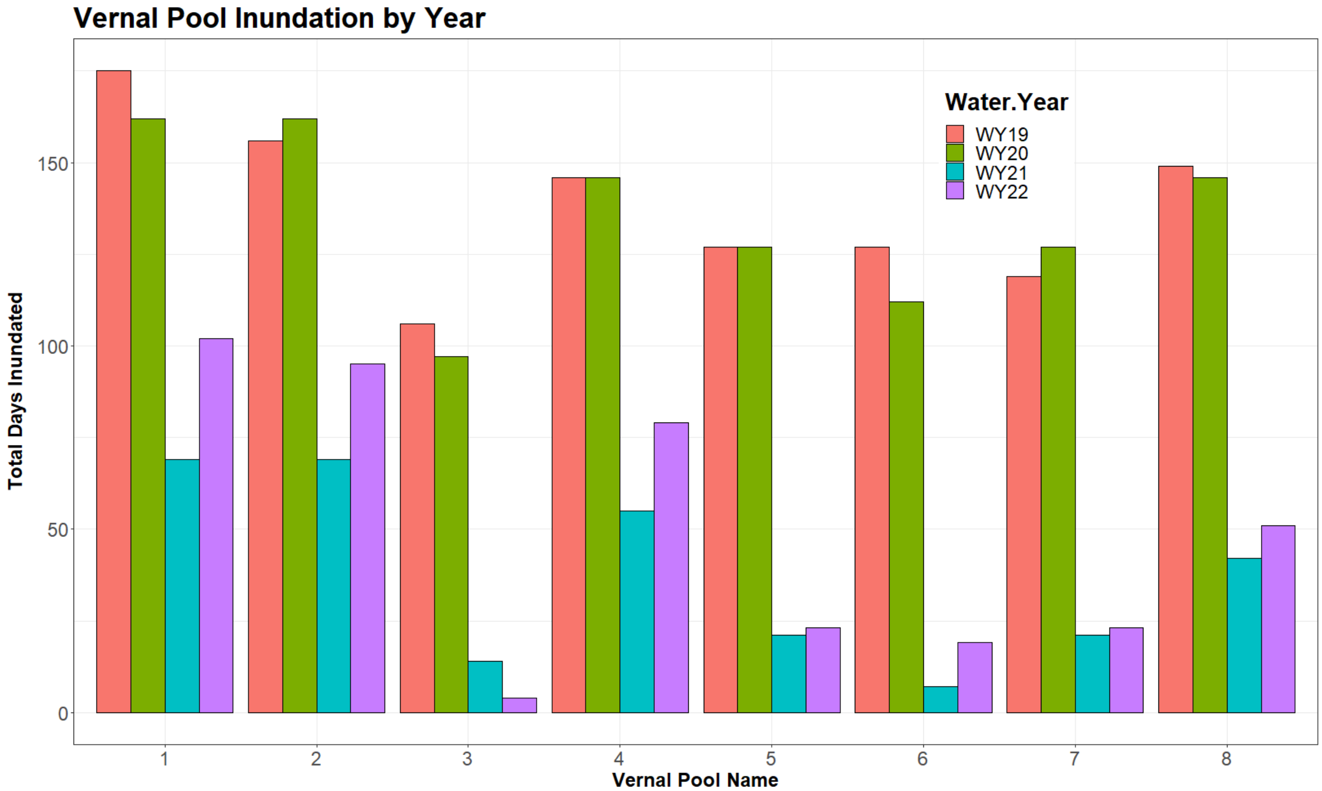


Figure 41. Number of days that Vernal Pools are inundated for each water year monitored. Vernal pool water depth is determined by Cheadle Center field staff and is monitored once per week. If vernal pools dry out between rain events, it is assumed that they are dry for 5 days, since days that are not monitored are not accounted for.

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 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 42. 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 has been 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. In summer of 2022 the piezometer at well 12 was removed due to low water levels and the slow filling of the shallow well. Well 12 is only about 4 feet deep and the well was drying up during summer therefore not producing reliable data. The 3 years of data that we were able to collect provided replicable data showing that the well is very responsive to rainfall events and has very low salinity throughout the year. 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.

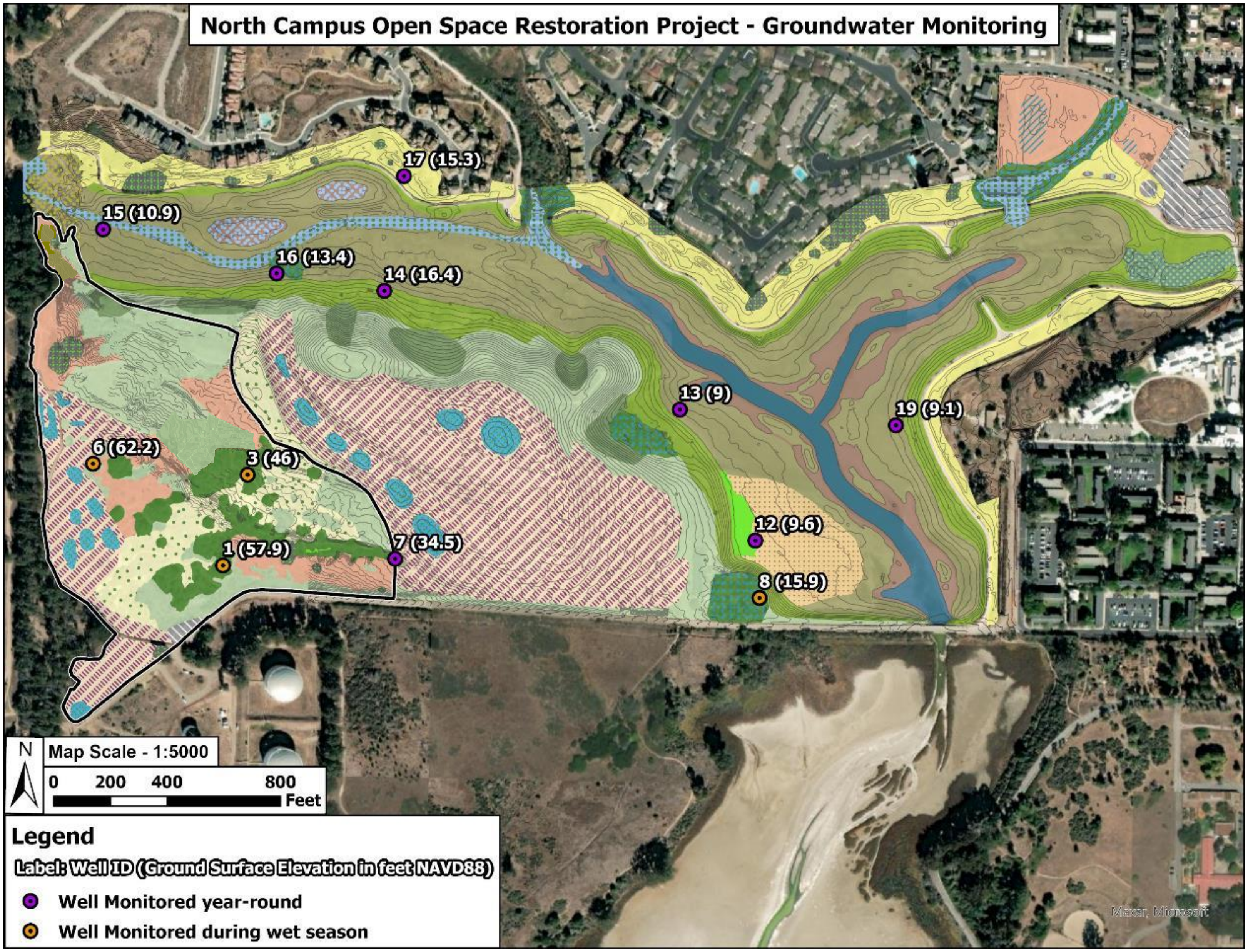


Figure 42. Map of the groundwater monitoring wells at North Campus Open Space, labeled with the well ID number and ground surface elevation in feet (NAVD88).

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 adjacent 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 4-5 feet below the surface until September 2020 when no water was detected (Appendix 6). In following years groundwater at well 3 was much deeper if detectable at all.

In the wet season the ground water of well 7 has measured 1.5-5.5 feet deep and the depth to water typically correlates with how heavy preceding storms are. Well 7 dries out a few weeks after the last rain of the season. 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.

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). 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. 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, but remained one of the most consistently high of the wells (Figure 42).

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). Though the water did not rise to the surface in the dry years of 2021 and 2022, the water was less than 8 feet from the surface year round.

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 in 2022 was higher than other years reaching a max of 93 ppt. Salinity is 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 8 and Figure 44). Salinity at all the upper wells remains between 0 to 2 parts per thousand (ppt) on average.

Throughout the year, groundwater salinity generally decreases during periods of rainfall in the winter and early spring months. During the large December storm of 2021 wells 15 and 13 dropped from around 70ppt to nearly zero ppt due to the fresh water influx (Figure 44). Salinity levels quickly rose back to what they were before the storm and were minimally affected by late season storms.

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 45). In 2022 there was no water in the well starting in August. The well was only 4 feet deep and there was still moisture at the bottom of the well, so the hydraulic head is still relatively high. 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. Because there is little to no change in salinity we stopped monitoring salinity in well 12 this year so we could use the instrument elsewhere.

Table 8. Pre-project and post-grading ground surface elevation and means of two parameters (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). "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 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 WY2022 Depth to Water from Surface (ft.)	4.9	NA	5.9	5.7	4.9	6.7	7.8	6.3
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
Mean WY2022 Salinity (ppt)	0.2	NA	56.1	2.5	32.2	5.2	4.2	71.9

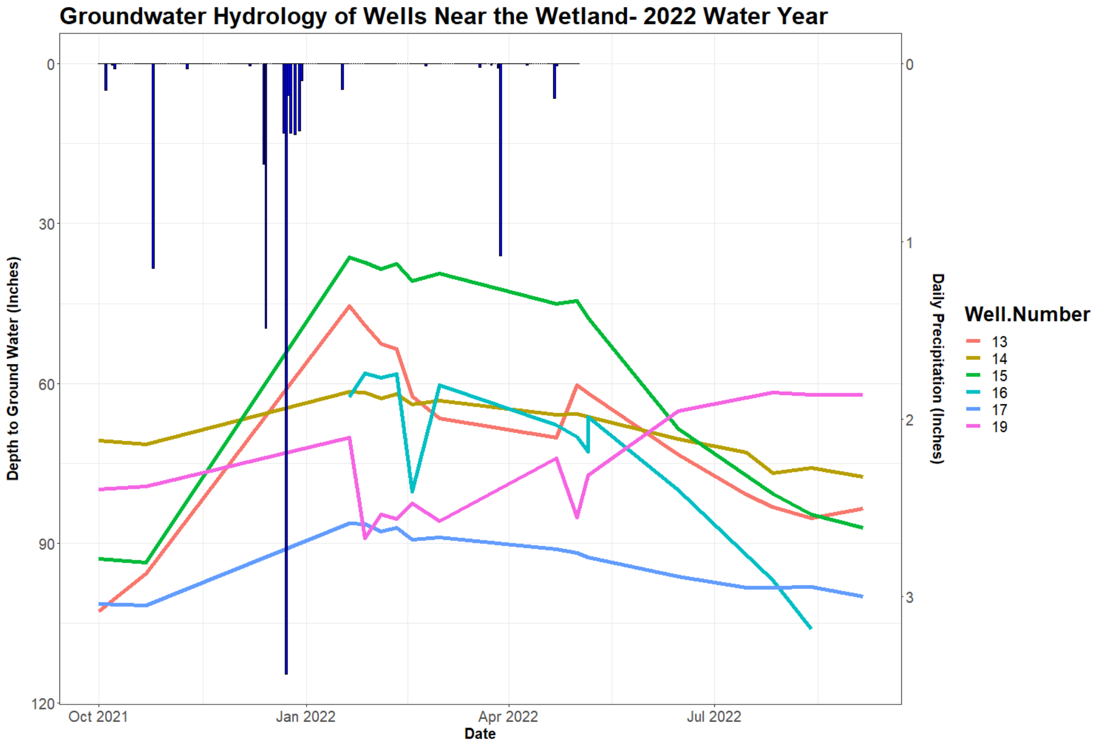


Figure 43. Depth to groundwater from surface (inches) measured every two weeks at six monitoring wells in salt marsh habitat near the North Campus Open Space wetland for water years 2022. Blue bars represent Daily precipitation (inches) recorded at a NOAA climate station on Coal Oil Point Reserve.

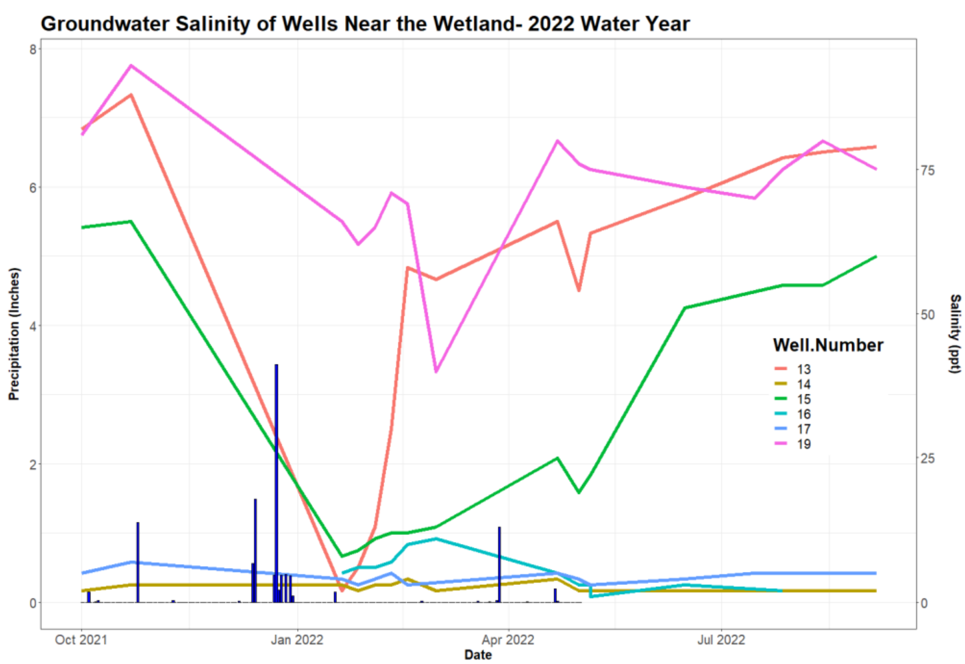


Figure 44. Groundwater salinity (in parts per thousand, ppt) measured every two weeks at six monitoring wells surrounding the North Campus Open Space wetland for water year 2022. Blue bars represent daily precipitation (inches)

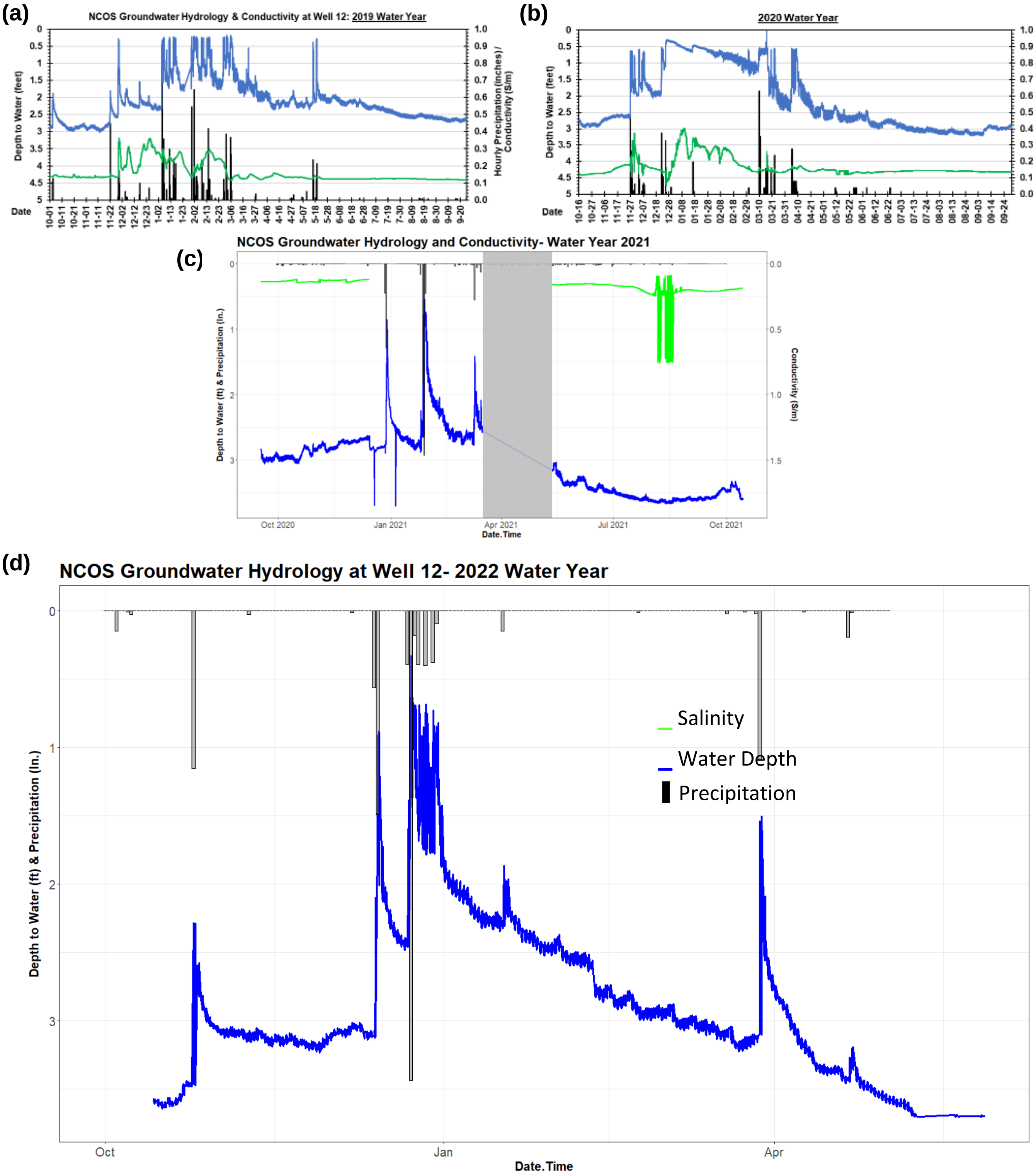


Figure 45. Depth to water from surface (feet) and conductivity (S/m) of groundwater recorded by a Solinst Levelogger every 15 minutes in well 12 in the (a) 2019, (b) 2020, (c) 2021 and (d) 2022 water years (October 1 to September 30) at North Campus Open Space (NCOS). Precipitation in recorded at a NOAA climate data station on the adjacent Coal Oil Point Reserve. The levelogger was pulled in June 2022 because the well is not deep enough to measure low water periods. 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. The Cheadle Center 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

Cheadle Center 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 32). 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, 2021 and 2022 water years, plotted in the four charts in Figure 46. These four water years differed greatly in the amount of precipitation received and the response of water quality measurements. Unfortunately, all four years experienced some extent of equipment malfunction. Each malfunction is represented by a blank or grey section in the figures. In the 2022 water year the EXO1 sonde malfunctioned in December with no way to retrieve the lost data. Due to the frequent malfunctions we will replace the sonde.

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 46(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 46).

The unusual heavy precipitation in December 2021 and subsequent breaching and minimal ensuing rainfall are reflected in the data shown in figure 43a for the 2022 water year. Dissolved oxygen levels were in the more normal range because water depth was low overall in the system for most of the year.

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. 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. Storms that produce a high amount of rainfall typically flush excess nutrients into the slough, which subsequently induces rapid growth of algae and phytoplankton 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 in 2021 and 2022 because it was lacking so many readings and we could not successfully calibrate it. Negative values should not be obtained from the pressure transducer therefore the values measured September- October 2021 and in much of 2022 are likely due to device malfunction.

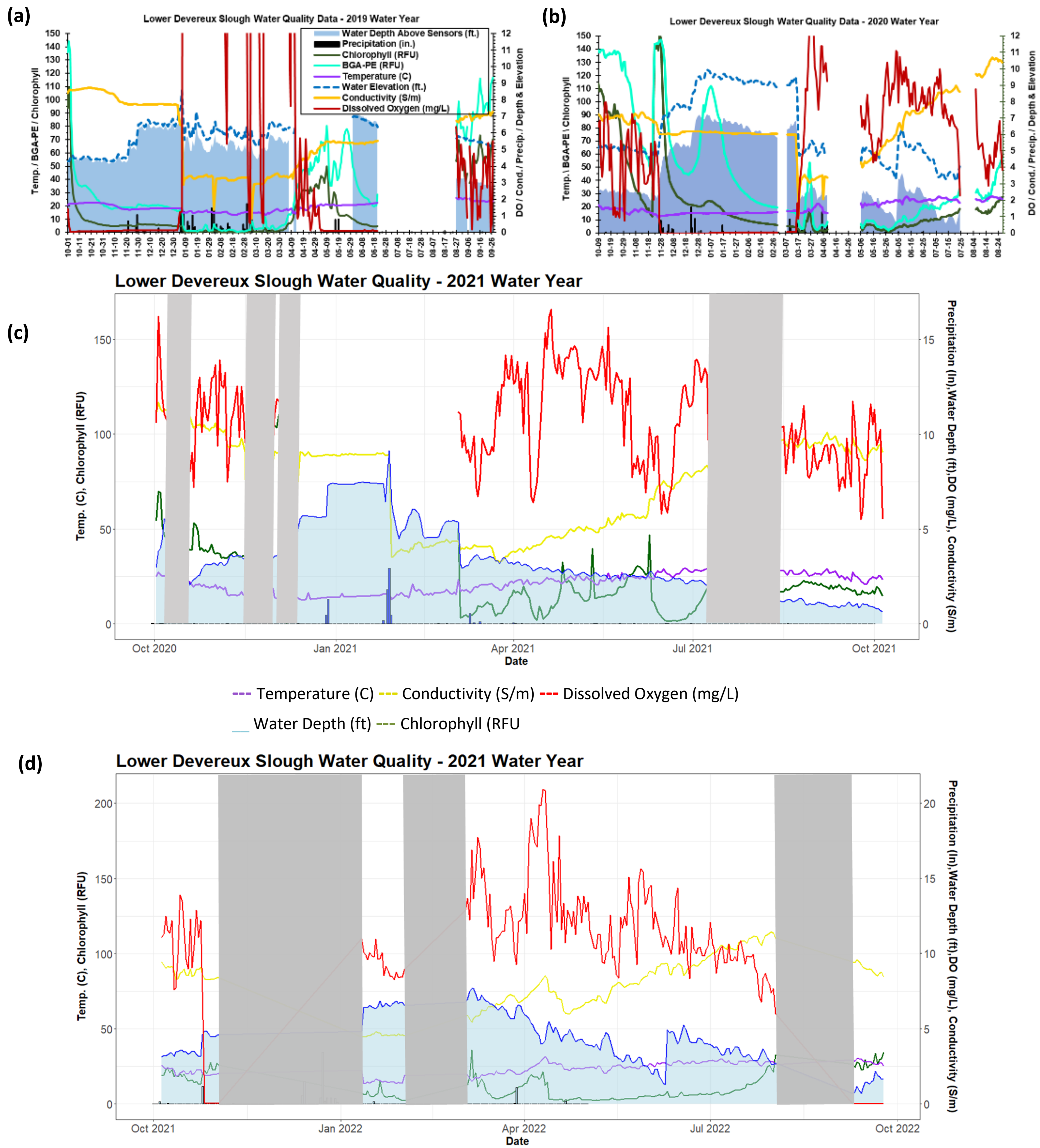


Figure 46. Daily average water quality and level data recorded in the (a) 2019 (b) 2020 (c) 2021 and (d) 2022 water years (October 1st to September 30th) with a YSI EXO1 sonde in the lower portion of Devereux Slough (see map in Figure 32). The water surface elevation is in NAVD 88. Precipitation data was recorded at a NOAA climate station on Coal Oil Point Reserve.

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 47-52). 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 32). 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 and oxygen can enter the surface from the air through diffusion which is facilitated by surface wind and mixing. 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.

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 48). 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 year, 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 51). 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 52).

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

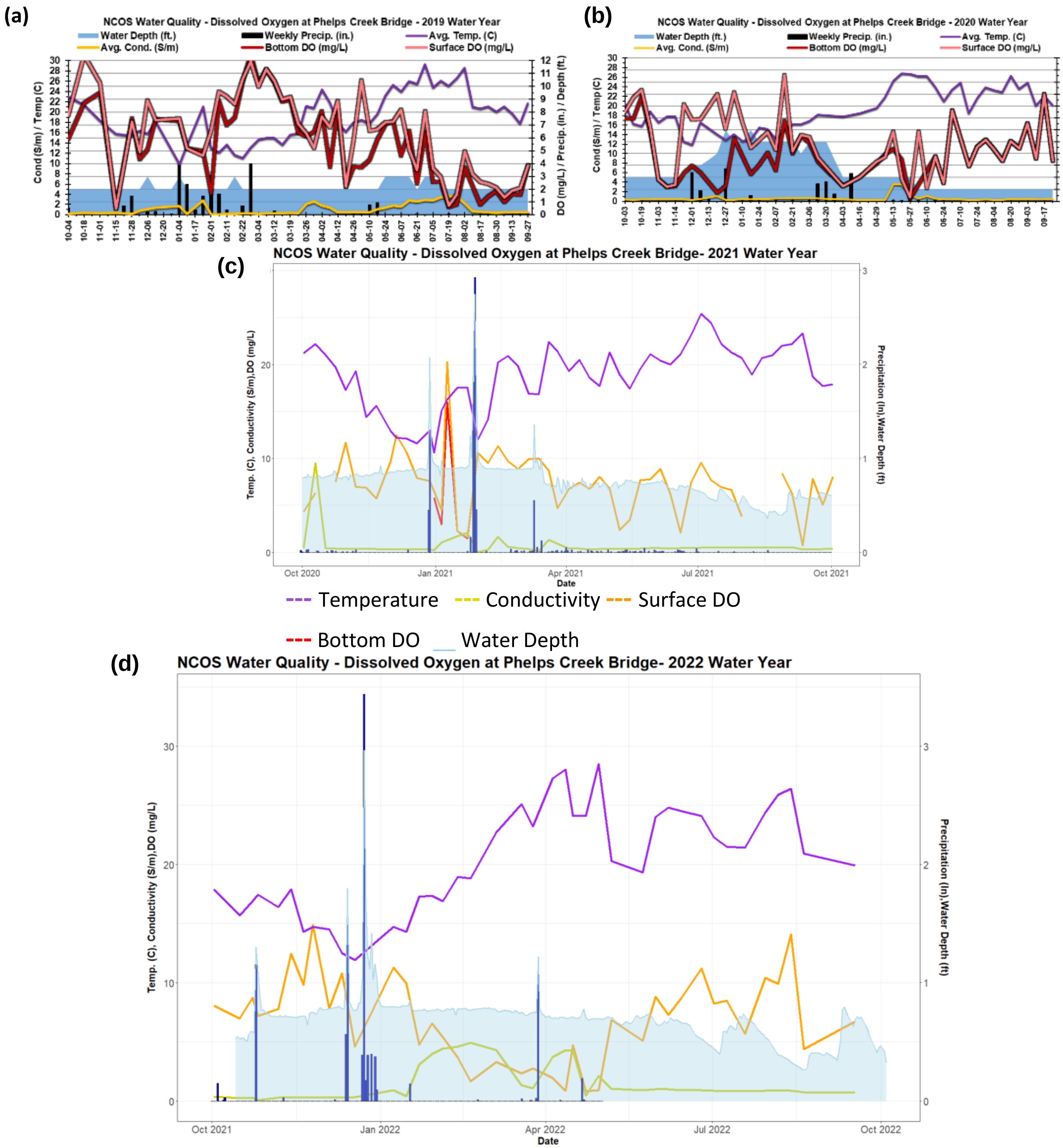


Figure 47. Dissolved oxygen (mg/L) at the surface (top 1-foot) and bottom of the water column recorded weekly in the (a) 2019 water year and (b) 2020 water year with a YSI Pro2030 at the Phelps Creek outlet into the upper Devereux Slough, North Campus Open Space. The temperature (Celsius – purple line) 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 32.

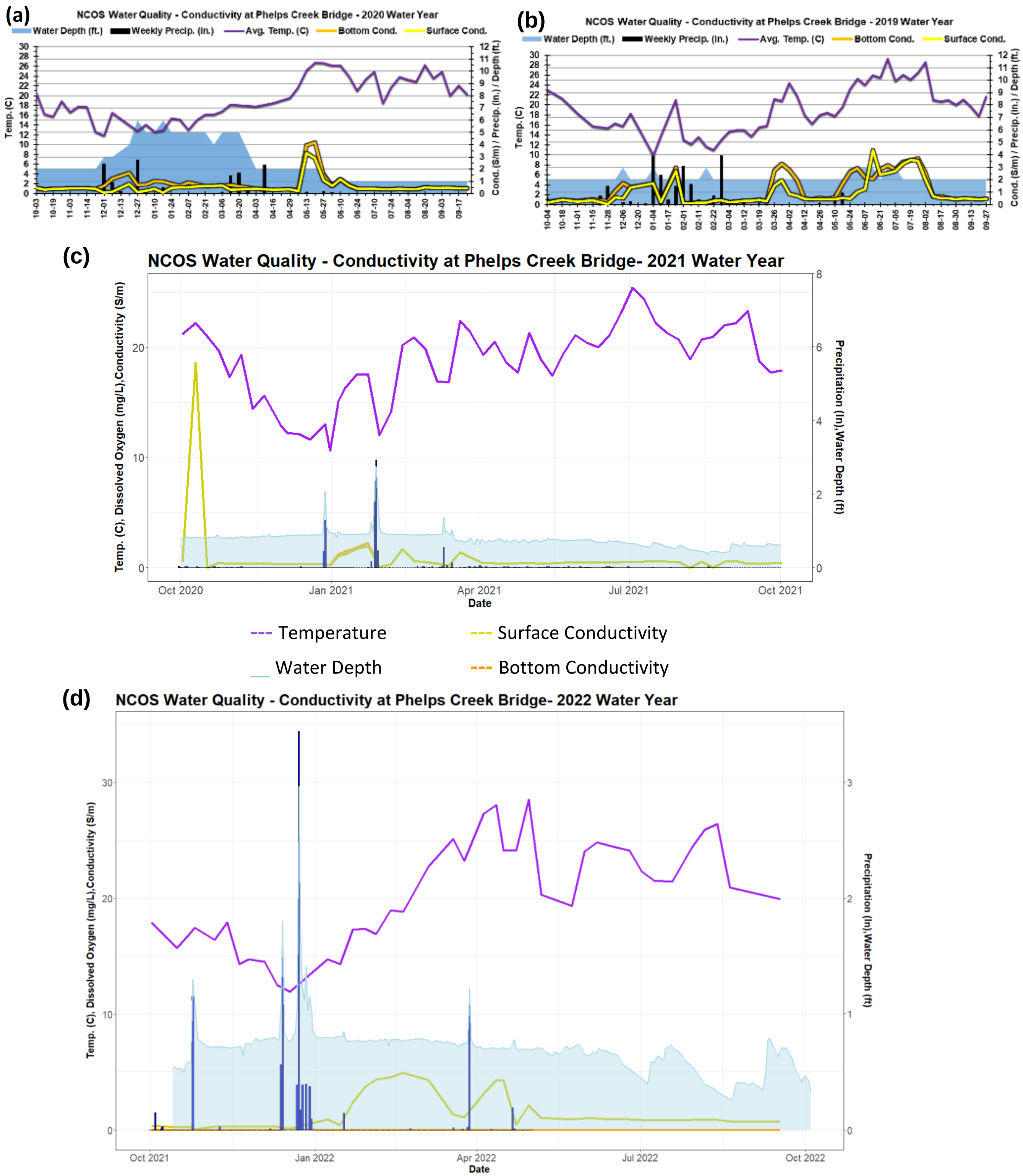


Figure 48. Conductivity (Siemens/meter) at the surface (top 1-foot of water column) and bottom of the water column recorded weekly in the (a) 2019 (b) 2020 (c) 2021 and (d) 2022 water year with a YSI Pro2030 at the Phelps Creek outlet into the upper Devereux Slough, North Campus Open Space. The temperature (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 32.

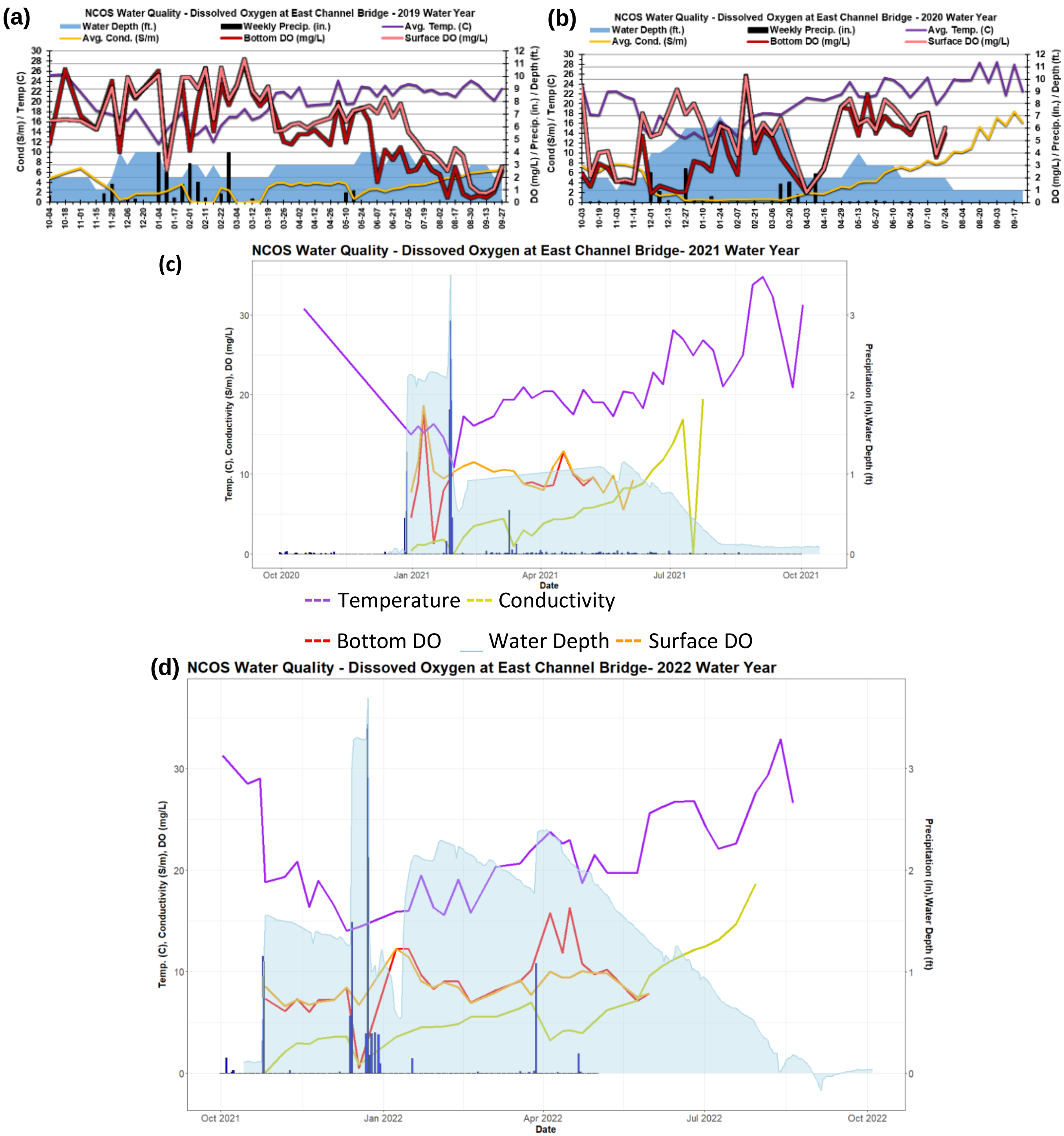


Figure 49. Dissolved oxygen (mg/L) at the surface (top 1-foot of water column) and bottom of the water column recorded weekly in the (a) 2019 and (b) 2020 (c) 2021 and (d) 2022 water year with a YSI Pro2030 in the east channel of the upper Devereux Slough, North Campus Open Space. The temperature (Celsius – 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 32. 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.

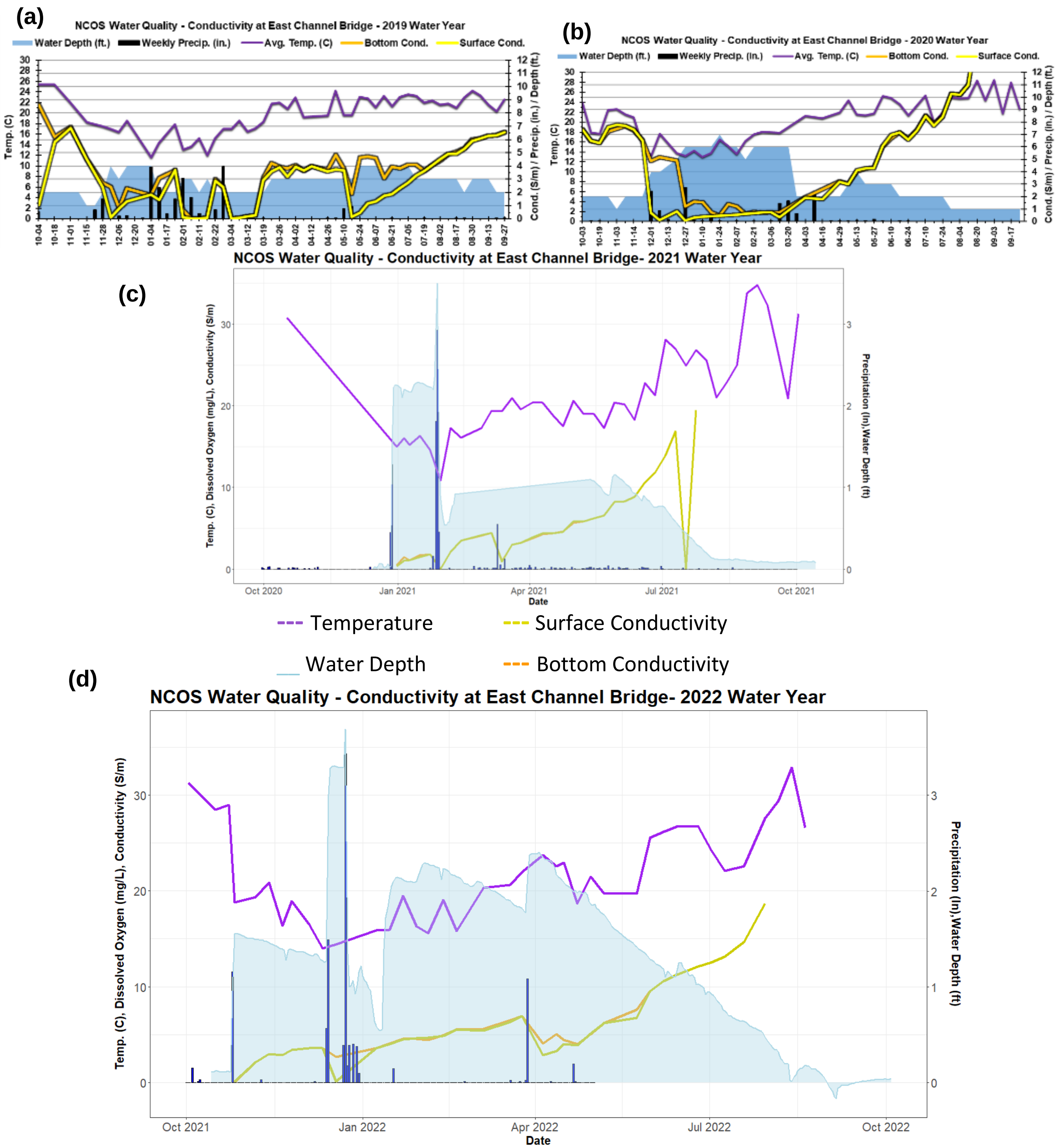


Figure 50. Conductivity (Siemens/meter) at the surface (top 1-foot of water column) and bottom of the water column recorded weekly in the (a) 2019 (b) 2020 (c) and (d) water year with a YSI Pro2030 in the east channel of the upper Devereux Slough, North Campus Open Space. The temperature (Celsius – purple 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 32.

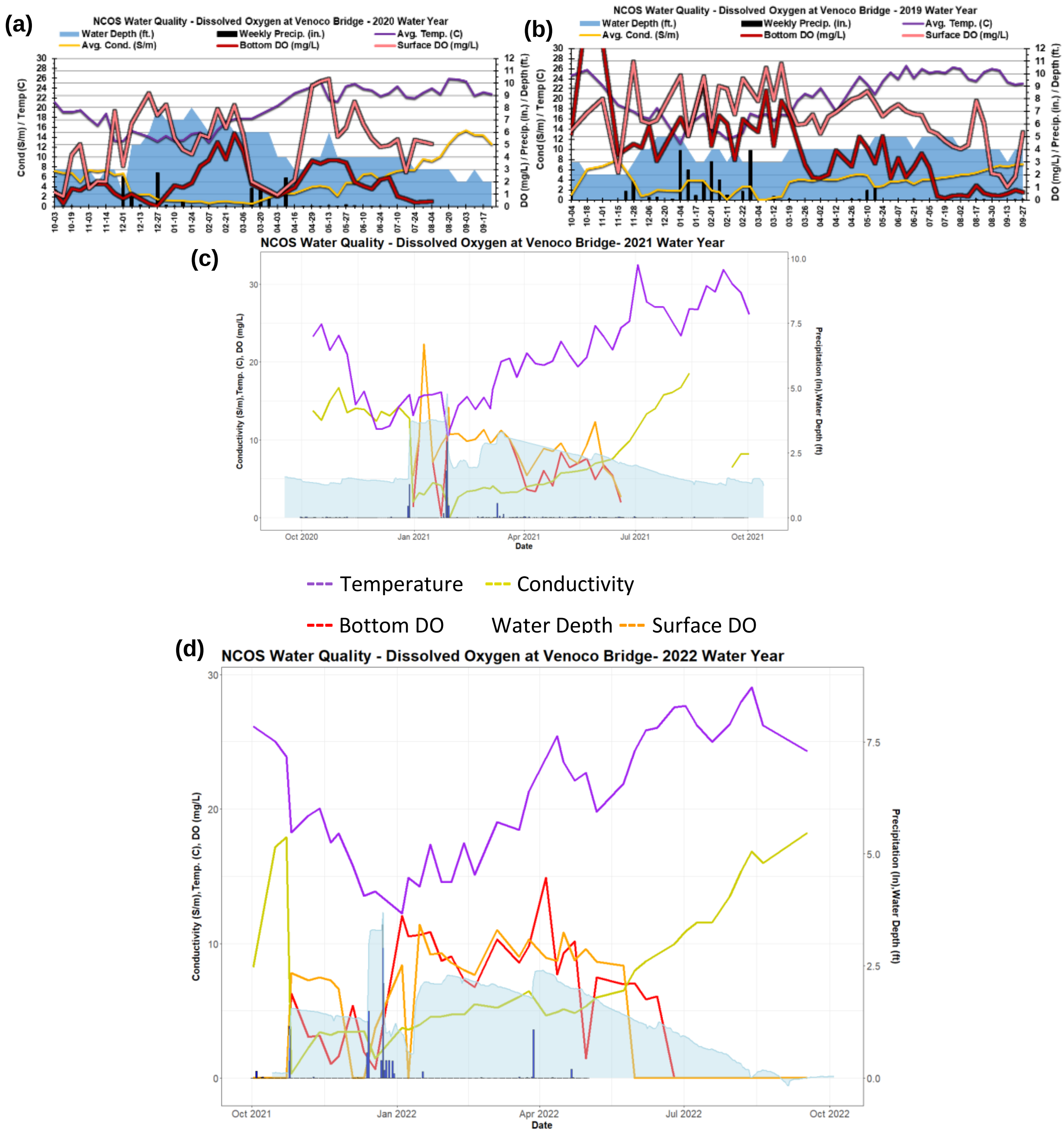


Figure 51. Dissolved oxygen (mg/L) recorded weekly in the (a) 2019 (b) 2020 (c) 2021 and (d) 2022 water year with a YSI Pro2030 at the surface (top 1-foot of water column) and bottom of the water column in the main channel of the upper Devereux Slough at the Venoco access road bridge, North Campus Open 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 32. 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.

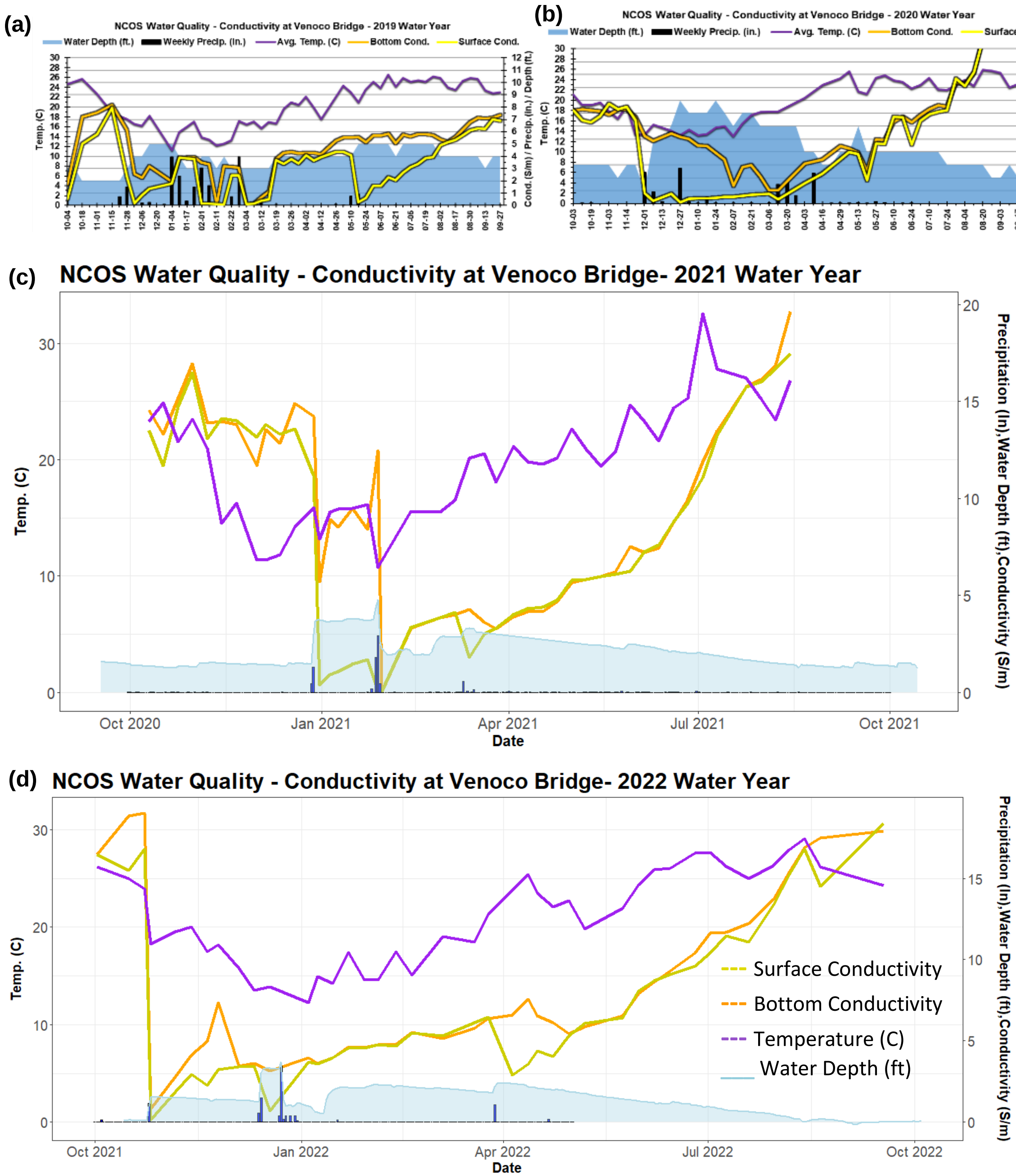


Figure 52. Conductivity (Siemens/meter) at the surface (top 1-foot of water column) and bottom of the water column recorded weekly in the (a) 2019 water year and (b) 2020 water year with a YSI Pro2030 in the main channel of the upper Devereux Slough at the Venoco access road bridge, North Campus Open 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 32.

Regular DO levels above 2 mg/L indicates that the wetland can functionally support aquatic wildlife year-round. DO was above this critical threshold throughout for all months of all monitoring years except for a few brie dips in DO and a longer dip in DO in the summer of 2022 at Veneco Bridge.

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 the Cheadle Center 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 32) and ISCO samples are collected in three of the four sites. UCSB professor John Melack, 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. ISCO samplers were typically set to collect samples at a one-hour interval, however the frequency varied depending on the predicted length of the storm. In 2022 water year we stopped collecting grab samples at the sites with ISCO samplers and increased the frequency of grab samples at the site (Devereux creek) with no ISCO sampler. The reason for this change is because in our past comparison of grab and ISCO samples we found that the results were very similar, with grab samples having consistently slightly lower nutrient concentration than the ISCO samples. With the consistency of the results we felt it no longer necessary to collect parallel grab samples.

The sampling and analysis of storm water conducted in the 2019, 2020 and 2021 water years can be seen in previous year’s reports (2019 water year, 2020 water year, 2021 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.

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. In 2021 we determined that due to the high salinity at some of the sites some samples measured using SSC method were forming a salt crust and preventing full evaporation. 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 2022 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. A total of 11 grab samples were analyzed for both nutrients and suspended solids; 69 ISCO samples were analyzed for nutrients and suspended solids.

Generally, the 2022 water year data suggest a higher concentration of nutrients in storms early in the water year. This is similar to previous year's results and other literature. Ammonia was detected at all sites with the first two large December storms, but concentrations were at 0 in the March storm at all sites aside from Devereux Creek.

Suspended sediment showed similar values in each storm with some variation throughout the storm. Venoco Bridge consistently has had lower nutrient concentrations than other sites, but much higher suspended sediments than other sites. After seeing these results in the first few years we hypothesized that it could be due to a high salinity. This year's data however continued to show that Venoco is higher than other sites even when salinity is accounted for (ppt salinity removed from total (mg/L))

Appendix 5 contains several charts of the nutrient and total suspended solids (TSS) 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).

The Venoco bridge site continues to show elevated suspended sediment concentrations compared to other sites, but similar levels of all nutrients analyzed. 2022 mean Ammonia and Nitrate are lower than 2021 results, mean phosphate was about the same and total suspended solid concentrations were much higher in 2022 than in 2021.

Table 9. 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 2022 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 - Storm					
Devereux Creek	11	0.03	0.13	0.29	0.10
ISCO - Storm Only	**69**				
Phelps Creek	21	0.00	0.05	0.47	0.10
Whittier Storm drain	23	0.01	0.08	0.38	0.10
Venoco Bridge	25	0.00	0.14	0.43	0.10
Grand Total					

Table 10. 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 2022 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 - Storm					
Devereux Creek	11	0.39	0.55	0.89	0.18
ISCO - Storm Only	**69**				
Phelps Creek	21	0.24	0.44	0.90	0.18
Whittier Storm drain	23	0.27	0.50	1.04	0.17
Venoco Bridge	25	0.03	0.26	0.48	0.16
Grand Total					

NITRITE+NITRATE (mg/L)					
Sample Type & Site	**Samples Analyzed**	**Minimum Concentration**	**Mean Concentration**	**Max Concentration**	**Standard Dev.**
GRAB - Storm					
Devereux Creek	11	0.95	1.84	3.33	1.0
ISCO - Storm Only	**69**		**0.81**		
Phelps Creek	21	0.002	0.77	2.56	0.82
Whittier Storm drain	23	0.13	1.03	2.87	0.71
Venoco Bridge	25	0.00	0.62	1.58	0.54
Grand Total					

Table 11. 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 - Storm	**11**				
Devereux Creek	11	13.9	348.85	1700.74	475.5
ISCO - Storm Only	**69**				
Phelps Creek	21	4.9	946.10	2332.40	863.0
Whittier Storm drain	24	5.6	193.66	997.69	235.3
Venoco Bridge	24	36.4	13902.47	49690.01	18866.33
Grand Total	80	4.9	4640.93	49690.01	12077.54

Future Storm water Plans

Cheadle Center will follow this storm water sampling regime in the 2023 water year. In 2022 we put together a rating curve for Phelps Creek. We plan to continue taking frequent flow measurements at the Phelps Creek location and other locations in the 2023 water year. We are working on more detailed analyses of nutrient and sediment flux during storm events. Our intention is to produce a separate report focused on the hydrology and water quality of Devereux Slough.

5. 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 2022, the fifth year of the project, is summarized below and compared with the 2021, 2020 and 2019 data to show changes in the proportion of effort by worker type, general task, and zone.

In 2020, safety restrictions related to the COVID-19 pandemic reduced the overall total hours contributed by all worker types, especially volunteers (Figure 53). Student hours increased in 2021. 2022 values are representative of just January- August while other years are representative of January-December, nevertheless, with the establishment of the restoration site and the reduction in restoration grant funding, total hours are reduced in 2022.

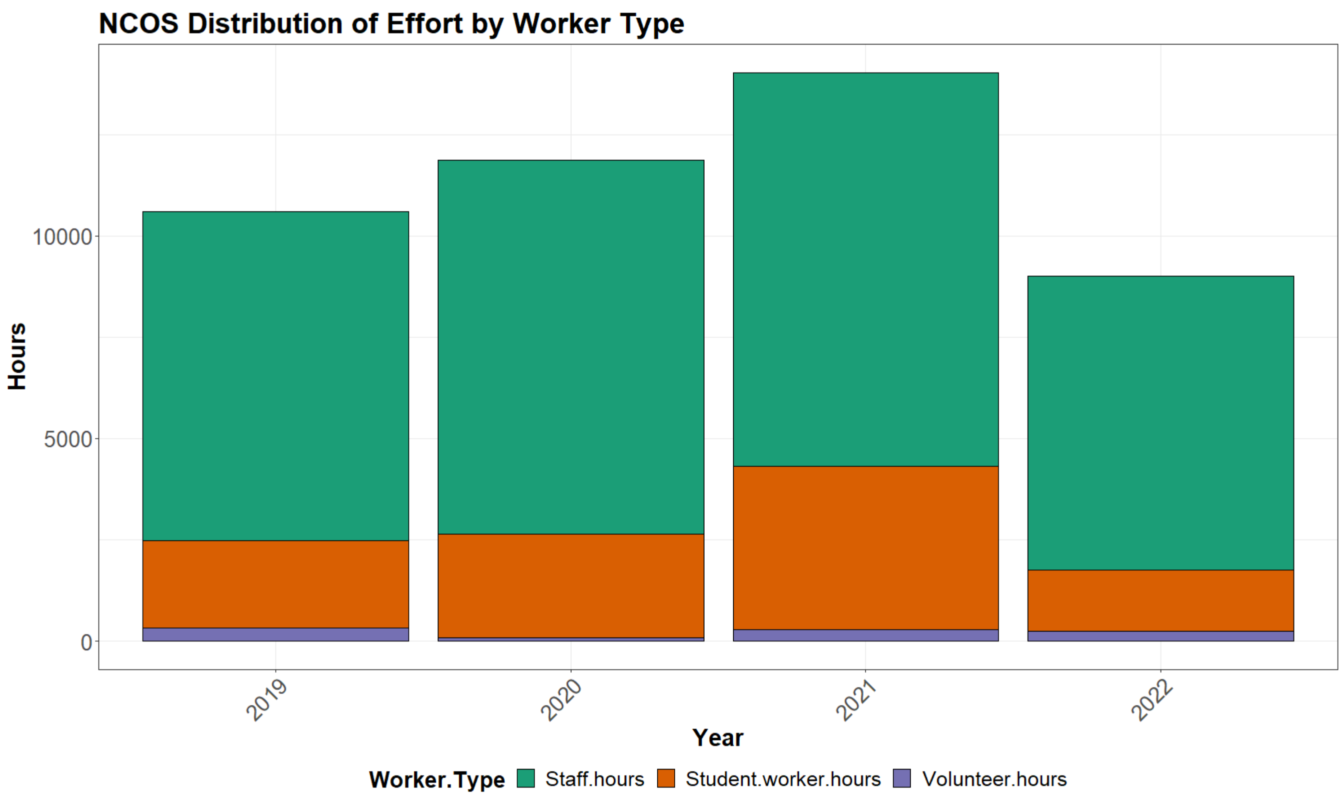


Figure 53. Proportion of effort (hours of work) at the North Campus Open Space restoration project by worker type in 2022, 2021, 2020 and 2019. The "Students" category includes paid workers and interns.

Over the years the majority of effort has been focused on planting and weeding. Monitoring and report also make up a substantial portion of the time and effort. Monitoring and reporting is important for informing future projects as well as for saving data for future climate change reference. While the yearly report touches on almost every project completed at NCOS, there are many more, in depth reports composed throughout the year.

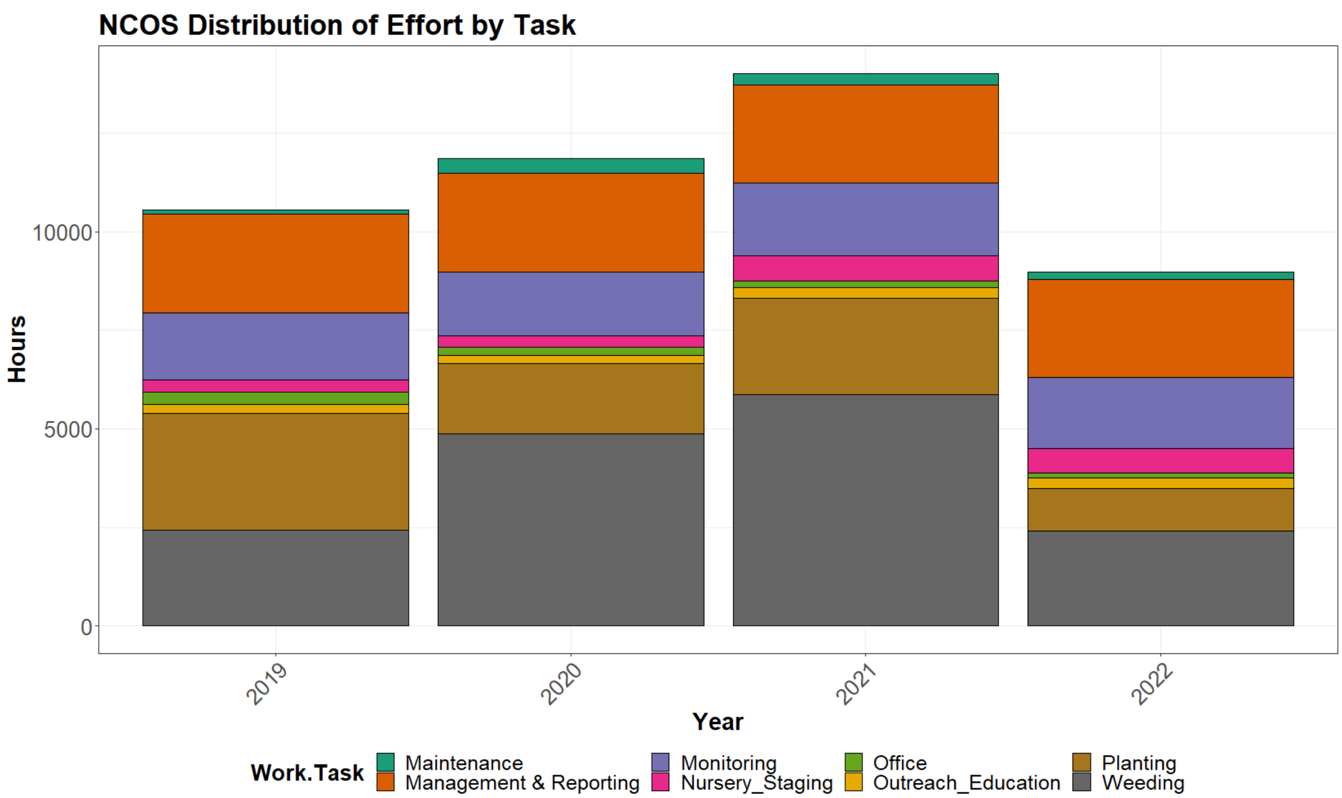


Figure 54. Proportion of effort (hours of work) at the North Campus Open Space restoration project by task in 2022, 2021, 2020 and 2019.

The distribution of effort (primarily planting and weeding) across the five main zones of the NCOS project has shifted each year (Figure 55). Planting and weeding were more heavily focused on the Mesa zone in 2019, and efforts in 2020 focused more on maintenance and weeding of the Mesa and Peripheral Uplands than in other zones. In 2020 the construction and establishment of the visitor plaza, pollinator garden, and discovery trail resulted in an increase in the Whittier area. In 2021 there was even more emphasis put on planting and weeding on the mesa and saltmarsh transition. The establishment of the outdoor classroom explains the increased work in “Whittier” in 2022. 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.

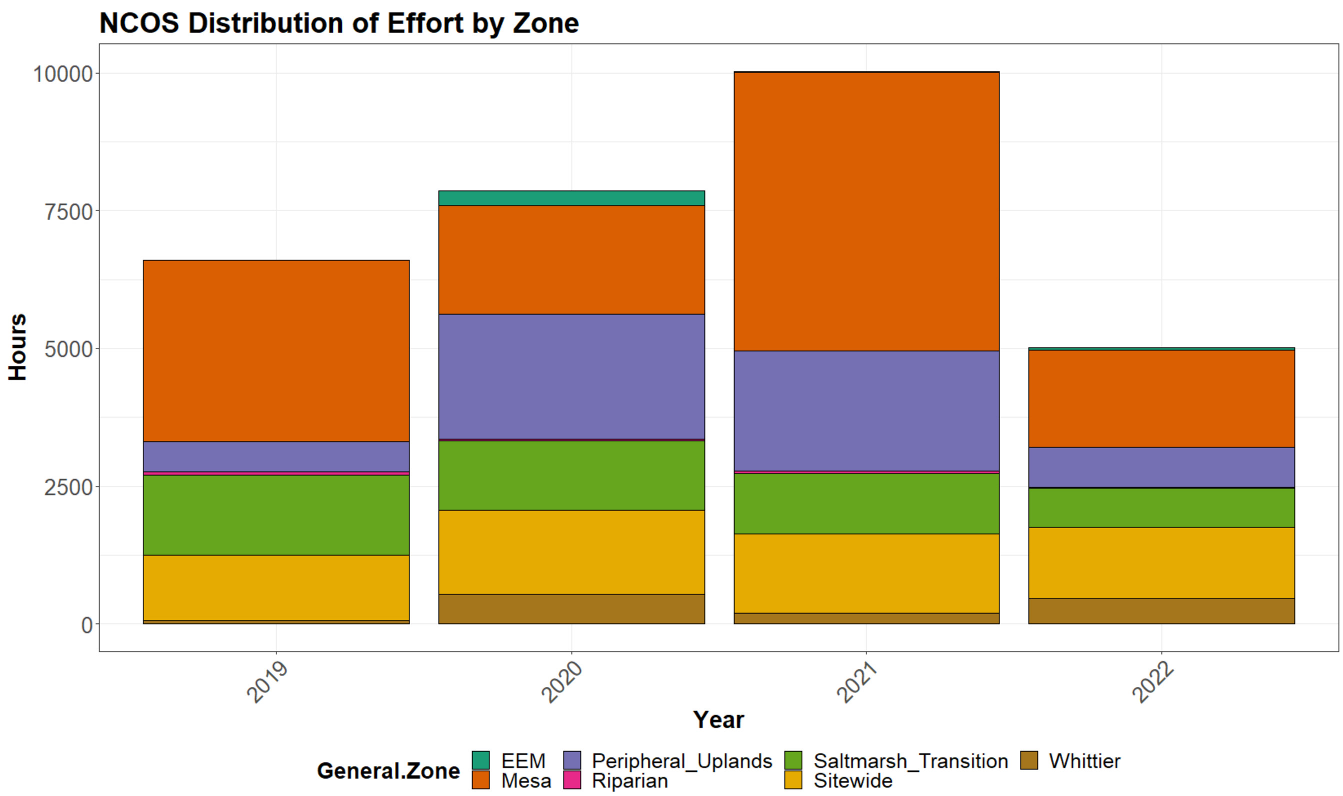


Figure 55. Proportion of effort (hours of work; primarily planting and weeding) at the North Campus Open Space restoration project by zone in 2022, 2021, 2020, 2019. Refer to the map in Figure 1 for the location and extent of each zone.

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

Year 2 – July 2019

Year 3 – July 2020

Year 4- July 2021

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

Year 5 – July 2022

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

Baseline (post-grading) - October 2017

Year 1 – October 2018

Year 2 – October 2019

Year 3 – October 2020

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

Year 4 – October 2021

Year 5 – October 2022

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

Baseline (post-grading) - October 2017

Year 1 – October 2018

Year 2- October 2019 **Year 3 – October 2020**

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

Year 4 – October 2021 **Year 5 – October 2022**

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

Baseline (post-grading) - October 2017

Year 1 – October 2018

Year 2 – October 2019 **Year 3 – October 2020**

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

Year 4 – October 2021

Year 5 – October 2022

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

Baseline (post-grading) - October 2017

Year 1 – October 2018

Year 2 – October 2019

Year 3 – October 2020

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

Year 4 – October 2021

Year 5 – October 2022

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, 5 = 2022).

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	5							4,5					
Alnus rhombifolia											2		
Alopecurus saccatus								3,5					
Ambrosia psilostachya	2,3	1,2,3,4,5			2,4,5	3	3	2,4,5				2,3,4,5	
Anemopsis californica										1			
Artemisia californica		1,2,3,4,5							3				
Arthrocnemum subterminale				1,2,3,4,5	3,5		3						
Astragalus pynostachyus var. lanosissimus													5
Atriplex lentiformis		1,2,5		3	1,2,3,4,5		3			1,2,3,4,5			

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
Baccharis glutinosa										2			
Baccharis pilularis	1,2,3,4,5	1,2,3,4,5		2,3,4,5	1,2,3,4,5			1,2,3,4	3,4,5	3	3,4,5	5	
Baccharis salicifolia								4		5			
Bolboschoenus maritimus		3		2,3,4	3	1,2,3,4	1,2,3,4,5	2,3,4,5		4			3
Brickellia californica								2,3,4,5					
Bromus carinatus		2,3,5							3	3			
Camissoniopsis micrantha												5	
Centromadia parryi australis		2,3,4		3	5			3,4,5					
Corethrogyne filaginifolia								5					
Crassula aquatic								5					
Cressa truxillensis	3,4,5	3	1,2,3,4,5	3	3,5								
Cyperus eragrostis	2,3	2,3,4,5		1,3	1,2,3	2,3,4,5		1,2,3,4,5					
Daucus pusillus		3											
Deinandra fasciculata	2,3,4,5	2,3,4		3	1,2,3,4,5	3		2,3,4,5					
Distichlis littoralis	4		3,4	1,2,3,4,5	2,3,4,5	3	1, 2, 3	4,5					

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
Distichlis spicata	2,3,4,5	1,2,3,4,5	1,2,3,4,5	1,2,3,4,5	1,2,3,4,5	1,2,3,4,5	1,3,4,5	4,5		3,4,5			3,4,5
Eleocharis acicularis	3,5	2		3	3		3,5	1,2,3,4,5					3
Eleocharis macrostachya	2,4	1,2,3,4,5	2	3	3	1,2,3,4,5		1,2,3,4,5					
Elymus condensatus		1,2,3,4							3,4,5				
Elymus glaucus		2,5						2,4	2,4,5	3			
Elymus triticoides		1,2,3,4,5		1,2,3,5	1,2,3,4,5	4	3		3,4	4,5			
Encelia californica		1,4,5			1,2,4,5				3,4,5				
Epilobium brachycarpum	2,3,4,5	2,3,4		3,5	1,2,3,4,5	1,2,3,4,5		1,2,3,4,5	3,4,5	3		2,3	
Epilobium canum		1,2,3,4,5											
Epilobium ciliatum		2, 3,4,5				4,5						2	
Erigeron canadensis	1,2,3,4,5	2,3,4		2,3,4,5	1,2,3,4,5	4,5	3	1,2,3,4,5	3,4,5	2	2,3,4,5	2,3,4,5	3
Eriogonum parvifolium		2,3,4,5											
Eriophyllum confertiflorum		3,4											
Eryngium vaseyi	4							1,2,3,4,5					
Euphorbia serpens		2, 3		3	2			2,4					
Euphorbia maculata		4											

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
Extriplex californica			3	1, 2, 3,4,5	1, 2, 3,4,5		3						3
Festuca microstachys	5												
Frankenia salina	1,4	4,5	1, 2, 3,4,5	1, 2, 3,4,5	1, 2, 3,4,5	4,5	3						3,4,5
Grindelia camporum								2, 3,4,5					
Hazardia squarrosa		4											
Heterotheca grandiflora	1,2,3,4, 5	2,3,4,5				3		1,2,3,4, 5	3,4,5			1,2,3,4, 5	
Hordeum brachyantherum	4		2	2, 3	3			2, 3,4					
Hordeum brachyantherum ssp.brachyantherum	2, 3	1, 2, 3	1, 3	1, 3,5	1,3,4,5			1, 2, 3,4	4,5				
Hordeum brachyantherum calif.			5										
Isocoma menziesii	2	2, 3,4		3,4	2,3,4,5								
Jaumea carnosa	4		3	1, 2, 3,4,5	3,4,5	3	1, 2, 3						3,4,5
Juncus bufonius	2, 3,4	1, 2, 3,4		3	2, 3		2,4	2, 3,4					5
Juncus occidentalis		2, 3,4						3					
Juncus patens		4											
Juncus phaeocephalus	3,4	2, 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
Laennecia coulteri	2, 3	2, 3		3	1, 2, 3,4,5	4,5		2, 3		3	3		
Lepidium nitidum	4												
Limonium californicum				3									
Lonicera subspicata v. subsp.		4							3,4,5				
Lupinus bicolor												1, 2, 3	
Lupinus succulentus	1	2						1, 2, 3,4					
Malacothrix Saxatilisv. Tenu		4											
Mimulus aurantiacus									3,4,5				
Persicaria lapathafolia		2				2, 3,4,5							
Phalaris lemmonii								1, 2, 3,4					4
Plagiobothrys undulatus								1, 2, 3,4					
Plantago erecta	1,3,4	2			1			2,4					
Platanus racemosa										1,2,4,5			
Populus trichocarpa											1,2,3,4, 5		
Pseudognaphalium californicum	3	1, 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
Psilocarphus brevissimus	2	2						1, 2, 3,4					
Quercus agrifolia		3,4						4	2, 3,4,5		2,4,5		
Rosa californica										1			
Rubus ursinus										3			
Salicornia pacifica	4		1, 2, 3,4,5	1, 2, 3,4,5	1, 2, 3,4,5	1, 2, 3,4,5	1, 2, 3,4,5			4,5			1, 2, 3,4,5
Salix exigua										1,2,3,4, 5			
Salix lasiolepis		2, 3,4	3	3	3			2, 3	4,5	3,4,5	1,2,3,4, 5		1
Salvia leucophylla		2, 3,4							3,4,5				
Schoenoplectus californicus	3			2, 3,5	3		1, 2, 3,4,5	2, 3,4			1, 2		
Scrophularia californica		4											
Sidalcea malvifora	4												
Sesuvium verrocosum													5
Sisyrinchium bellum	4	2, 3.,4						1, 2, 3,4	4,5				
Solanum douglasii		2, 3			1, 2	5		3				2	
Spergularia marina				5	5								5
Spergularia macrotheca				4	4,5								

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
Stebbinsoseris heterocarpa	1, 2, 3,4							2,4					
Stipa pulchra	1, 2, 3,4	2, 3,4						1, 2, 3,4	3,4,5				
Suaeda taxifolia			3	3,5	1, 2, 3,4,5	3	3						3,5
Symphyotrichum chilense					2					3			
Symphyotrichum subulatum	2, 3,4	1, 2, 3,4	3	1, 2, 3,4,5	1, 2, 3,4,5	1, 2, 3,4,5	2, 3	1, 2, 3,4	3,4,5	2, 3			2,3,4,5
Typha latifolia								1, 2, 3,4					
Vulpia microstachys	3												
Xanthium strumarium			1, 2,5	2	3	1,2,4,5	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, 4 = 2021, 5 = 2022). 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, 3,5	1, 2, 3,5	1, 2,4,5	2, 3						2, 3,4
Atriplex rosea				5	3,5								
Atriplex semibaccata **(M)**	1	1, 2, 3,4		2,5	1, 3,4,5								
Avena barbata **(M)**	4,5	3,4,5			4,5			4,5	4			3,4,5	
Avena fatua **(M)**	1,2,3,4,5	1,2, 3,4,5	5	5	1, 2, 3,4,5	4		1, 2, 3,4,5	2, 3,4,5	4		2	
Bassia hyssopifolia **(L)**		2											
Beta vulgaris **(L)**	1				4								
Brachypodium distachyon **(M)**	1, 2, 3,4,5	2, 3,4,5			1, 2, 3,4,5			1, 2, 3,4,5	3,4,5			1, 2	
Brassica nigra **(M)**	1,4,5	3,4		4,5	1			5	1, 3			1,4	
Bromus catharticus	2, 3,4	1,2,3,4,5		1, 2, 3	1, 2, 3,4	3,4		2	5				

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 diandrus **(M)**	1, 2, 3,4,5	1,2,3,4,5	5		1, 2, 3,4,5	2,4		1, 2, 3,4,5	2, 3,5			1, 2, 3,4,5	
Bromus hordeaceus **(L)**	1, 2, 3,4,5	1,2,3,4,5			1, 2, 3,4,5	4		2, 3,4,5		4			
Bromus madritensis		4							4				
Capsella bursa-pastoris		1, 2, 3		2									
Carduus pycnocephalus **(M)**	1, 3,4			5				5	5				
Centaurium sp.	4	4			3	4				4			
Centaurium tenuiflorum	2, 3	2, 3				5		1, 2, 3,5					
Chenopodium album		2				3							3,4
Chenopodium murale		3		1, 3			2						2
Convolvulus arvensis		2, 3,4,5		1				1, 3,4					
Cortaderia selloana **(H)**	4										1, 2, 3		
Cotula coronopifolia **(L)**		4,5		2, 3,4	3,4	2,4		2, 3,4,5		3			4,5
Crypsis schoenoides				2, 3,4		1	2, 3,4,5	1, 2, 3,4,5					3
Cyclospermum sp.		3											
Cynodon dactylon **(M)**	5	1,2,3,4,5		1, 2, 3,4,5	1, 2, 3,4,5	1, 2, 3,4							
Dichondra micrantha	2, 3	2			1								
Dysphania ambrosioides		2											
Erharta erecta **(M)**		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
Erigeron bonariensis	3,4	2, 3,4		2	2, 3,4					2, 3			
Erigeron sumatrensis		3											
Erodium botrys	1, 2	3,4,5	2		1,4			2,4,5				2,4,5	
Erodium cicutarium **(L)**	1, 2, 3,5	2,4,5			1,5			4,5	3,4			1, 2, 3	
Eucalyptus globulus **(L)**		2											
Eucalyptus sp.		3,5											
Euphorbia maculata		3			3								
Euphorbia serpens		5						5					
Festuca bromoides	5	1,2,3,5			3,4,5			2,5					
Festuca myuros **(M)**	1, 2, 3,4,5	1,2,3,4,5	1	1, 2	1, 2, 3,4,5	4,5		1, 2, 3,4,5				1, 2, 3,4,5	
Festuca perennis **(M)**	1,2,3,4,5	1,2,3,4,5	1,2,3,4,5	1,2,3,4,5	1,2,3,4,5	2, 3,4,5		1,2,3,4,5	1, 3,4,5	3,4		1, 3	
Foeniculum vulgare **(M)**	1				1, 3,4,5			5					
Geranium dissectum **(L)**	1,2,3,4,5	2, 3,4,5	3,4,5		3,5			1 2,3,4,5	4			2	
Hedypnois cretica								5					
Helminthotheca echioides **(L)**	1,2,3,4,5	1,2,3,4,5	1, 2,5	2, 3,4,5	1, 2, 3,,5	1,2,3,4		2,3,4,5	4,5	2,3			
Hirschfeldia incana **(M)**	2			5									
Hordeum marinum **(M)**	1, 3,4,5	1,3,4,5		1,2,3,4,5	1,2,3,4,5	3,4,5		2,4				4	
Hordeum murinum **(M)**	2, 3,4,5	1,2,3,4,5		1, 2,4	1,2,3,4,5			5					

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**
Hypochaeris glabra **(L)**	2,4,5							2, 3,4,5				2, 3,4	
Lactuca saligna								5					
Lactuca serriola	1, 3	1,2,3,4,5	3,5	5	1,2,3,4,5			1, 2,4,5	5				
Lepidium didymum	1	1,2,3,4,5		1	1,4,5								
Logfia gallica	3,4,5	2						3,5				2	
Lotus corniculatus					2								
Lysimachia arvensis	1,2,3,4,5	1,2,3,4,5		2,5	1,2,3,4,5			1,2,3,4,5	4		2, 3,4	2, 3,4	
Lythrum hyssopifolia **(M)**	2, 3,4	1, 2, 3,4,5			1, 3	4,5		1, 2, 3,4,5					
Malva parviflora	1, 2, 3,4,5	1, 2, 3,4			1, 2, 3,4,5			2	3,4				
Matricaria discoidea					1								
Medicago lupulina	1, 3,4	2, 3,5						2, 3,4,5	3,4				
Medicago polymorpha **(L)**	1, 2, 3,4,5	1, 2, 3,4,5	1	1, 3,4,5	1, 2, 3,4,5	4		1, 2, 3,4,5	1, 2, 3,4,5	2		1, 2, 3,4	
Melilotus albus	1,4,5				3			5				5	2, 3
Melilotus indicus	1, 2, 3,4,5	1, 2, 3,4,5		1, 2, 3,4,5	1, 2, 3,4,5			1, 2, 3,4,5	1, 2, 3,4,5	2		2, 3	2,4,5
Mesembranthemum nodiflorum				5									
Oxalis pes-caprae **(M)**								2					
Parapholis incurva	1, 2, 3,4,5	1, 2, 3,4		1, 2, 3,4,5	1, 2, 3,4,5			2, 3,4,5					2,4,5

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**
Paspalum dilatatum		1, 2, 3,4,5			1, 2								
Pennisetum clandestinum **(L)**		2,5		1	1, 2								
Phalaris aquatica **(M)**								1,5					
Pinus halepensis		3											
Pinus pinea		2,4									1, 2		
Pinus sp.											1		
Plantago coronopus	1, 2, 3,4,5	1, 2, 3,4,5		1, 2, 3,4,5	1, 2, 3,4,5	2, 3,4,5	2	2, 3,4,5		4			4
Plantago lanceolata **(L)**	1, 2, 3,4,5	1, 2, 3.4,5			1, 2, 3,4			1, 2, 3,4,5				1	
Plantago major		2											
Poa annua	5	1, 2, 3			1, 3,4			4		3			
Polycarpon tetraphyllum		3									3		
Polygonum aviculare depressum	2, 3	1, 2, 3,4,5		1, 2, 3,4,5	1, 2, 3,4,5	2, 3,5		2, 3,4,5	5	2			2
Polypogon interruptus	3	3,4,5		3	3,4			1, 2, 3,4,5					
Polypogon monspeliensis **(L)**	1, 3,4,5	2, 3,4,5		2, 3,4,5	2, 3,4,5	2, 3,4,5		1, 2, 3,4,5		4			3,4,5
Polypogon viridis	4	4			3			2,4	4	4			
Portulaca oleracea		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**
Pseudognaphalium luteoalbum	2, 3,4,5	2, 3,4			2, 3,4,5	2, 3,4		3,4,5					
Raphanus sativus **(L)**			1, 2, 3,4,5										
Rumex crispus **(L)**	2	1, 2, 3,4	2, 3		1, 3	1, 3,4,5		1, 2,4	2				
Salsola tragus **(L)**	2	1, 2,4,5		2,4,5	1,4,5			5					
Senecio vulgaris		2											
Silene gallica								2					
Sonchus asper	1, 2,5	1,4,5	5	1,5	1,4,5	3		1, 2,4,5					
Sonchus oleraceus	1, 2,4,5	1, 2, 3,4,5	4	1,5	1			2, 3,4,5	5	3			
Sonchus sp.	2, 3,4	2, 3,4		2,4,5	2, 3,4	4		2, 3,4,5	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, 3,4,5	2, 3,5	3,4,5		3			2, 3,4
Spergularia villosa								5					
Stipa miliacea		2,4,5						2					5
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**
Tragopogon porrifolius		5											
Trifolium hirtum **(L)**	3,4,5	2, 3,4		2	1, 2	4		1, 2,4,5					
Trifolium repens		2,5				5		5					
Trifolium tomentosum	3												
Triticale	1, 2, 3			2	1				1				
Urospermum piciroides								5					
Vicia sativa	1, 2	1, 2,4	1, 3,4	5	1			2,4,5				2,5	
Vicia sp.			1										
Vicia villosa	1	5	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 five 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).

Guild & Common Name	Year 1 # of Obs.	Year 2 # of Obs.	Year 3 # of Obs.	Year 4 # of Obs.	Year 5 # of Obs.
Cormorants and Anhingas	**1**	**3**	**5**	**8**	**6**
Double-crested Cormorant	1	3	5	8	6
Gulls, Terns, and Skimmers	**13**	**28**	**27**	**13**	**28**
California Gull	2	4	5	1	9
Caspian Tern			2		1
Mew Gull		3	1		
Ring-billed Gull	3	6	4	4	5
Western Gull	8	15	15	8	13
Herons, Egrets, and Ibis	**34**	**43**	**78**	**45**	**65**
Black-crowned Night-Heron	2	2	15	20	23
Great Blue Heron	14	5	17	6	9
Great Egret	6	13	20	11	17
Green Heron	7	3	2	1	3
Snowy Egret	4	19	24	7	12
White-faced Ibis	1	1			1
Hummingbirds	**88**	**84**	**104**	**135**	**150**
Allen's Hummingbird	5	5	9	13	19
Anna's Hummingbird	81	78	94	117	124
Black-chinned Hummingbird			1	1	
Rufous Hummingbird	2	1			
Selasphorus sp				4	7
Insectivores	**429**	**670**	**765**	**815**	**795**
Blackbirds	***37***	***50***	***35***	***33***	***50***
Bullock's Oriole	1		1		1
Great-tailed Grackle	1		3	1	
Hooded Oriole	4	7	10	4	3

Guild & Common Name	# of Obs.	# of Obs.	# of Obs.	# of Obs.	# of Obs
Red-winged Blackbird	12	22	7	12	32
Western Meadowlark	19	20	13	15	14
Yellow-headed Blackbird		1	1	1	0
Cardinals, Grosbeaks, and Allies		***2***		***1***	***0***
Western Tanager		2		1	0
Catbirds, Mockingbirds, and Thrashers	***2***		***3***	***1***	***1***
California Thrasher	2		3	1	1
Gnatcatchers	***8***	***25***	***48***	***66***	***32***
Blue-gray Gnatcatcher	8	25	48	66	32
Kinglets	***5***	***15***	***16***	***32***	***33***
Ruby-crowned Kinglet	5	15	16	32	33
Martins and Swallows	***46***	***39***	***40***	***31***	***26***
Barn Swallow	6	8	6	2	3
Cliff Swallow	26	25	27	22	18
Northern Rough-winged Swallow	10	3	2	3	2
Tree Swallow	4	2	4	4	3
Violet-green Swallow		1	1		0
New World Sparrows	***117***	***212***	***271***	***292***	***308***
Fox Sparrow	1				
Golden-crowned Sparrow	1		1		3
Lincoln's Sparrow		5	9	17	8
Savannah Sparrow	1	10	17	9	34
Savannah Sparrow (Belding's)	8	8	5	8	
Song Sparrow	69	121	154	183	166
White-crowned Sparrow	37	68	85	75	97

Guild & Common Name	# of Obs.	# of Obs.	# of Obs.	# of Obs.	# of Obs.
Nuthatches		***3***	***8***	***7***	***5***
Red-breasted Nuthatch			8	5	
White-breasted Nuthatch		3		2	5
Parrotbills, Wrentit, and Allies		***3***	***3***	***5***	***2***
Wrentit		3	3	5	2
Penduline-Tits and Long-tailed Tits	***9***	***21***	***31***	***24***	***31***
Bushtit	9	21	31	24	31
Starlings and Mynas	***6***	***11***	***14***	***7***	***19***
European Starling	6	11	14	7	19
Swifts	***1***	***1***			***1***
Vaux's Swift	1	1			1
Thrushes	***28***	***31***	***32***	***38***	***30***
Hermit Thrush		1	1	1	2
Western Bluebird	28	30	31	37	28
Tits, Chickadees, and Titmice		***5***	***4***	***11***	***9***
Oak Titmouse		5	4	11	9
Tyrant Flycatchers: Pewees, Kingbirds, and Allies	***121***	***193***	***184***	***173***	***182***
Ash-throated Flycatcher		3			4
Black Phoebe	65	112	89	86	92
Cassin's Kingbird	11	28	30	20	27
Pacific-slope Flycatcher	1	1	3		
Say's Phoebe	42	47	51	59	52
Tropical Kingbird		1	3	2	2
Western Kingbird	1		7	6	4
Western Wood-Pewee	1	1			
Willow Flycatcher			1		1
Wagtails and Pipits	***24***	***19***	***8***	***9***	***23***
American Pipit	24	19	8	9	23

Guild & Common Name	# of Obs.	# of Obs.	# of Obs.	# of Obs.	# of Obs.
Woodpeckers	***6***	***11***	***15***	***12***	***11***
Acorn Woodpecker	2		1		3
Downy Woodpecker	2	2	6	5	1
Hairy Woodpecker	2		6	1	1
Northern Flicker		3	1	2	
Nuttall's Woodpecker		6	1	4	6
Wrens	***19***	***29***	***53***	***73***	***34***
Bewick's Wren	13	14	17	21	17
House Wren	4	9	26	33	12
Marsh Wren		3	10	19	5
Rock Wren	2	3			
Kingfishers		**5**	**4**	**1**	**4**
Belted Kingfisher		5	4	1	4
Omnivores	**152**	**140**	**144**	**156**	**159**
Blackbirds		***1***			
Brewer's Blackbird		1			
Catbirds, Mockingbirds, and Thrashers	***6***	***18***	***15***	***7***	***6***
Northern Mockingbird	6	18	15	7	6
Jays, Magpies, Crows, and Ravens	***53***	***47***	***72***	***77***	***75***
American Crow	53	46	72	75	74
Common Raven				1	
California Scrub-Jay		1		1	1
New World Sparrows	***79***	***57***	***47***	***62***	***61***
California Towhee	78	56	47	57	57
Spotted Towhee	1	1		5	4
Old World Sparrows	***14***	***17***	***10***	***13***	***17***
House Sparrow	14	17	10	13	17
Raptors	**64**	**79**	**86**	**98**	**97**
Falcons and Caracaras	***5***	***6***	***5***	***8***	***12***
American Kestrel	5	5	4	7	6

Guild & Common Name	# of Obs.	# of Obs.	# of Obs.	# of Obs.	# of Obs.
Peregrine Falcon				1	3
Merlin		1	1	1	3
Owls		***7***	***6***	***10***	***2***
Burrowing Owl		6	3	9	
Great Horned Owl		1	3	1	2
Shrikes	***9***	***9***	***11***	***5***	***1***
Loggerhead Shrike	9	9	11	5	1
Vultures, Hawks, and Allies	***50***	***57***	***64***	***74***	***82***
Cooper's Hawk	11	16	19	23	23
Accipiter sp.				1	
Northern Harrier			2	4	3
Osprey		1		1	
Red-shouldered Hawk	8	8	15	8	17
Red-tailed Hawk	17	19	15	16	25
Turkey Vulture	7	7	9	12	13
White-tailed Kite	7	6	4	9	1
Seed & Fruit Eaters	**174**	**205**	**201**	**245**	**255**
Blackbirds	***1***	***1***	***2***	***1***	***1***
Brown-headed Cowbird	1	1	2	1	1
Cardinals, Grosbeaks, and Allies	***1***	***1***	***1***		
Black-headed Grosbeak			1		
Blue Grosbeak	1	1			
Estrildids	***23***	***33***	***28***	***27***	***40***
Scaly-breasted Munia	23	33	28	27	40
Finches, Euphonias, and Allies	***85***	***99***	***95***	***61***	***145***
House Finch	72	76	73	16	88
Lesser Goldfinch	13	22	20	43	56
American Goldfinch				1	1
Purple Finch		1	2	1	

Guild & Common Name	# of Obs.	# of Obs.	# of Obs.	# of Obs.	# of Obs.
Grouse, Quail, and Allies		***1***			
California Quail		1			
New World Sparrows	***3***	***16***	***20***	***10***	***15***
Chipping Sparrow		2	1		
Clay-colored Sparrow		1			
Dark-eyed Junco	1			1	5
Lark Sparrow	2	13	19	9	10
Pigeons and Doves	***61***	***54***	***55***	***46***	***54***
Eurasian Collared-Dove	9	2	5	5	1
Mourning Dove	23	19	18	13	23
Rock Pigeon (Feral Pigeon)	29	33	32	28	30
Shorebirds	**224**	**189**	**175**	**99**	**112**
American Avocet			2		1
Black-necked Stilt	5	11	23	4	12
Dunlin	1	1			1
Greater Yellowlegs	18	14	18	12	11
Killdeer	94	93	71	45	36
Least Sandpiper	45	30	17	18	28
Lesser Yellowlegs			1	1	1
Long-billed Curlew	2	3	2		2
Long-billed Dowitcher		2	5	1	2
Pectoral Sandpiper		1	1		
Red-necked Phalarope	2	3	5		3
Sanderling		1			
Semipalmated Plover	16	7	7	4	4
Solitary Sandpiper		1			
Spotted Sandpiper	1	1	5		1
Western Sandpiper	36	17	11	10	5
Western Snowy Plover	1	2	4		4
Whimbrel		1			1

Guild & Common Name	# of Obs.	# of Obs.	# of Obs.	# of Obs.	# of Obs.
Willet	1				
peep sp.				1	
Wilson's Snipe	2	1	3	3	
Warblers	**56**	**114**	**193**	**185**	**188**
Common Yellowthroat	16	41	77	107	93
Orange-crowned Warbler	3	3	11	6	12
Yellow Warbler	1	4	4		3
Yellow-rumped Warbler	36	66	101	72	80
Waterfowl & ALLIES	**104**	**202**	**262**	**136**	**219**
Grebes	***2***	***10***	***21***	***8***	***7***
Clark's Grebe			5		
Eared Grebe	2	6	4		2
Pied-billed Grebe		2	11	8	5
Western Grebe		2	1		
Rails, Gallinules, and Allies	***7***	***59***	***48***	***23***	***31***
American Coot	5	45	39	16	29
Sora	2	14	7	4	2
Virginia Rail			2	3	
Waterfowl	***95***	***133***	***193***	***105***	***181***
American Wigeon	3		8	10	16
Blue-winged Teal	1	2	2		
Bufflehead	2	4	2		3
Cackling Goose (Aleutian)	5	1		1	1
Canada Goose	16	22	21	17	25
Canvasback			1		
Cinnamon Teal	7	8	17	5	1
Cinnamon Teal x Northern Shoveler (hybrid)		1			
Gadwall	7	10	21	11	25
Greater White-fronted Goose	7	2	4	2	2
Green-winged Teal		3	5	1	4

Guild & Common Name	# of Obs.	# of Obs.	# of Obs.	# of Obs.	# of Obs.
Hooded Merganser	1	2	1	2	2
Mallard	35	53	62	40	63
Mute Swan		1			2
Northern Pintail	2		6		2
Northern Shoveler	3	14	17	6	20
Redhead	1	2	8	4	6
Ring-necked Duck			1		1
Ross's Goose		2	1	1	1
Ruddy Duck	5	4	15	3	5
Snow Goose		2	1	2	2
Grand Total	**1339**	**1763**	**2044**	**1936**	**2080**

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 2018-2022. 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**	**2022**	**2018**	**2019**	**2020**	**2021**	**2022**
American Crow			2		2			3	1	1
Allen's Hummingbird										1
Anna's Hummingbird		1								1
Ash-throated Flycatcher					1					
Barn Swallow								1	1	
Bewick's Wren								1		
Black-necked Stilt										1
Black Phoebe	3	2	1		2		1	3	2	3
Bushtit	1								1	
California Towhee	2		1	1		1		2	1	
Canada Goose		2	2	3			1	1		1
Cassin's Kingbird							1			1
Cliff Swallow	5	4	1	3	1	3	3	3	2	1
Common Yellowthroat										1
Cooper's Hawk	1		2					1		
Dark-eyed Junco									1	
European Starling					2		1	1		
Gadwall		2					3	1	2	
Great Egret							1			

Great Horned Owl						1		1	1	
Hooded Oriole										1
House Finch	2	3	3	3	1	2	4	3	5	1
House Sparrow	2				1	2	1			
Killdeer	4	3	2		2	5	6	2	2	3
Lark Sparrow		2	1					1	2	3
Lesser Goldfinch		1	1				1	1	1	2
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	2
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		1	2
Song Sparrow		2	1	4	1		7	1	2	
Western Bluebird	1					1			1	2
Western Kingbird				1					1	
Western Sandpiper	1									
Western Snowy Plover			1		2	2	1	1		2
White-tailed Kite				2						
White-breasted Nuthatch									1	

Wrentit			1							
Grand Total	**25**	**25**	**24**	**21**		**21**	**34**	**34**	**37**	

APPENDIX 4 – JULY 2020 AQUATIC SPECIES SURVEY REPORT

Tuesday, 27 September 2022

Survey Report

Date:	09/27/22
To:	Lisa Stratton, UCSB; Chris Kofron, USFWS; Justin Garcia & Jennifer Pareti, CDFW
From:	Hannah Donaghe
RE:	Devereux Slough and UCSB North Campus Open Space 2022 Post-Construction Aquatic Species Survey Report

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 in 2016, and post-construction surveys in the fall of 2017, 2018, 2020, and 2021 found no tidewater gobies to be present. The 2019 post-construction tidewater goby survey conducted on October 17, 2019, by Dr. Rosemary Thompson and CCBER staff 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 September 9, 2022, in Devereux Slough, the restored channels, and lower Phelps Creek by Hannah Donaghe (federal permit TE14532C-1, state permit S-201000002-20167001) with assistance from Tim Lee (Catalyst scientist) and CCBER staff (Lisa Stratton, Darwin Richardson, and Chris Berry). 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. Three of these sites were not sampled, the Main Channel, East Arm, and West Arm, due to low water depth (or no water present) and hypersaline water with a salt crust present. Sampling was conducted between 9:00 AM and 1:00 PM. A minnow seine 10-feet long by 4-feet high with 1/8-inch mesh was used for the sampling. Seine hauls varied in length from about 15 to 40 feet. The seine was pulled across the channel in Devereux Slough and then swept into the shoreline, lifted, and placed on the shore. Seining was generally performed by walking the seine off the bank and then performing the haul directly towards shore. In areas where water depth dropped off and substrate was very silty (North of Pier), seining was performed parallel to shore and then pulled to shore. Fish were removed from the net immediately, identified, and counted. After counting, all species were immediately released back into the water. At sites where the substrate was too rocky to conduct an effective seine haul, dip net sweeps were completed to sample the area. Many sweeps were made wherever open water occurred with minimal obstructions. Organisms captured were identified and released. Water depth at the lower estuary sites were generally 2 to 3 feet, and other sites were shallower, ranging from 6 inches to 2 feet. The West Arm and Main Channel sites were completely dry at the time of sampling.

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).

Removal of the weir at the Venoco Road crossing has allowed fish access to upstream areas. However, due to water level and water quality conditions the restored estuarine channels on NCOS were likely not suitable for fish at the time of sampling. 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 live fish were captured at the Venoco Bridge sites, which had very low dissolved oxygen levels and hypersaline conditions. The East Arm channel had very shallow water with a salt crust on the surface, and water quality parameters were consistent with the Venoco Bridge sites. Fish were captured lower in the estuary north of the pier and estuary mouth.

The non-native red swamp crayfish continues to occur in Phelps Creek. Crayfish were only observed in Phelps Creek in 2022. Its spread into the restored channels will likely be limited by its intolerance of high salinity. Several dragonfly nymphs were also captured during dip net sampling in Phelps Creek.

Table 1: Fish Captured during 2022 Survey

<table>
<tr><th>Site</th><th>Common Name</th><th>Scientific Name</th><th colspan="4">Number</th><th>Method</th></tr>
<tr><td rowspan="2">Phelps Creek</td><td>Mosquitofish</td><td>Gambusia affinis</td><td colspan="4">14</td><td rowspan="2">Dip net</td></tr>
<tr><td>Red swamp crayfish</td><td>Procambarus clarkii</td><td colspan="4">2</td></tr>
<tr><td>Phelps Bridge</td><td>Mosquitofish</td><td>Gambusia affinis</td><td colspan="4">35</td><td>Dip net</td></tr>
<tr><td>West Arm</td><td>Not sampled[1]</td><td>N/A</td><td colspan="4">N/A</td><td>N/A</td></tr>
<tr><td>East Arm</td><td>Not sampled[2]</td><td>N/A</td><td colspan="4">N/A</td><td>N/A</td></tr>
<tr><td>Main Channel (Central NCOS)</td><td>Not sampled[1]</td><td>N/A</td><td colspan="4">N/A</td><td>N/A</td></tr>
<tr><td>Venoco Bridge North</td><td>California killifish (dead)[3]</td><td>Fundulus parvipinnis</td><td colspan="4">2</td><td>Dip net</td></tr>
<tr><td>Venoco Bridge South</td><td>California killifish (dead)[3]</td><td>Fundulus parvipinnis</td><td colspan="4">3</td><td>Dip net</td></tr>
<tr><td rowspan="3">Devereux Slough-North of Pier</td><td>Longjaw mudsucker</td><td>Gillichthys mirabilis</td><td colspan="2">48</td><td colspan="2">17</td><td rowspan="3">Seine (2 hauls)</td></tr>
<tr><td>California killifish</td><td>Fundulus parvipinnis</td><td colspan="2">12</td><td colspan="2">5</td></tr>
<tr><td>Topsmelt</td><td>Atherinops affinis</td><td colspan="2">12</td><td colspan="2">0</td></tr>
<tr><td rowspan="3">Devereux Slough-North of Mouth</td><td>Longjaw mudsucker</td><td>Gillichthys mirabilis</td><td>3</td><td>14</td><td>3</td><td>2</td><td rowspan="3">Seine (4 hauls)</td></tr>
<tr><td>California killifish</td><td>Fundulus parvipinnis</td><td>27</td><td>16</td><td>26</td><td>40</td></tr>
<tr><td>Topsmelt</td><td>Atherinops affinis</td><td>14</td><td>11</td><td>6</td><td>8</td></tr>
</table>

Table Notes:

[1] This site was dry at the time of sampling.

[2] This site was not sampled due to very low water level (<6 inches) and a salt crust formed on the surface due to hypersaline conditions.

[3] No live fish were captured at this location.

Table 2: Water Quality at Fish Sample Sites

Location	Approx. Latitude	Approx. Longitude	DO (mg/L)	Salinity (ppt)	Temperature (C)
Phelps Creek	34.422963	-110.879851	2.55	0	21.7
Phelps Bridge	34.421244	-119.878893	1.2	2.0	22.3
West Arm	34.420759	-119.878412	Not sampled	Not sampled	Not sampled
East Arm	34.420628	-119.874310	Not detectable	> sensor limit	26.7

Main Channel (Central NCOS)	34.420057	-119.876934	Not sampled	Not sampled	Not sampled
North of Venoco Bridge	34.417846	-119.874249	Not detectable	> sensor limit	27.1
South of Venoco Bridge	34.416734	-119.874077	Not detectable	> sensor limit	27.1
Devereux Slough-North of Pier	34.412124	-119.876542	Not detectable[2]	> sensor limit	26
Devereux Slough-North of Mouth	34.409813	-119.879393	Not detectable[1]	> sensor limit[3]	26.1

Table Notes:

Figure 1. Creeks and Channels at NCOS

[2] Dissolved oxygen level was not detected by the water quality meter for these sites. However, there may have been an issue with the sensor, because dissolved oxygen levels supported fish at both Devereux Slough sites north of the pier and north of the mouth.

[3] Conductivity was over 119,000 uS/cm.

Figure 2. Approximate fish sampling and water quality locations (yellow labeled points)

References

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

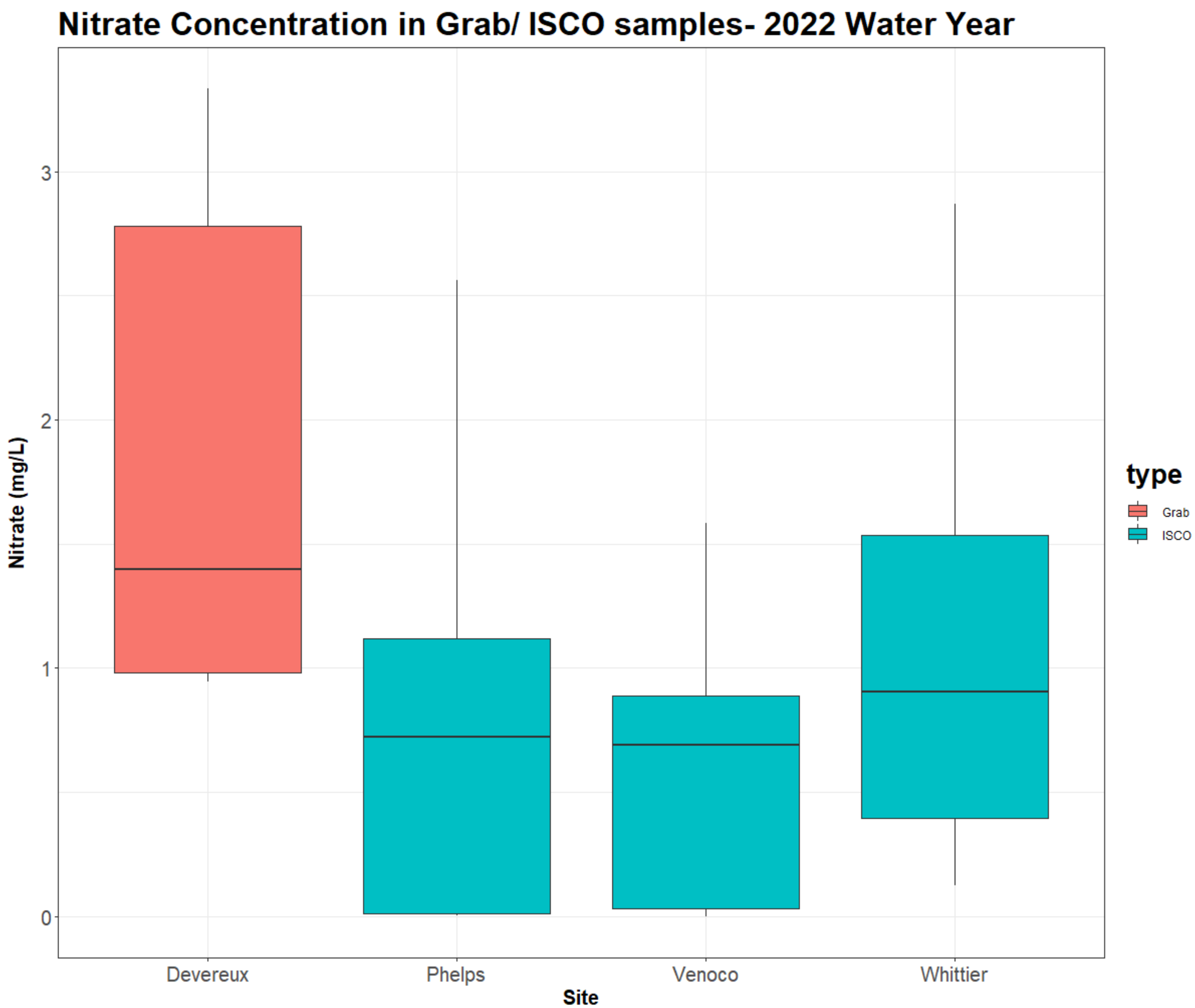
Swift, C., J. L. Nelson, C. Maslow, and T. Stein. 1989. Natural History Museum of Los Angeles County, Contributions in Science, Number 404:1-19.

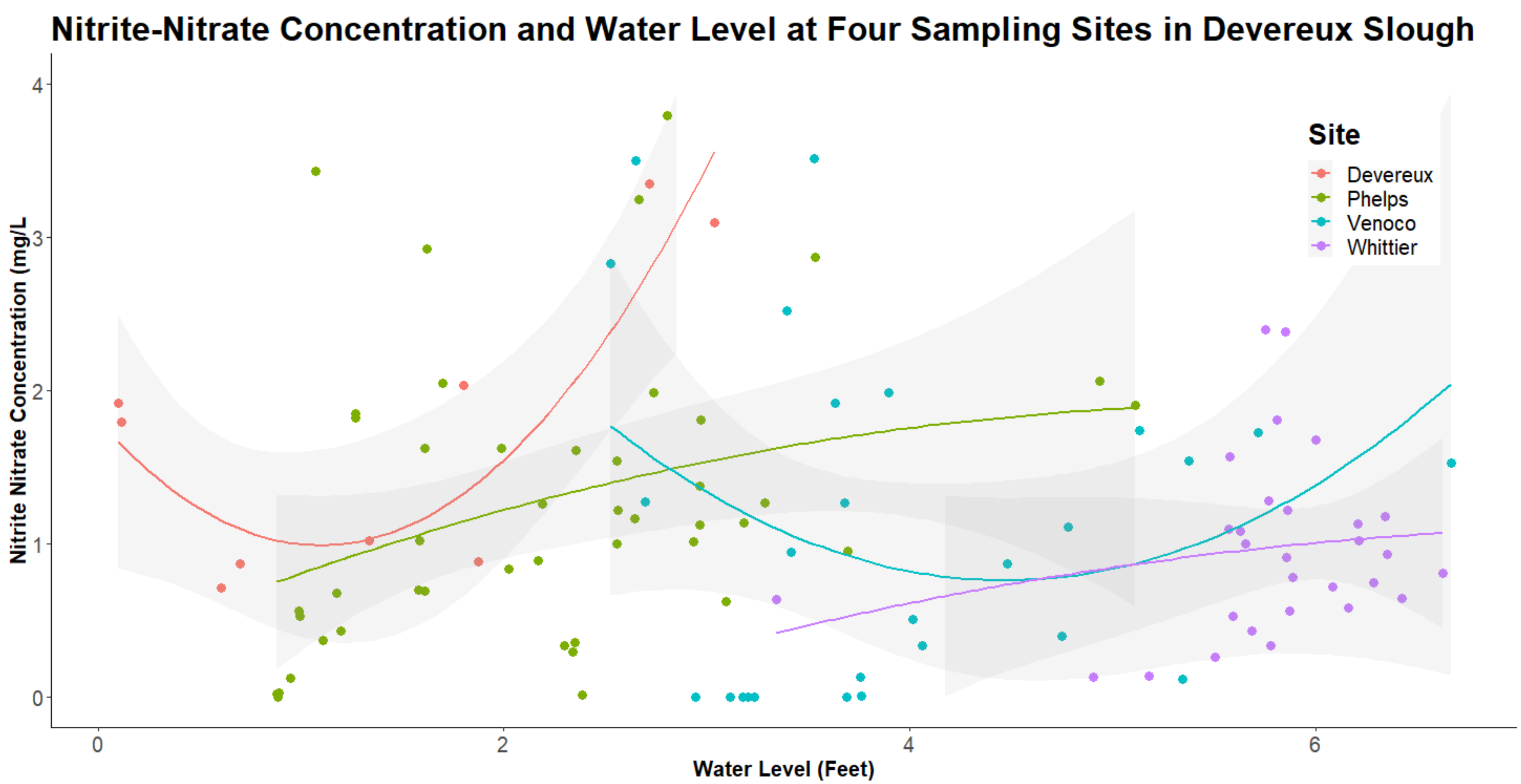
APPENDIX 5 – 2022 WATER YEAR STORM WATER DATA

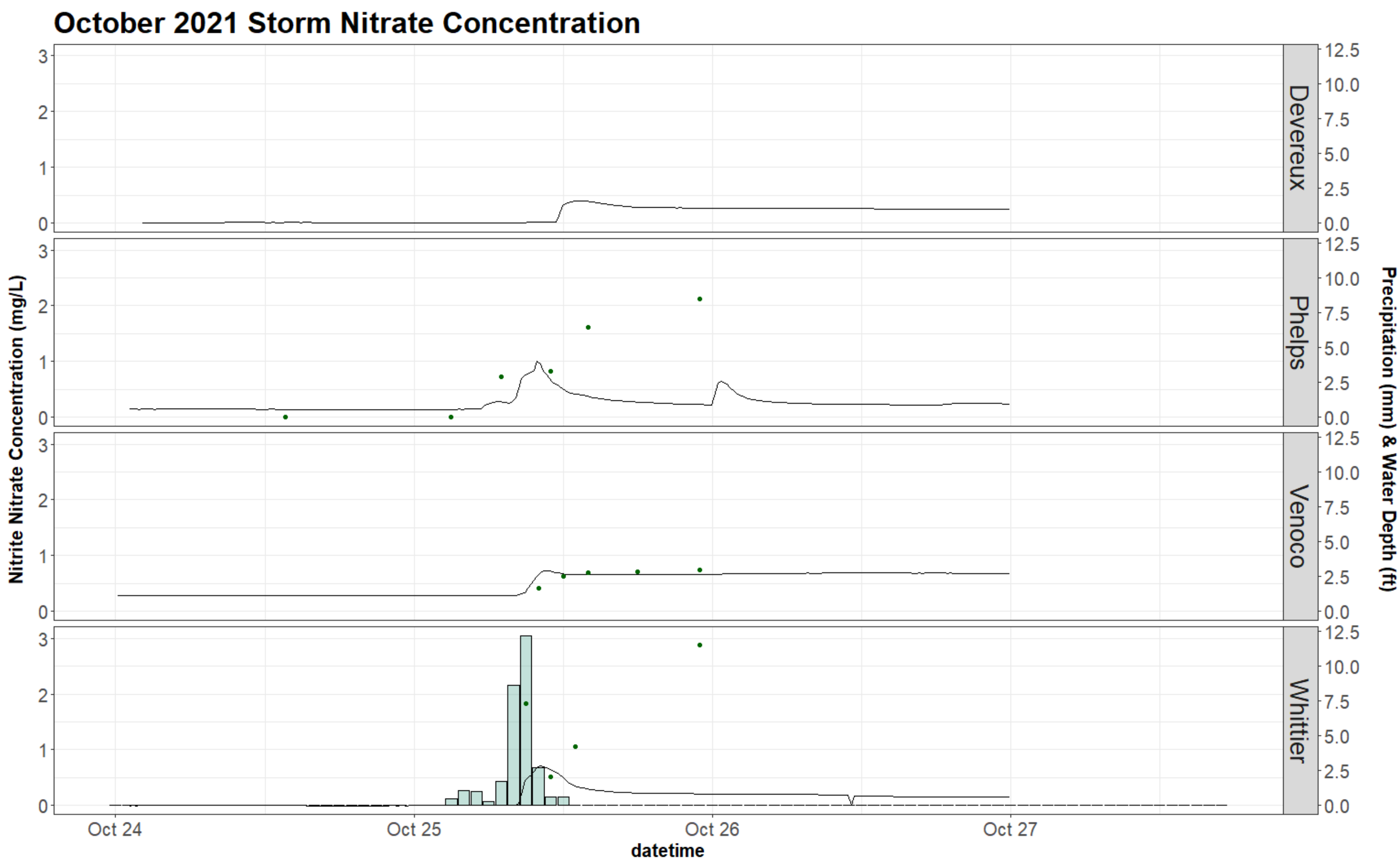
Table A5.1. Grab and ISCO samples analyzed for nutrients (N) and suspended solids concentrations (SSC) at each sampling site for each storm and baseline event in the 2022 Water Year (October 1, 2021, to September 30, 2022) at North Campus Open Space. At Devereux Creek, only Grab samples were collected and analyzed.

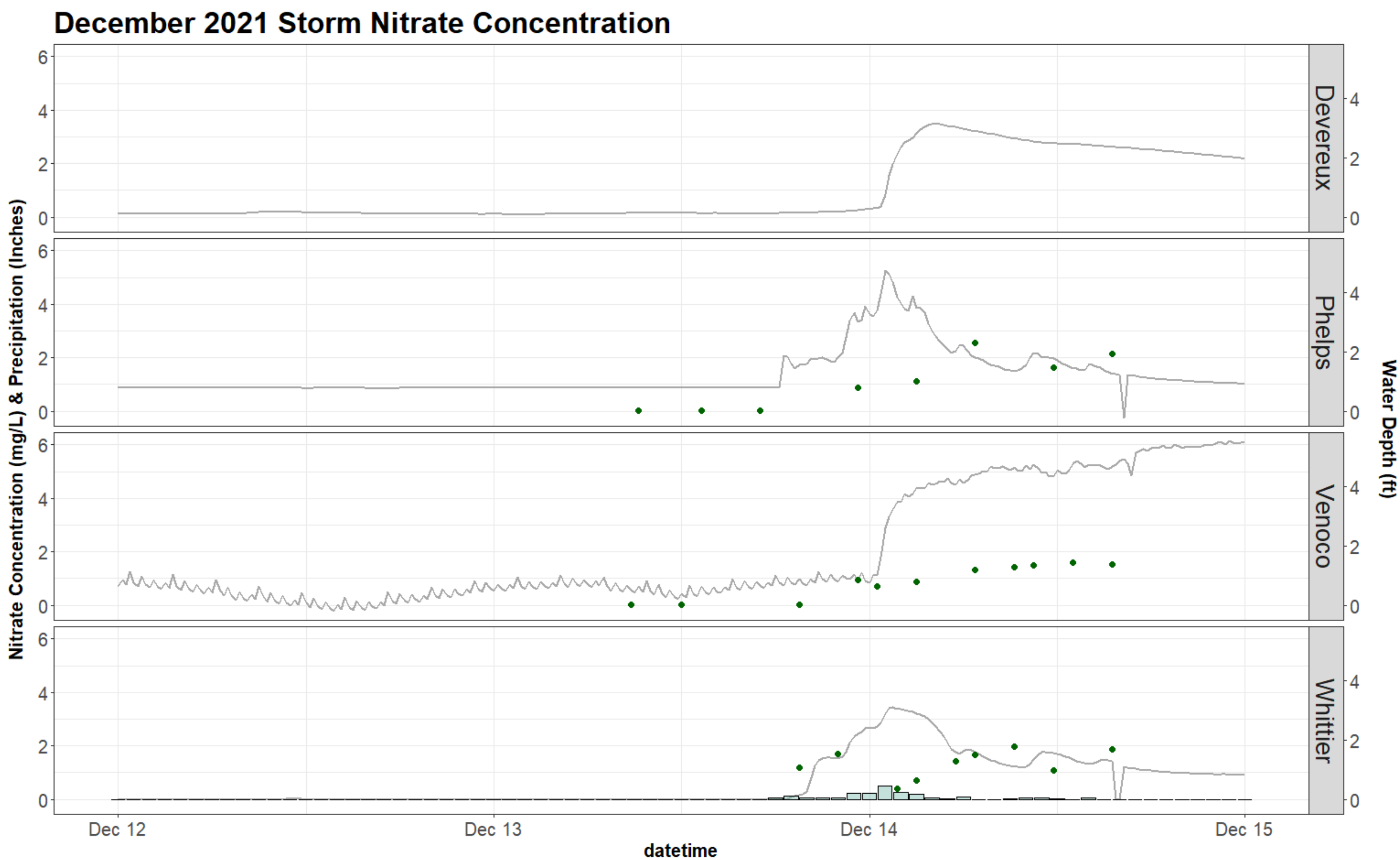
		Devereux Creek	Phelps Creek	Whittier Storm drain Outfall	Venoco Bridge
Date	**Event Type**	**Grab**	**ISCO**	**ISCO**	**ISCO**
10/24-10/26/2021	Storm	2	6	4	5
12/13-12/14/2021	Storm	3	8	9	11
12/29/2021	Storm	2	0	5	5
03/27-03/28/2022	Storm	3	7	5	4

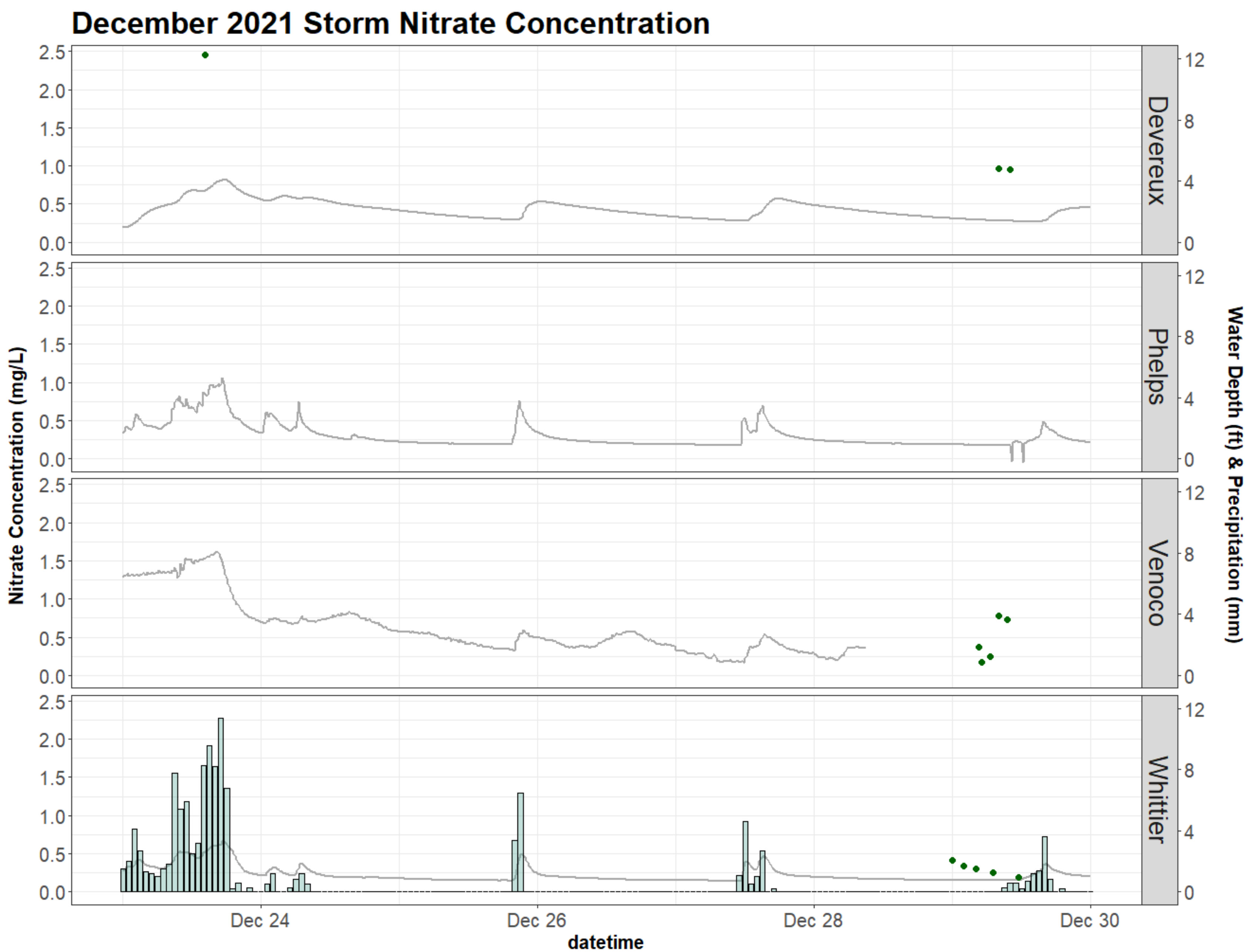
NUTRIENT CONCENTRATIONS DATA: Nitrite+Nitrate – Site Comparisons

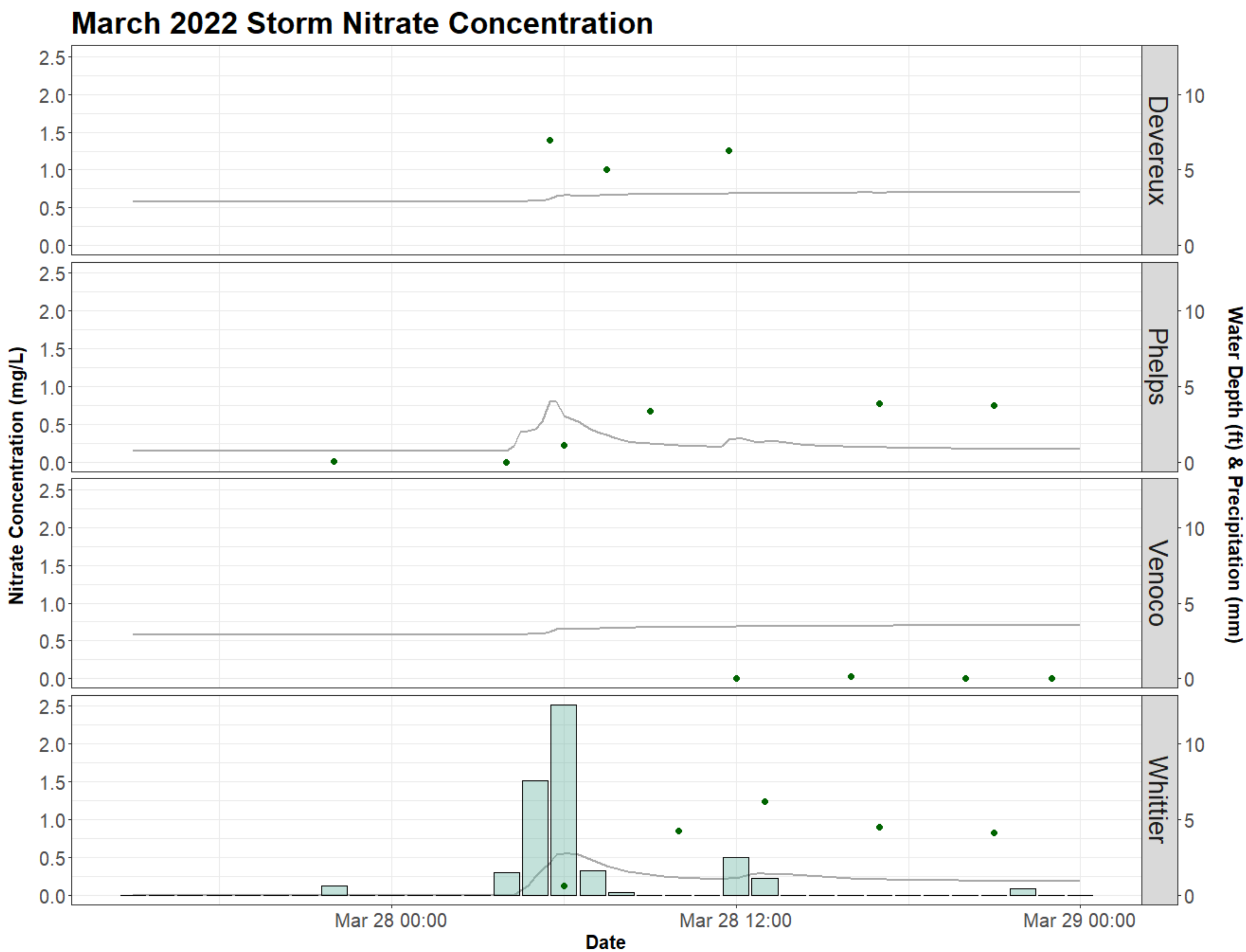



Nitrite-Nitrate Concentration and Water Level at Four Sampling Sites in Devereux Slough
Nitrite Nitrate Concentration (mg/L
Water Level (Feet)
0
1
2
3
4
0
2
4
6
Site
Devereux
Phelps
Venoco
Whittier


October 2021 Storm Nitrate Concentration
Nitrite Nitrate Concentration (mg/L)
Precipitation (mm) & Water Depth (ft)
Devereux
Phelps
Venoco
Whittier
0
1
2
3
0.0
2.5
5.0
7.5
10.0
12.5
Oct 24
Oct 25
Oct 26
Oct 27
datetime

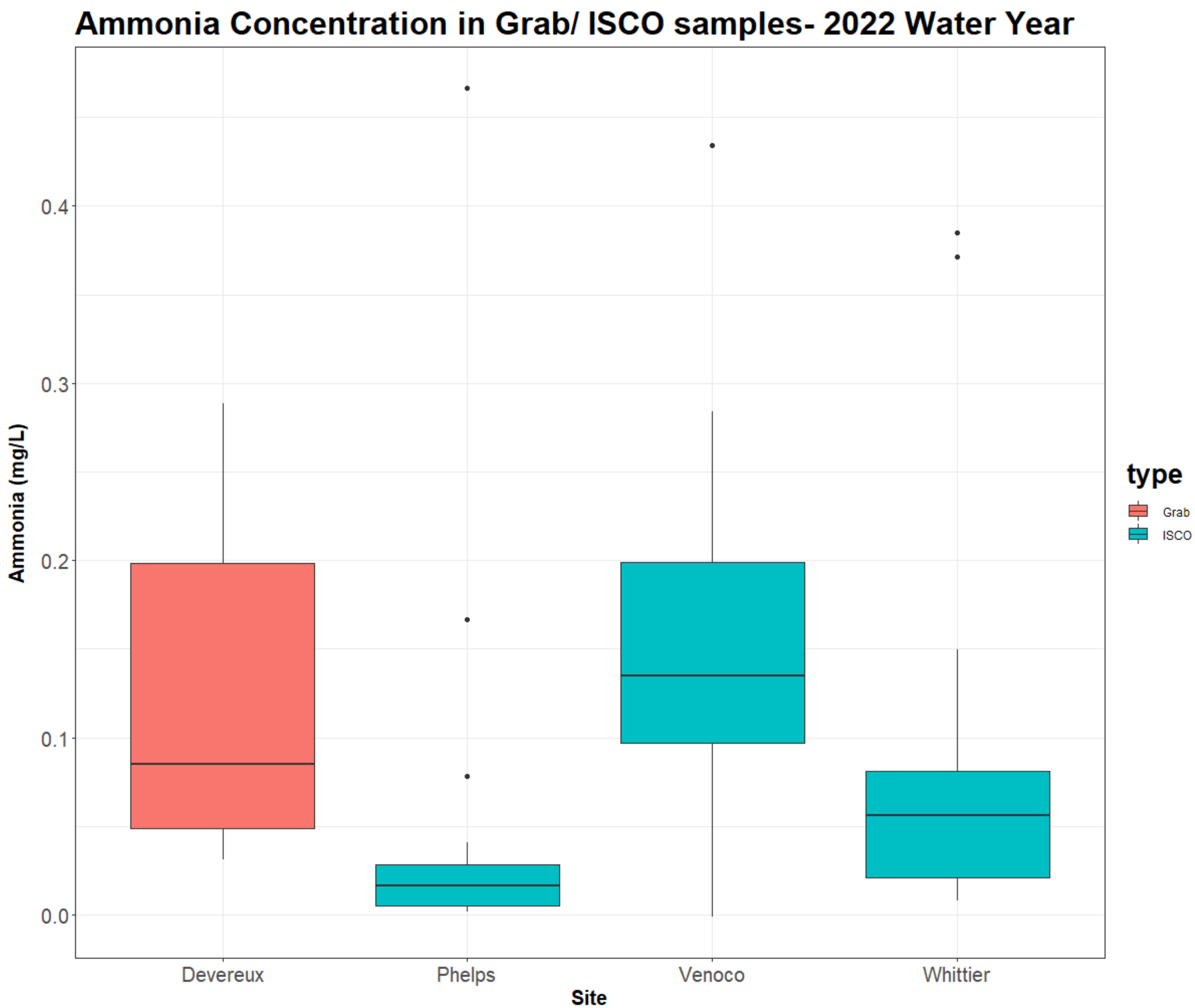

December 2021 Storm Nitrate Concentration
Nitrate Concentration (mg/L) & Precipitation (Inches)
Water Depth (ft)
Devereux
Phelps
Venoco
Whittier
Dec 12
Dec 13
Dec 14
Dec 15
datetime

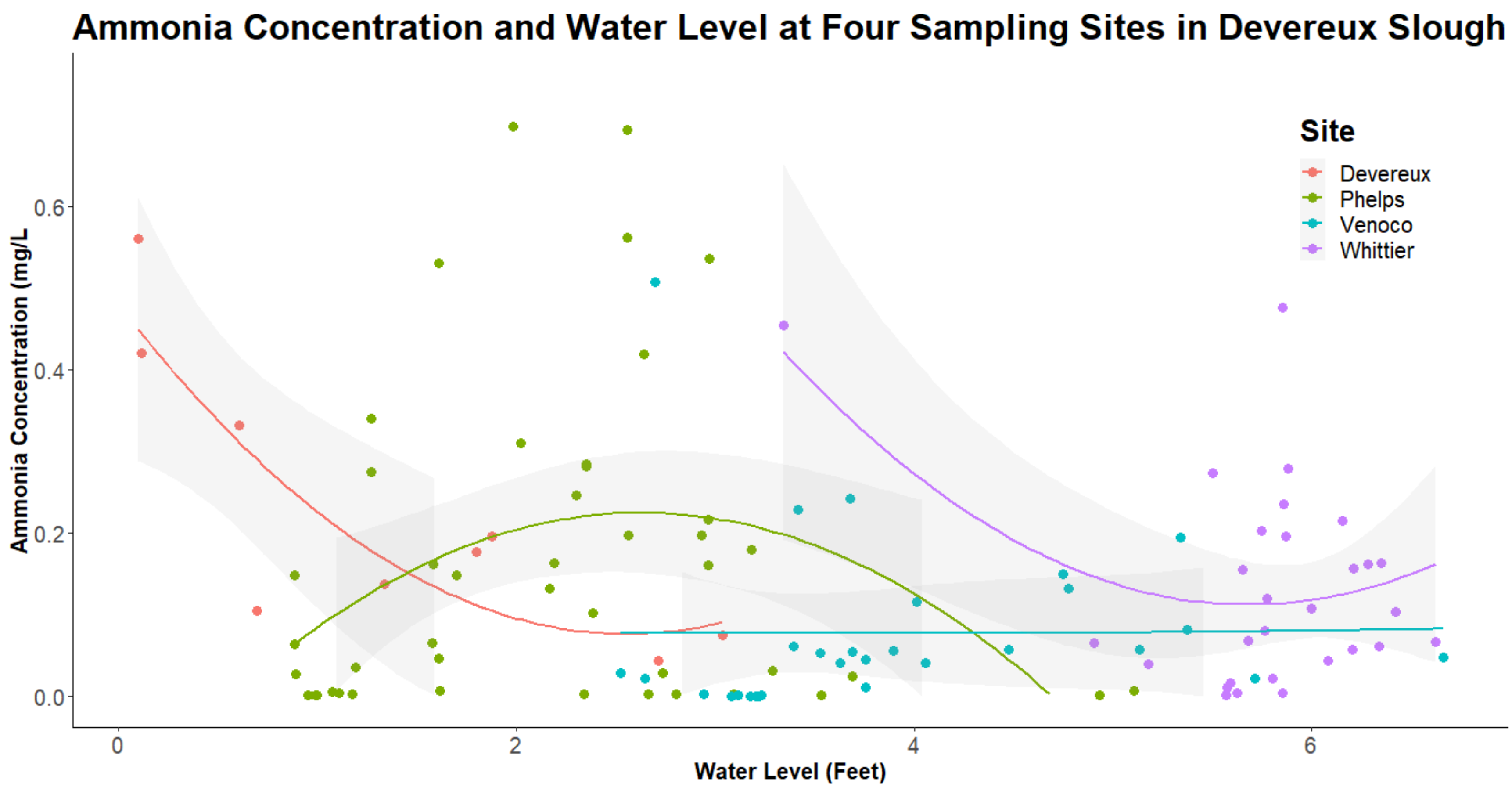

December 2021 Storm Nitrate Concentration
Nitrate Concentration (mg/L)
Water Depth (ft) & Precipitation (mm)
Devereux
Phelps
Venoco
Whittier
0.0
0.5
1.0
1.5
2.0
2.5
0
4
8
12
Dec 24
Dec 26
Dec 28
Dec 30
datetime



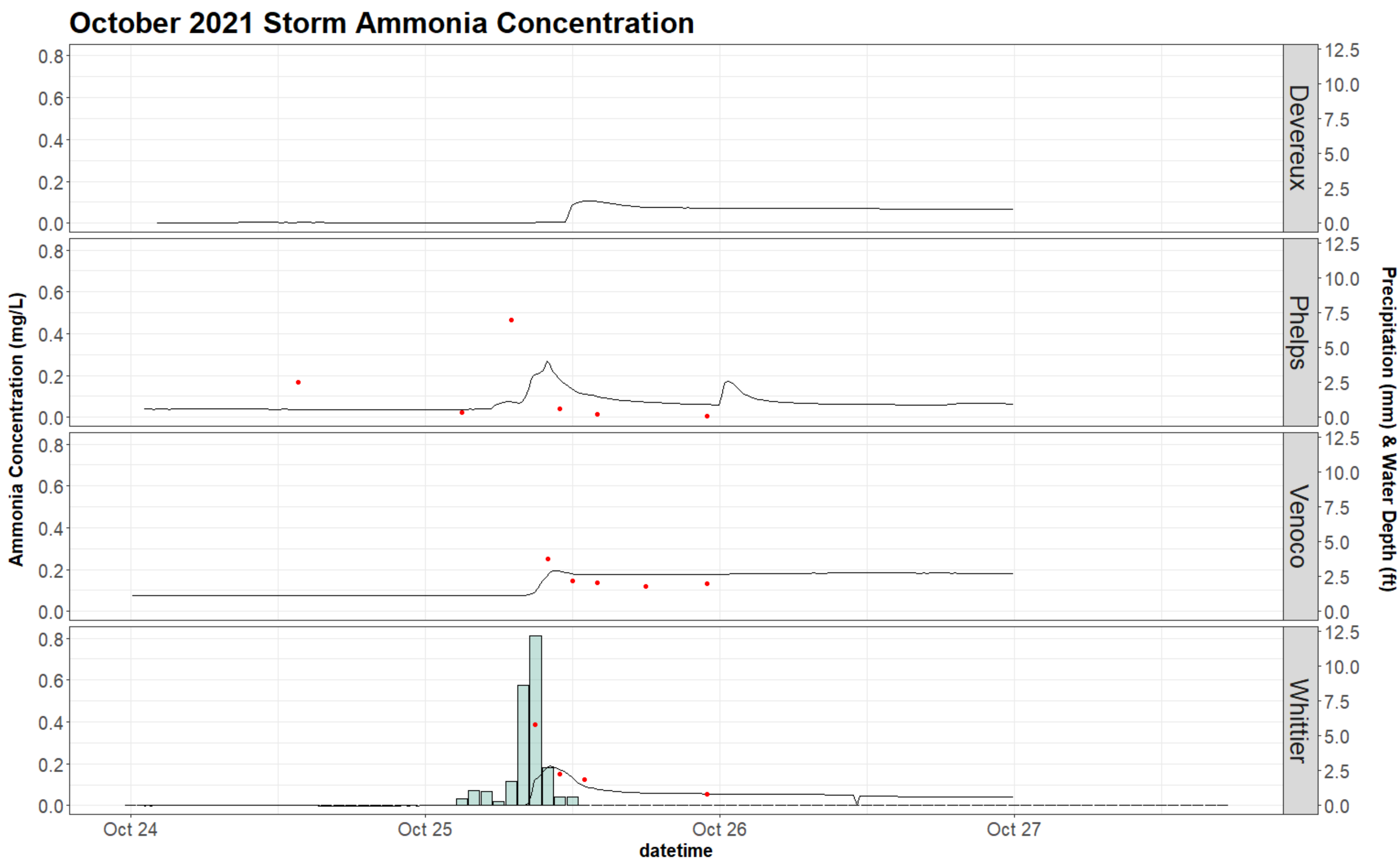
March 2022 Storm Nitrate Concentration
Nitrate Concentration (mg/L)
Water Depth (ft) & Precipitation (mm)
Devereux
Phelps
Venoco
Whittier
0.0
0.5
1.0
1.5
2.0
2.5
0
5
10
Mar 28 00:00
Mar 28 12:00
Mar 29 00:00
Date

NUTRIENT CONCENTRATIONS DATA: Ammonia – Site Comparisons

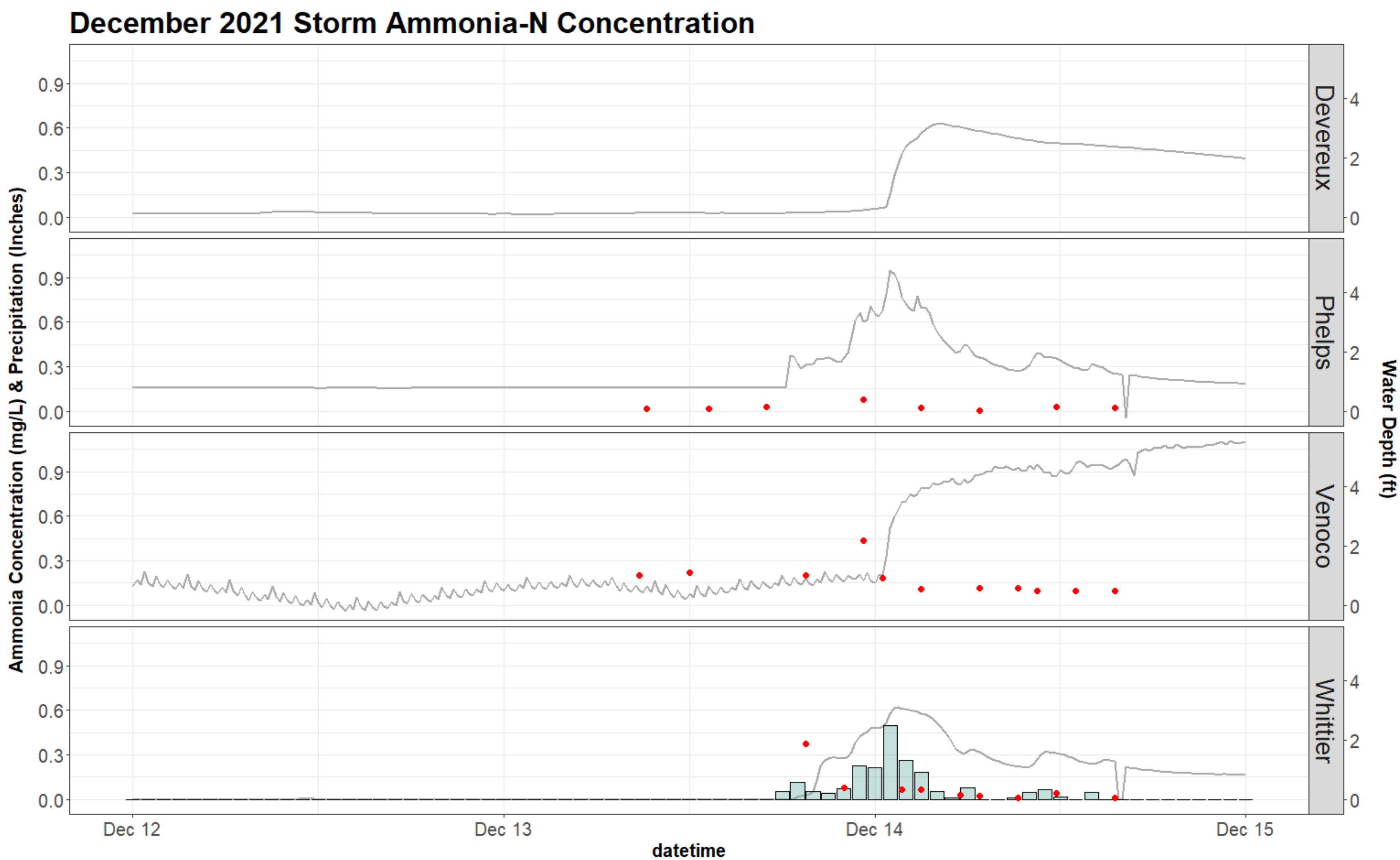


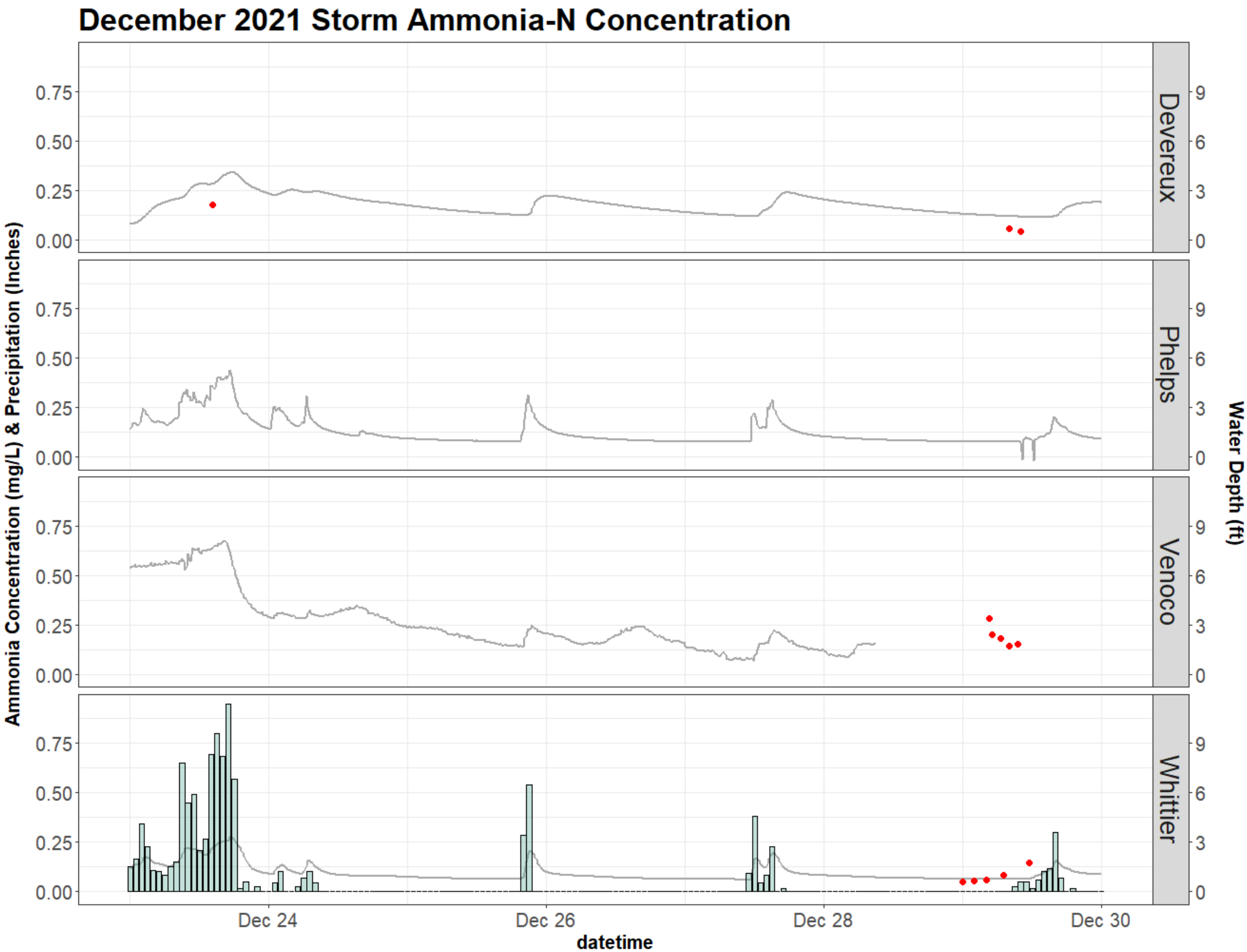


Ammonia Concentration and Water Level at Four Sampling Sites in Devereux Slough
Ammonia Concentration (mg/L
0.0
0.2
0.4
0.6
0
2
4
6
Water Level (Feet)
Site
Devereux
Phelps
Venoco
Whittier

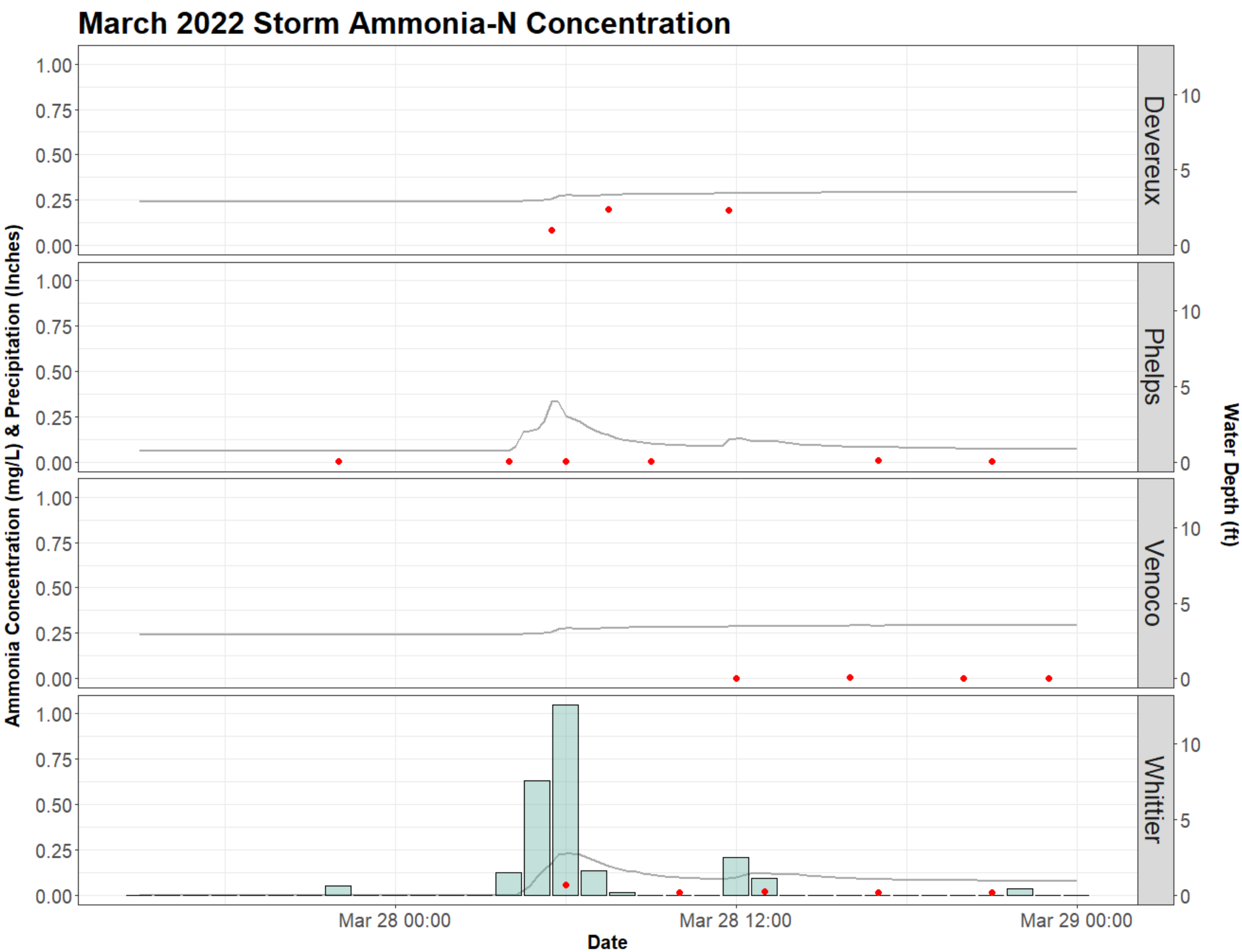


October 2021 Storm Ammonia Concentration
Ammonia Concentration (mg/L)
Precipitation (mm) & Water Depth (ft)
Devereux
Phelps
Venoco
Whittier
0.0
0.2
0.4
0.6
0.8
0.0
2.5
5.0
7.5
10.0
12.5
Oct 24
Oct 25
Oct 26
Oct 27
datetime

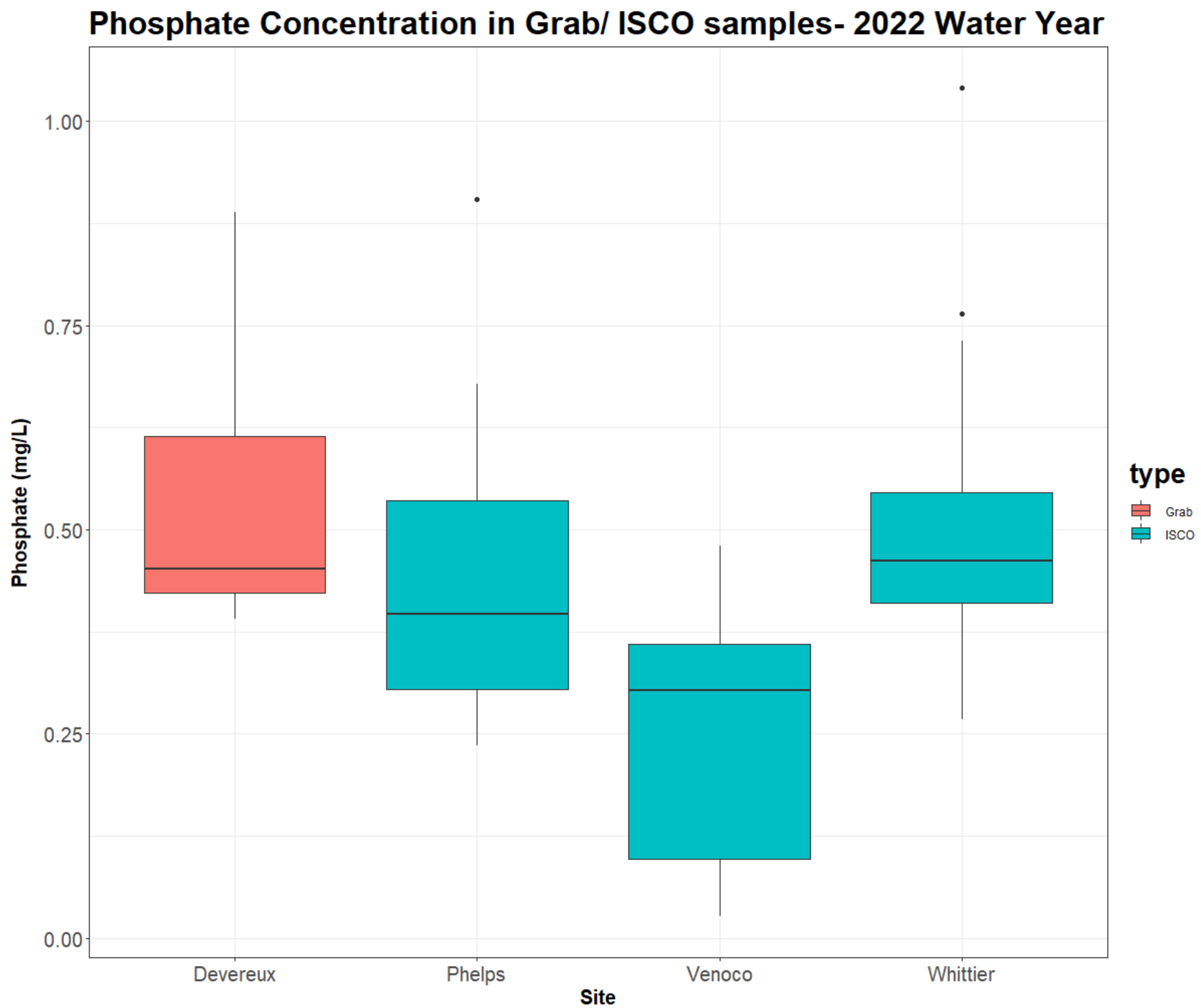

December 2021 Storm Ammonia-N Concentration
Ammonia Concentration (mg/L) & Precipitation (Inches)
Water Depth (ft)
Devereux
Phelps
Venoco
Whittier
0.0
0.3
0.6
0.9
0
2
4
Dec 12
Dec 13
Dec 14
Dec 15
datetime

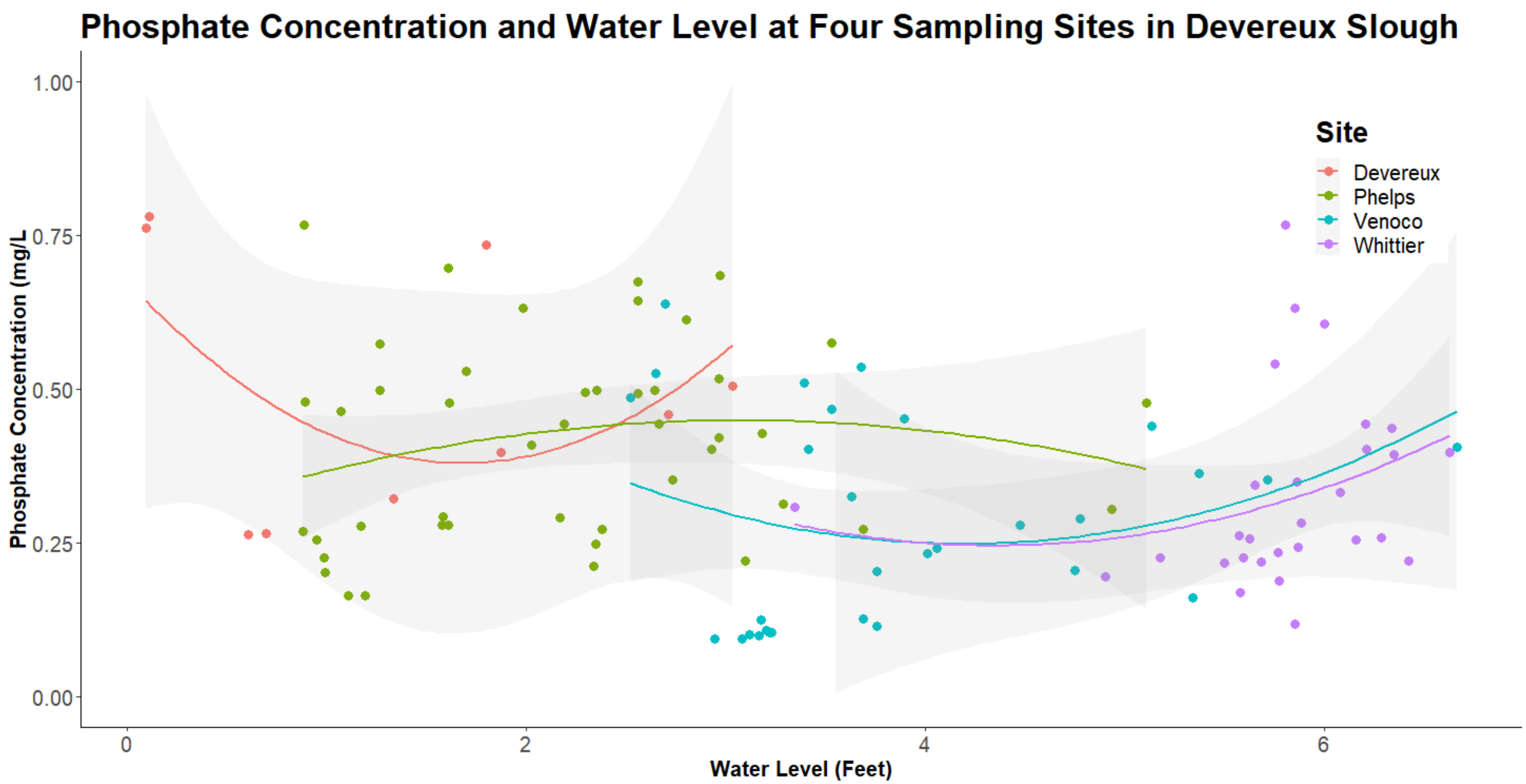


December 2021 Storm Ammonia-N Concentration
Ammonia Concentration (mg/L) & Precipitation (Inches)
Water Depth (ft)
Devereux
Phelps
Venoco
Whittier
0.00
0.25
0.50
0.75
0
3
6
9
Dec 24
Dec 26
Dec 28
Dec 30
datetime

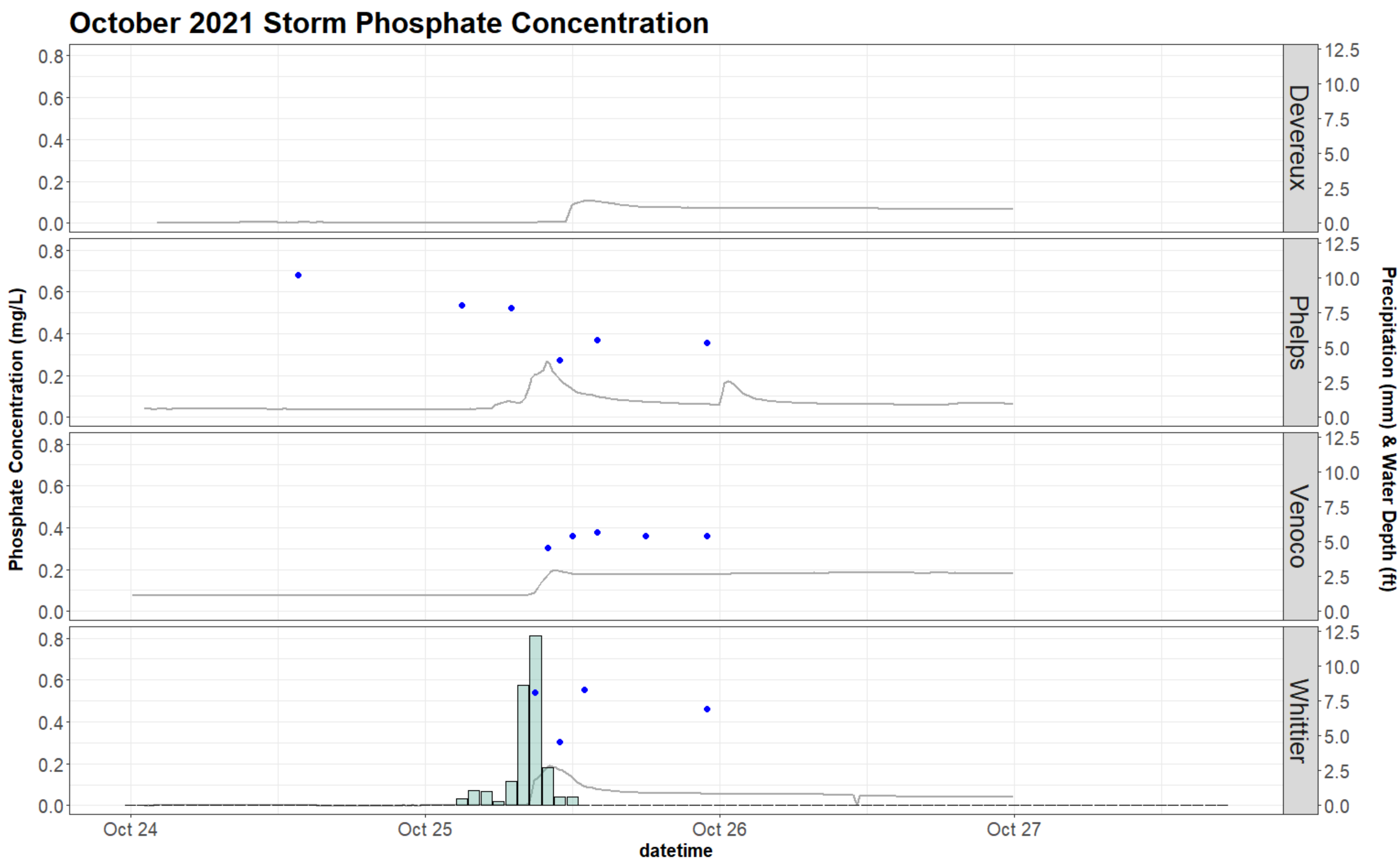

March 2022 Storm Ammonia-N Concentration
Ammonia Concentration (mg/L) & Precipitation (Inches)
Water Depth (ft)
Devereux
Phelps
Venoco
Whittier
1.00
0.75
0.50
0.25
0.00
10
5
0
Mar 28 00:00
Mar 28 12:00
Mar 29 00:00
Date

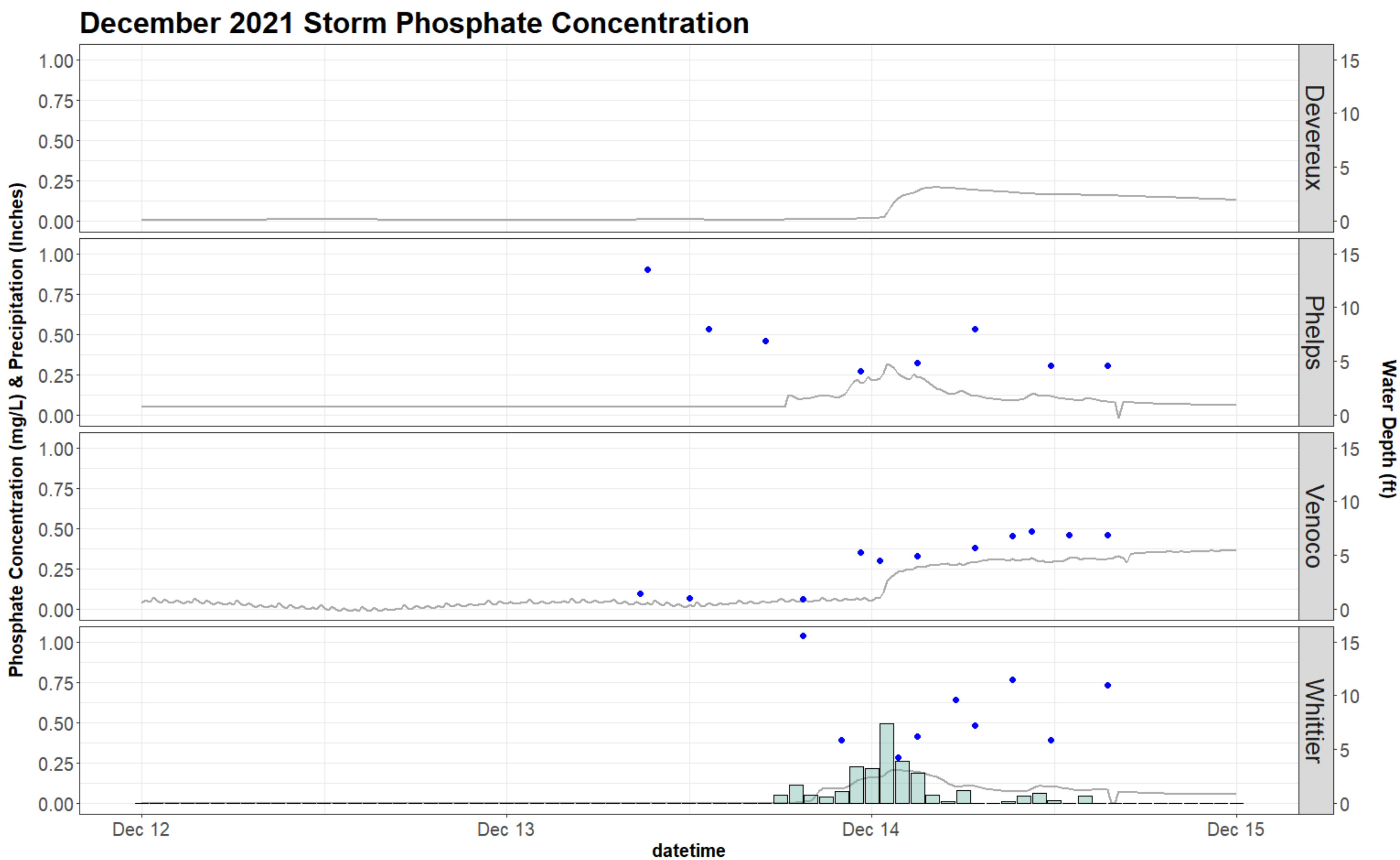
NUTRIENT CONCENTRATIONS DATA: Phosphate – Site Comparisons

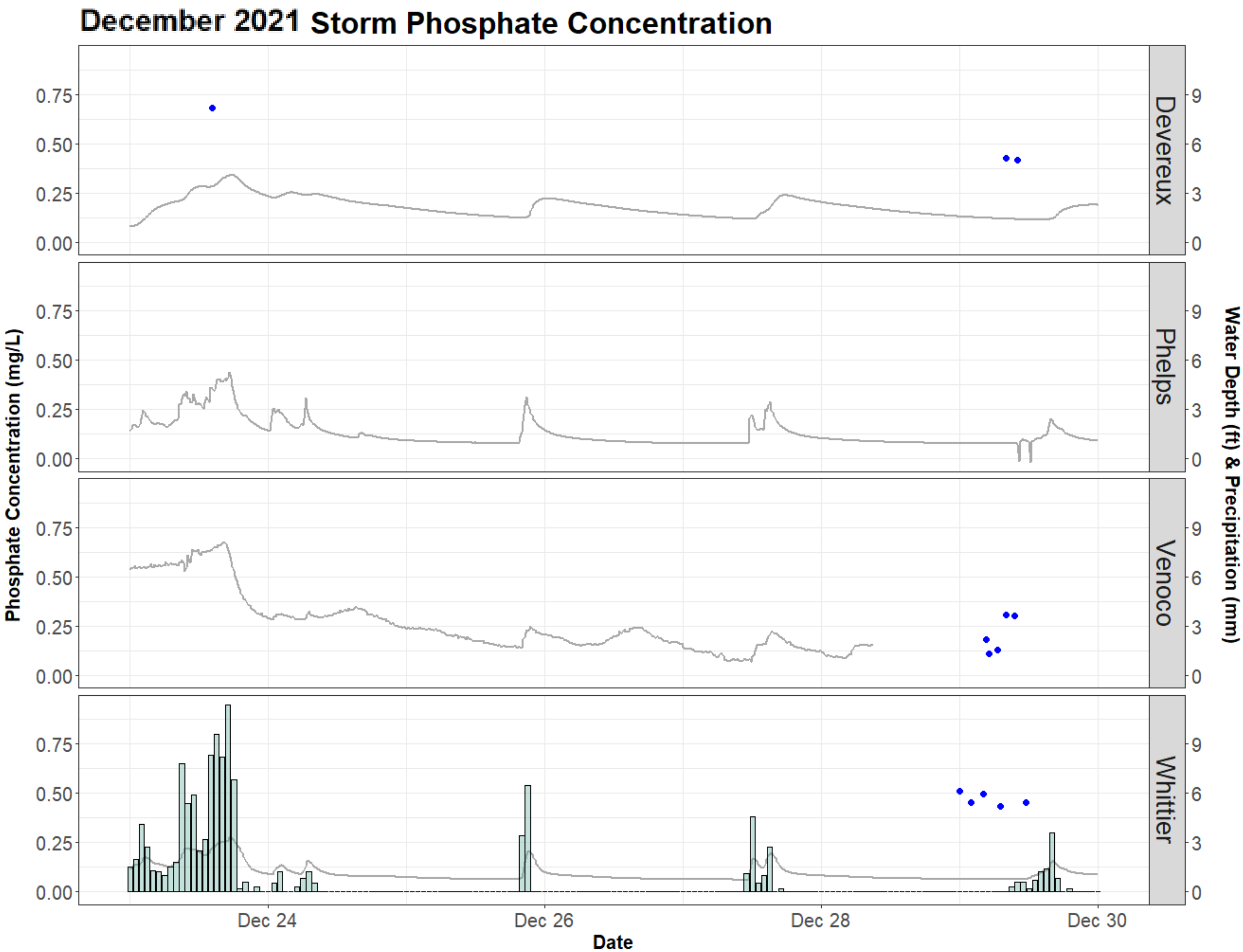


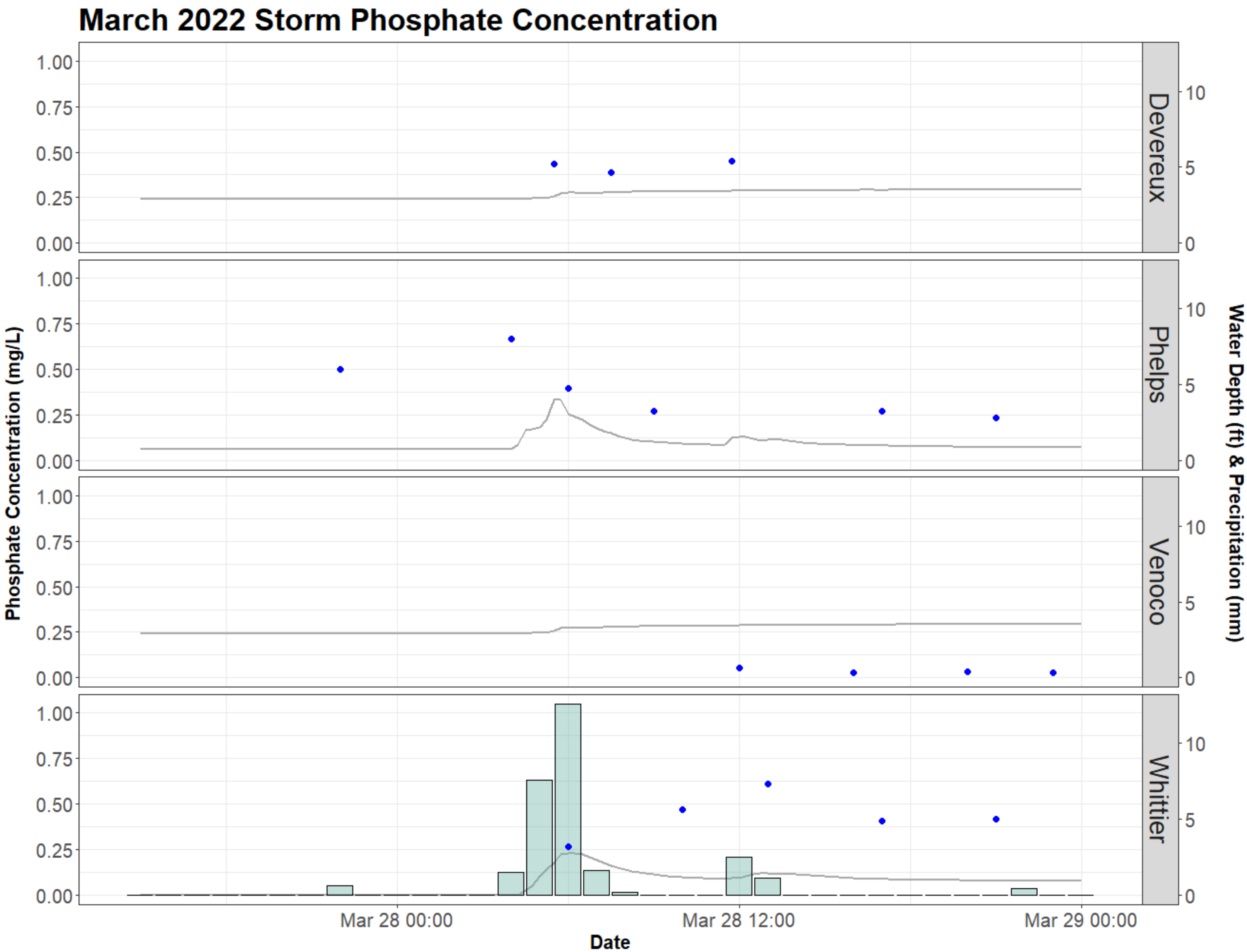


Phosphate Concentration and Water Level at Four Sampling Sites in Devereux Slough
Phosphate Concentration (mg/L
1.00
0.75
0.50
0.25
0.00
0
2
4
6
Water Level (Feet)
Site
Devereux
Phelps
Venoco
Whittier


October 2021 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
10.0
12.5
Oct 24
Oct 25
Oct 26
Oct 27
datetime

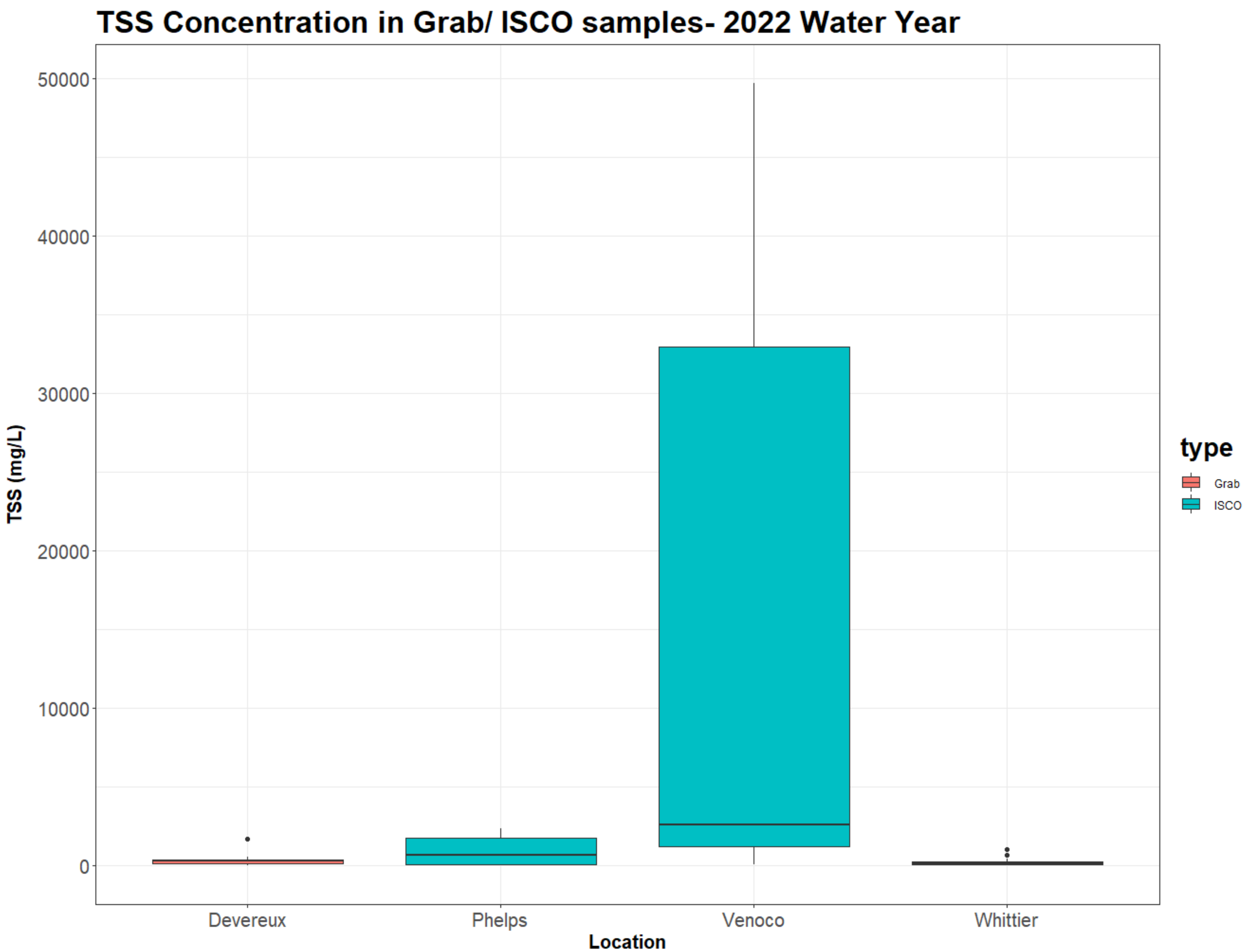

December 2021 Storm Phosphate Concentration
Phosphate Concentration (mg/L) & Precipitation (Inches)
Water Depth (ft)
Devereux
Phelps
Venoco
Whittier
1.00
0.75
0.50
0.25
0.00
15
10
5
0
Dec 12
Dec 13
Dec 14
Dec 15
datetime


December 2021 Storm Phosphate Concentration
Phosphate Concentration (mg/L)
Water Depth (ft) & Precipitation (mm)
Devereux
Phelps
Venoco
Whittier
0.00
0.25
0.50
0.75
0
3
6
9
Dec 24
Dec 26
Dec 28
Dec 30
Date

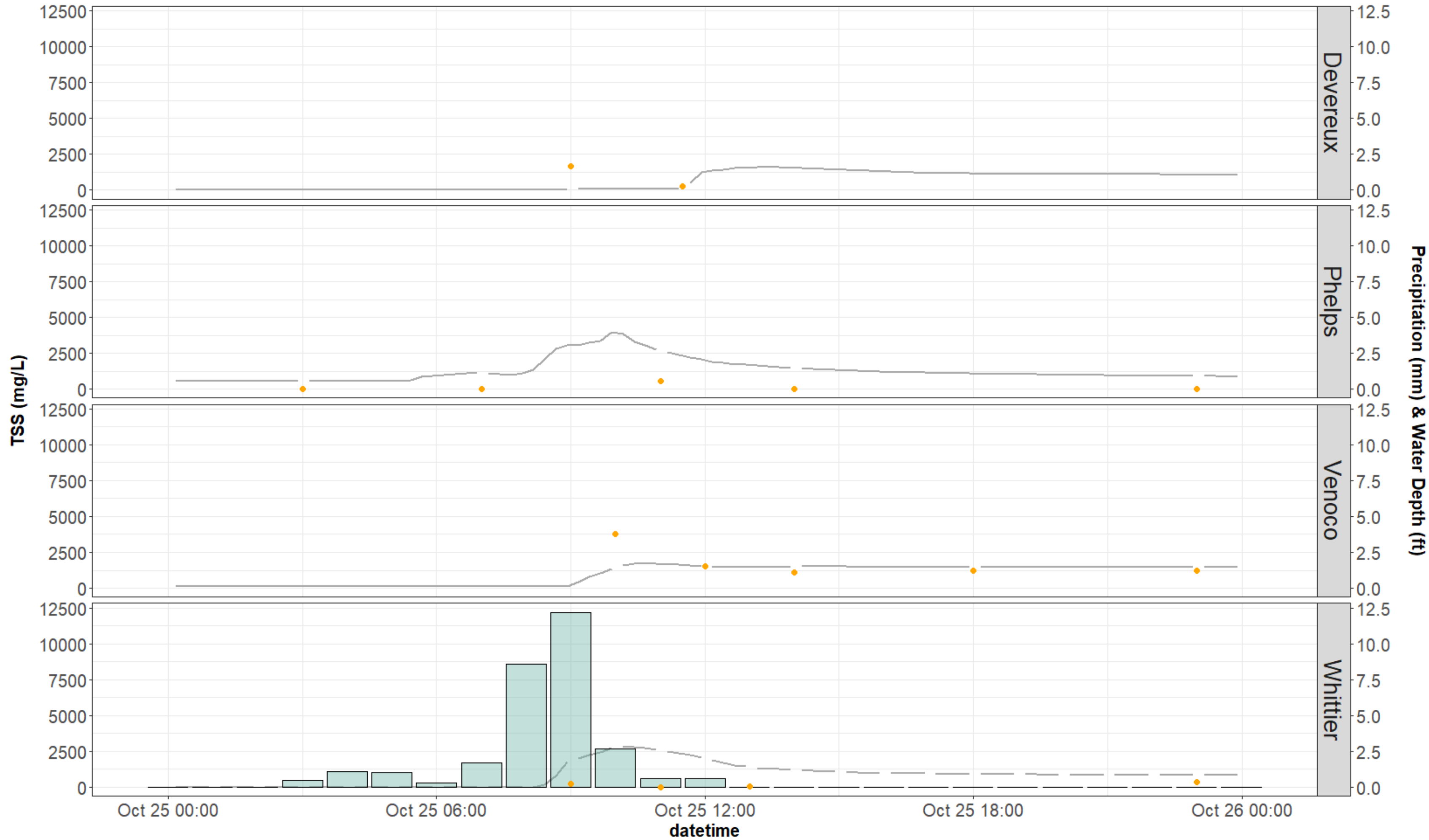


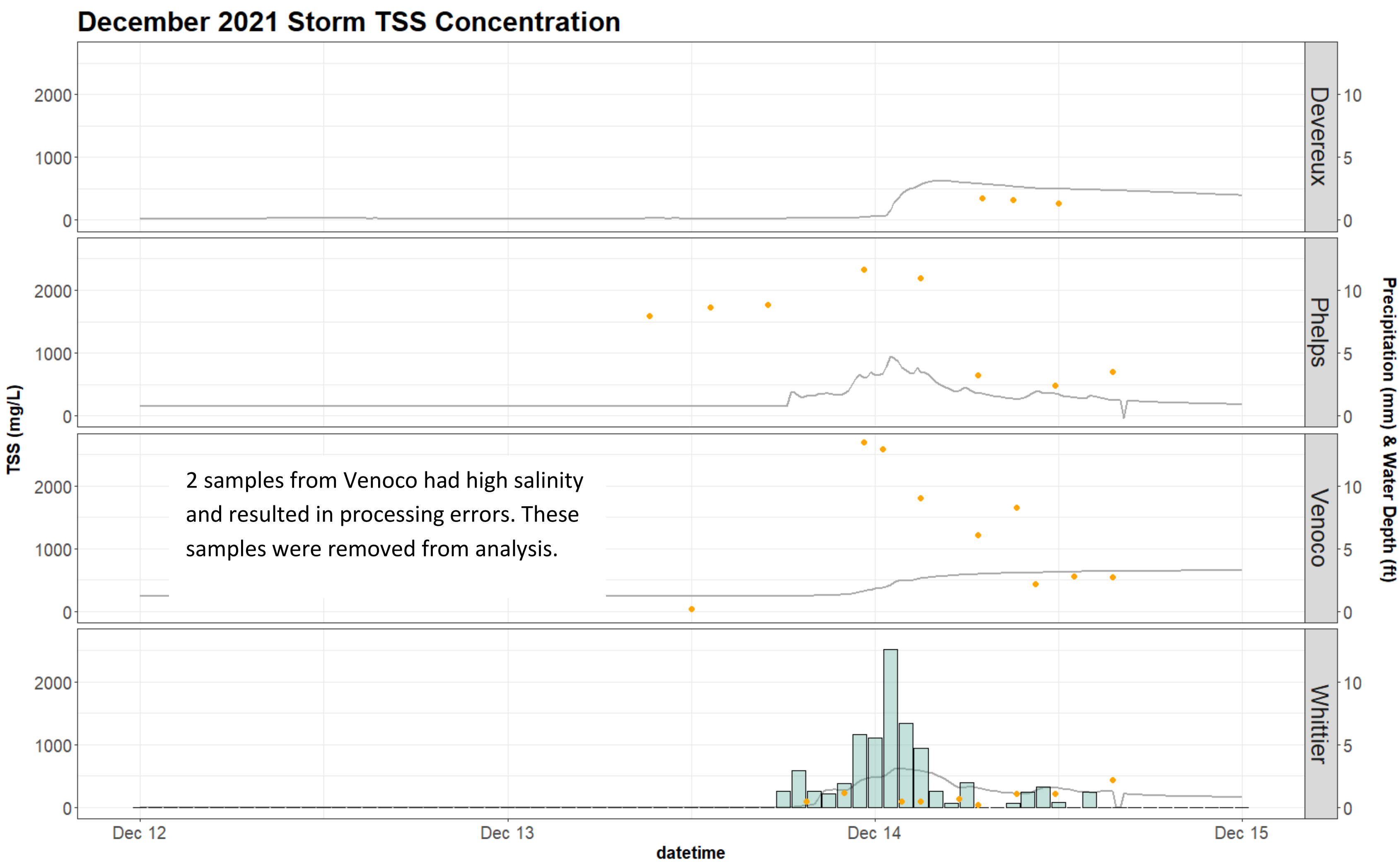
March 2022 Storm Phosphate Concentration
Phosphate Concentration (mg/L)
Water Depth (ft) & Precipitation (mm)
Devereux
Phelps
Venoco
Whittier
1.00
0.75
0.50
0.25
0.00
10
5
0
Mar 28 00:00
Mar 28 12:00
Mar 29 00:00
Date

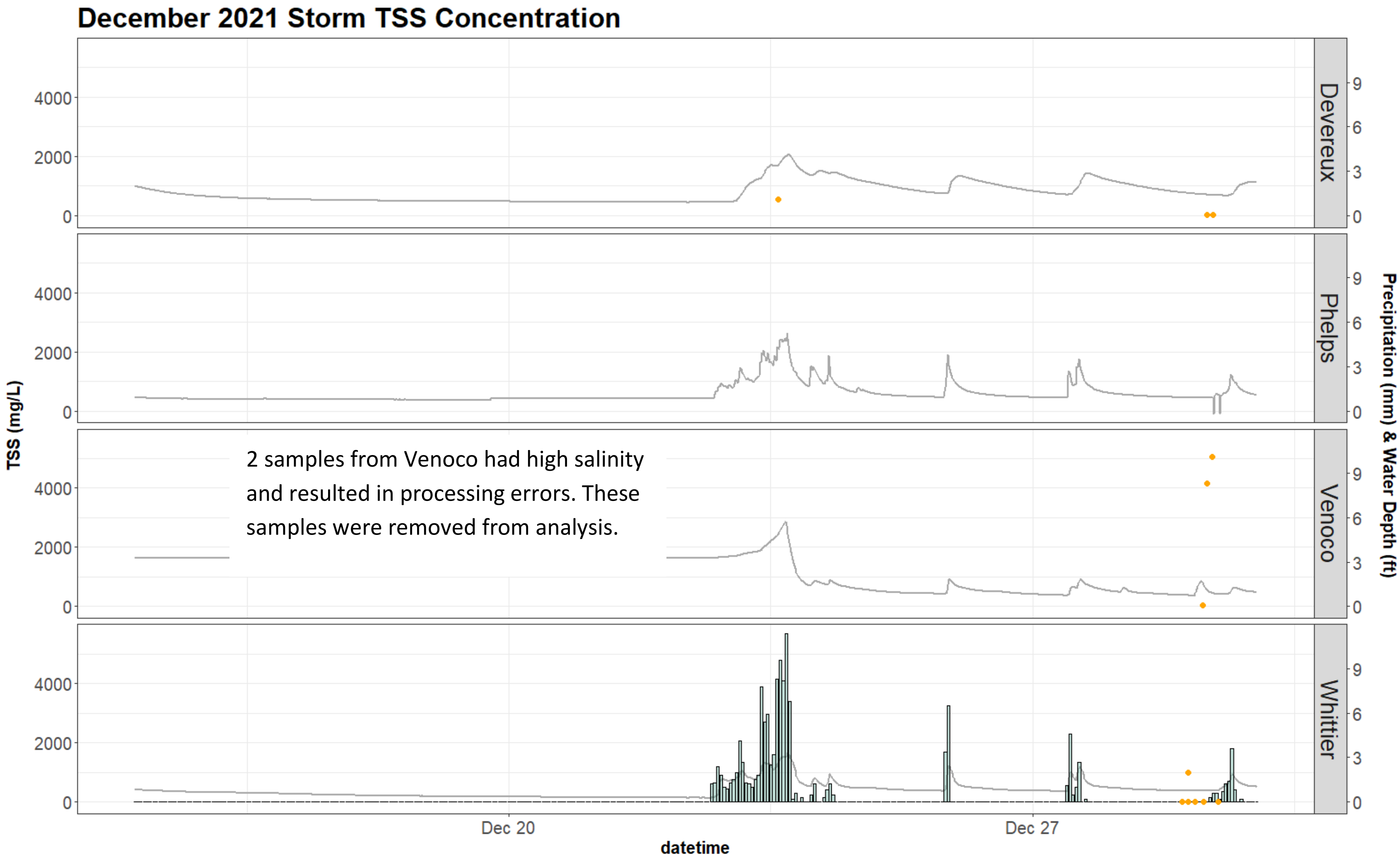
Suspended solid concentrations- WY 2021: TSS & SSC – Site Comparisons



October 2021 Storm TSS Concentration

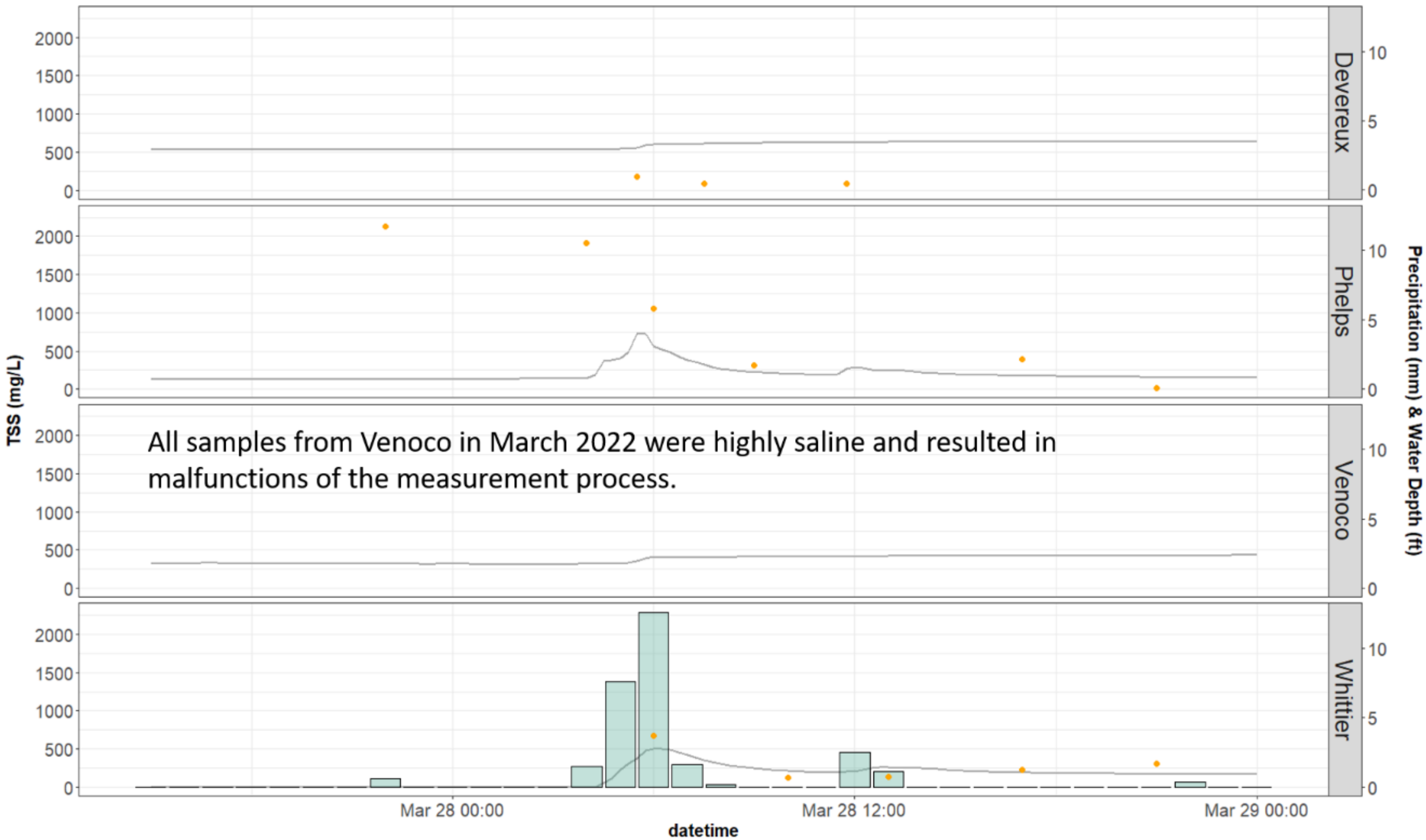



December 2021 Storm TSS Concentration
TSS (mg/L)
Precipitation (mm) & Water Depth (ft)
Devereux
Phelps
Venoco
Whittier
2 samples from Venoco had high salinity and resulted in processing errors. These samples were removed from analysis.
datetime
Dec 12
Dec 13
Dec 14
Dec 15
2000
1000
0
10
5
0



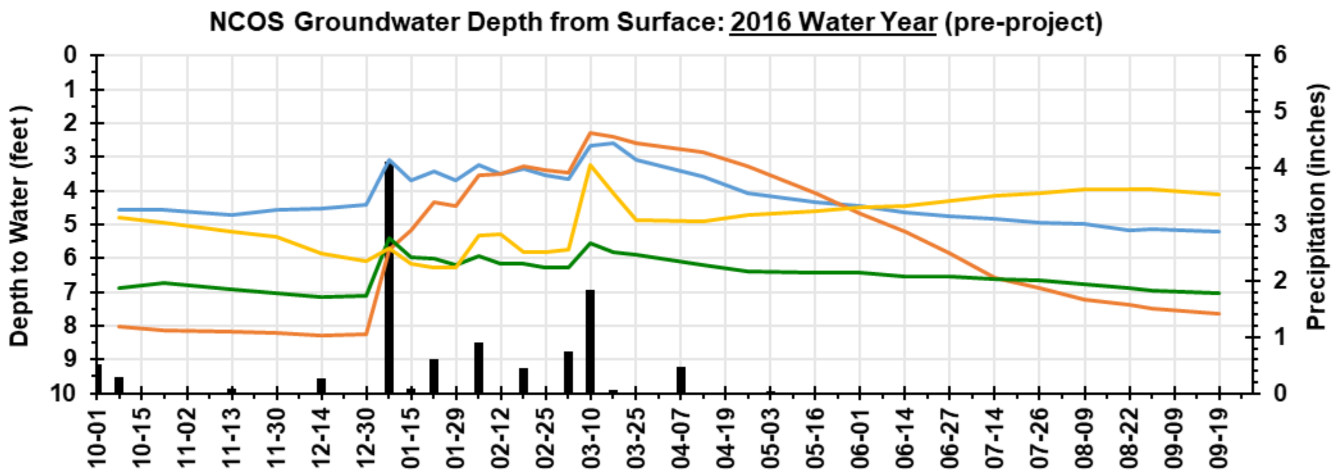
December 2021 Storm TSS Concentration
TSS (mg/L)
Precipitation (mm) & Water Depth (ft)
Devereux
Phelps
Venoco
Whittier
4000
2000
0
9
6
3
0
2 samples from Venoco had high salinity and resulted in processing errors. These samples were removed from analysis.
Dec 20
Dec 27
datetime

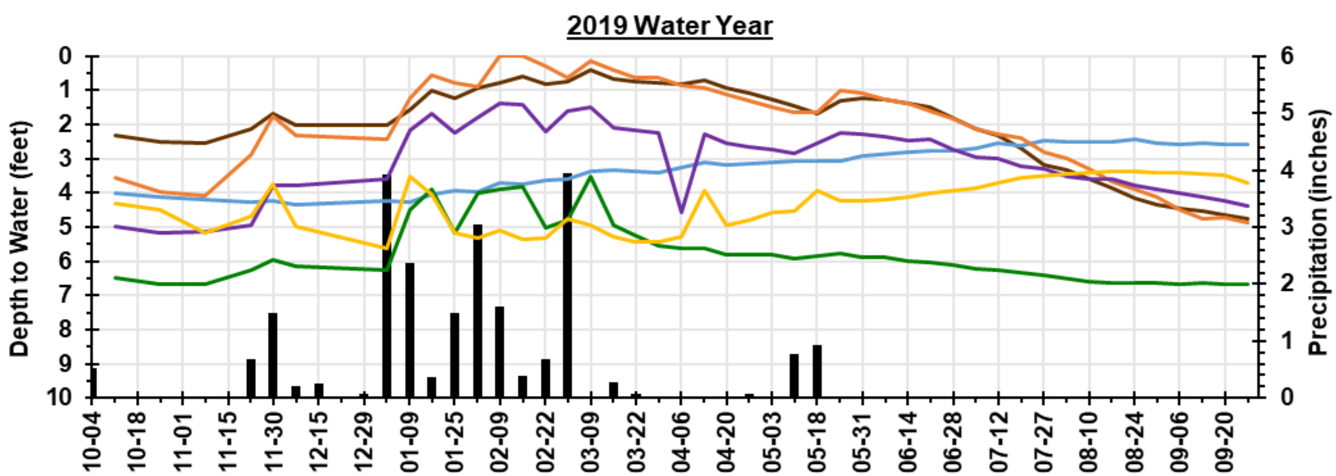
March 2022 Storm TSS Concentration



APPENDIX 6 – Previous years groundwater data

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





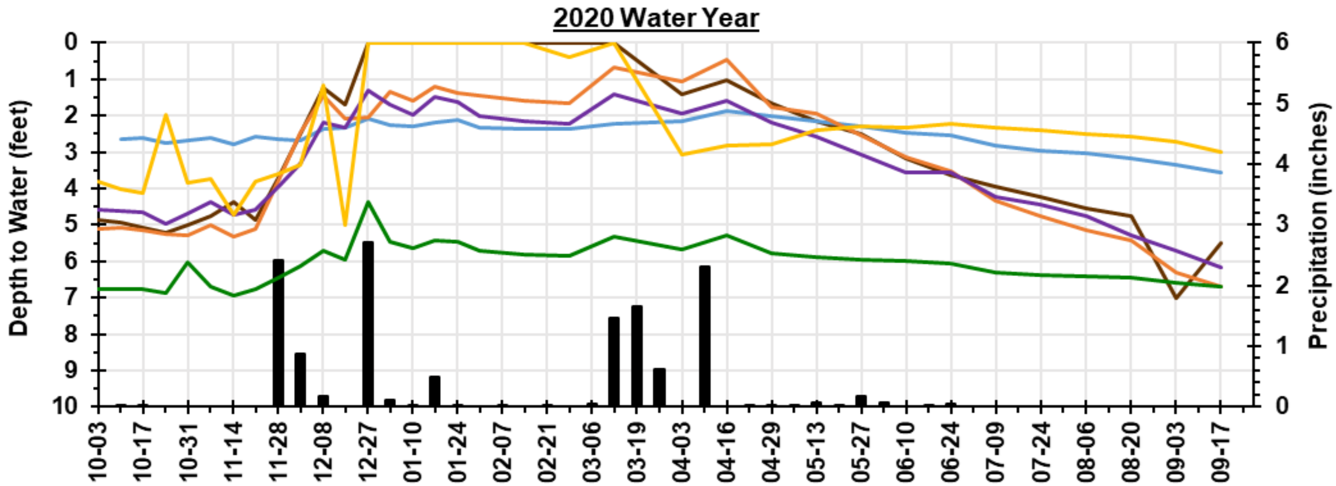
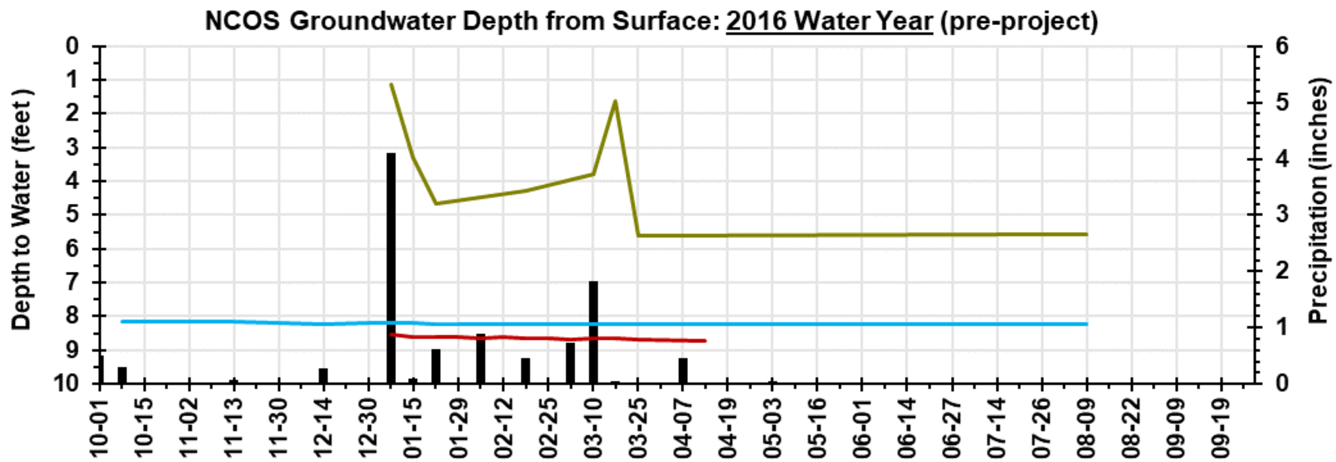
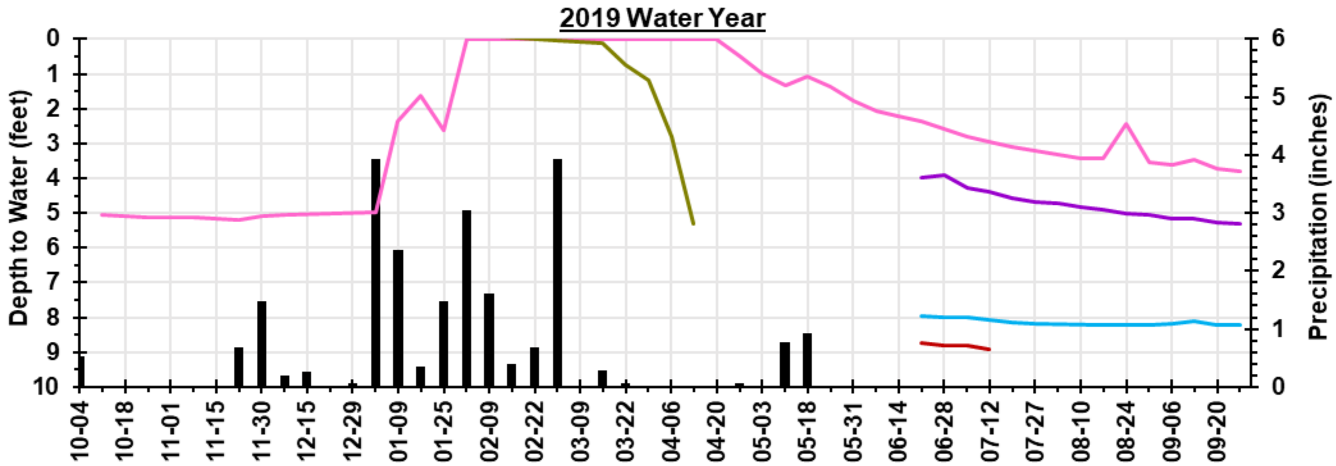


Figure 36. Plots of the depth to groundwater from surface (feet) measured every two weeks at six piezometers (monitoring wells) surrounding the North Campus Open Space wetland. Chart (a) is pre-project data collected in the 2016 water year at four wells installed in the same location after grading. Charts (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





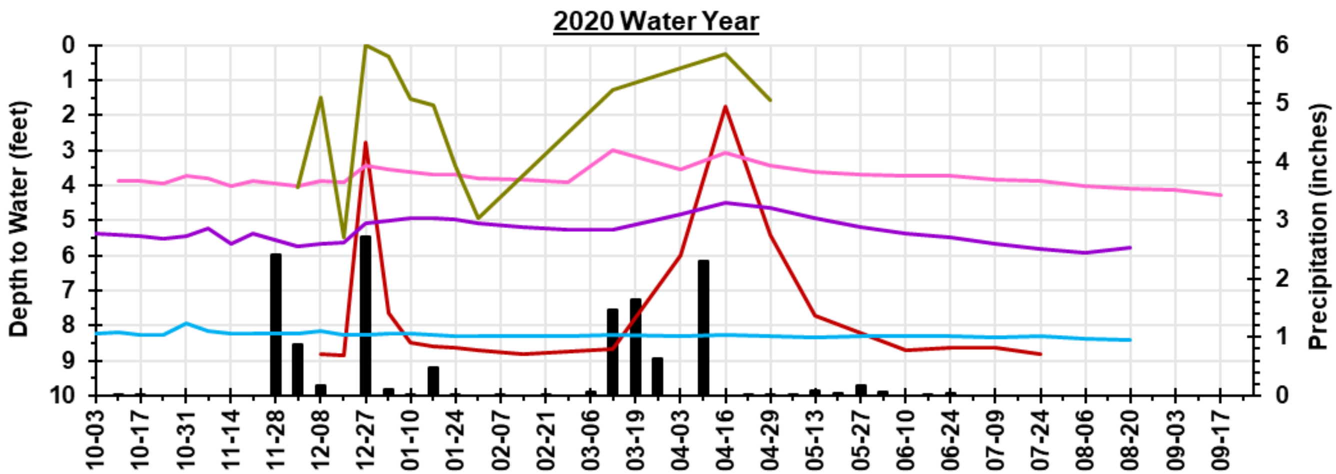
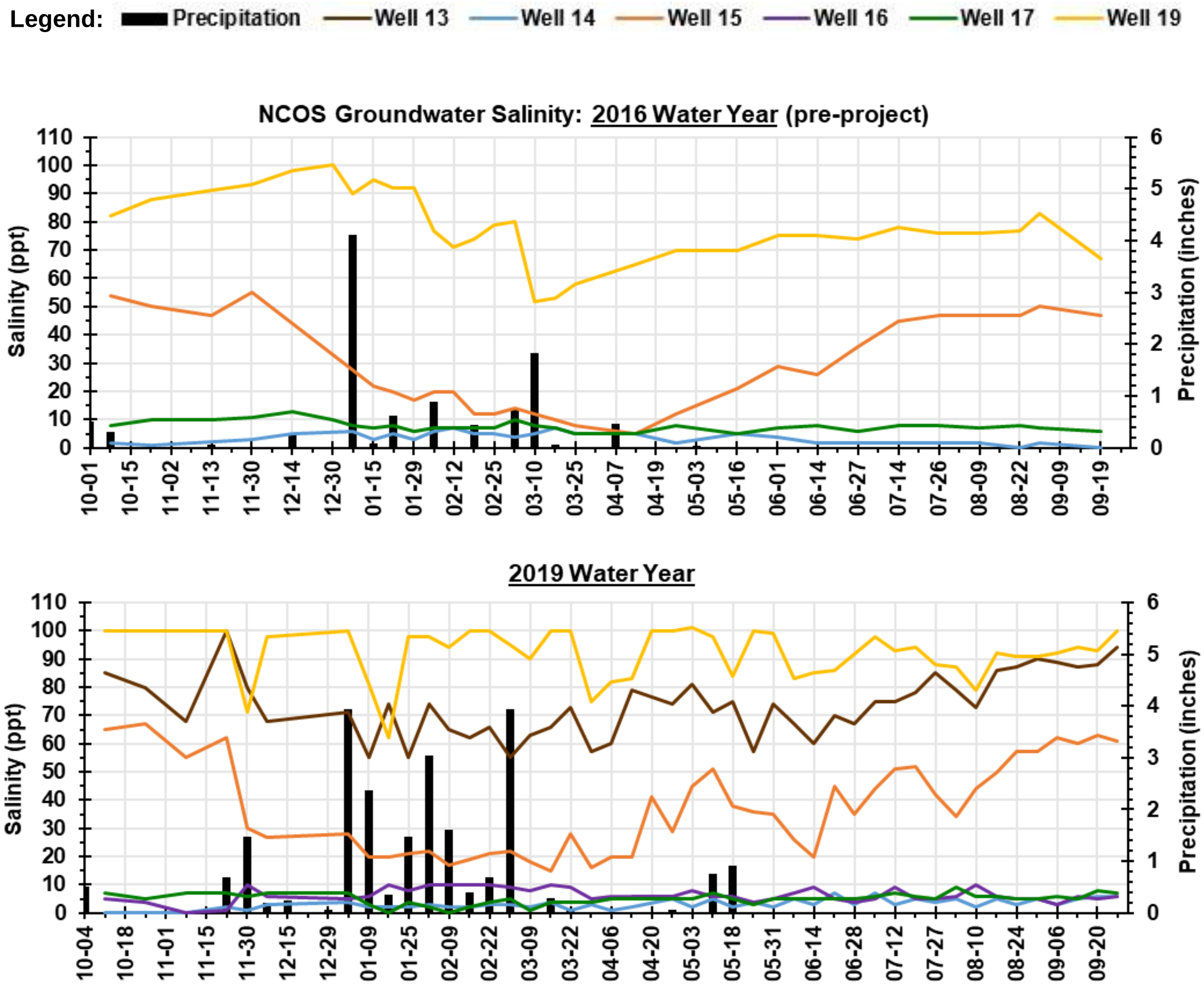


Figure 37. Plots of the depth to groundwater from surface (feet) measured periodically at five piezometers (monitoring wells) on the upper areas of North Campus Open Space. Chart (a) is pre-project data collected in the 2016 water year (no water detected in wells 3 and 7). Charts (b) and (c) are data 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)
110 100 90 80 70 60 50 40 30 20 10 0
6 5 4 3 2 1 0
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)
110 100 90 80 70 60 50 40 30 20 10 0
6 5 4 3 2 1 0
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

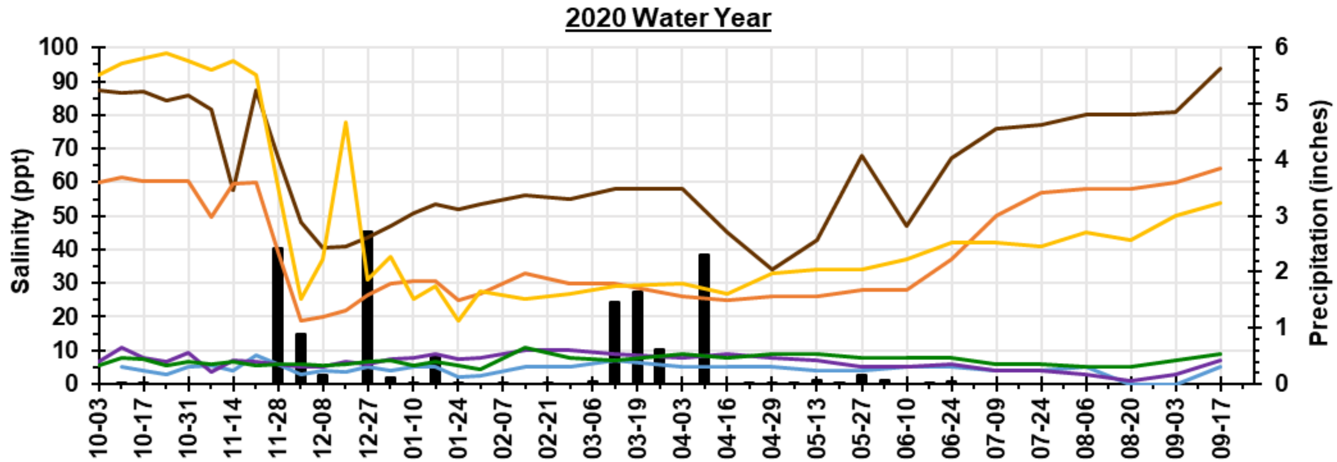


Figure 38. Plots of groundwater salinity (in parts per thousand, ppt) measured every two weeks at six piezometers (monitoring wells) surrounding the North Campus Open Space wetland. Chart (a) is pre-project data collected in the 2016 water year at four wells installed in the same location after grading. 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.