North Campus Open Space Restoration Project

Monitoring Report: Year 7, December 2024

UC SANTA BARBARA
Cheadle Center for Biodiversity
& Ecological Restoration

Restoration and associated monitoring for the North Campus Open Space Restoration Project are made possible with funding from the following agencies: USFWS, State Coastal Conservancy, Wildlife Conservation Board, California Department of Fish and Wildlife, Ocean Protection Council, Department of Water Resources Urban Streams Program, California Natural Resources Agency Urban Greening program, CalTrans, California State Parks, State Coastal Conservancy Wetlands Recovery project community grant program, Environmental Mitigation Program through CalTrans and California Department of Natural Resources with funding through California Climate Initiative, Proposition 1, Proposition 84. Additional funding has come from smaller contributions from SoCalGas, the UC Santa Barbara Associated Students' Coastal Fund, California Native Plant Society, local foundations, and individual donors as well as funding from the County of Santa Barbara and the City of Santa Barbara which supported the planning and design process. (Cover photo from December 2023)

EXECUTIVE SUMMARY

In addition to more than 40 acres of wetland and 60 acres of upland habitat restoration, the North Campus Open Space Restoration project has successfully reduced flood levels, supports threatened and endangered species, incorporates public access, and provides diverse educational opportunities.

Currently in its seventh year since groundbreaking, project efforts are focused primarily on weed control, public access support, research and monitoring projects, and introducing special status species such as the federally endangered Ventura marsh milk-vetch (*Astragalus pycnostachys* var*. lanosissimus*) and the newly established salt marsh bird's beak (*Chloropyron maritimum var maritimum*). This report describes the methods and results of monitoring for the seven years of the project, with a primary focus on the seventh year (2023-24). 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 conducted on a quarterly basis since December of 2016. Methods can be found in section 2 and a set of representative photos in Appendix 1. These photographs provide a visual record of the transformation from pre restoration to post restoration. Photos document both gradual growth of vegetation as well as events such as bird viewing area construction, outdoor classroom construction and cultural burns.

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 7 success criteria for total vegetation cover, and native biodiversity. Relative percent native cover is the only category in which the criteria for previous years has not been met for a few habitat types.

Overall, the results from year 7 monitoring show consistent improvement over time. There have been 89 native species identified in the quadrat transect monitoring over the past seven years.

Multiple other species recognized by the California Native Plant Society as special status species are establishing robust populations, including southern tarplant (*Centromadia parryi* var. *australis*), Parish's glasswort (*Anthrocemum subterminale),* Salt marsh birds' beak and Ventura marsh milk-vetch.

Wildlife

In the seventh year of wildlife monitoring at the NCOS project we documented tidewater goby throughout the NCOS portion of Devereux Slough as well as at the mouth. Monitoring was conducted in June while there was still significant water in the system. One burrowing owl was spotted at NCOS in October 2024, a burrowing owl was also spotted on the new Ellwood marine terminal, adjacent to North Campus Open Space on September 15, 2024, suggesting that we may have some overwintering use. Additionally, Wildlife Care Network, released a burrowing owl rescued from the ocean to NCOS on mid October. 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 documented on site during the breeding season for the last seven years with evidence of breeding in 2023-24. Interestingly, this year, water levels were high enough throughout the breeding season to retain the island effect and five pairs of black-necked stilts successfully fledged chicks on site.

Gulls, terns, herons, egrets, ibis, and shorebirds all increased from year 6 to year 7. Other species stayed the same or slightly decreased. This is likely because the rainfall across the whole county created many other ideal wetland habitats for birds to use.

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 seven 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. 2024 was another especially wet year with 27.3 inches which is 143% of the normal rainfall according to Santa Barbara County Historical Rainfall & Reservoir Information | Santa Barbara County, CA - Official Website (countyofsb.org). The restoration project supports a natural floodplain and protects adjacent structures. This was recognized by FEMA in September 2021. FEMA officially issued a Letter of Map Revision (LOMR), 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. Water nutrient concentration monitoring was paused in 2023. Water nutrient concentration from previous years can be found in the earlier reports. All other water quality and quantity monitoring continued.

There were 28 days with more than 0.1 inches of precipitation in the 2024 water year and 7 days with more than an inch of precipitation. The largest single storm was on February 19th producing 3.4 inches of rain in a single day. Due to the many heavy storms, the slough opened 3 times in the 2023-24 water year. It opened for the first time on January 22nd at 9:00 am and closed for the season on approximately March 15th.

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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 Natural 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. 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.

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. For a full description of progress made on site see year 1-6 progress reports (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.

Planting and activity summary

See year 6 report for a complete planting summary (https://escholarship.org/uc/item/4zc561cw). Year 7 activities included completing an aquatic survey as a part of the California Bight project, studying the effect of cultural (low temperature) burns on the grassland, using sheep grazing as a grassland management strategy, and studying the effect of water elevation on the success of endangered Salt marsh bird's beak.

Report Structure and Content

Monitoring and research efforts as well as data presented in previous reports that are not included in this year 7 report include the development of the bathymetry of the wetland, carbon sequestration, trail use surveys, tick presence, bird recording, bat species surveys, water nutrient concentrations, small rodent monitoring 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, and equipment is accessible we plan to re-measure the elevation cross-sections of the wetland this fall to better understand sediment transport in the wetland.

The monitoring efforts described herein include:

- Photo-documentation
- Vegetation, including trees
- Wildlife, including bird surveys, special status species, aquatic arthropods and reptiles
- Hydrology, water quality and nutrient flux of Devereux Slough. The hydrology of the restored vernal pools on the Mesa

Key data and related information about the project are posted on the EcoAtlas website (www.ecoatlas.org/regions/ecoregion/statewide/projects/9462) and dryad (https://doi.org/10.25349/D9RP7X). Monitoring reports and associated data are also available through eScholarship (escholarship.org/uc/ccber) and the Cheadle Center's website (www.ccber.ucsb.edu/ecosystem/management-areas/north-campus-open-space).

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.

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 from year one and year seven 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 1. 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 modified monitoring plan and schedule is outlined in Table 1. The goal of this monitoring is to record changes in the absolute cover of native and non-native vegetation in each habitat by species as well as the percent cover of thatch, bare ground, and other cover such as mulch/woodchips or algae, all of which can provide habitat in one form or another for different organisms and potentially increase the level of biodiversity across the site. Habitats comprised primarily of low growing vegetation, such as grasslands and wetlands, are monitored with quadrat transects (QT), and habitats with taller vegetation such as riparian woodland are monitored with point-intercept transects (PIT). Trees planted by NCOS staff and volunteer groups such as *My Children's 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. 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. 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 extent of these habitats. The quadrats are subdivided into 100 ten-centimeter squares and the percent cover is estimated for 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.

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 per 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, if an individual tree intersects the point in both the canopy and subcanopy it is recorded present for both strata. When no vegetation crosses the point in the sub-canopy, other cover such as thatch or mulch or bare ground is recorded.

Absolute cover of native and non-native plants in the point-intercept transect is measured by tallying the proportion of sample points (31) that natives or non-natives, were encountered at least once in each transect.The mean of all transects is presented in figures 12-14. Relative plant cover is the proportion

of native and non-native hits out of the total number of plant hits. Relative cover is also presented as the proportion of all intercept data including both plants and substrate (e.g., bare dirt, litter, etc.).

Table 1. Vegetation monitoring plan for the habitats/vegetation communities at the North Campus Open Space restoration project. Figure 2 contains a map of the habitats and monitoring transects. Methods include PIT (point intercept transect), QT (quadrat transect), and individual tree measurements.

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/ lengthwise transects- minimum 5 quadrats per pool.
Salt Marsh – Restored low (6-8 ft.) and mid (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	2 / 22

Transect Locations & Orientations

Figure 2 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.

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).

Trees

All trees planted at NCOS are monitored annually by measuring the height and diameter at breast height (DBH), 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 measure the height of most trees by reading a six-foot long pole marked with inches and feet that is held up right next to the tree. For trees taller than 6 feet we use a Nikon Forestry Pro II laser rangefinder.

Data Collection & Management Methods

At the start of each monitoring season, all surveyors are trained on cover estimation and species identification. Transect and quadrat data are recorded using the ESRI Survey123 app on tablets, while the individual tree monitoring data is recorded in Google Sheets. 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 2. Map of the vegetation monitoring transects at the North Campus Open Space restoration project.

Vegetation Monitoring Data

Native Vegetation Summary

The heavy precipitation events experienced in the 2023 and 2024 water years presented uniquely difficult conditions for controlling non-native species While we strive to eliminate all non-native species, many permitting agencies now consider annual Mediterranean grasses to be naturalized components of California ecosystems.

The wet winter/spring, following the October 2023 cultural burn in the grassland, stimulated the growth of the non-native sweet clover (*Melilotus indicus*) which grows to ~ 2.5 feet tall and has a branching structure. During spring bird surveys, we noted nesting in the invasive plant and decided not to conduct a spring mowing which we usually conduct to reduce seed set of annual grasses and create openings for *Stipa pulchra* (purple needle grass) growth later in the spring/summer. Thus, the early summer grassland monitoring reflects the cover of this invasive species. This October we experimented with using sheep to target the seeds and plant biomass associated with the invasive nitrogen fixing forbs that they prefer and that were abundant in the grassland.

The overall vegetation cover increased in every habitat. Native species absolute cover is 50% or more of every habitat.

Overall, there were 64 native species identified site wide in quadrat monitoring in 2024. All salt marsh habitats were similar to the year 6 results with only slight fluctuations of native and non-native cover. Overall *Salicornia pacifica* and *Distichlis spicata* were the most frequently occurring native species in quadrat monitoring.

Non-Native Vegetation Summary

Seasonal brackish marsh, remnant salt marsh and the sandy annual habitats all had a decreased relative non-native vegetation cover. Most of the other habitats only increased slightly in non-native cover compared to past years. This is likely due to the heavy rains experienced in the last 2 years. Total non-native diversity has decreased site-wide from 65 species to 60 species in 2024.

Italian rye grass, *Festuca perennis* (ranked “Moderate” by Cal-IPC), continues to be the most frequently recorded invasive species found in 56% 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, 251 in year 5, 284 in year 6 and 299 in year 7. Another non-native recorded frequently is *Polypogon monspeliensis*. Table A2.2 in Appendix 2 contains a figure of all non-native species recorded in each habitat in each year

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 to below 5% percent in all non-wetland habitats and the Sand Flat (50%) which is expected to retain bare ground in the form of mud flats or salt flats. Two years of high-water levels in the slough appear to have reduced lower elevation salt marsh vegetation in transect SML-03 which raised the average for bare ground in this plant community.

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.

Other cover, which primarily consists of mulch, erosion control wattles, and/or dried algae is minimal in all habitats except peripheral uplands (~25% other cover) which is mainly due to temporary impacts associated with the adjacent housing construction project in their construction easement captured in one of the transects (PU-07). 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.

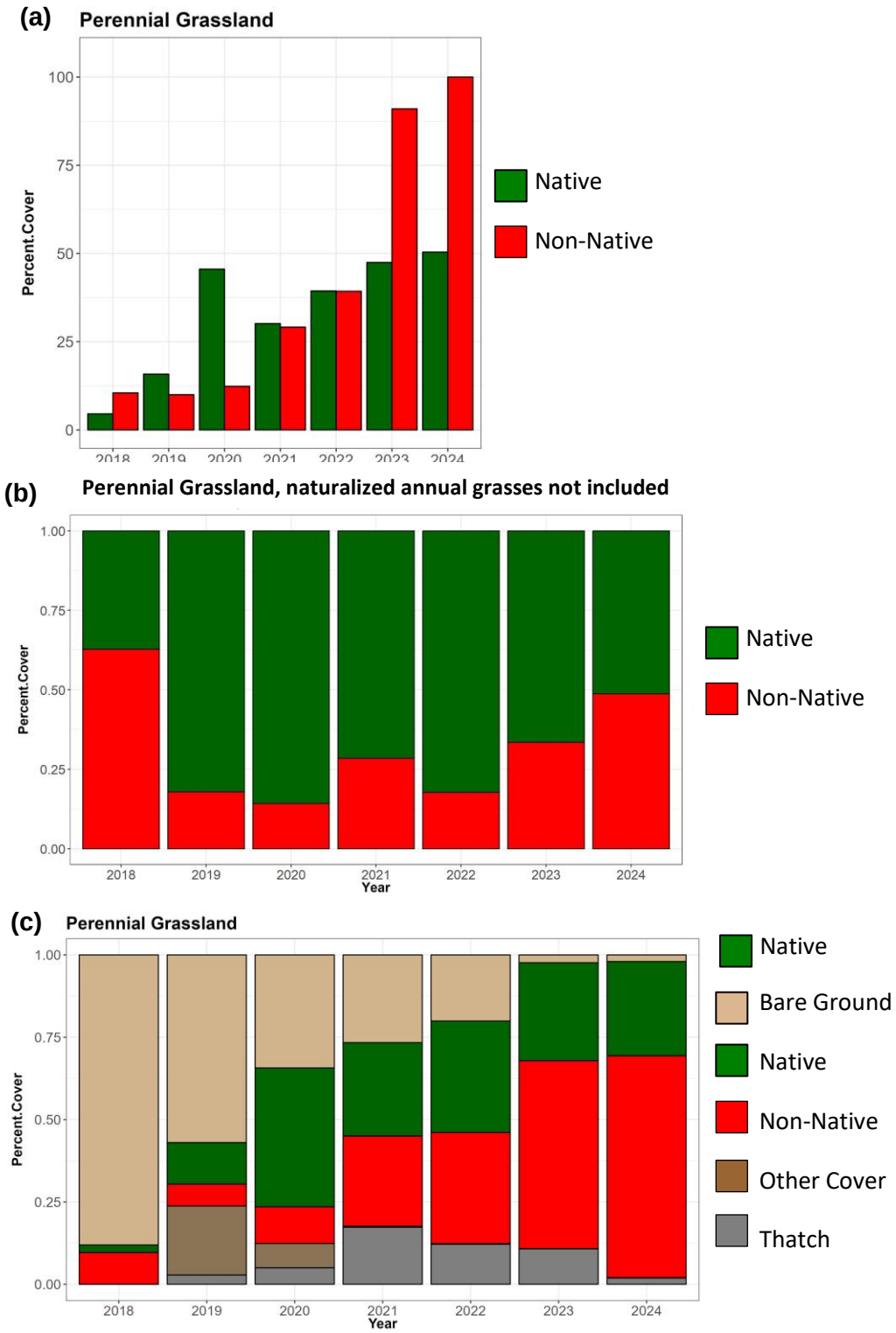


Figure 3. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation (annual naturalized grass species are not included in graph b), and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the Native Perennial Grassland habitat at the North Campus Open Space restoration project.

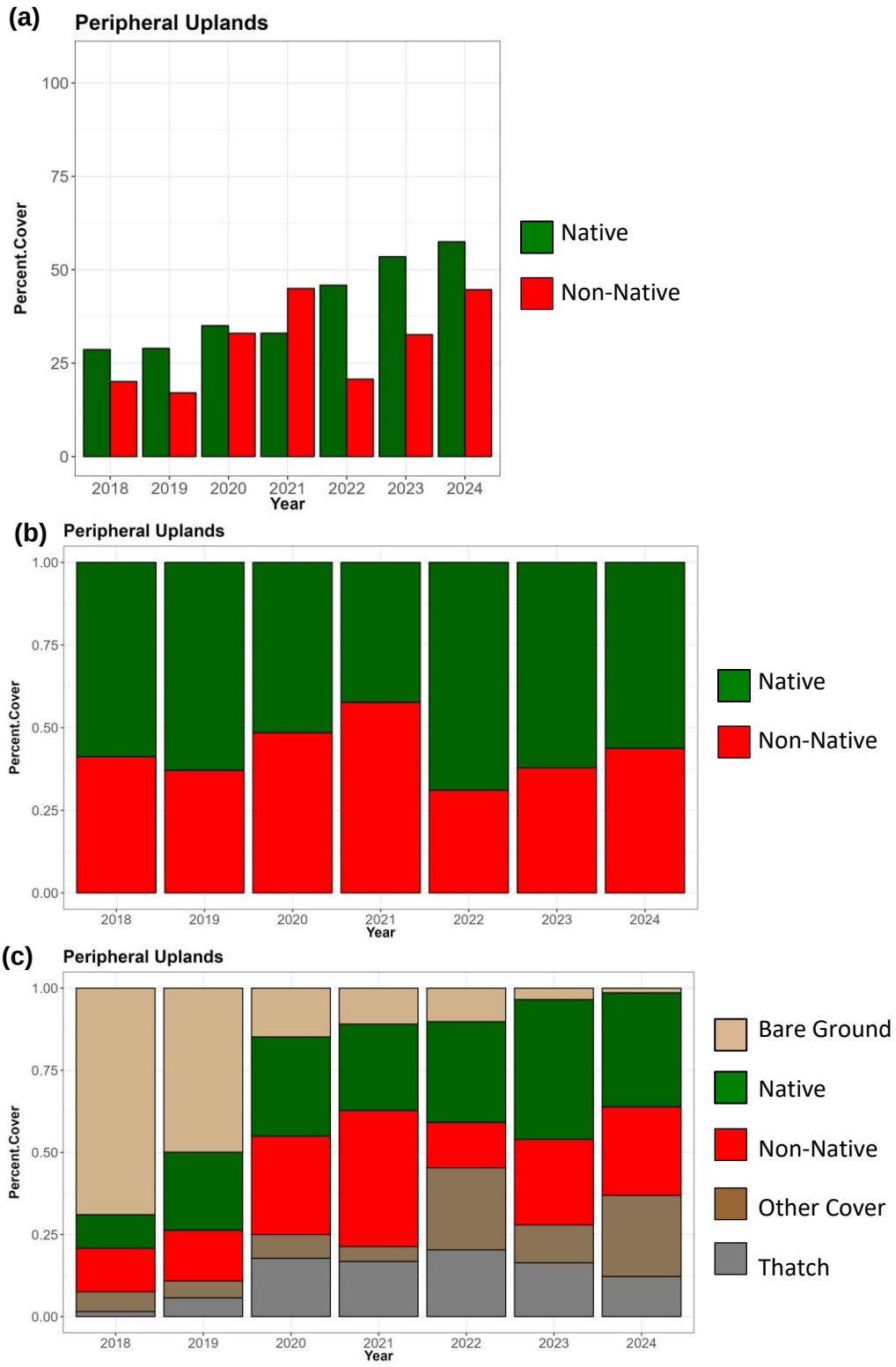


Figure 4. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the Peripheral Upland Mosaic habitat at the North Campus Open Space restoration project.

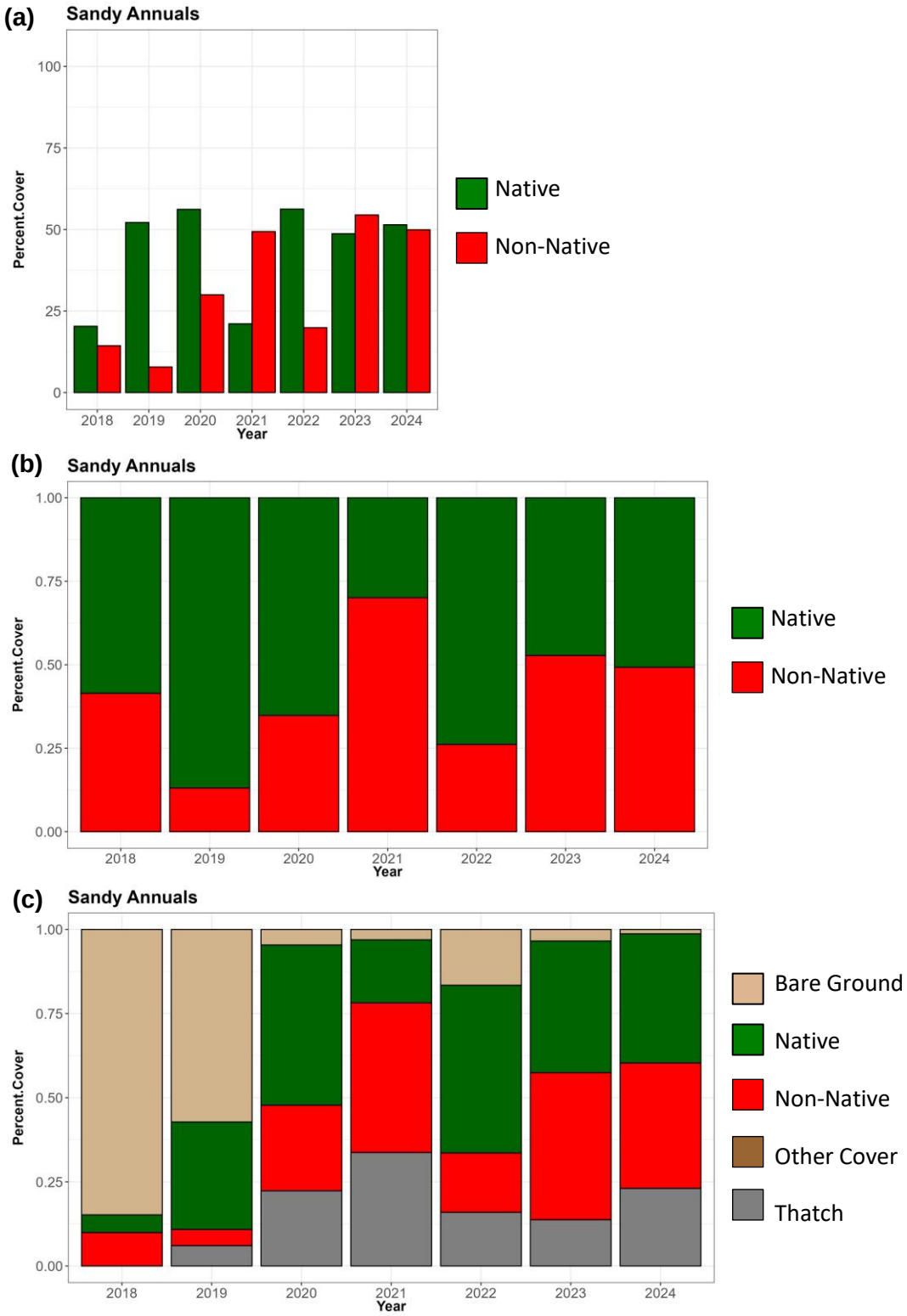


Figure 5. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the Sandy Dune Annuals habitat at the North Campus Open Space restoration project

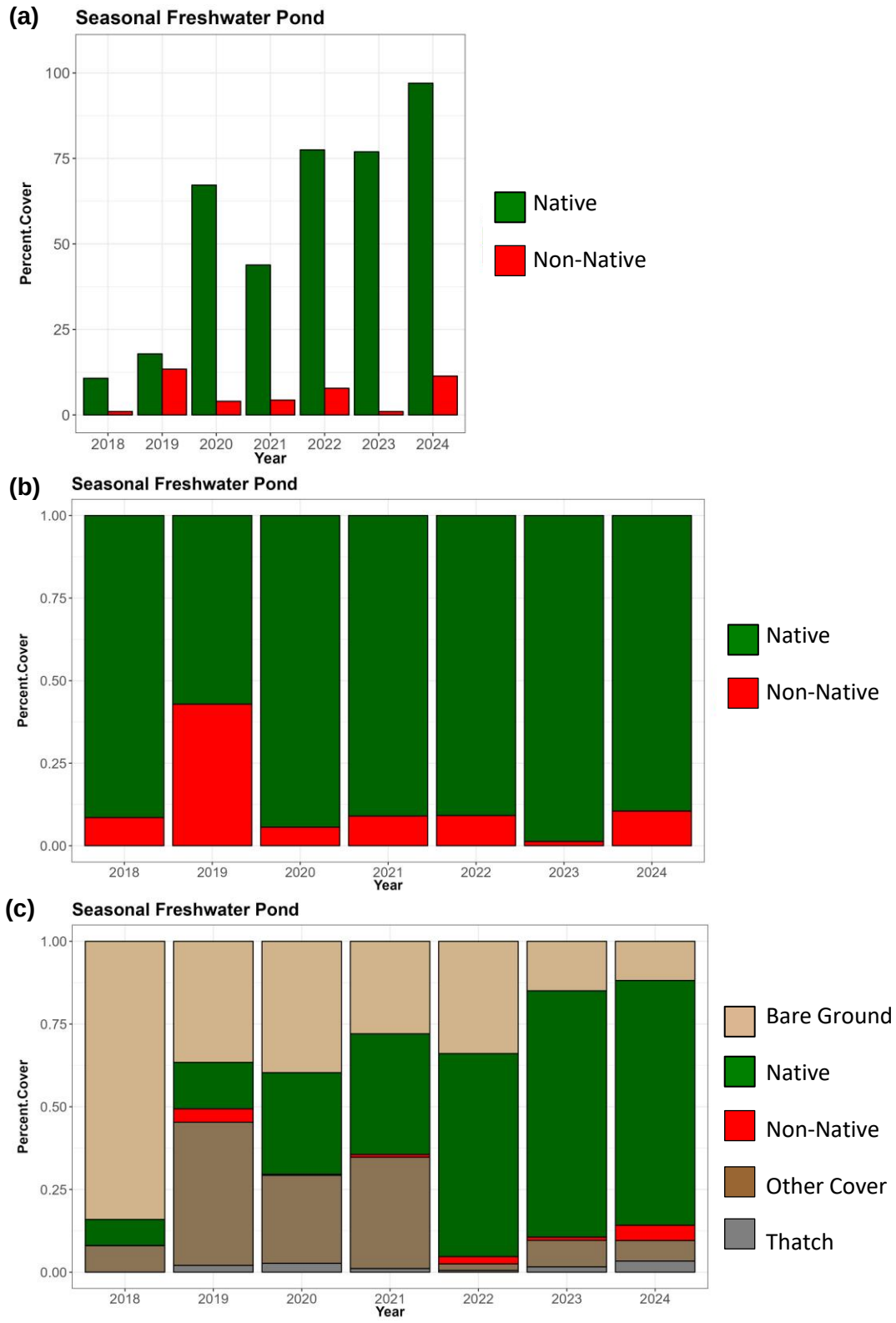


Figure 6. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the Seasonal Freshwater Pond habitat at the North Campus Open Space restoration project.

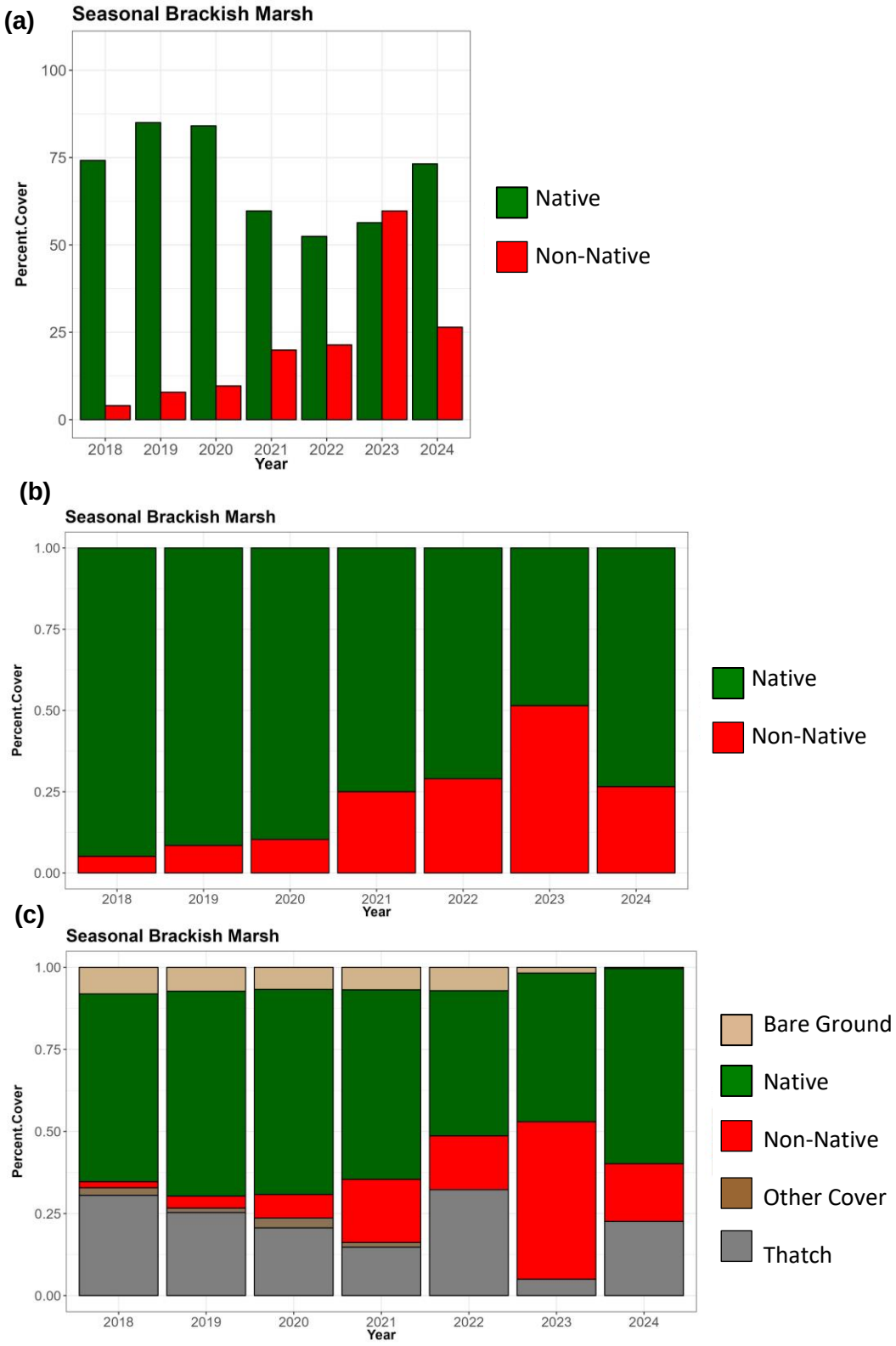


Figure 7. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the Seasonal Brackish Marsh habitat at the North Campus Open Space restoration project.

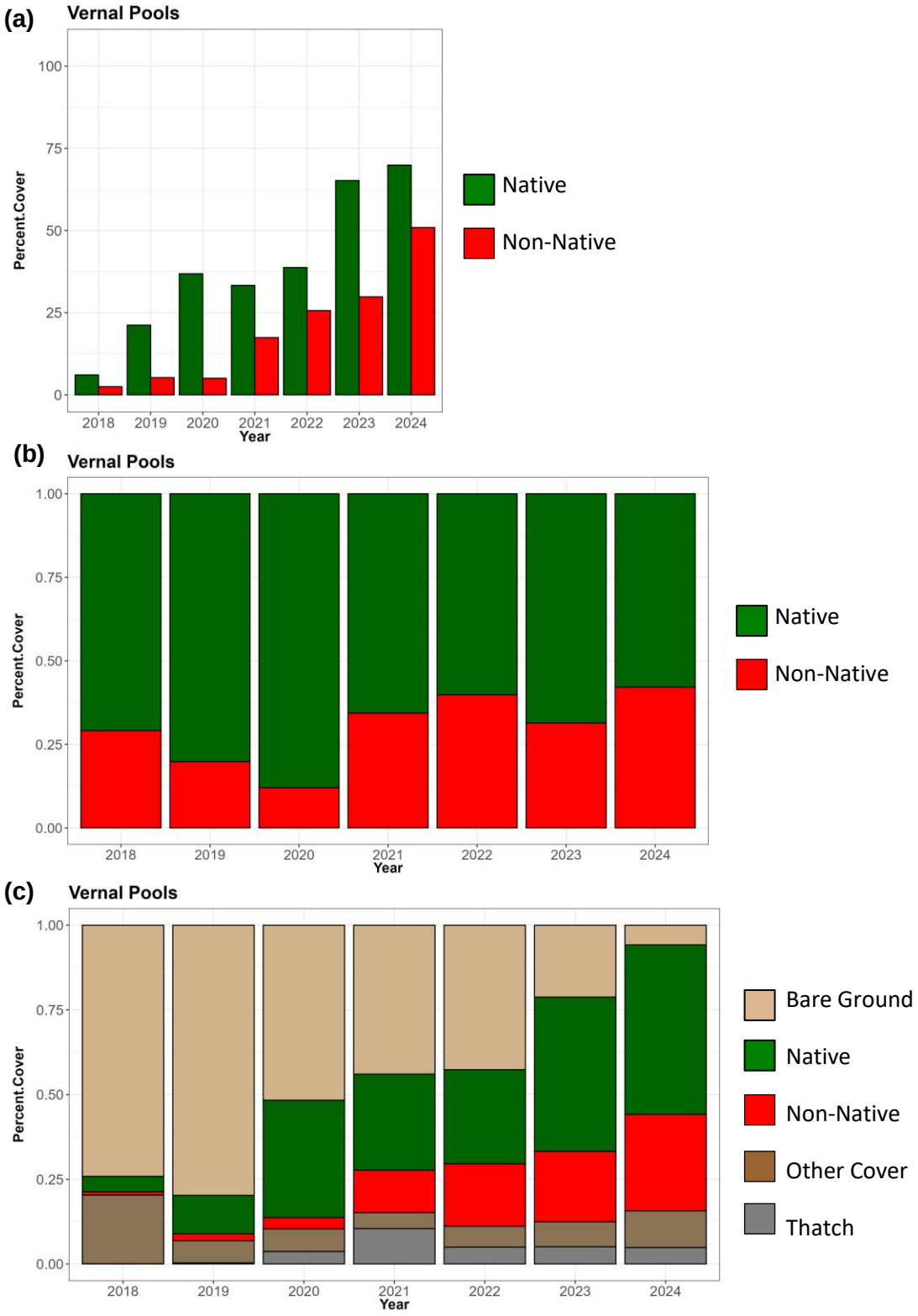


Figure 8. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the eight vernal pools on the mesa of the North Campus Open Space restoration project.

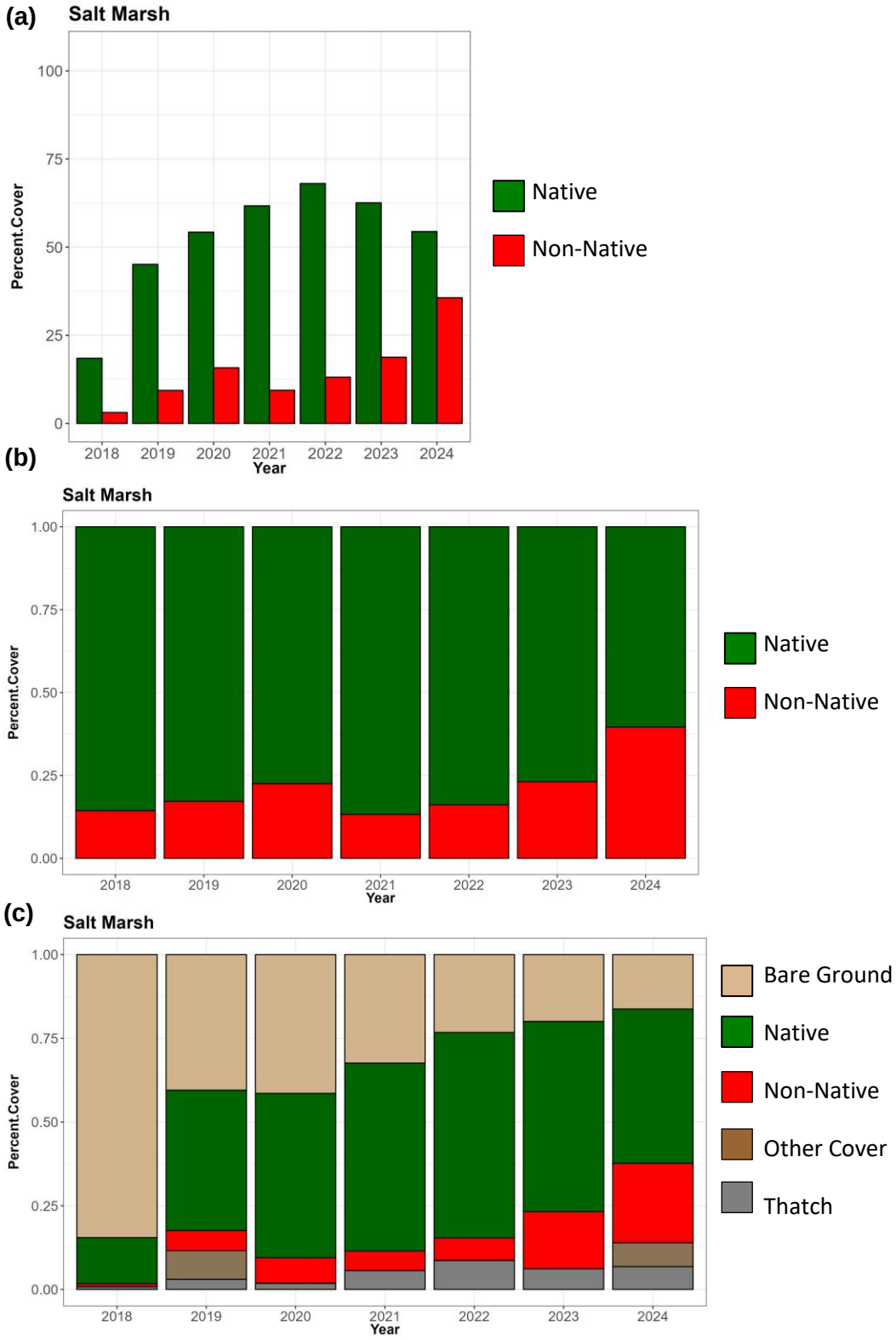


Figure 9. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the Low and Mid Elevation Restored Salt Marsh habitats at the North Campus Open Space restoration project.

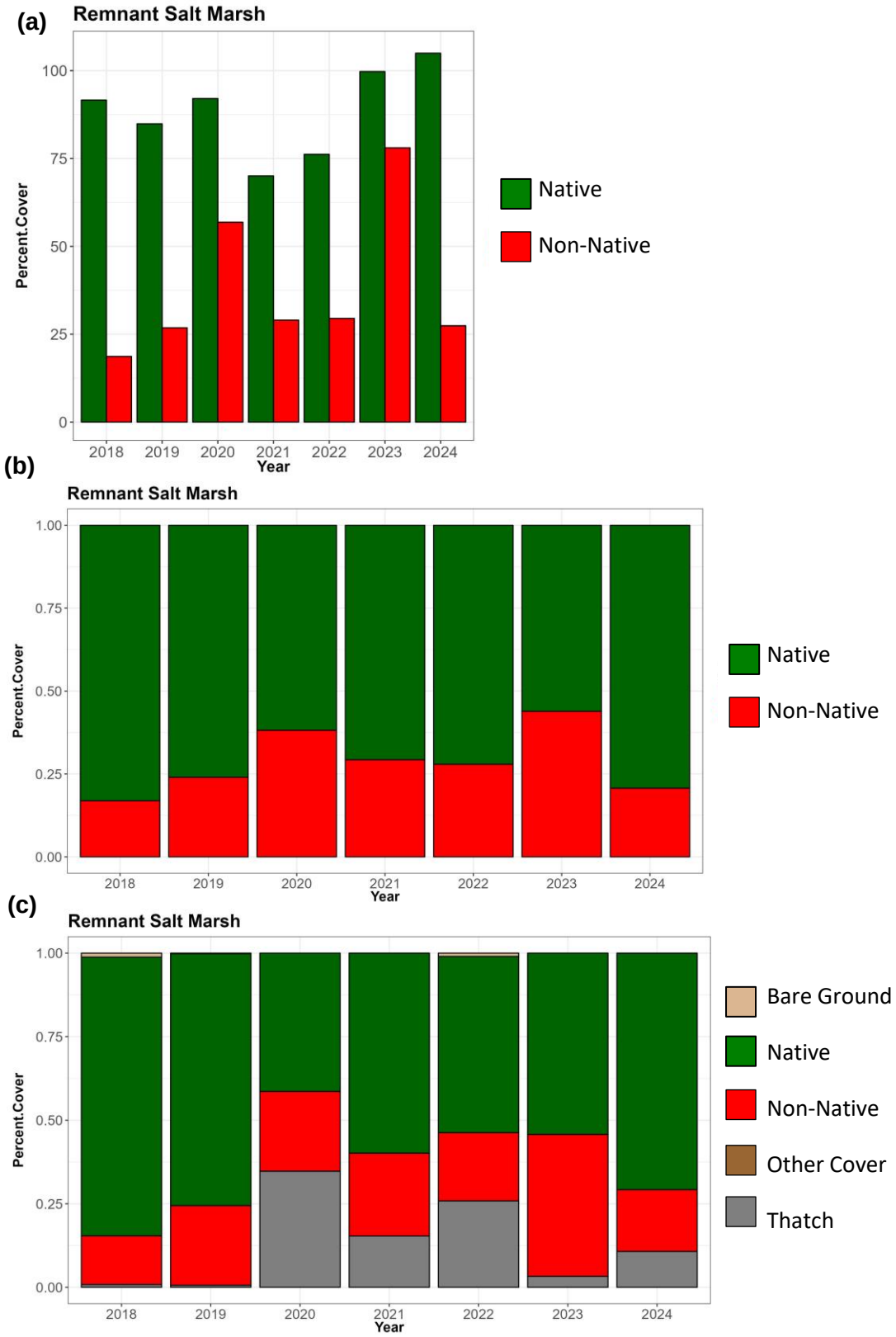


Figure 10. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the Remnant Salt Marsh at the North Campus Open Space restoration project.

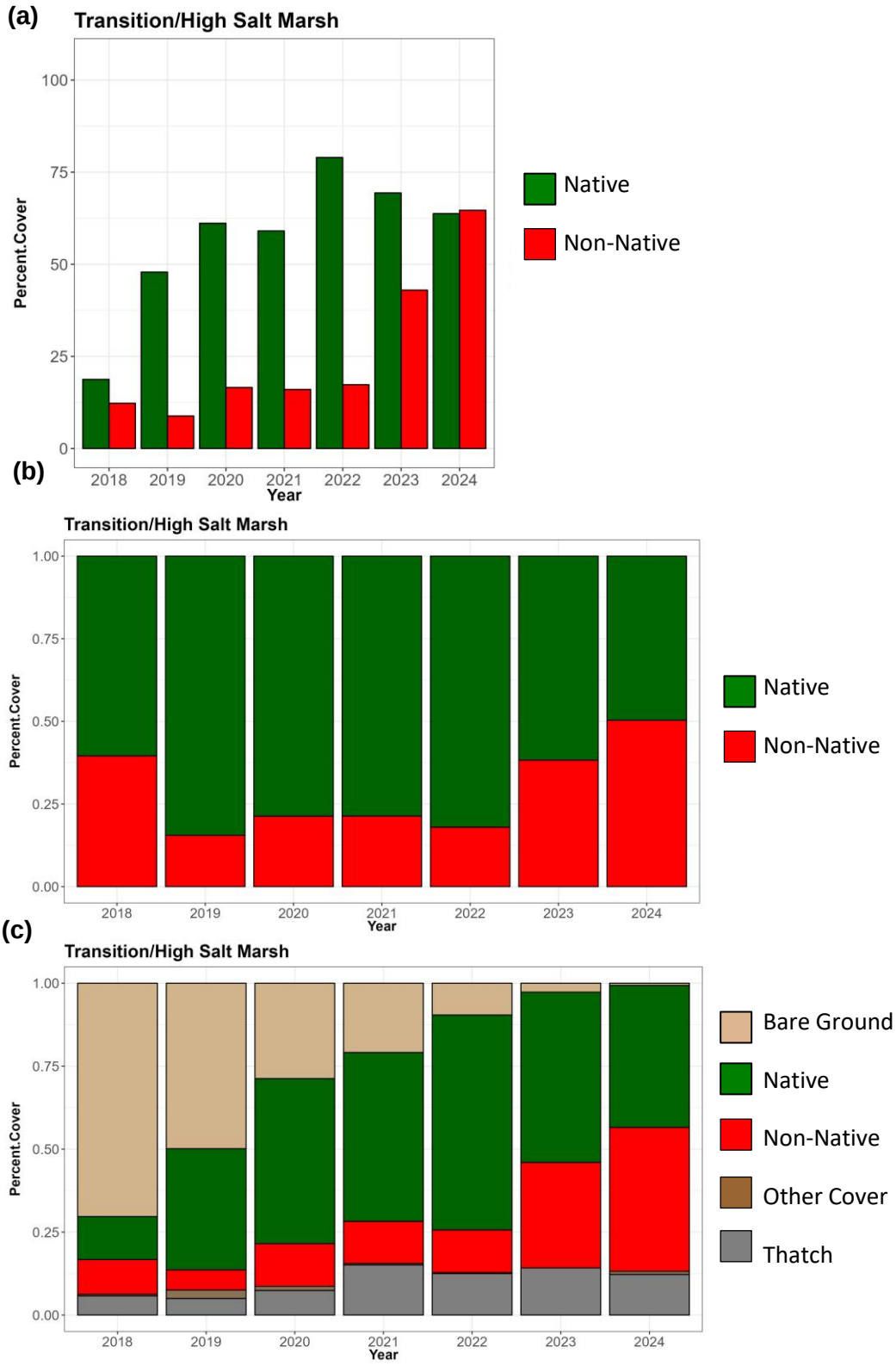


Figure 11. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the Transition/ High Salt Marsh habitat at the North Campus Open Space restoration project.

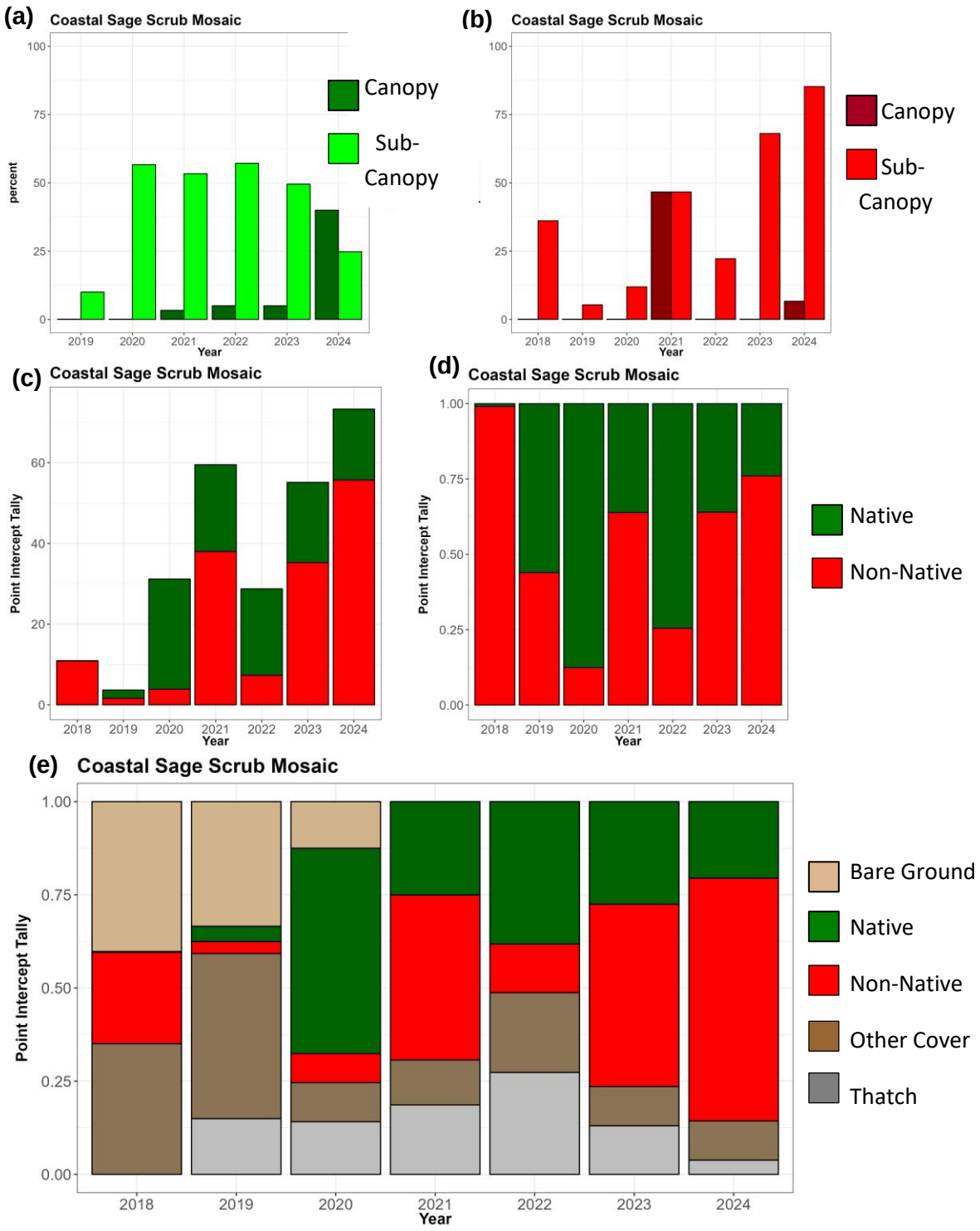


Figure 12. Mean percent of point intercept points per transect (Elzinga et al.*, Chapter 8. Field Techniques for Measuring Vegetation* 1998) of (a) native, (b) non-native (c) mean of all intercepts per transect of native and non-native vegetation (d) relative cover: total native hits & total non-native hits each divided by total hits of native and non-native combined and (e) relative cover of vegetation, thatch, other cover types, and bare ground in the Coastal Sage Scrub (sampled using point of intercept transect) at the North Campus Open Space restoration project.

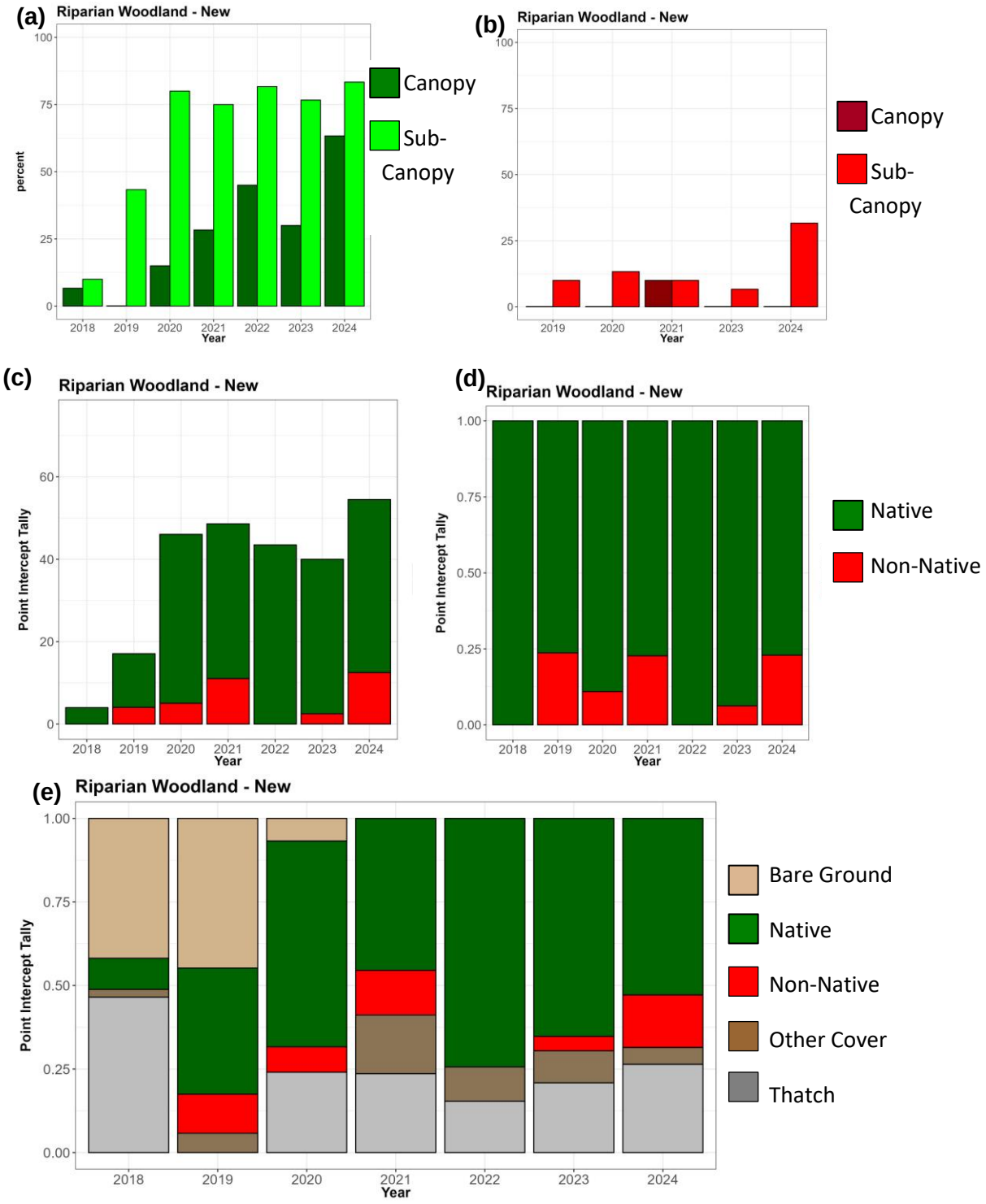


Figure 13. Mean percent of point intercept points per transect (Elzinga et al.*, Chapter 8. Field Techniques for Measuring Vegetation* 1998) of (a) native, (b) nonnative (c) mean intercepts per transect of native and non-native vegetation (d) relative cover: total native hits & total non-native hits divided by the sum of native and non-native plant hits and (e) relative cover of vegetation, thatch, other cover types, and bare ground in the New riparian woodland at NCOS.

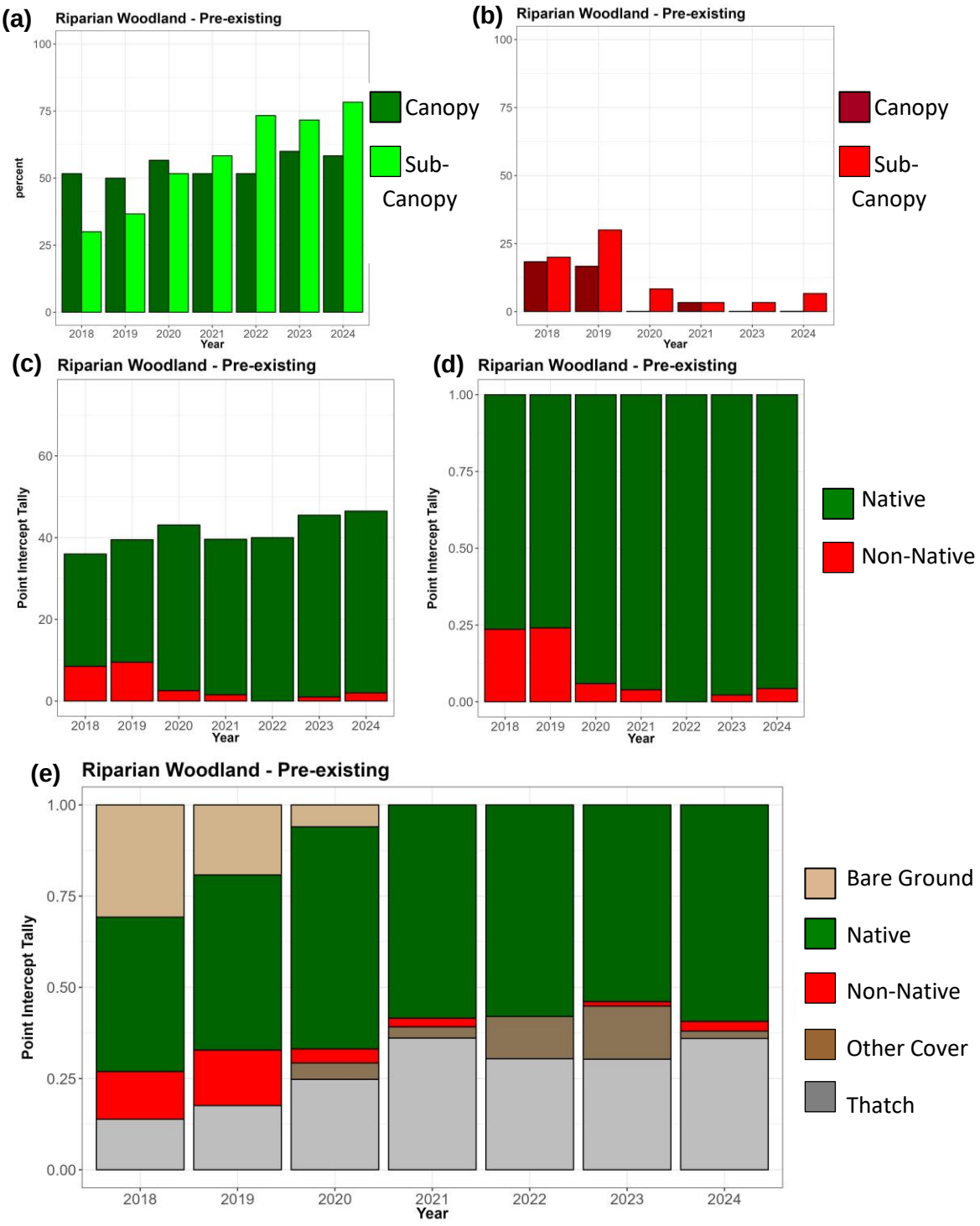


Figure 14. Mean percent of point intercept points per transect (Elzinga et al.*, Chapter 8. Field Techniques for Measuring Vegetation* 1998) of (a) native, (b) non-native (c) mean intercepts per transect of native and non-native vegetation (d) relative cover: total native hits & total non-native hits divided by the sum of native and non-native hits and (e) relative cover of vegetation, thatch, other cover types, and bare ground in the pre-existing riparian woodland habitat at the North Campus Open Space restoration project.

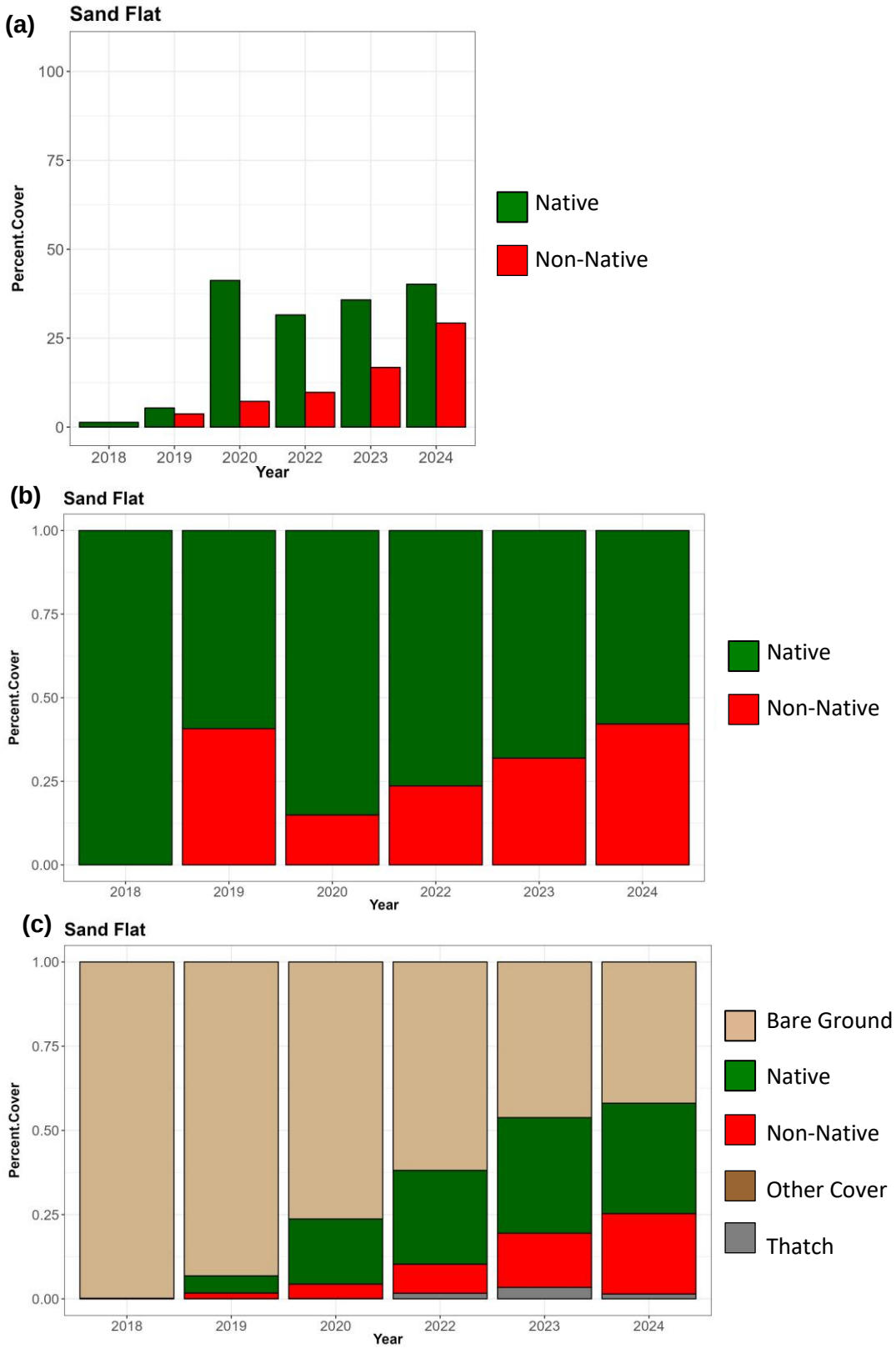


Figure 15. Mean percent of (a) absolute and (b) relative cover of native and non-native vegetation, and (c) relative cover of vegetation, thatch, other cover types, and bare ground in the Sand Flat habitat at the North Campus Open Space restoration project.

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.

Vegetation Success Results

The monitoring data collected in 2024 shows that all criteria other than the absolute percent native cover were met in all habitats. If annual grasses were not included in the total non-native plant cover or the native cover (e.g. considered naturalized) then all criteria would be met. In a site as large as NCOS that contains so many acres of low growing grassland and salt marsh transitional habitats, it is unrealistic to expect to eliminate annual grasses, particularly in wet years.

In the Fall 2023 we conducted the first prescribed burn in partnership with Chumash elders and using traditional Chumash techniques in the county. This was a collaborative effort to reinstate traditional Chumash management. An analysis of 60 experimental seeding and monitoring plots that were resampled this spring (see appendix 5 for report) indicated that the burn reduced annual grass cover where it was high but appeared to provide an opening for the establishment of sweet clover (*Melilotus indicus*) and bur clover (*Medicago polymorpha*). Both of these species increased in the unburned plots as well due to the significantly higher than normal rainfall, however the increase in sweet clover was significantly higher in the burned plot. In areas that were seeded with native seeds and bulbs, the burned plots showed a significant increase in the diversity of native forbs that was particularly strong in clay soils (see Appendix 5). One species that responded well to the fire was the native fascicled tarplant (*Deinandra fasciculata*).

The vegetation monitoring as well as visual assessment reflects success in the goal of eradicating all species rated as “High” by Cal-IPC at NCOS. No high rated invasives have been documented at NCOS since 2021.

Table 2. Comparison of vegetation monitoring data with proposed minimum success criteria for target habitats/plant communities from the Restoration Plan for the North Campus Open Space project. The proposed minimum criteria are italicized for the first 5 years (left) and the monitoring data is in the columns on the right-hand side of the table. We used year 5 monitoring criteria for year 6 and 7 of data collection. Table cells that are bold and green indicate monitoring data that meets or exceeds the corresponding criteria.

	Proposed Minimum Criteria					Monitoring Data						
	Y1	***Y2***	***Y3***	***Y4***	***Y5***	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Native Perennial Grassland												
% Total cover	*35*	*45*	*60*	*70*	*80*	12	24	58	58	**77**	**100**	**100**
% Native Relative	*50*	***60***	***70***	*70*	*70*	19	**65**	**79**	51	51	68	30
% Invasive Relative	***<5***	***<5***	***<5***	***<5***	***<5***	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Diversity (Native Species)	***3***	***4***	***6***	***7***	***7***	**8**	**18**	**21**	**25**	**23**	**19**	**24**
Peripheral Upland (Mixed Grassland/Shrubland)												
% Total cover	*35*	*45*	***60***	***70***	*80*	24	42	**66**	**71**	50	**86**	**72**
% Native Relative	*50*	***60***	*70*	*70*	***70***	43	**61**	50	39	**70**	62	55
% Invasive Relative	***<5***	***<5***	***<5***	***<5***	*<5*	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Diversity (Native Species)	***3***	***4***	***6***	***7***	***7***	**15**	**40**	**36**	**35**	**31**	**24**	**26**
Salt Marsh												
% Total cover	*30*	***40***	***60***	*70*	***70***	15	**50**	**62**	68	**73**	**100**	**100**
% Native Relative	***70***	***80***	***80***	***80***	*90*	**94**	**88**	**87**	**91**	88	68	71
% Invasive Relative	***<5***	***<5***	***<5***	***<5***	***<5***	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Diversity (Native Species)	***4***	***6***	***7***	***7***	***8***	**11**	**15**	**30**	**14**	**17**	**29**	**22**
Transitional/High Salt Marsh												
% Total cover	*30*	***40***	***50***	***60***	***65***	24	**46**	**74**	**72**	**92**	**100**	**100**
% Native Relative	***50***	***60***	***65***	***70***	***80***	**55**	**86**	**79**	**80**	77	61	50
% Invasive Relative	***<5***	***<5***	***<5***	***<5***	***<5***	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Diversity (Native Species)	***8***	***8***	***10***	***12***	***15***	**20**	**22**	**28**	**20**	**25**	**25**	**27**
Fresh/Brackish Marsh (Seasonal Pond)												
% Total cover	*50*	*50*	*60*	*70*	***80***	8	20	43	39	**96**	78	99
% Native Relative	***70***	***70***	***70***	***80***	***80***	**99**	**78**	**99**	**98**	**91**	**97**	**80**
% Invasive Relative	***<5***	***<5***	***<5***	***<5***	***<5***	**0**	**0**	**0**	**0**	**0**	**0**	**0**

	Proposed Minimum Criteria					Monitoring Data						
	Y1	***Y2***	***Y3***	***Y4***	***Y5***	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Diversity (Native Species)	*7*	***7***	***10***	***12***	***14***	6	**7**	**17**	**16**	**16**	**16**	**19**
Vernal Pools												
% Total cover	*30*	*40*	***40***	*45*	***50***	6	13	**40**	42	**50**	**95**	**100**
% Native Relative	***70***	***70***	***70***	*80*	*80*	**83**	**84**	**91**	69	60	68	57
% Invasive Relative	***<5***	***<5***	***<5***	***<5***	*<5*	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Diversity (Native Species)	***7***	***7***	***10***	***12***	***15***	**17**	**28**	**33**	**37**	**43**	**46**	**28**
Sandy Dune Annuals												
% Total cover (variable by season)	*20*	***25***	***30***	***35***	***40***	16	**38**	**86**	**56**	**44**	**100**	**100**
% Native Relative	*50*	***60***	*70*	*70*	*80*	35	**87**	65	17	75	47	51
% Invasive Relative	***<5***	***<5***	***<5***	***<5***	***<5***	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Diversity (Native Species)	*3*	***3***	***4***	*5*	***5***	2	**7**	**5**	3	**6**	**4**	**6**
Coastal Sage Scrub/Chaparral Mosaic												
% Total cover	*30*	*40*	***50***	*60*	***65***	30	7	**66**	**79**	**77**	**100**	**93**
% Native Relative	*50*	*60*	***65***	*70*	***80***	0	43	**83**	59	**74**	48	
% Invasive Relative	***<5***	***<5***	***<5***	***<5***	***<5***	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Diversity (Native Species)	*8*	*8*	***10***	***12***	***15***	0	3	**16**	**16**	**24**	**23**	**20**
Riparian												
% Total cover	*50*	***50***	***60***	***70***	***80***	13	**53**	**90**	**88**	**81**	**100**	**83**
% Native Relative	***70***	***70***	***70***	***80***	***80***	**100**	**81**	**88**	**85**	**100**	78	
% Invasive Relative	***<5***	***<5***	***<5***	***<5***	***<5***	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Diversity (Native Species)	*7*	*7*	***10***	***12***	***14***	4	6	**12**	**12**	12	11	12

Spatial analysis of sediment accumulation and soil carbon storage in a restored wetland

After wetland grading, feldspar plots were created in collaboration with Dr. Jenifer King's lab at UCSB. PhD student Jesse Landesman sampled and analyzed the soil data and plans to publish the findings in the next year. The following is from the abstract of the thesis which will be available through the UCSB library:

> Sediment accumulation rate averaged 2.16 mm/year, with a range of 0.4 mm/yr to 5.4 mm/yr. Sediment accumulation, surface soil carbon density, and subsurface carbon density all varied significantly by plot location. The spatial dynamics of vertical accretion were primarily driven by mineral rather than organic material, whereas surface soil carbon was primarily driven by aboveground plant biomass. Sediment accumulation was greatest downstream, whereas soil carbon accumulation was greatest upstream at the freshwater stream inputs. Some areas showed a negative relationship between sediment accumulation and soil carbon density, with high sediment accumulation associated with low surface soil carbon density. Although wetlands are touted to mitigate sea level rise and climate change through sediment accretion and carbon sequestration, these results suggest that sediment accumulation and carbon accumulation do not necessarily co-occur. The results imply that sediment accumulation alone cannot reliably predict carbon accumulation. (Jessica Jayne Landesman, Spatial dynamics of sediment accumulation and soil carbon storage in a restored wetland, September 2024, in press)

Tree Monitoring Data

Monitoring the height, diameter at breast height (DBH), and vigor of the 243 trees that were planted in years 1-5 of the restoration project continued. No additional trees were planted in 2024.

Six trees were found to be dead in year 7 monitoring (vigor rating of 4). The overall success rate of tree survival for the 7 years of monitoring is 97.5%.

Overall, every year of monitoring reflected healthy growth for all six species. There has been an increase from year 6 to year 7 in overall mean tree height from an average of 91 to 100 inches. We used a tree measuring laser in year 7 to increase our accuracy in measuring tree height because some trees exceeded the height of our measuring devices in 2023 and data plateaued at 24 feet in 2023. DBH increased from 1.5 to 1.95 inches. The mean overall vigor rating is 1.1 (high). The greatest average tree diameter increase was seen in white alder. Similar growth patterns were observed in all previous years.

The white alders are significantly taller than other species and also have one of the largest diameters compared to other tree species (Figure 17).

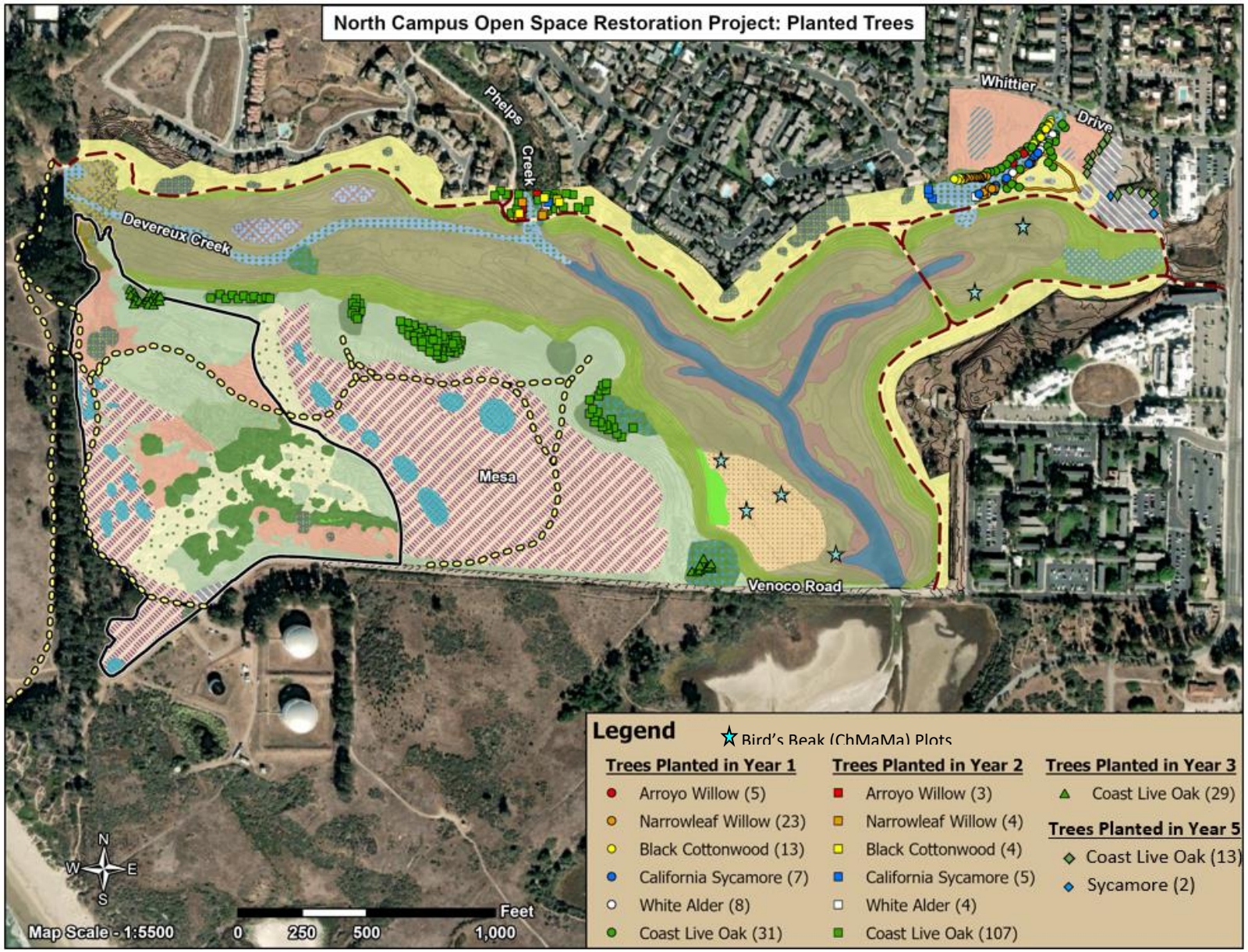


Figure 16. Map of trees planted during the first three years of the North Campus Open Space restoration project. See Figure 1 for a legend of the habitats/plant communities and trails.

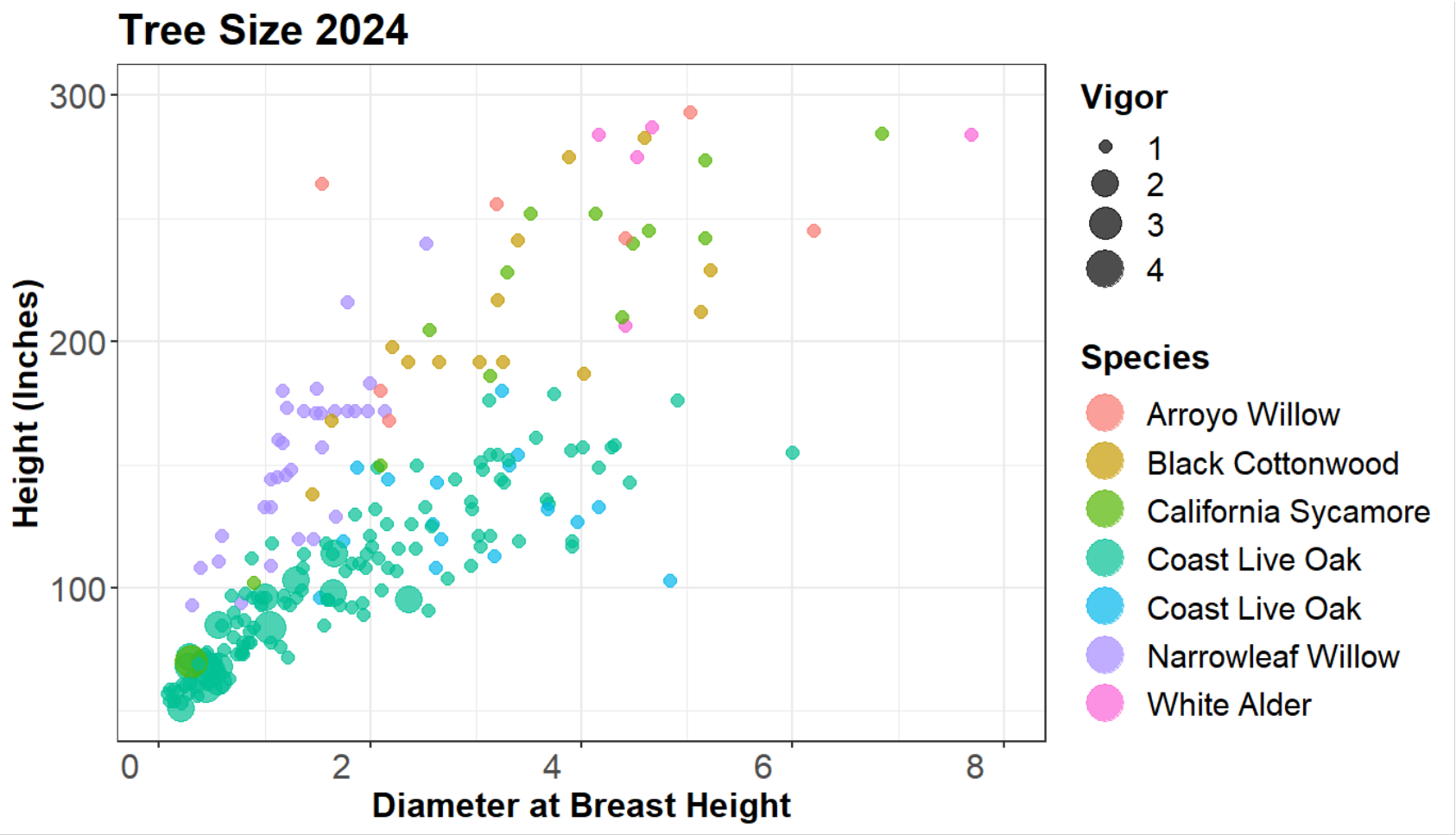


Figure 17. Scatter plot of tree height and diameter. This figure represents all living planted trees that are part of the study at NCOS in year 7.

Special Status Plant Species

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. 2024 was a difficult year for the main population of VMMV. The population declined from 814 adults to 308. This was due to a combination of factors including both native and non-native weed competition and more prominently the first and second generation of VMMV have reached the end of their life span. Since VMMV is a nitrogen fixer it is thought that the existence of this population for years has improved the soil quality for native and non-native competitors. There is a new study funded by USFWS in collaboration with an undergraduate student to better understand the levels of nitrogen in this soil. New VMMV seedlings have been spotted despite this decline. The VMMV has also increased its range with several volunteers popping up in distant locations on NCOS. These locations include one plant at the outdoor classroom, one at Dilling's Link bridge and several in the Mesa area, at a higher elevation.

This year also marked the second year of the salt marsh bird's beak (*Chloropyron maritimum var maritimum*) experimental seeding. Seed was acquired from Carpinteria Salt Marsh through our partners at Tidal Influence and USFWS and planted across 96 plots in 8 experimental sites in 2023; and in winter 2024 50,000 seeds were spread in the sandy area in February and March.1853 individuals were tallied in the 2024 monitoring. Results show that birds beak thrives in sandy soil on site but in 2024 we found that seeds that were spread in 2023 germinated in clay soils at three of the sites in 2024. Distributing seeds early and allowing them to experience a flood appears to support germination.

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 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, and reptiles.

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 2 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 Field Maps on a tablet, each team records every individual of every species of bird seen or heard on site, including birds flying between habitats or structures on or adjacent to the site. The Field Maps app 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.

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.

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 groups;, one that is predominately aerial insectivores (*e.g*. swallows and flycatchers), and and another that is predominantly terrestrial insectivores (e.g. blackbirds, sparrows, woodpeckers, and wrens).

Comparison of Survey Years

A bar chart comparing the mean count per quarter are presented in Figure 18. 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 varies by year, with 431 in year one to 570 in year two, 731 in year three (September 2019 – August 2020), 470 in year 4 and 563 in year 5 and was 498 in year 6 and 492 in year 7.

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, 122 in year 5 and 116 in year 6 and 108 in year 7. We did not observe any new species in year 7. Collectively, 169 species have been recorded over the seven years of surveys. This covers 66 percent of the 256 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 (Figure 18). We observed breeding from a downy woodpecker for the first time at NCOS in 2024.

Discussion of Slough Water Level Influence on Bird Trends

The year 7 estuary water level was higher than average in spring and summer. The bird survey water elevation is representative of a single day; however, the slough water level changed a lot in the 2024 water year due to the heavy rainfall and frequent breaching of the slough. There is both the highest diversity and the highest bird count in winter months when water elevation is high.

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.

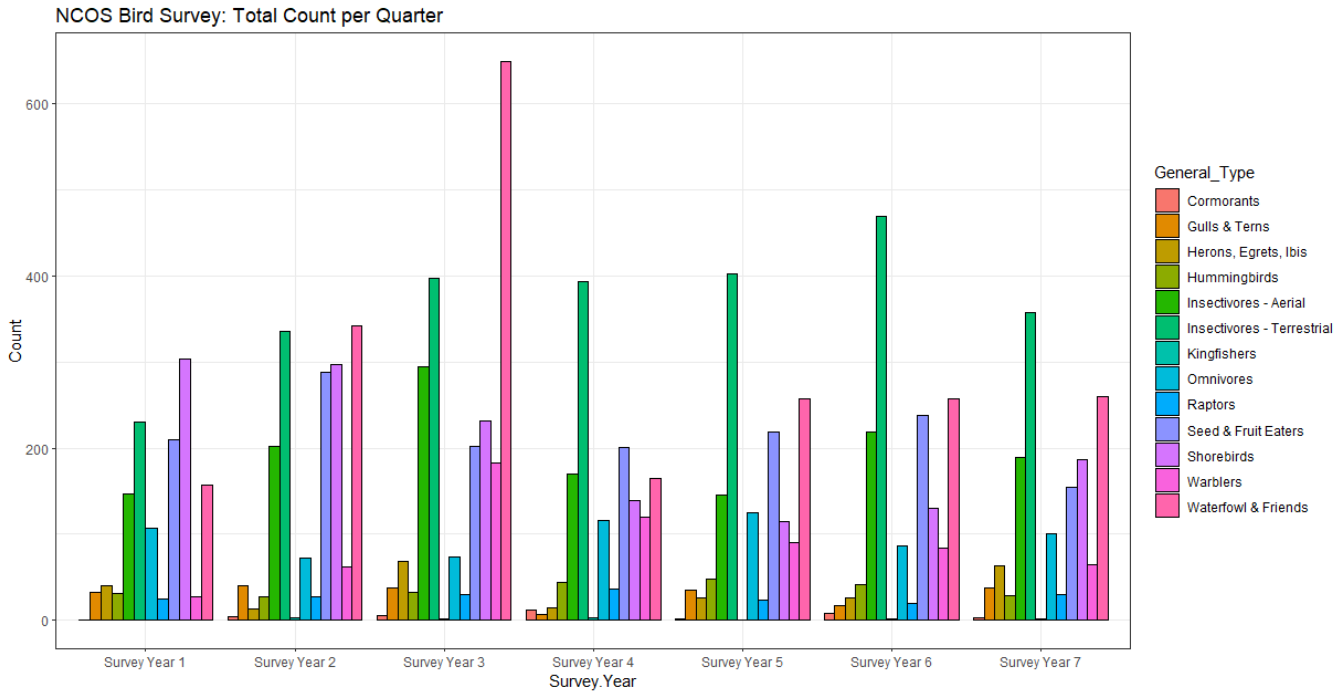


Figure 18. Mean of counts per quarter of birds in 13 guilds observed in each year (September through August) of monthly surveys at NCOS (2017 – 2024).

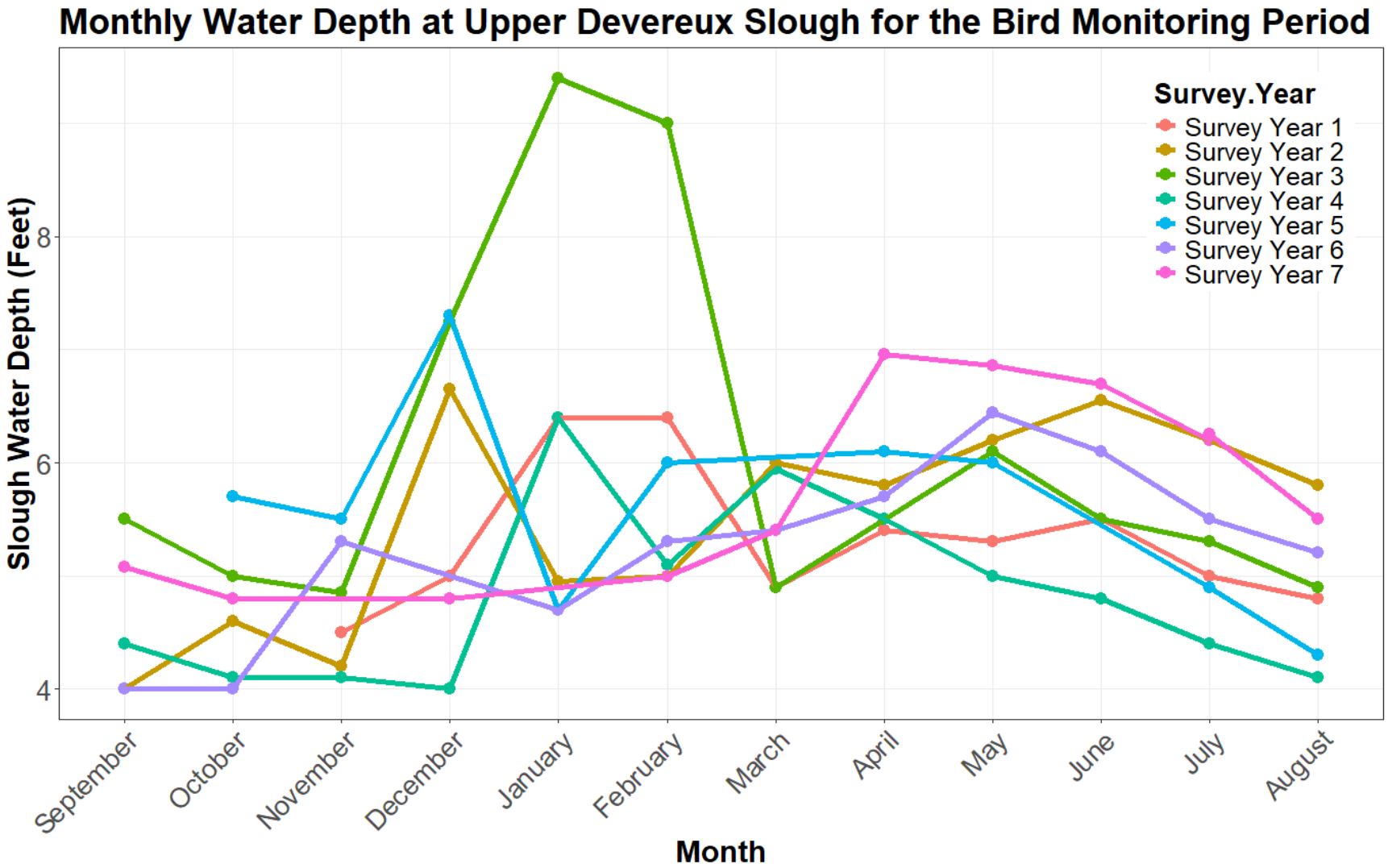


Figure 19. Line graph comparing the water surface elevation (in feet) of Venoco Bridge for each year (September through August) of monthly bird surveys at NCOS. Year 1 (2017-18), Year 2 (2018-19), Year 3 (2019-20), Year 4 (2020-21), Year 5 (2021-22), Year 6 (2022-23) and Year 7 (2023-24)

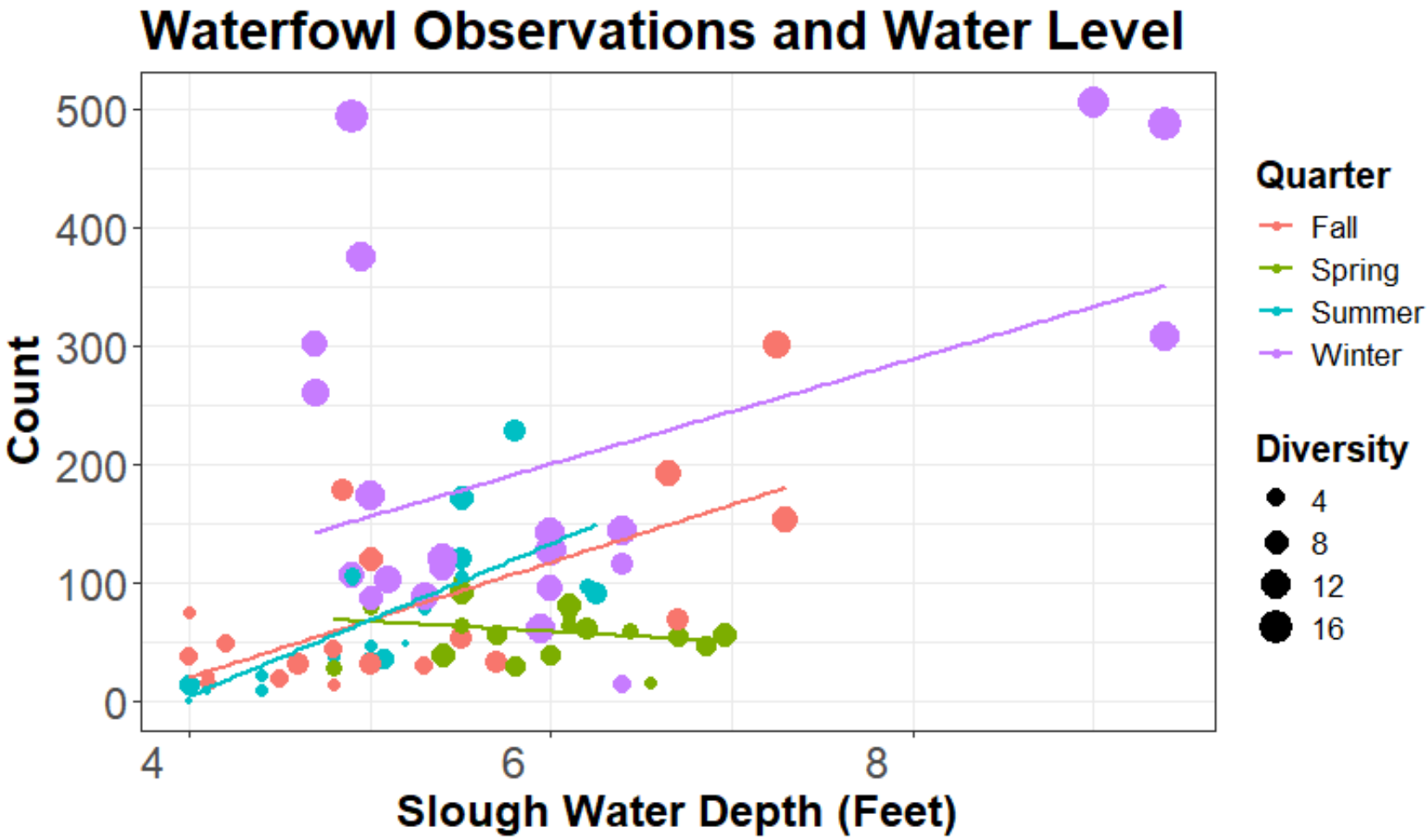


Figure 20. Number of waterfowl observed in monthly surveys from 2017-2024 and a linear trend line for each season. The size of each point represents the number of species seen in that survey. Season has a strong effect on observations because of migration patterns.

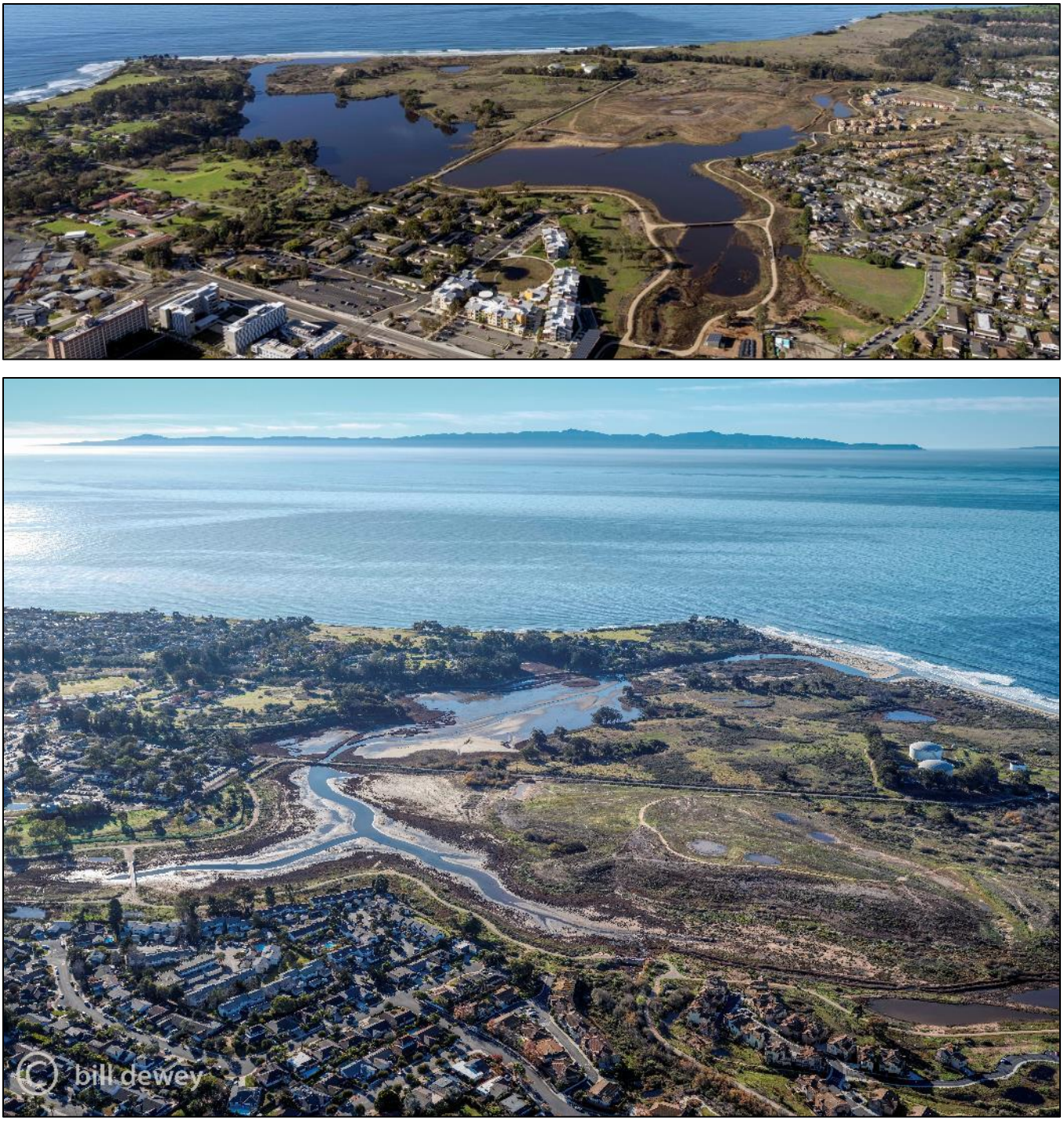


Figure 21. Aerial photos of North Campus Open Space by Bill Dewey. Top: December 2019 showing the high-water level when the Slough is full; Bottom: January 2022 showing the low water level after the slough has opened, Credit: Bill Dewey

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 five 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. No Western Snowy Plovers attempted nesting on site in 2021. In 2022 there were two breeding pairs with 2 chicks each that fledged. No nesting attempts were recorded in 2023 or 2024. One likely explanation for the small population and absence of Western Snowy Plover nesting at NCOS is the simultaneous optimization of snowy plover habitat at Coal Oil Point. Coal Oil Point Reserve management began crow control in early 2021, reducing the potential for snowy plover chick predation at the beach. The beach is an optimal habitat when predation is reduced.

Belding's Savannah Sparrow have been recorded in each year either in surveys or noted by confident birders, particularly in the spring and summer breeding seasons. Five breeding observations in a single year is the highest count recorded to date.

Burrowing owls were observed on site for most of the overwintering period (October – March) in the first four years in one of the 50 created hibernacula. In year five, 2021-22, the newly arrived burrowing owl was harassed by a peregrine falcon and disappeared soon after that, no burrowing owls have been documented in the 2022-23 year. In September 2024 there was a burrowing owl spotted at the Ellwood marine terminal adjacent to NCOS while it was under construction and after the large stand of Eucalyptus trees were removed. One reason for removing the trees was to reduce perches for raptors that prey on burrowing owls and other ground-oriented birds. There have been additional burrowing owl observations in several of the NCOS hibernacula in October 2024.

A UCSB undergraduate student dissected owl pellets, and documented that burrowing owl at NCOS mainly consume insects such as earwigs, ground beetles, woodlice, and wasps as well as field and harvest mice while literature shows that burrowing owls at other locations consume a higher ratio of small vertebrates such as mice. Our small mammal study shows that there is not a large population of mice at NCOS. The findings of this research are published in Nature Conservation and can be found at doi: 10.3897/natureconservation.56.127231. (Invertebrate-biased diet of burrowing owls in a newly-restored coastal grassland).

While not endangered, the black necked stilt is a species of particular interest to the public. There were 5 successful nests documented in the NCOS wetland in year 7- the nesting habitat was optimized by the heavy water year and creation of small islands along the wetland.

Figure 22. 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 2024

Figure 25. 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 seven years of data, we now have observations of breeding behavior recorded for 36 species, including observations of breeding behavior of the downy woodpecker, Selaphorus sp. and house wren for the first time in 2024. There is an average of 12 species and 22 breeding behavior observations per year with a total of 184 breeding behavior observation during all survey years combined (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 41 species exhibiting breeding behavior at the site since 2017 at an average of 15 species and 30 observations per year. This database does include some of the records from our monthly bird surveys (Table A3.2 in Appendix 3).

Special Status Aquatic Species

To fulfill project grant and permit monitoring requirements, and for general interest, the Cheadle Center has conducted pre- and post-restoration surveys for three sensitive and special status aquatic species: California Red-legged Frog, Tidewater Goby, and Southwestern Pond Turtle. Surveys were led by a permitted biologist, with the assistance of Cheadle Center staff.

In the 2024 survey, 94 tidewater gobies were found in total and they were found as far up the estuary as the bridge over Phelps Creek. We recorded 5 tidewater gobies in the October 2019 survey and 67 in the 2023 survey. There were no tidewater gobies found in all other surveys (2017, 2018, 2020-22). A Technical Memorandum about the results of the June 2024 survey is provided in Appendix 4 of this report. The 2024 survey was completed earlier in the year than previous surveys.

There were no California Red-legged Frog or Southwestern Pond Turtle in any of the surveys. 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. Two southwestern pond turtles have been documented in Phelps Creek upstream of the restoration project multiple times in 2024 (34.423783°, -119.880466°).

Invertebrate Surveys & Studies

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 Natural Reserve (COPR) began in the spring of 2018 through a collaboration with the Santa Barbara Audubon Society and the COPR Nature Center. Several undergraduate interns, volunteers and student leaders collect aquatic macroinvertebrate samples using the filtered bucket method and dip net 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 was 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.

Scrutiny of the EDNA data revealed that the invasive New Zealand mudsnail was present in Phelps Creek. The species was physically observed in follow-up field studies and appropriate protections and notifications are now in place regarding this species.

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. 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. In 2023 we transitioned to dip netting methodology focused on the benthic layer. We have also expanded to include submerged aquatic vegetation and algae into our sampling protocol. NCOS was part of the Southern California Coastal Water Research Project (SCCWRP) Bight 2023 estuarine study.

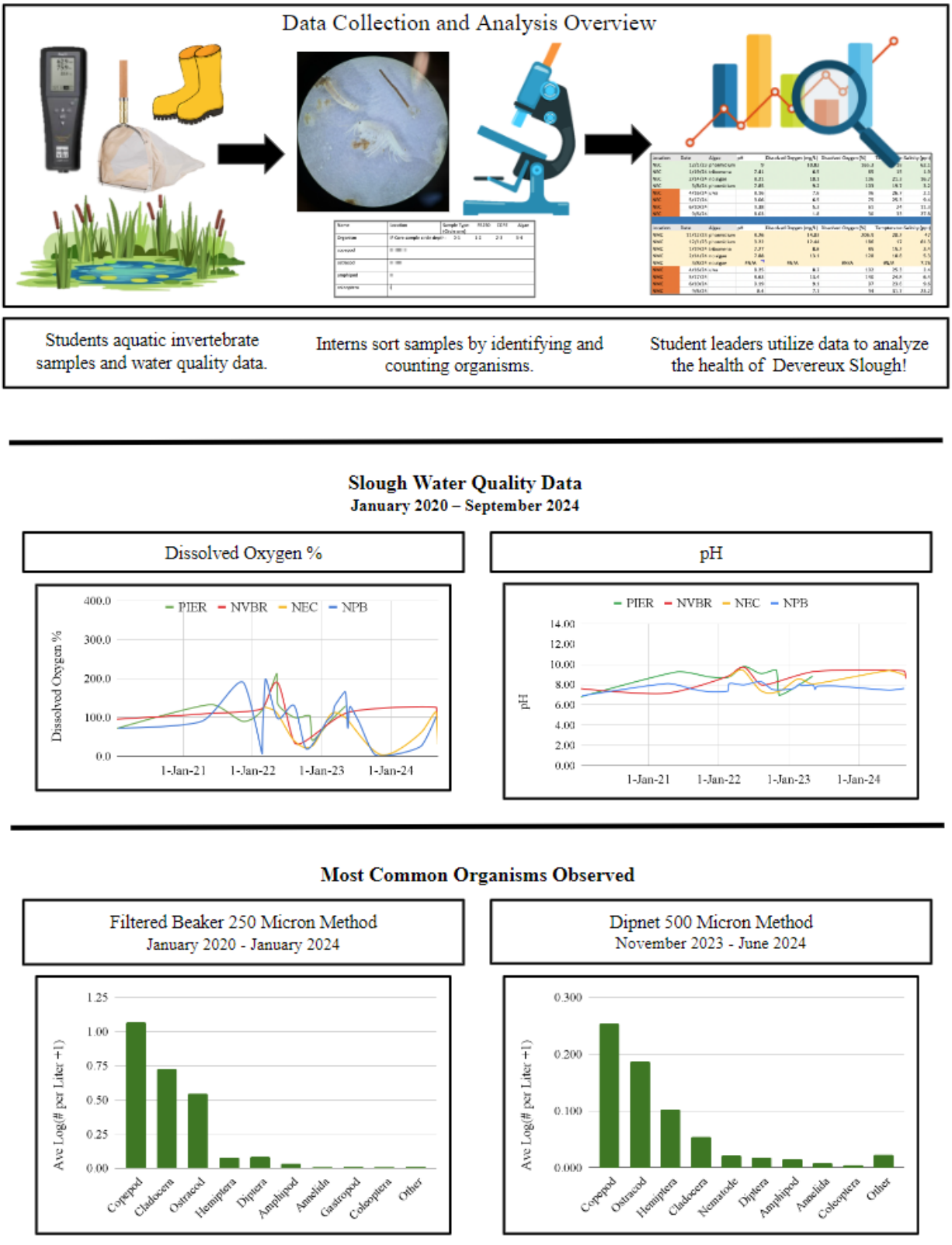


Figure 23. Aquatic invertebrate lab data collection and analysis (Complete by student leaders Kylie Malone and Elyse Hartmann)

Non-Avian Wildlife Studies

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 (Figure 24). 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 (figure 25). 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. The western fence lizard has been the most commonly found species in previous years. In 2024, the pacific tree frog numbers greatly increased, and the western fence lizard numbers dropped in 2024 causing the pacific tree frog to surpass the number of western fence lizard and the western skink for the first time since monitoring started.

In addition, a camera trap 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. The poster can be found here.

Figure 24. Coverboard plot locations

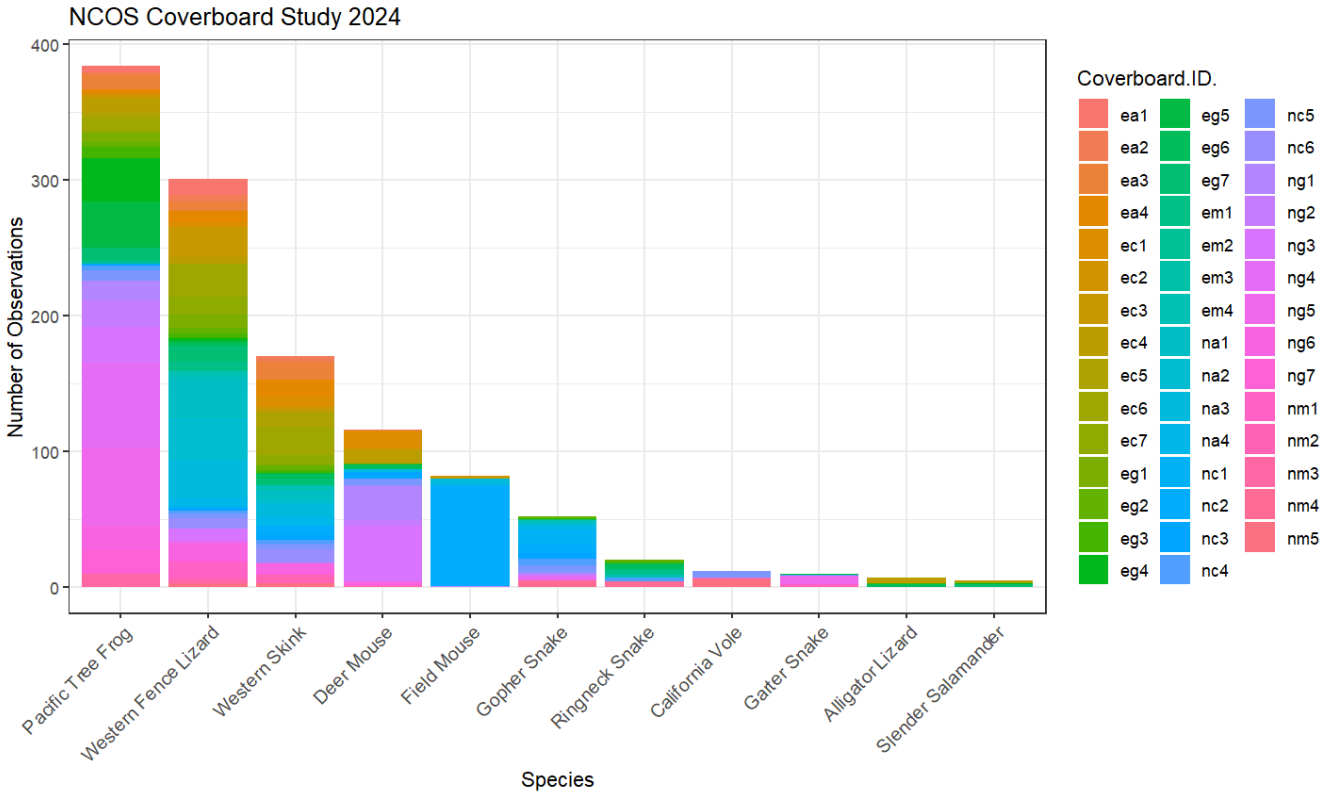


Figure 25. Location that species are found in the 2024 coverboard surveys.

5. HYDROLOGY AND WATER QUALITY

Hydrology and water quality monitoring at North Campus Open Space contributes to several objectives of the restoration project, such as: documenting the reduction of flood levels, monitoring the development and functionality of wetland habitats such as Devereux Slough and the newly created vernal pools, and developing long-term datasets that help improve knowledge and understanding of coastal ecosystems and how they may be affected by predicted future sea-level rise. Water quantity and quality is also correlated with our other monitoring efforts 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,
- dissolved oxygen and salinity levels at different locations and depths in the 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. 2023 was

an especially wet water year. The frequent and intense rainstorms caused the sand berm to breach 3 times in 2023. The total 2023 water year had nearly twice as much rain as the average (32 inches). 2024 was another very wet year (27.3 inches) but not as intense as 2023. There was late season rain in 2024 which resulted in the slough remaining full longer in the season and a significant amount of fog throughout the summer that reduced evaporation rates relative to other years.

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 2024 water year the persistent rain caused the berm to breach 3 times in January, February and March (Table 3). The breaches during 2024 water year were near the timing of high tide, therefore once they breached, they remained tidal for many days.

Table 3. Dates that the Devereux Slough breached, had tidal influence and closed

Water Year	Start date	End date	days tidal	Days not tidal
2019	Jan 7, 2019	March 21, 2019	47	26
2020	March 16, 2020	April 5, 2020	9	11
2021	Jan 28, 2021	Feb 15, 2021	18	0
2022	Dec 23, 2021	Jan 16, 2022	22	2
2023	Dec 31, 2022	Feb 4, 2023	28	7
2023	Feb 25, 2023	March 4, 2023	7	1
2023	March 10, 2023	March 30, 2023	20	1
2024	January 22, 2024	January 29, 2024	8	0
2024	February 1, 2024	February 20, 2021	20	0
2024	March 7, 2024	March 15, 2024	9	0

The water stage monitoring loggers were relocated in the 2023 water year. The lower slough now contains a Solinst LTC levelogger and a minidot DO monitor, Venoco bridge has a YSI EXO and all other sites have a Sonlinst LT levelogger. 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 4. Deployment location and elevation (in feet NAVD88) of pressure transducer loggers (YSI EXO1 and Solinst Leveloggers) that record water levels every 15 minutes in Devereux Slough and the North Campus Open Space. The deployment locations are indicated in the map in Figure 30.

Deployment Location	Logger Elevation (ft. NAVD88)
Devereux Slough Pier	3.4
East Arm Trail Bridge	4.51
Phelps Creek - Marymount Bridge	9.99
Venoco Bridge - north side (YSI EXO1 sonde)	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 Solinst loggers are compensated using barometric pressure data from a solinst barrologger at the ROOST. Water level data is converted to water surface elevation (WSE) in feet (NAVD88) using either the known elevations of the loggers or regular readings of a WSE staff. Some of our older leveloggers had issues in recording data due to age and technical difficulties.

Elevation profiles of the beach berm at the mouth of the slough are measured most years. 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.

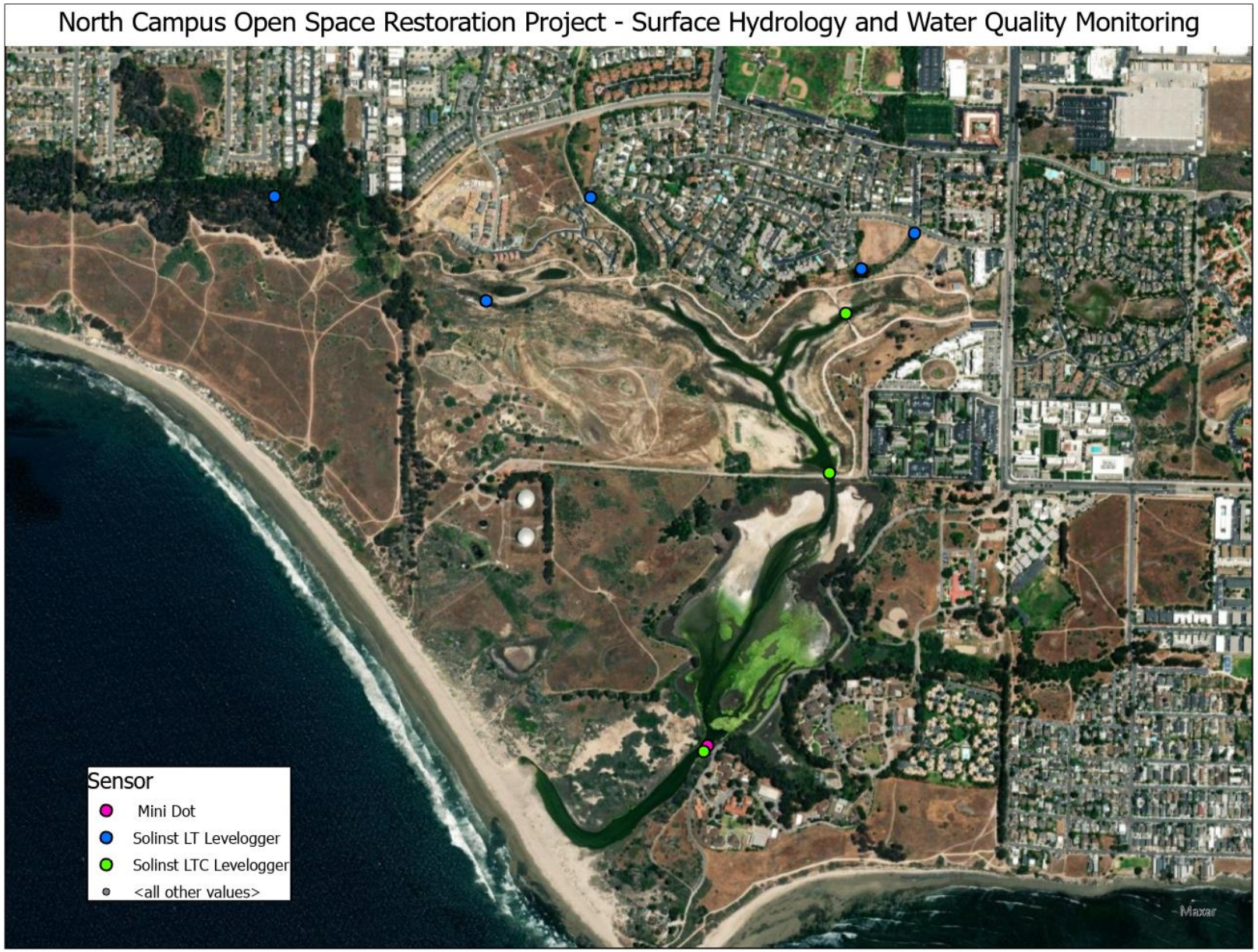


Figure 26. Map of the surface hydrology and water quality monitoring sites at North Campus Open Space and lower Devereux Slough. See Figure 1 for a legend of the habitats/vegetation communities.

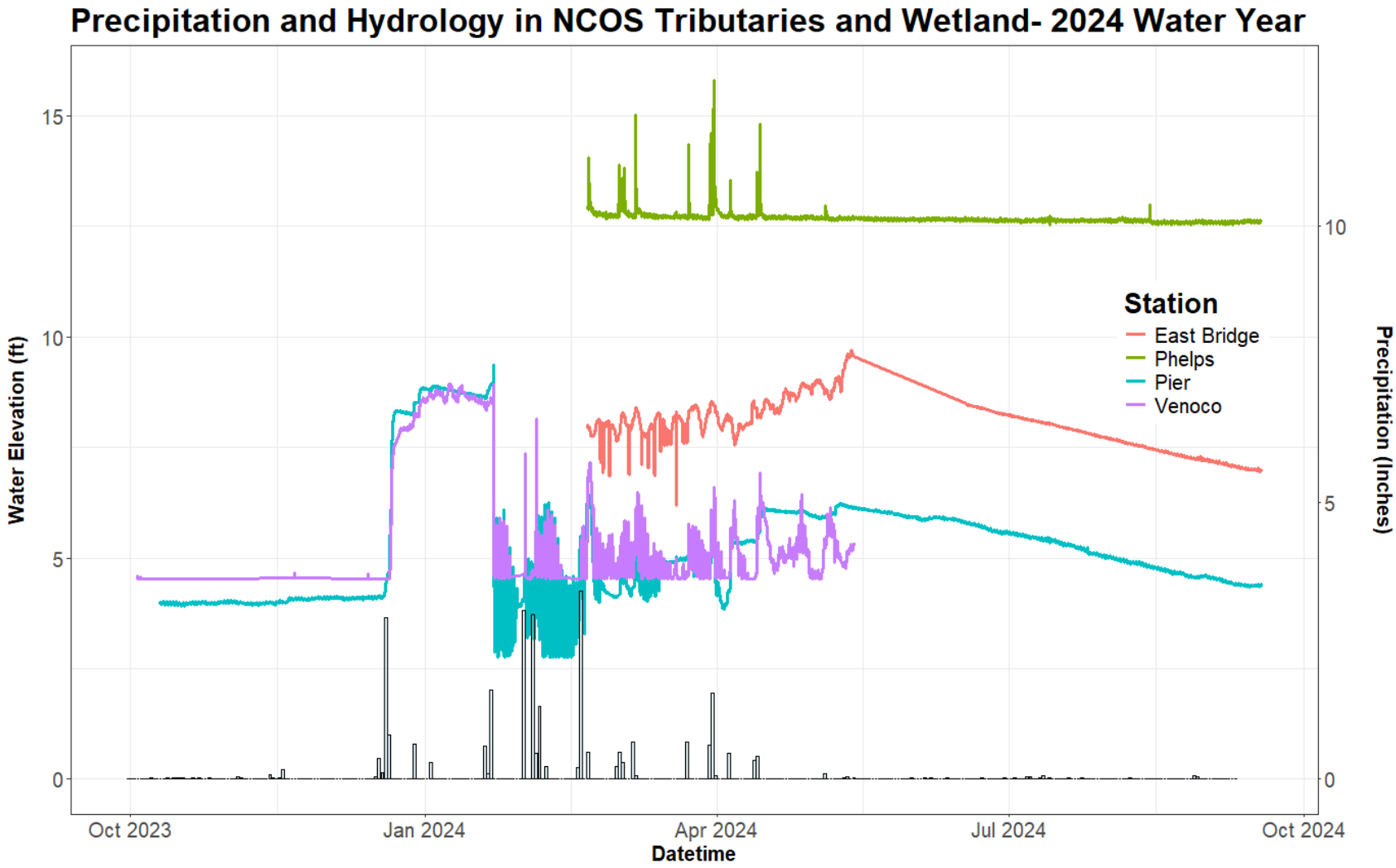


Figure 27. Water elevation collected from leveloggers located at NCOS tributaries and the Wetland (Devereux Slough). Rainfall from NOAA for Water year 2024.

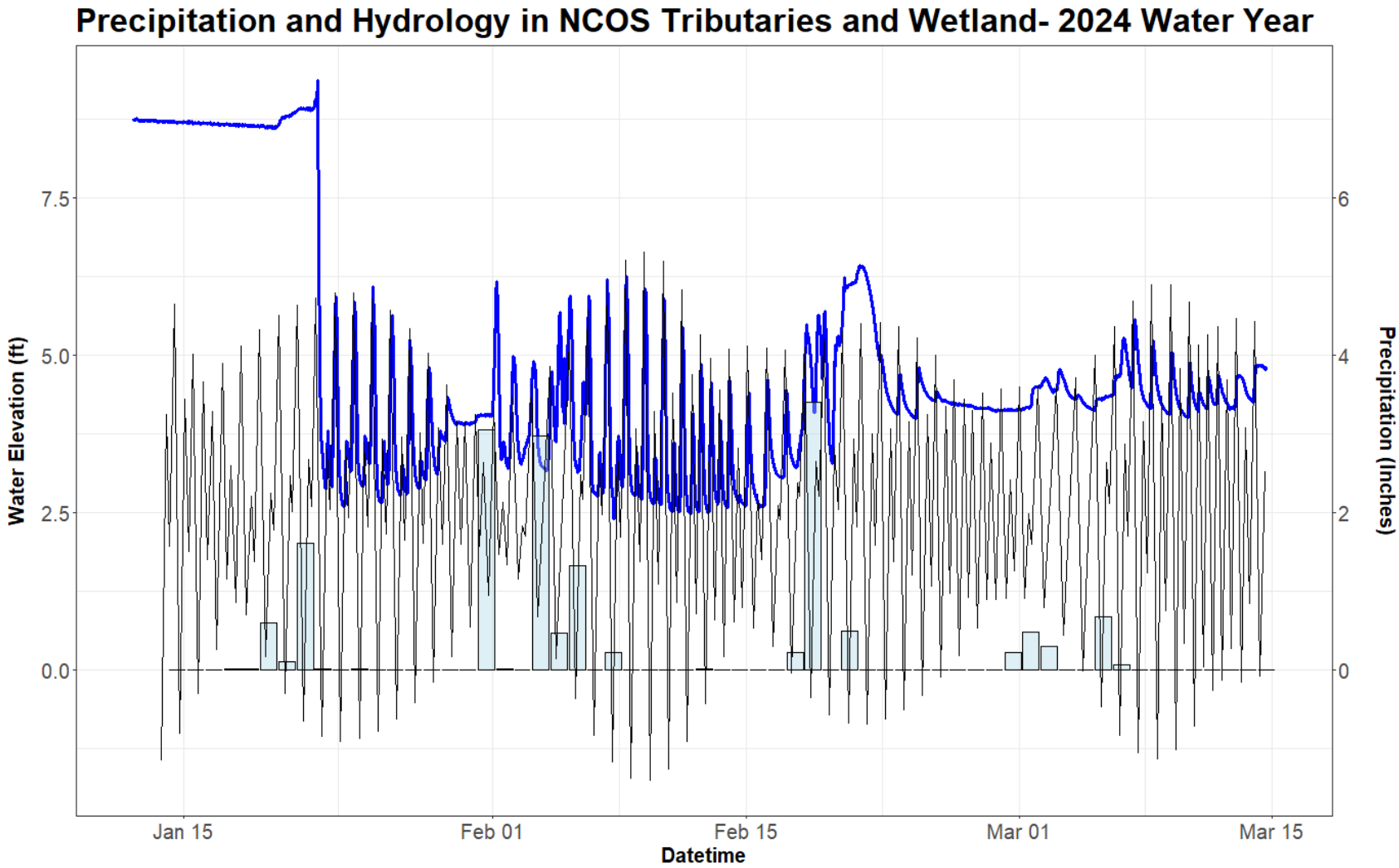


Figure 28. Water elevation collected from Solinst levelogger at Coal Oil Point Pier. Tidal predictions (ft) and rainfall from NOAA for Water year 2024.

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. The excavation of the wetlands resulted in a 1.5-2ft decrease in flood water elevations around the wetland. 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 no adjacent residents are considered to be in a flood hazard zone. The full article can be found on the CCBER webpage.

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 on the mesa (see map in Figure 29) 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 seventh year of vernal pool hydrology monitoring (water year 2024) began on December 22nd, 2023 after the first rainstorm. Vernal pools 1, 2, 3, 4, 7 and 8 were all inundated for more than 100 days indicating that they can provide the ecological function of a natural vernal pool.

Figure 29. 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.

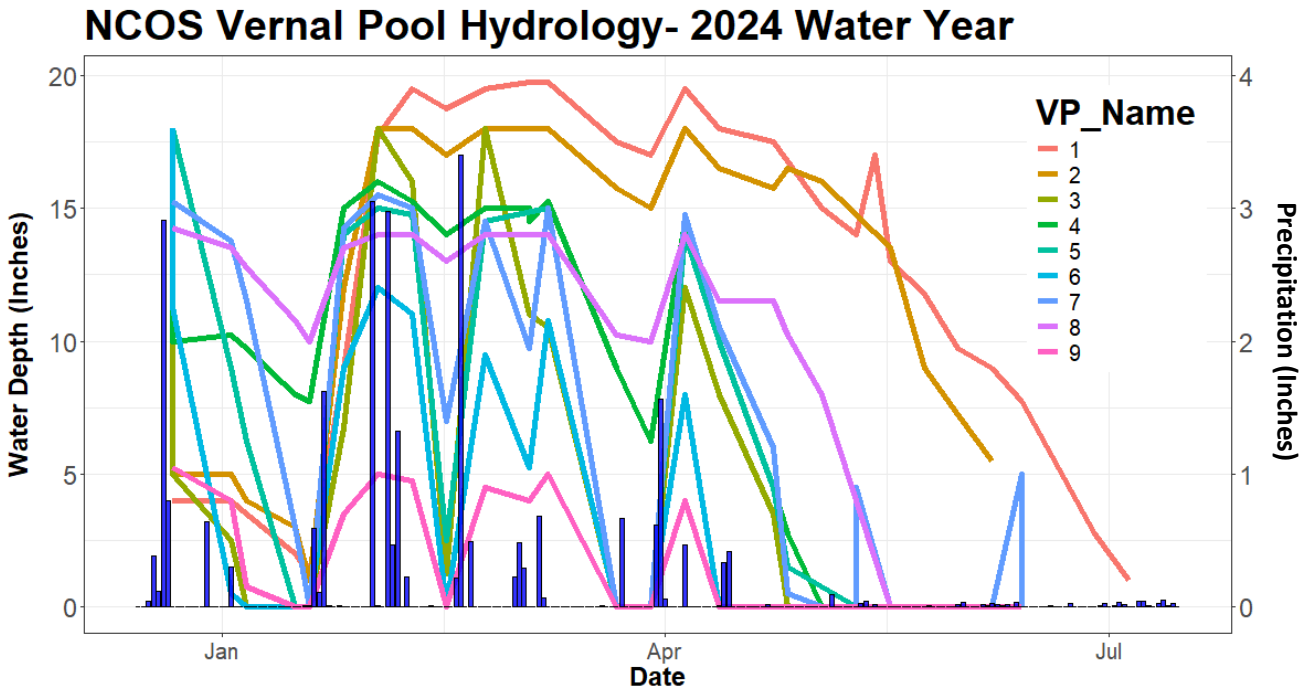


Figure 30. Hydrograph of weekly water depth (inches) in nine of the restored vernal pools on the North Campus Open Space (NCOS) mesa in the 2024 water year

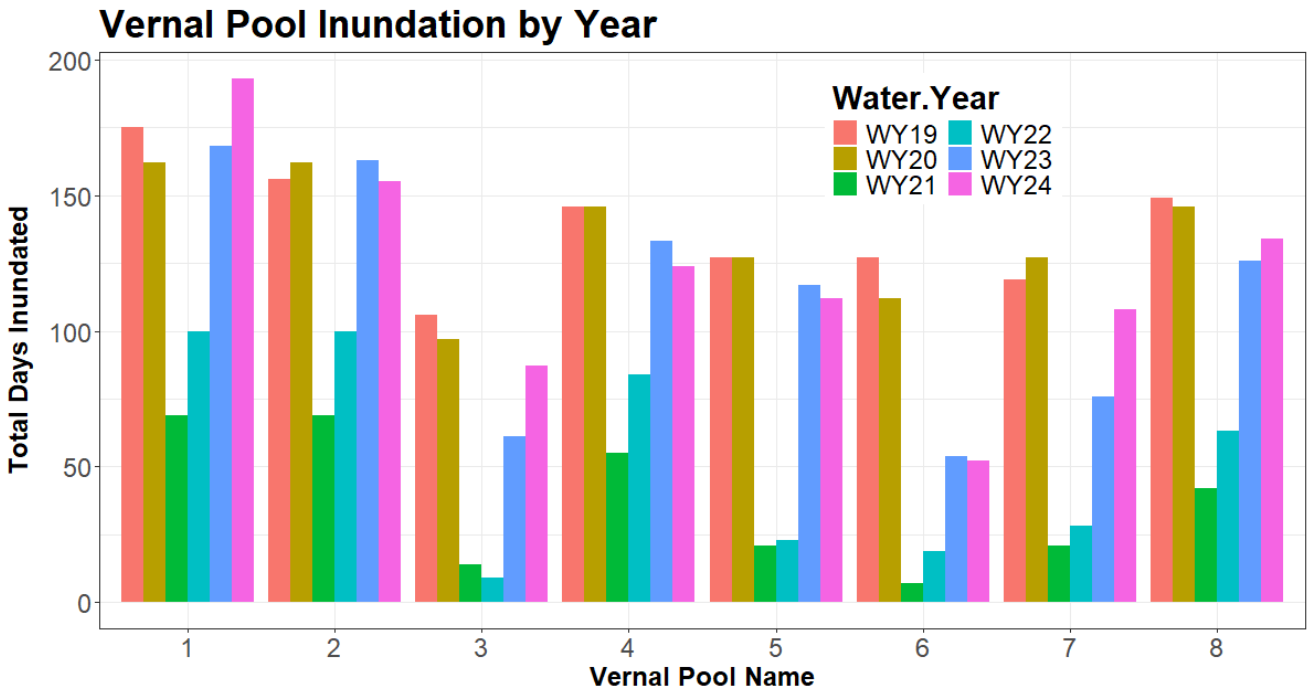


Figure 31. Number of Days that each Vernal Pool is inundated by year.

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. In year seven this monitoring consisted of two components:

1. Automated collection of data on dissolved oxygen, conductivity, salinity and temperature 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.

In years 1-5 we also collected storm nutrient data. This can be found in the Year 1-5 reports.

Lower Slough Water Quality Data - Methods

In this report, we present the daily average of the parameters recorded for the 2024 water year. Data from previous years can be found in previous reports. Water years differed greatly in the amount of precipitation received and the response of water quality measurements. Unfortunately, all years experienced some extent of equipment malfunction.

Lower Slough Water Quality Data – Data Summary & Main Observations

The conductivity in the 2024 water year is significantly lower than the conductivity in all other monitoring years. This is likely due to the increased precipitation and scattered late season precipitation after the slough mouth had closed.

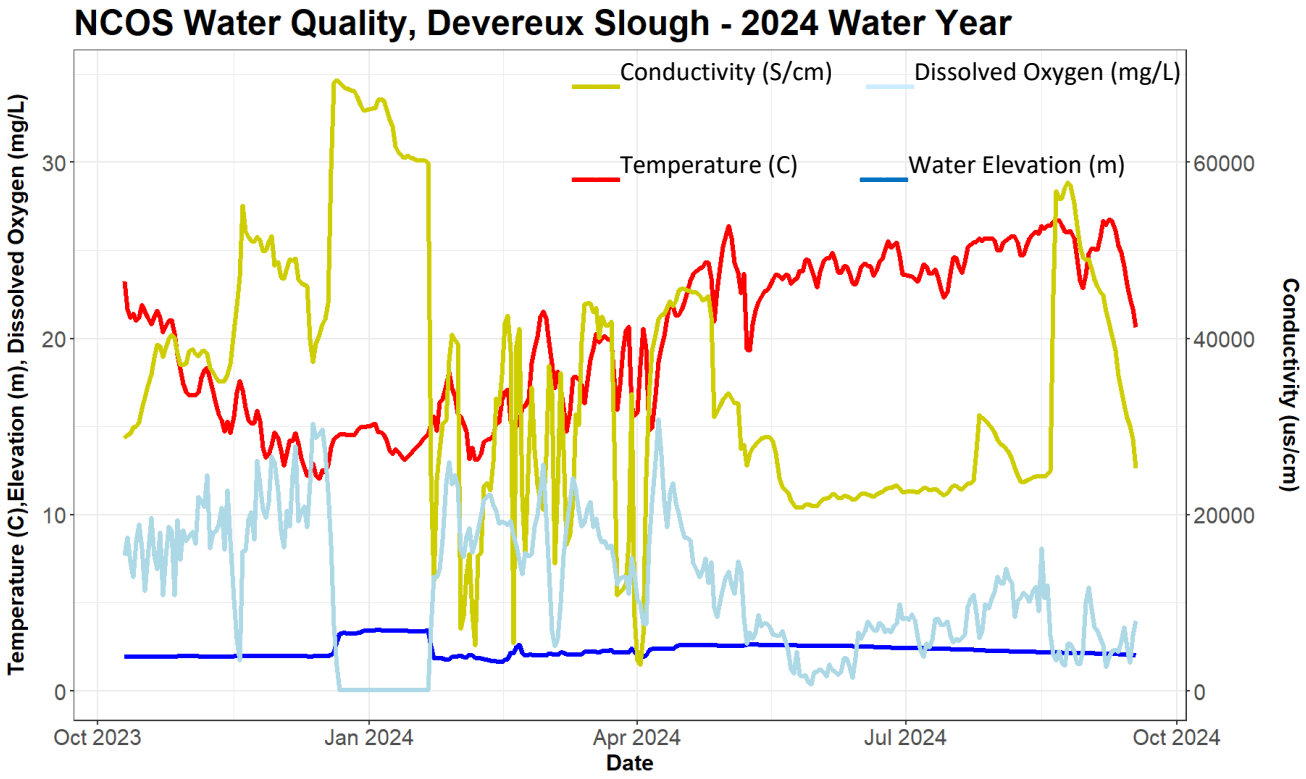


Figure 32. Daily average water quality and level data recorded in the 2023 water year (October 1st to September 30th) with a Solinst levelogger and minidot logger in the lower portion of Devereux Slough (see map in Figure 32). The water surface elevation is in NAVD 88. Precipitation data was recorded at a NOAA climate station on Coal Oil Point Reserve.

Restored Upper Slough Water Quality Monitoring - Methods

In the restored upper Devereux Slough, we collect dissolved oxygen, conductivity/salinity, and temperature data at three locations on a weekly basis (figures 33-35) using a portable YSI Pro2030 at the three bridges that cross the upper slough: the Marsh trail bridges over the Phelps Creek outlet and "Dilling's Link" across the east channel, and the Venoco access road bridge. 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 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.

In most years we see stratification of the DO levels, however there was no clear stratification in 2024 due to the frequent heavy rainstorms and the long periods of tidal connectivity. Regular DO levels above 2 mg/L indicates that the wetland can functionally support aquatic wildlife year-round. DO was above this critical threshold for most weeks in 2024 at all sites. The dip in winter at the PIER is due to a device malfunction.

Venoco Bridge has the highest conductivity of the 3 sites due to its juxtaposition to the open slough. East bridge will experience some slight tidal influence and therefore salinity increase during high tide events after slough breaks. 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. In the 2024 water year there were many heavy rainstorms accompanied with the frequent opening of the Slough. This caused more mixing of the water than usual and therefore stratification was less evident.

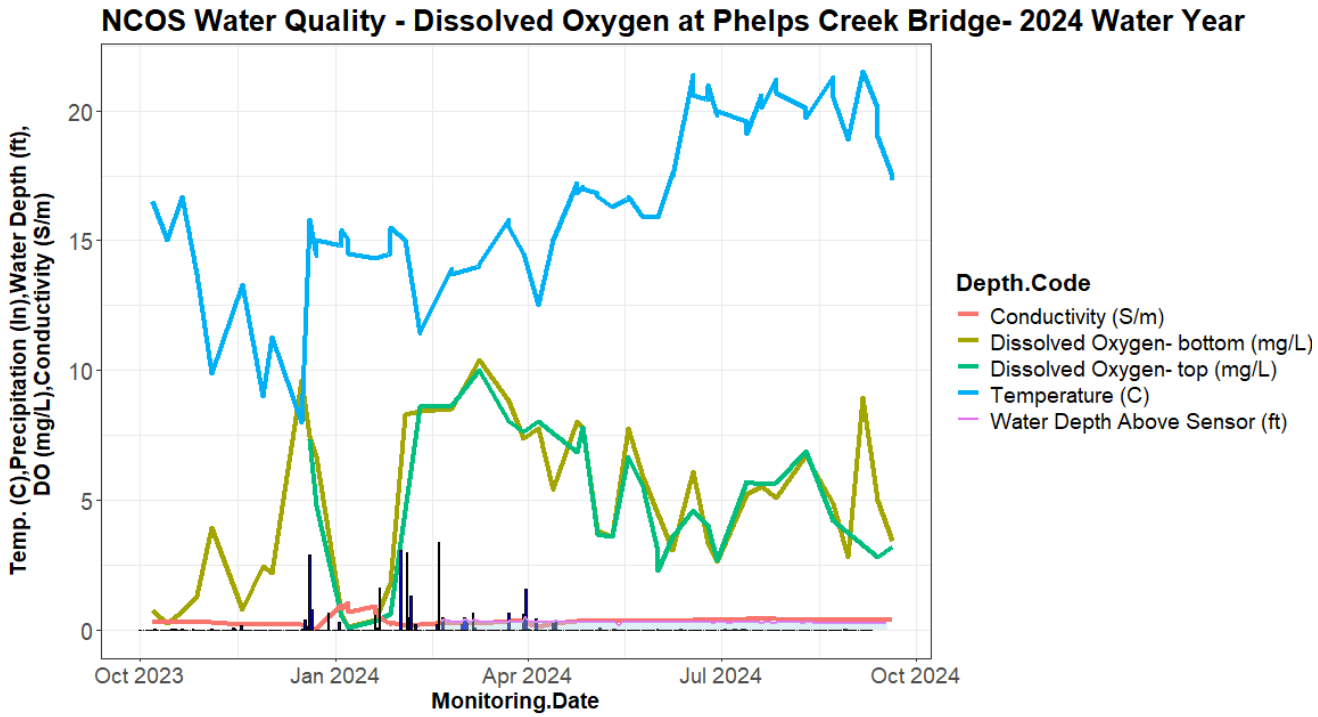


Figure 33. Dissolved oxygen (mg/L) at the surface (top 1 ft) and bottom of the water column recorded weekly in the 2023 water year with a YSI Pro2030 at the Phelps Creek outlet to the upper Devereux Slough, North Campus Open Space. The temperature and Conductivity is averaged across all depths. Precipitation data was obtained from a NOAA climate station.

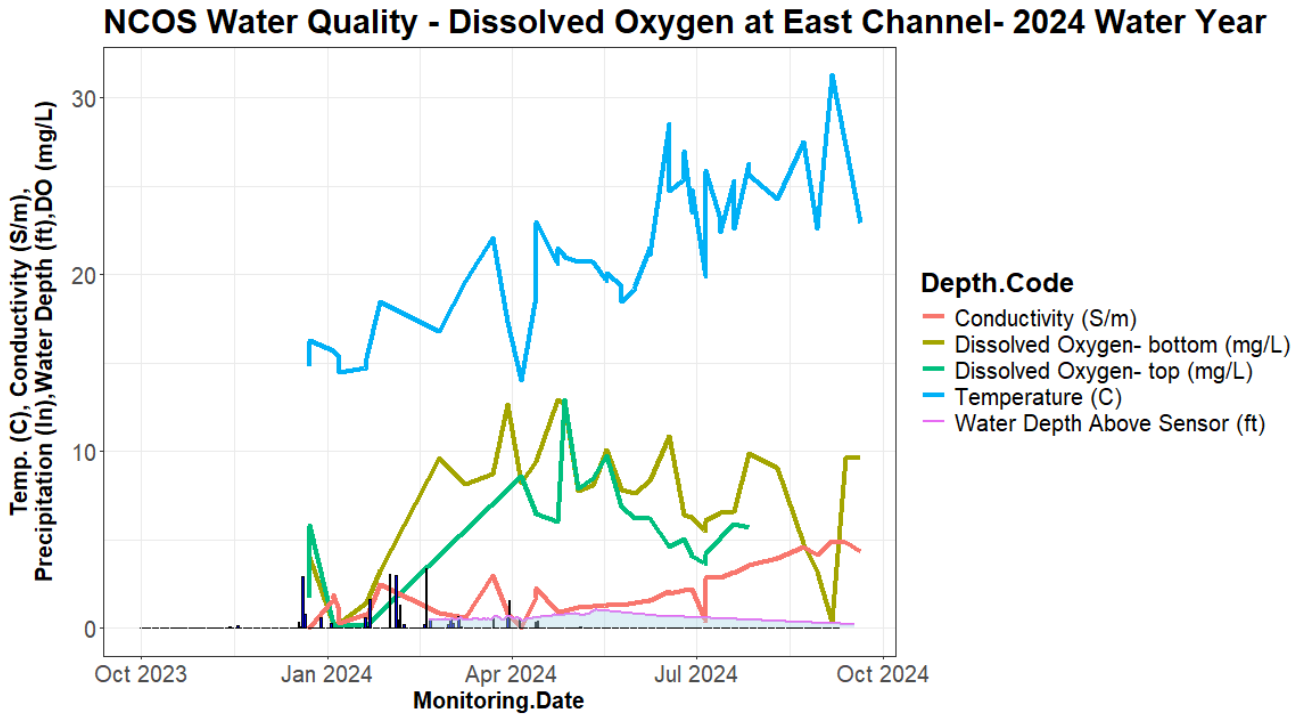


Figure 34. Dissolved oxygen at the surface (top 1 ft) and bottom of the water column recorded weekly in the 2023 water year with a YSI Pro2030 at the East Channel of the Devereux Slough, North Campus Open Space. The temperature and Conductivity is averaged across all depths. Precipitation data was obtained from a NOAA climate station.

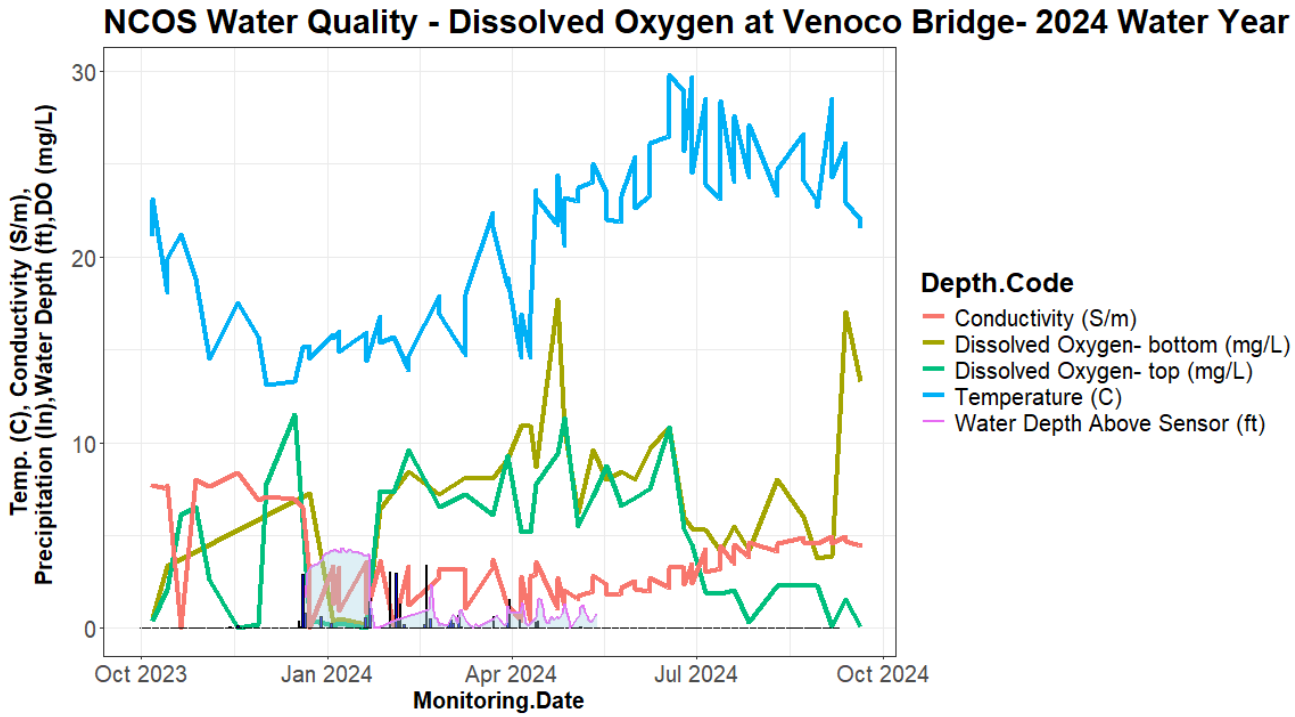


Figure 35. Dissolved oxygen at the surface (top 1 ft) and bottom of the water column recorded weekly in the 2023 water year with a YSI Pro2030 at the Venoco Bridge of the Devereux Slough, North Campus Open Space. The temperature and Conductivity are averaged across all depths. Precipitation data was obtained from a NOAA climate station.

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 5 - October 2022

Year 6 – October 2023 (post cultural burn)

Year 7 – October 2024

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

Year 1 – October 2018

Year 6 – October 2023

Year 7 – October 2024

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

Year 1 – October 2018

Year 6 – October 2023

Year 7 – October 2024

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

Year 1 – October 2018

Year 6 – October 2023

Year 7 – October 2024

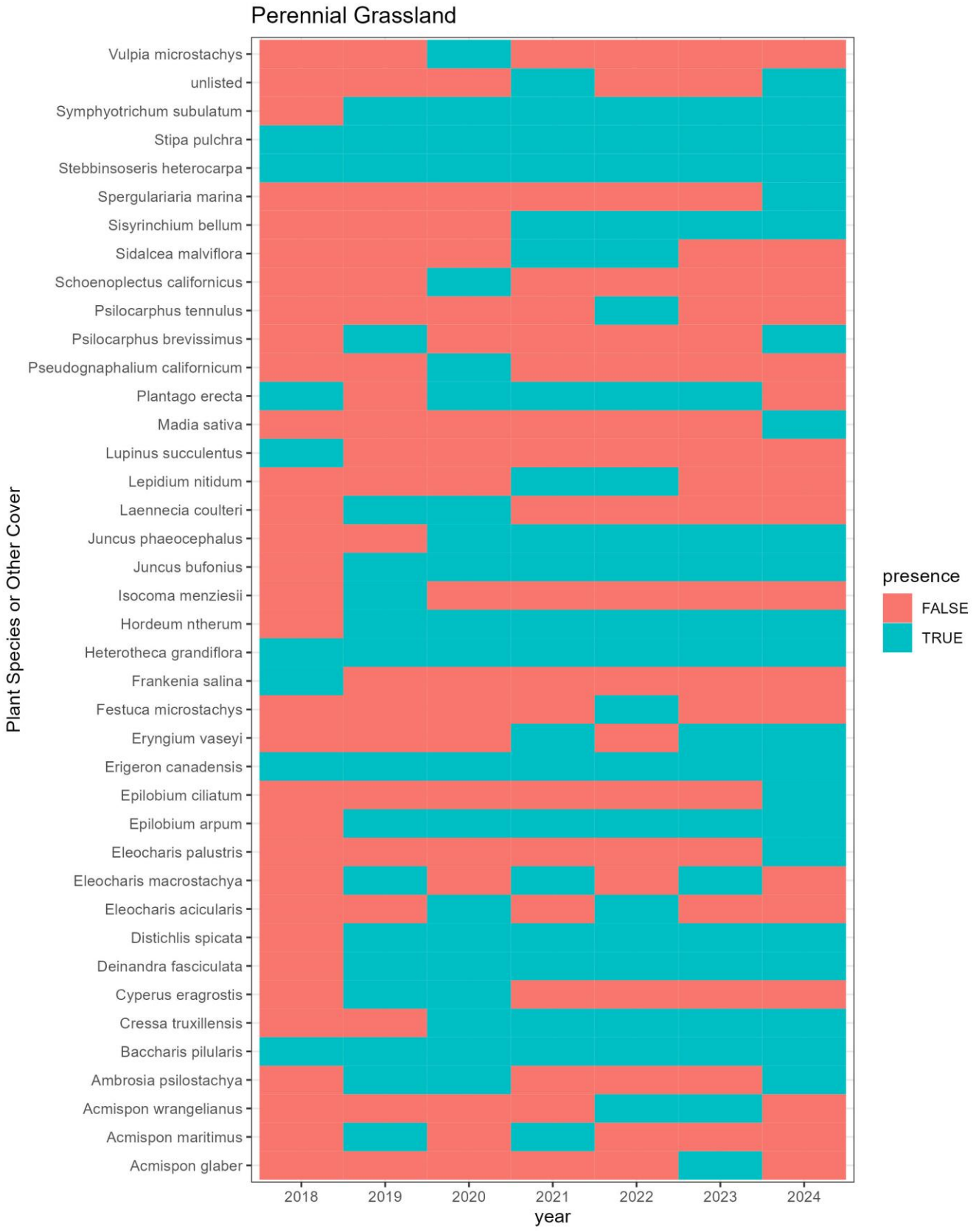
Photo point 41 – looking south from trail along north side of east arm of restored wetland

Year 1 – October 2018

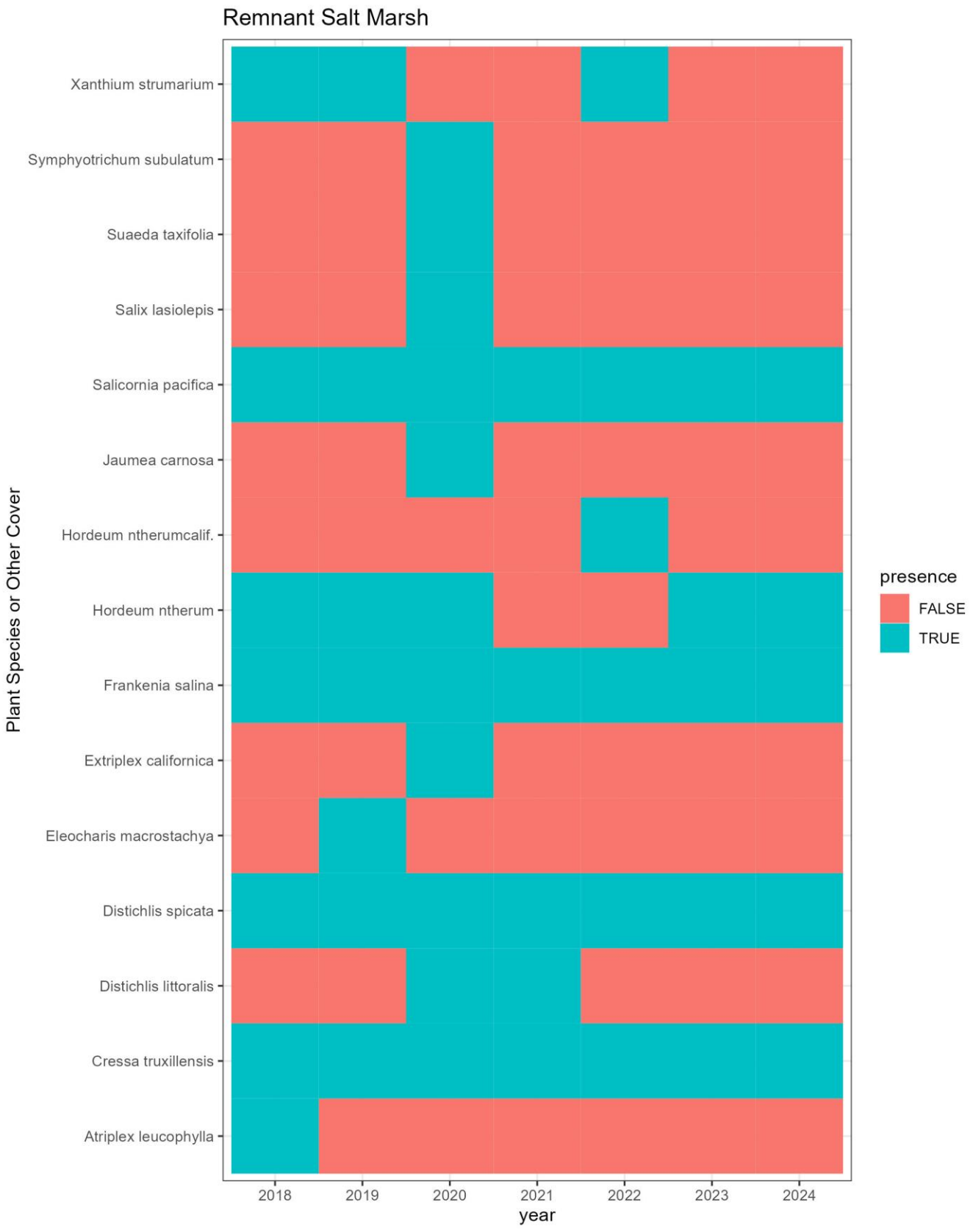
Year 6 – October 2023

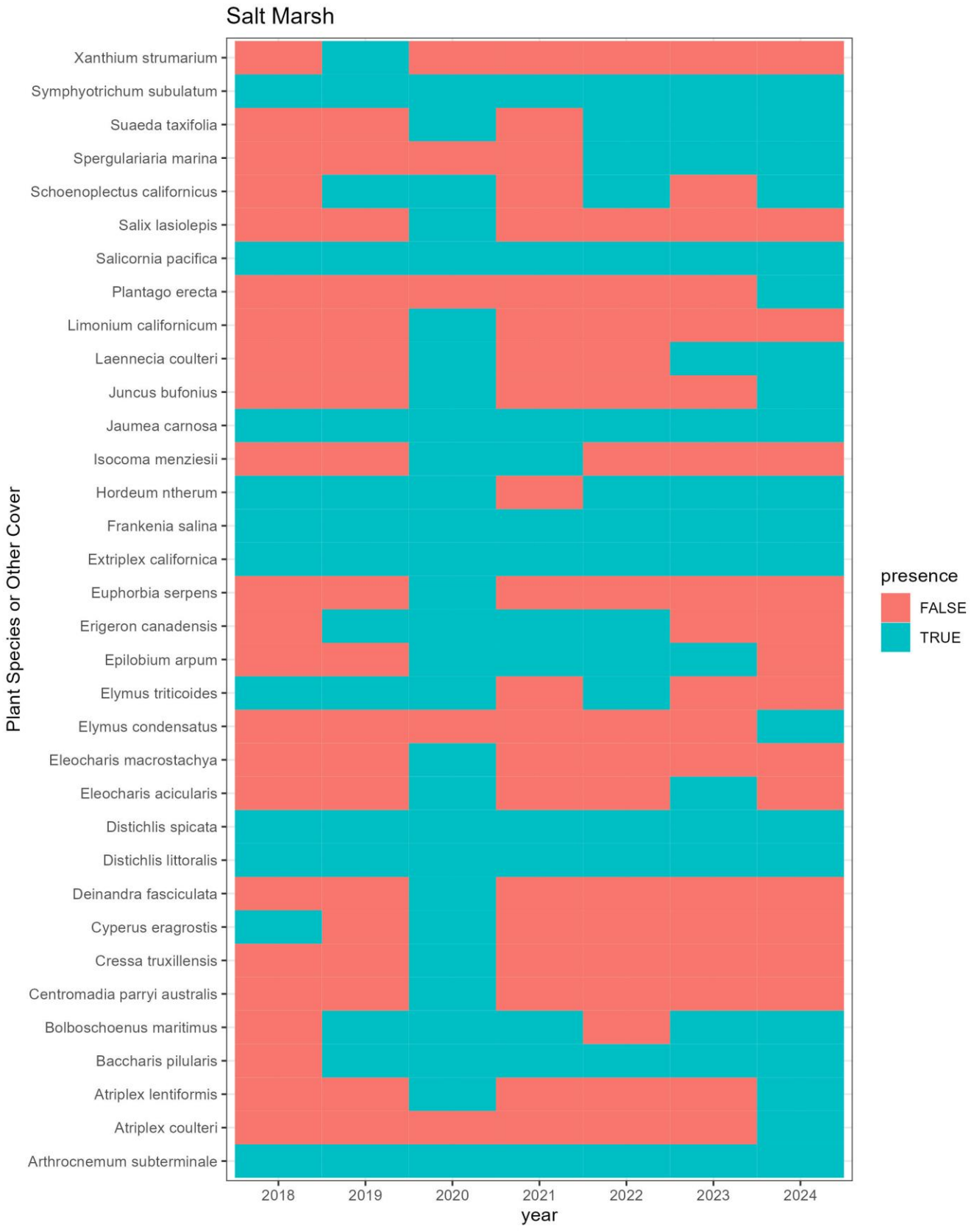
Year 7 – October 2024

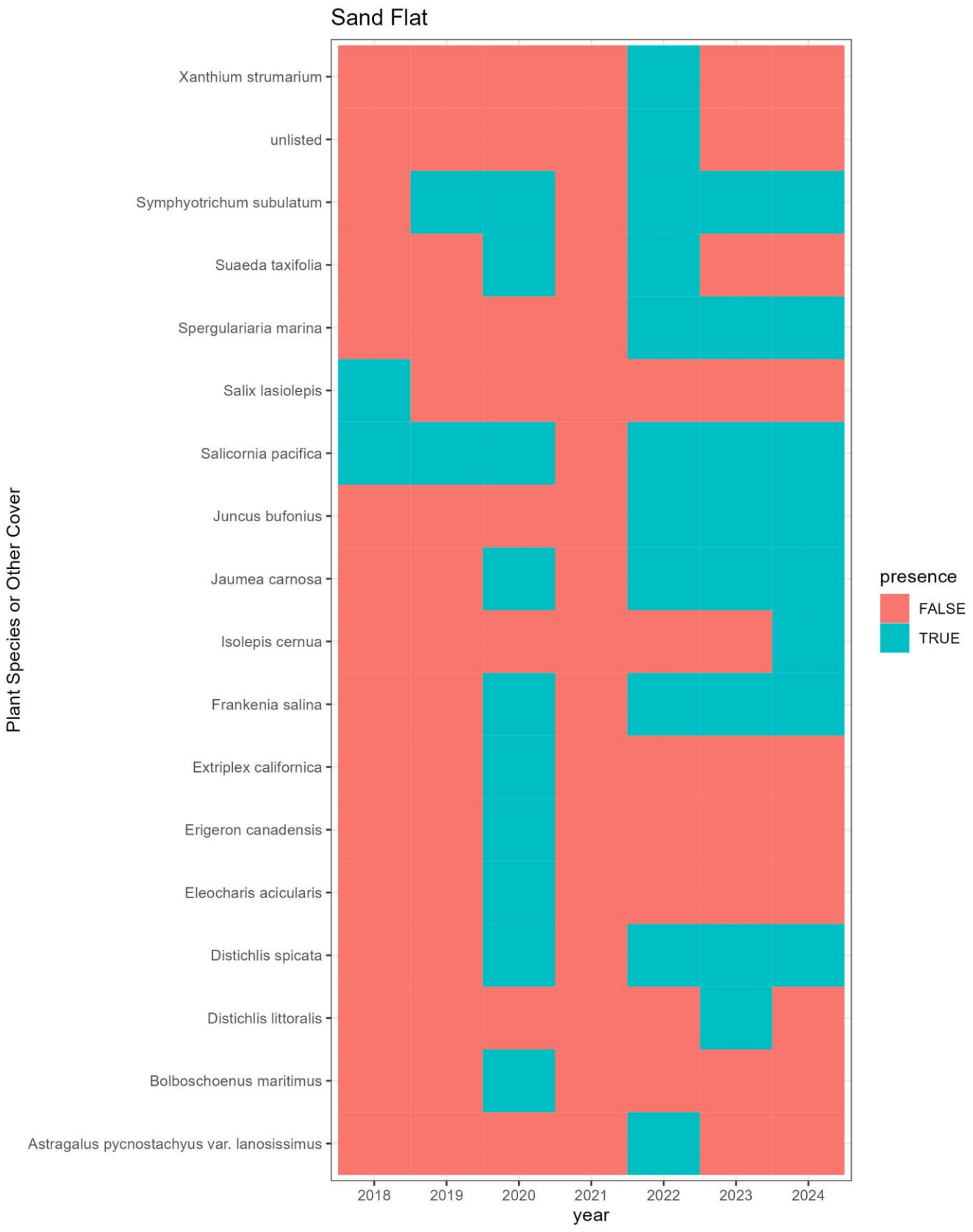
Table A2.1. Native plant species recorded during vegetation monitoring at the North Campus Open Space project by plant community and covering presence/absence by year.

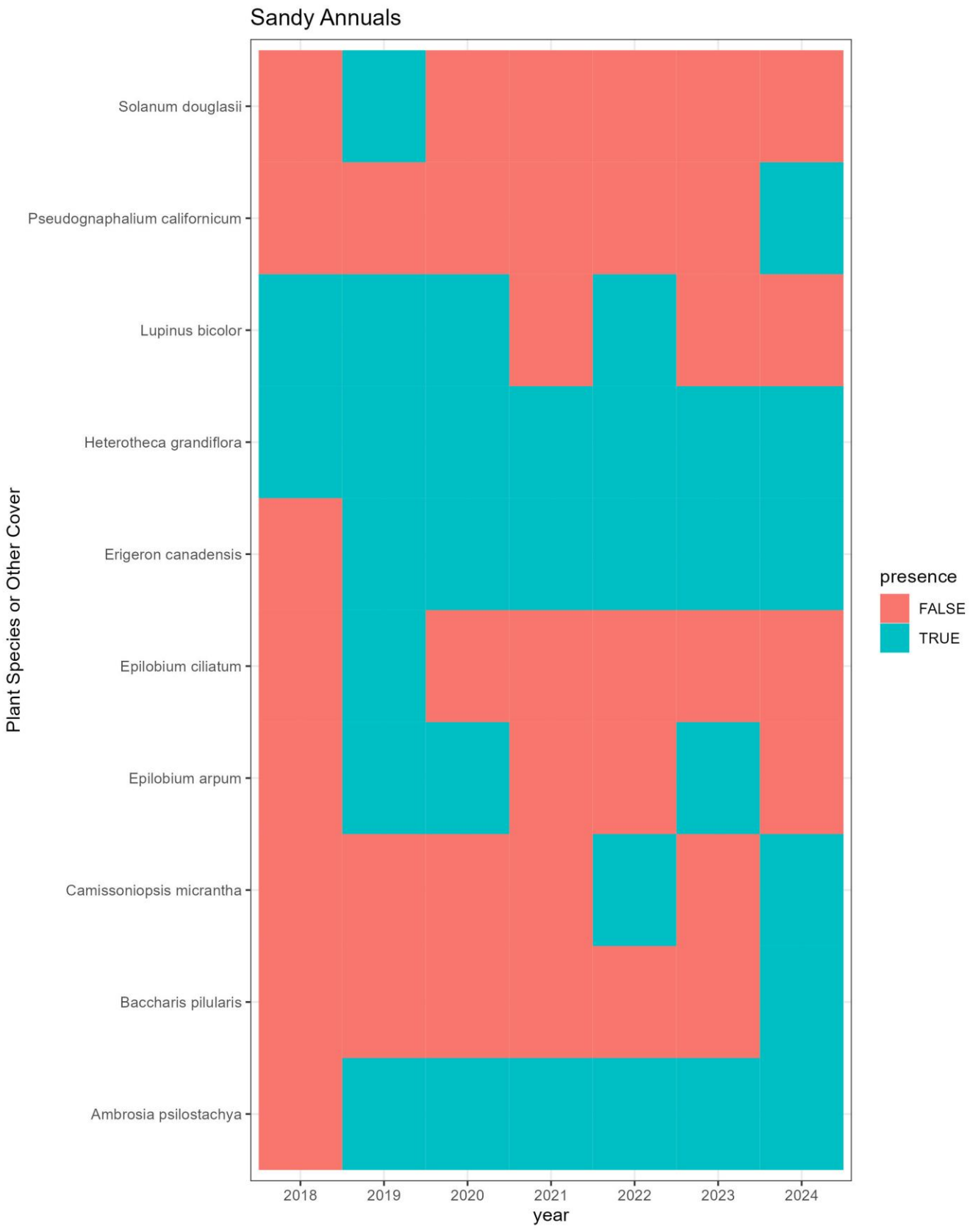

Perennial Grassland
Plant Species or Other Cover
Vulpia microstachys
unlisted
Symphyotrichum subulatum
Stipa pulchra
Stebbinsoseris heterocarpa
Spergulariaria marina
Sisyrinchium bellum
Sidalcea malviflora
Schoenoplectus californicus
Psilocarphus tennulus
Psilocarphus brevissimus
Pseudognaphalium californicum
Plantago erecta
Madia sativa
Lupinus succulentus
Lepidium nitidum
Laennecia coulteri
Juncus phaeocephalus
Juncus bufonius
Isocoma menziesii
Hordeum ntherum
Heterotheca grandiflora
Frankenia salina
Festuca microstachys
Eryngium vaseyi
Erigeron canadensis
Epilobium ciliatum
Epilobium arpum
Eleocharis palustris
Eleocharis macrostachya
Eleocharis acicularis
Distichlis spicata
Deinandra fasciculata
Cyperus eragrostis
Cressa truxillensis
Baccharis pilularis
Ambrosia psilostachya
Acmispon wrangelianus
Acmispon maritimus
Acmispon glaber
2018
2019
2020
2021
2022
2023
2024
year
presence
FALSE
TRUE

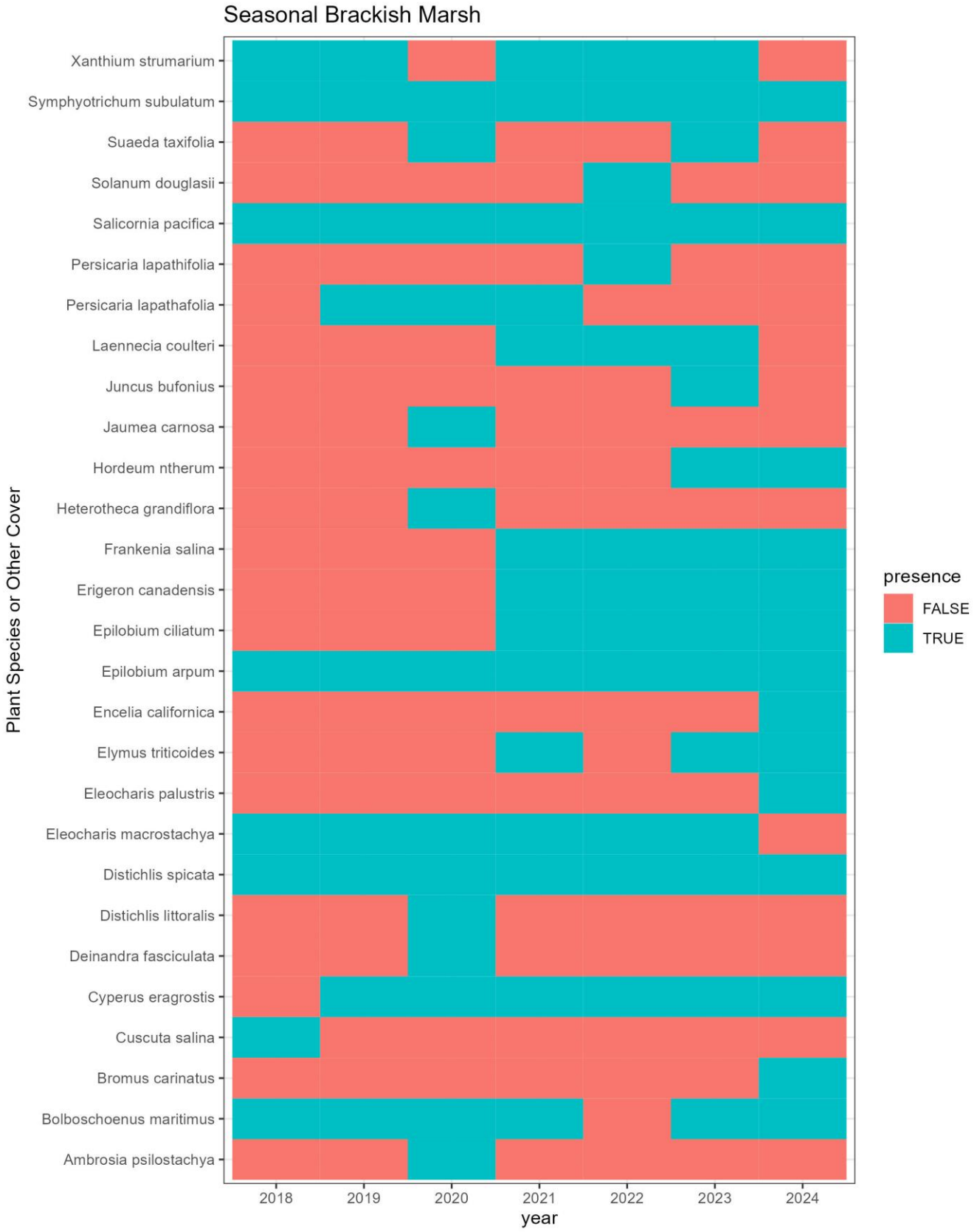

Peripheral Uplands
unlisted
Symphyotrichum subulatum
Stipa pulchra
Spergularia marina
Solanum douglasii
Sisyrinchium bellum
Scrophularia californica
Salvia leucophylla
Salix lasiolepis
Quercus agrifolia
Psilocarphus brevissimus
Pseudognaphalium californicum
Plantago erecta
Persicaria lapathafolia
Moss (Ceratodon purpureus)
Melica imperfecta
Malacothrix saxatilis v. tenu.
Malacothris saxatilis var implicata
Lupinus succulentus
Lonicera subspicata v. subsp.
Lepidium nitidum
Laennecia coulteri
Juncus phaeocephalus
Juncus patens
Juncus occidentalis
Juncus bufonius
Isolepis cernua
Isocoma menziesii
Isocoma menziesii
Hordeum ntherum
Heterotheca grandiflora
Hazardia squarrosa
Frankenia salina
Euphorbia serpens
Euphorbia maculata
Eriophyllum confertiflorum
Eriogonum parvifolium
Erigeron canadensis
Epilobium ciliatum
Epilobium canum
Epilobium arpum
Encelia californica
Elymus triticoides
Elymus glaucus
Elymus condensatus
Eleocharis palustris
Eleocharis macrostachya
Eleocharis acicularis
Distichlis spicata
Deinandra fasciculata
Daucus pusillus
Datura wrightii
Cyperus eragrostis
Cressa truxillensis
Centromadia parryi australis
Bromus carinatus
Bolboschoenus maritimus
Baccharis pilularis
Atriplex lentiformis
Artemisia californica
Ambrosia psilostachya
Plant Species or Other Cover
2018
2019
2020
2021
2022
2023
2024
year
presence
FALSE
TRUE

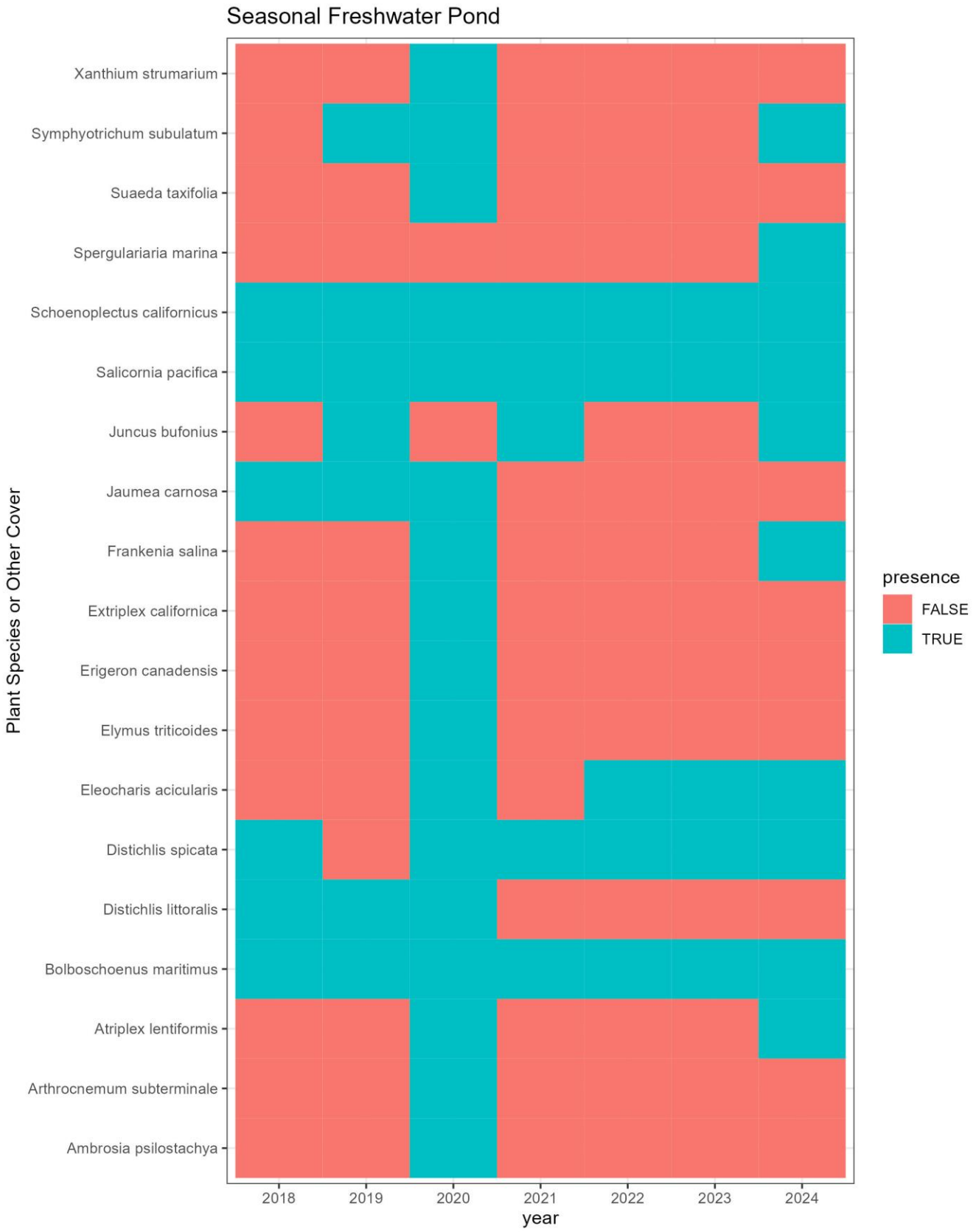

Remnant Salt Marsh
Xanthium strumarium
Symphyotrichum subulatum
Suaeda taxifolia
Salix lasiolepis
Salicornia pacifica
Jaumea carnosa
Hordeum ntherumcalif.
Hordeum ntherum
Frankenia salina
Extriplex californica
Eleocharis macrostachya
Distichlis spicata
Distichlis littoralis
Cressa truxillensis
Atriplex leucophylla
Plant Species or Other Cover
2018
2019
2020
2021
2022
2023
2024
year
presence
FALSE
TRUE


Salt Marsh
Xanthium strumarium
Symphyotrichum subulatum
Suaeda taxifolia
Spergulariaria marina
Schoenoplectus californicus
Salix lasiolepis
Salicornia pacifica
Plantago erecta
Limonium californicum
Laennecia coulteri
Juncus bufonius
Jaumea carnosa
Isocoma menziesii
Hordeum ntherum
Frankenia salina
Extriplex californica
Euphorbia serpens
Erigeron canadensis
Epilobium arpum
Elymus triticoides
Elymus condensatus
Eleocharis macrostachya
Eleocharis acicularis
Distichlis spicata
Distichlis littoralis
Deinandra fasciculata
Cyperus eragrostis
Cressa truxillensis
Centromadia parryi australis
Bolboschoenus maritimus
Baccharis pilularis
Atriplex lentiformis
Atriplex coulteri
Arthrocnemum subterminale
Plant Species or Other Cover
2018
2019
2020
2021
2022
2023
2024
year
presence
FALSE
TRUE


Sand Flat
Xanthium strumarium
unlisted
Symphyotrichum subulatum
Suaeda taxifolia
Spergulariaria marina
Salix lasiolepis
Salicornia pacifica
Juncus bufonius
Jaumea carnosa
Isolepis cernua
Frankenia salina
Extriplex californica
Erigeron canadensis
Eleocharis acicularis
Distichlis spicata
Distichlis littoralis
Bolboschoenus maritimus
Astragalus pycnostachyus var. lanosissimus
Plant Species or Other Cover
2018
2019
2020
2021
2022
2023
2024
year
presence
FALSE
TRUE

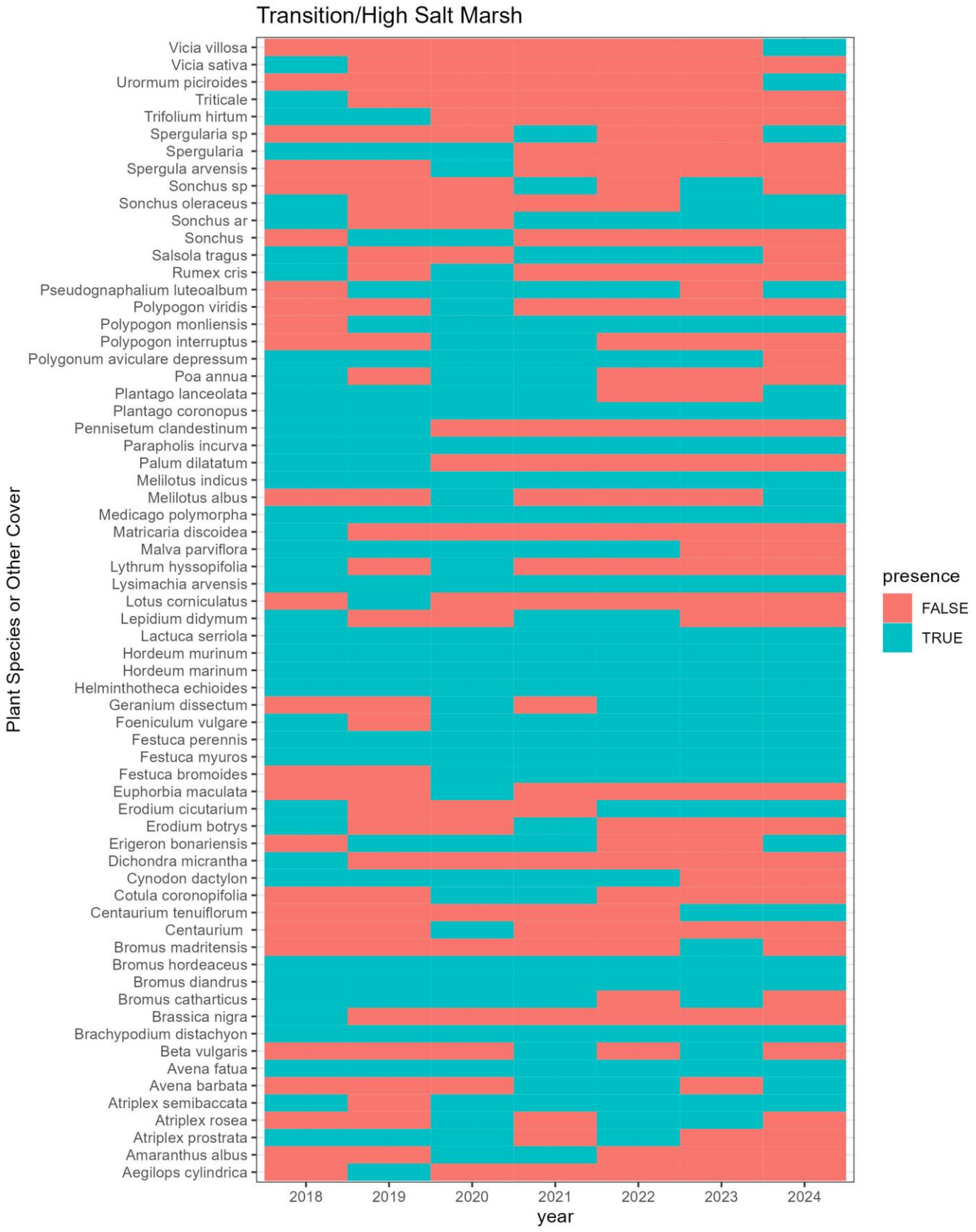

Sandy Annuals
Solanum douglasii
Pseudognaphalium californicum
Lupinus bicolor
Heterotheca grandiflora
Erigeron canadensis
Epilobium ciliatum
Epilobium arpum
Camissoniopsis micrantha
Baccharis pilularis
Ambrosia psilostachya
Plant Species or Other Cover
2018
2019
2020
2021
2022
2023
2024
year
presence
FALSE
TRUE


Seasonal Brackish Marsh
Xanthium strumarium
Symphyotrichum subulatum
Suaeda taxifolia
Solanum douglasii
Salicornia pacifica
Persicaria lapathifolia
Persicaria lapathafolia
Laennecia coulteri
Juncus bufonius
Jaumea carnosa
Hordeum ntherum
Heterotheca grandiflora
Frankenia salina
Erigeron canadensis
Epilobium ciliatum
Epilobium arpum
Encelia californica
Elymus triticoides
Eleocharis palustris
Eleocharis macrostachya
Distichlis spicata
Distichlis littoralis
Deinandra fasciculata
Cyperus eragrostis
Cuscuta salina
Bromus carinatus
Bolboschoenus maritimus
Ambrosia psilostachya
Plant Species or Other Cover
2018
2019
2020
2021
2022
2023
2024
year
presence
FALSE
TRUE


Seasonal Freshwater Pond
Xanthium strumarium
Symphyotrichum subulatum
Suaeda taxifolia
Spergulariaria marina
Schoenoplectus californicus
Salicornia pacifica
Juncus bufonius
Jaumea carnosa
Frankenia salina
Extriplex californica
Erigeron canadensis
Elymus triticoides
Eleocharis acicularis
Distichlis spicata
Distichlis littoralis
Bolboschoenus maritimus
Atriplex lentiformis
Arthrocnemum subterminale
Ambrosia psilostachya
Plant Species or Other Cover
2018
2019
2020
2021
2022
2023
2024
year
presence
FALSE
TRUE

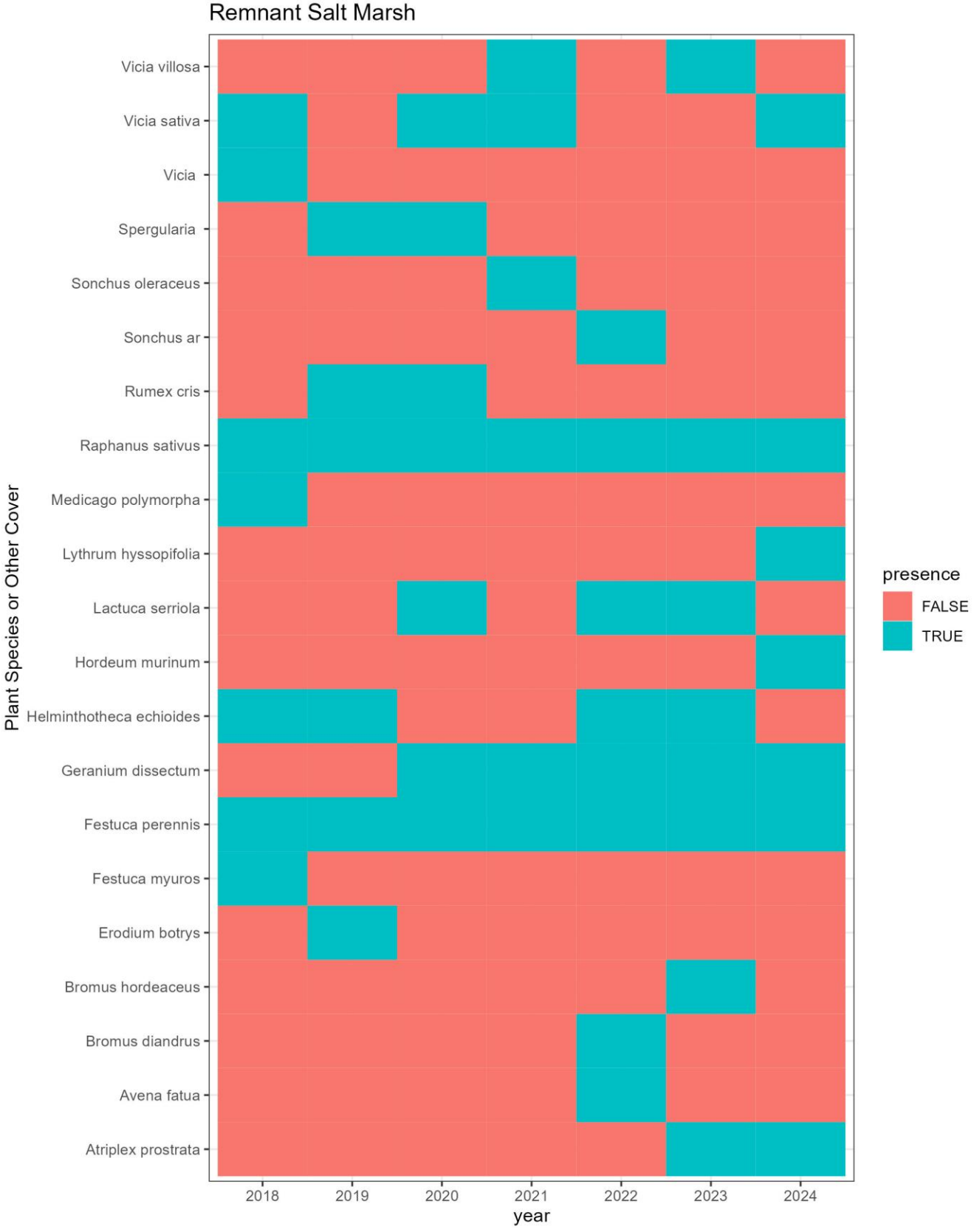

Vernal Pool
unlisted
Typha latifolia
Symphyotrichum subulatum
Symphyotrichum chilense
Stipa pulchra
Stebbinsoseris heterocarpa
Spergulariaria marina
Spergularia marina
Solanum douglasii
Sisyrinchium bellum
Schoenoplectus californicus
Salvia leucophylla
Salix lasiolepis
Rhus integrifolia
Quercus agrifolia
Psilocarphus tennulus
Psilocarphus brevissimus
Plantago erecta
Plagiobothrys undulatus
Plagiobothrys bracteatus
Phalaris lemmonii
Melica imperfecta
Madia sativa
Lupinus succulentus
Lepidium nitidum
Laennecia coulteri
Juncus phaeocephalus
Juncus patens
Juncus occidentalis
Juncus mexicanus
Juncus bufonius
Hordeum ntherumcalif.
Hordeum ntherum
Heterotheca grandiflora
Grindelia camporum
Frankenia salina
Euphorbia serpens
Eryngium vaseyi
Eriophyllum confertiflorum
Eriogonum parvifolium
Erigeron canadensis
Epilobium arpum
Encelia californica
Elymus glaucus
Eleocharis palustris
Eleocharis macrostachya
Eleocharis acicularis
Distichlis spicata
Distichlis littoralis
Deinandra fasciculata
Datura wrightii
Cyperus eragrostis
Crassula aquatica
Corethrogyne filaginifolia
Centromadia parryi australis
Bromus carinatus
Brickellia californica
Bolboschoenus maritimus
Baccharis salicifolia
Baccharis pilularis
Artemisia californica
Ambrosia psilostachya
Alopecurus saccatus
Acmispon wrangelianus
Acmispon maritimus
Acmispon glaber
Plant Species or Other Cover
2018
2019
2020
2021
2022
2023
2024
year
presence
FALSE
TRUE

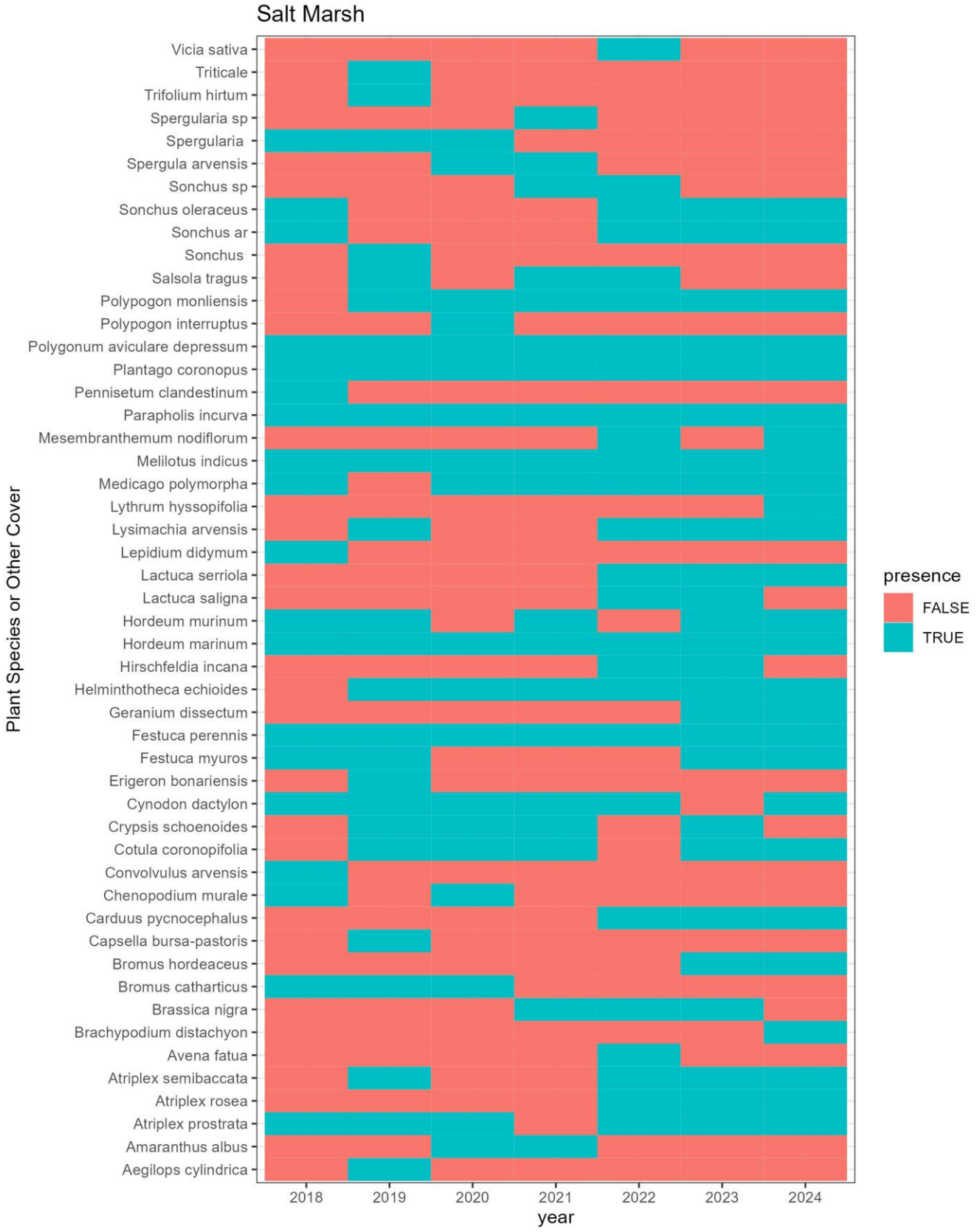
Table A2.2. Non-native plant species recorded during vegetation monitoring at the North Campus Open Space project.

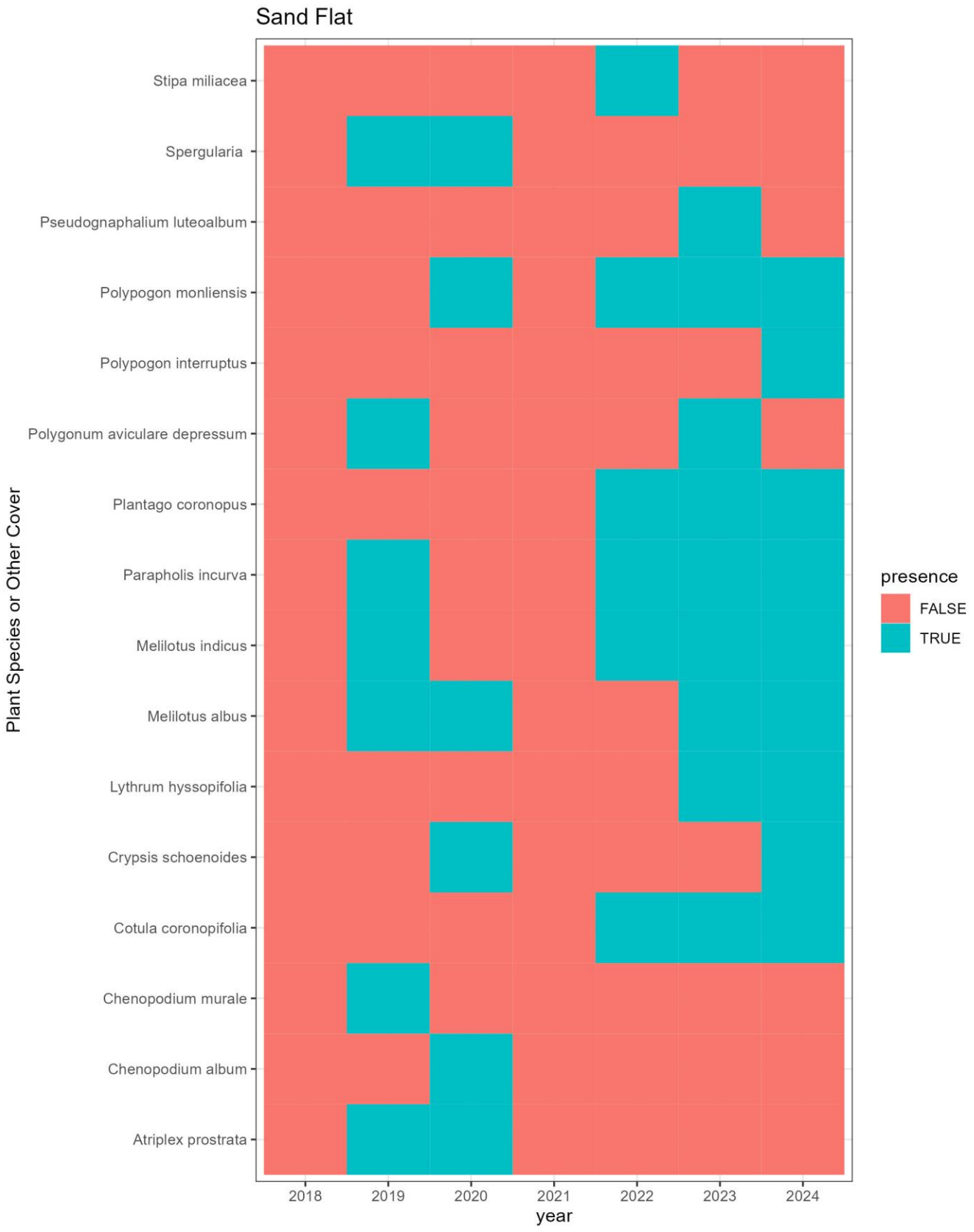


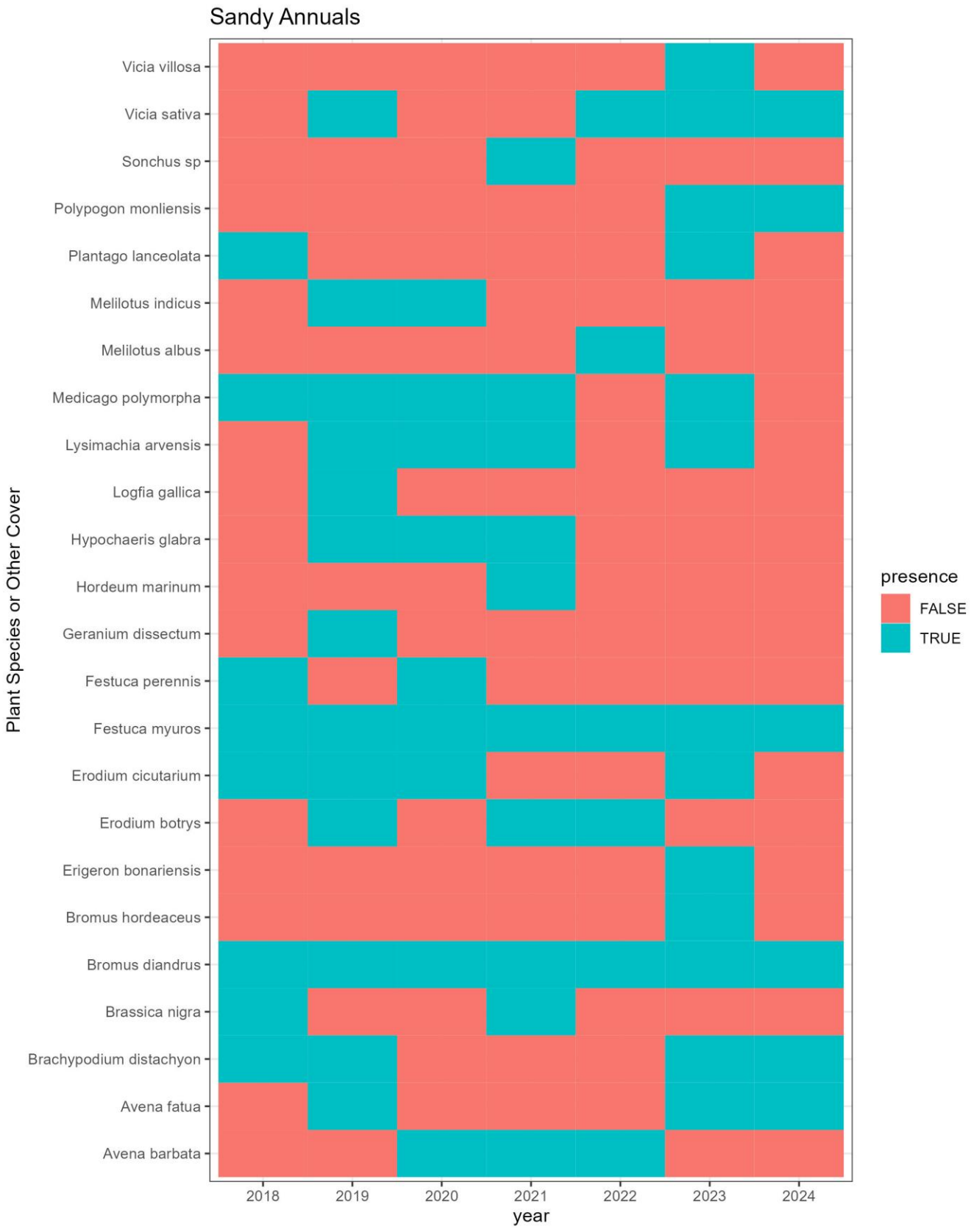

Perennial Grassland
Plant Species or Other Cover
Vicia villosa
Vicia sativa
Triticale
Trifolium tomentosum
Trifolium hirtum
Spergularia sp
Spergularia rubra
Spergularia
Sonchus sp
Sonchus oleraceus
Sonchus ar
Sonchus
Salsola tragus
Rumex cris
Pseudognaphalium luteoalbum
Polypogon viridis
Polypogon monliensis
Polypogon interruptus
Polygonum aviculare depressum
Poa annua
Plantago lanceolata
Plantago coronopus
Parapholis incurva
Melilotus indicus
Melilotus albus
Medicago polymorpha
Medicago lupulina
Malva parviflora
Lythrum hyssopifolia
Lysimachia arvensis
Logfia gallica
Lepidium didymum
Lactuca serriola
Hypochaeris glabra
Hordeum murinum
Hordeum marinum
Hirschfeldia incana
Helminthotheca echioides
Geranium dissectum
Foeniculum vulgare
Festuca perennis
Festuca myuros
Festuca bromoides
Erodium cicutarium
Erodium botrys
Erigeron bonariensis
Dittrichia graveolens
Dichondra micrantha
Cynodon dactylon
Crypsis schoenoides
Cortaderia selloana
Centaurium tenuiflorum
Centaurium
Carduus pycnocephalus
Bromus hordeaceus
Bromus diandrus
Bromus catharticus
Brassica nigra
Brachypodium distachyon
Beta vulgaris
Avena fatua
Avena barbata
Atriplex semibaccata
Araujia sericifera
Aegilops cylindrica
2018
2019
2020
2021
2022
2023
2024
year
presence
FALSE
TRUE

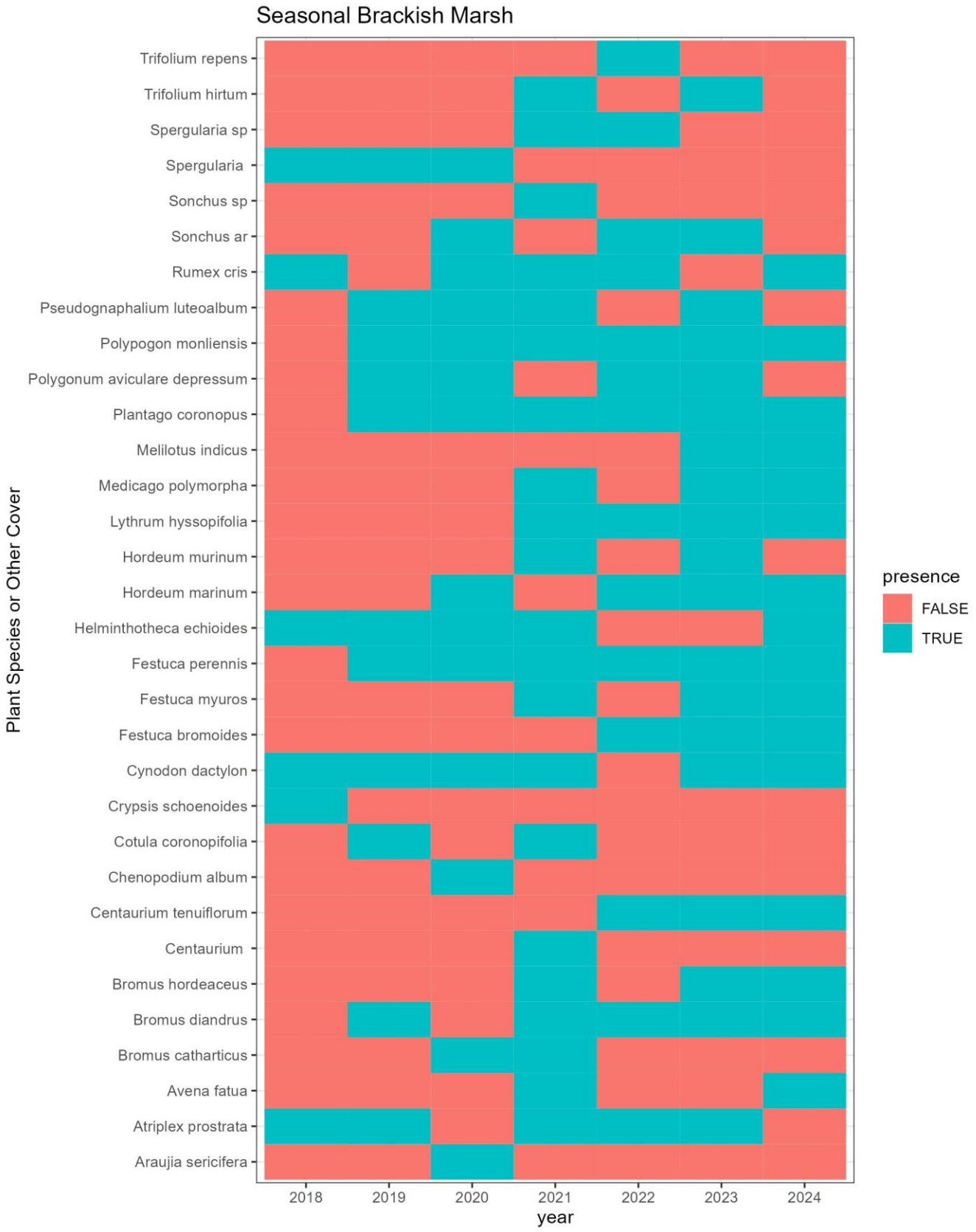

Peripheral Uplands
Washingtonia robusta
Vicia villosa
Vicia sativa
Trifolium repens
Trifolium hirtum
Tragopogon porrifolius
Taraxacum officinale
Stipa miliacea
Spergularia sp
Spergularia bocconi
Spergularia
Sonchus sp
Sonchus oleraceus
Sonchus ar
Sonchus
Senecio vulgaris
Salsola tragus
Rumex cris
Pseudognaphalium luteoalbum
Portulaca oleracea
Polypogon viridis
Polypogon monliensis
Polypogon interruptus
Polygonum aviculare depressum
Polycarpon tetraphyllum
Poa annua
Plantago major
Plantago lanceolata
Plantago coronopus
Pinus pinea
Pinus halepensis
Pennisetum clandestinum
Parapholis incurva
Palum dilatatum
Melilotus indicus
Medicago polymorpha
Medicago lupulina
Malva parviflora
Lythrum hyssopifolia
Lysimachia arvensis
Logfia gallica
Lepidium didymum
Lactuca serriola
Hordeum murinum
Hordeum marinum
Helminthotheca echioides
Geranium dissectum
Festuca perennis
Festuca myuros
Festuca bromoides
Euphorbia serpens
Euphorbia maculata
Eucalyptus sp
Eucalyptus globulus
Eucalyptus
Erodium cicutarium
Erodium botrys
Erigeron sumatrensis
Erigeron bonariensis
Erharta erecta
Dyania ambrosioides
Dichondra micrantha
Cynodon dactylon
Cyclormum leptophyllum
Cyclormum
Cotula coronopifolia
Convolvulus arvensis
Chenopodium murale
Chenopodium album
Centaurium tenuiflorum
Centaurium
Capsella bursa-pastoris
Bromus madritensis
Bromus hordeaceus
Bromus diandrus
Bromus catharticus
Brassica nigra
Brachypodium distachyon
Bassia hyssopifolia
Avena fatua
Avena barbata
Atriplex semibaccata
Atriplex prostrata
Aloe maculata
Aegilops cylindrica
Plant Species or Other Cover
2018
2019
2020
2021
2022
2023
2024
year
presence
FALSE
TRUE

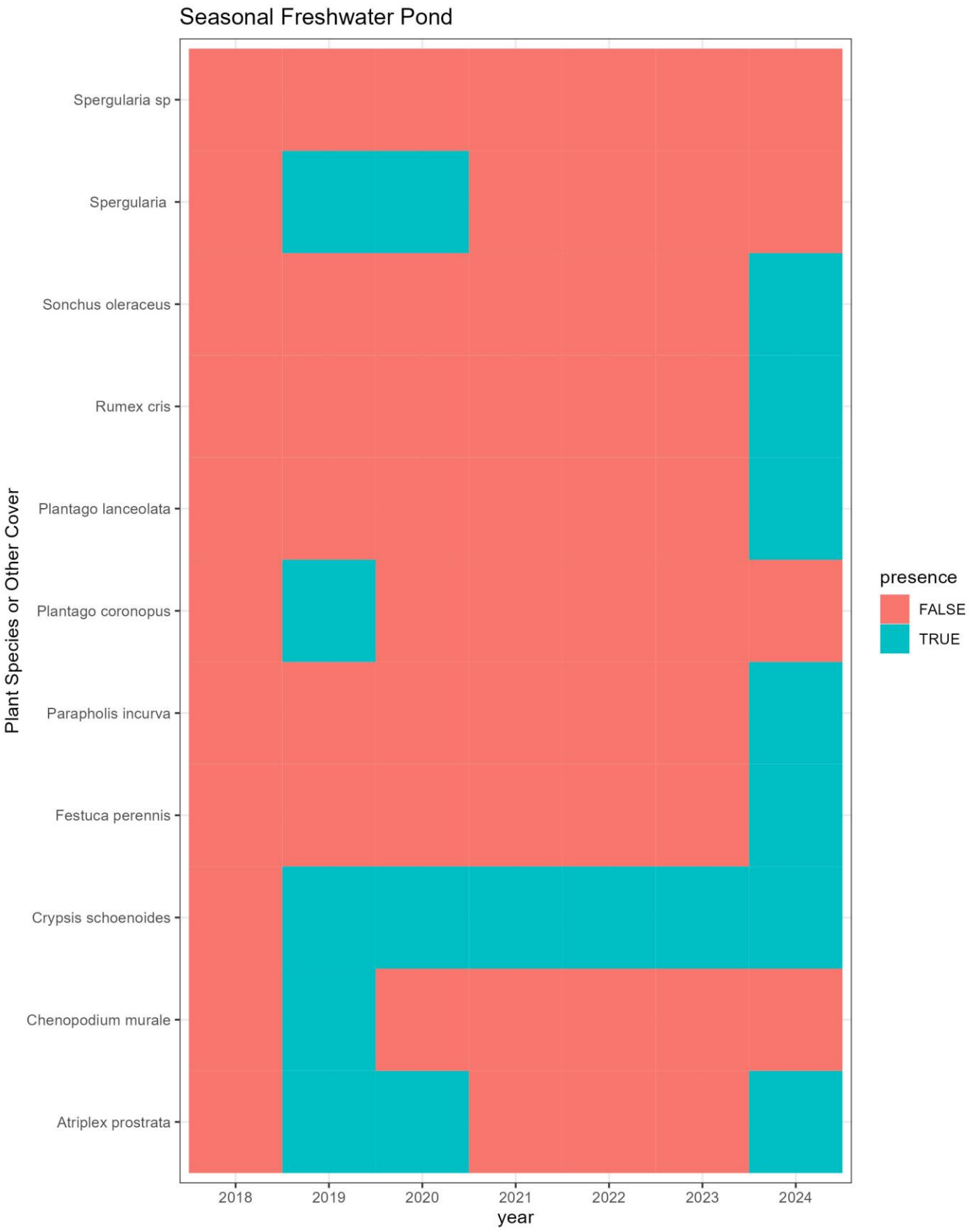

Remnant Salt Marsh
Vicia villosa
Vicia sativa
Vicia
Spergularia
Sonchus oleraceus
Sonchus ar
Rumex cris
Raphanus sativus
Medicago polymorpha
Lythrum hyssopifolia
Lactuca serriola
Hordeum murinum
Helminthotheca echioides
Geranium dissectum
Festuca perennis
Festuca myuros
Erodium botrys
Bromus hordeaceus
Bromus diandrus
Avena fatua
Atriplex prostrata
Plant Species or Other Cover
2018
2019
2020
2021
2022
2023
2024
year
presence
FALSE
TRUE

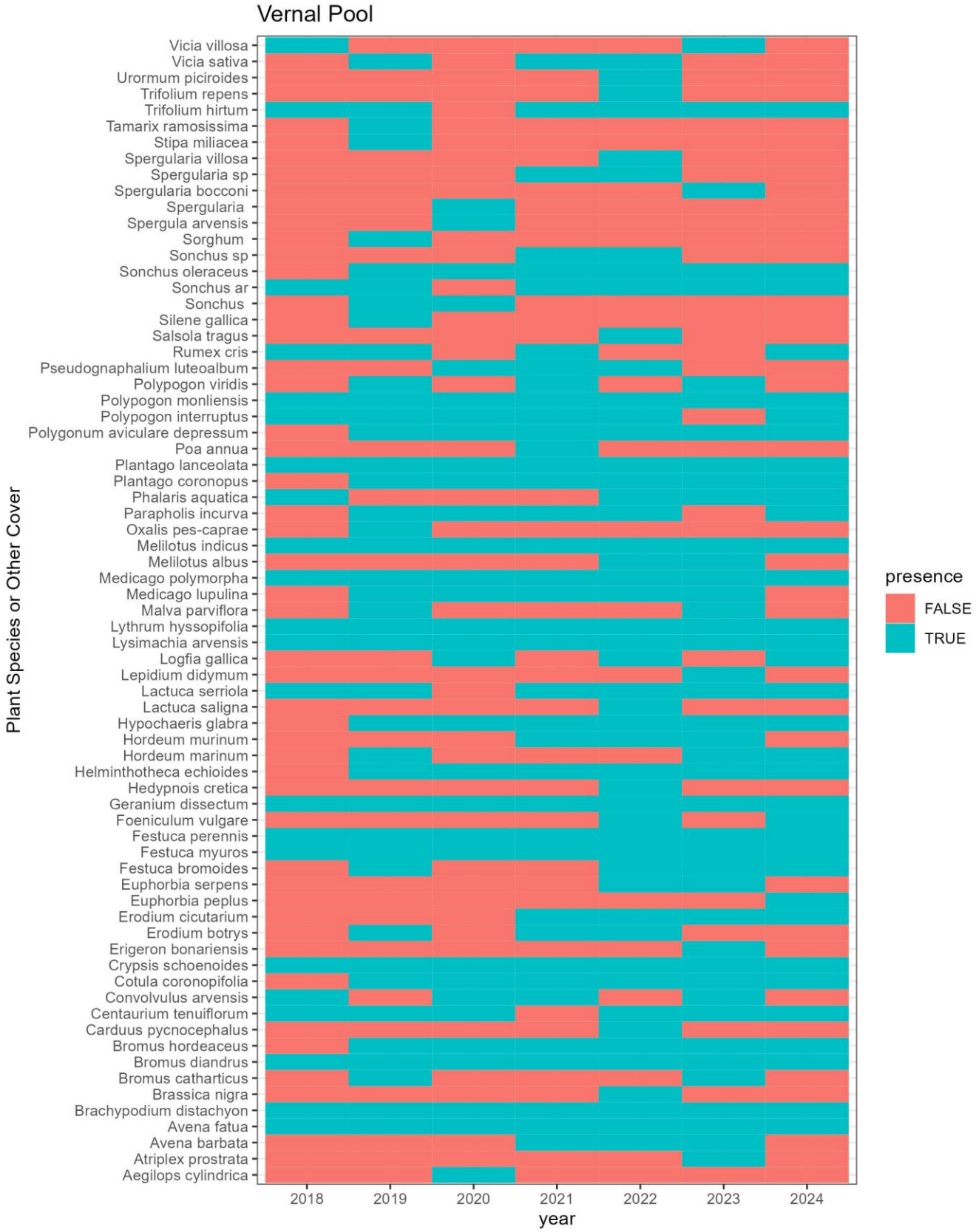

Salt Marsh
Vicia sativa
Triticale
Trifolium hirtum
Spergularia sp
Spergularia
Spergula arvensis
Sonchus sp
Sonchus oleraceus
Sonchus ar
Sonchus
Salsola tragus
Polypogon monliensis
Polypogon interruptus
Polygonum aviculare depressum
Plantago coronopus
Pennisetum clandestinum
Parapholis incurva
Mesembranthemum nodiflorum
Melilotus indicus
Medicago polymorpha
Lythrum hyssopifolia
Lysimachia arvensis
Lepidium didymum
Lactuca serriola
Lactuca saligna
Hordeum murinum
Hordeum marinum
Hirschfeldia incana
Helminthotheca echioides
Geranium dissectum
Festuca perennis
Festuca myuros
Erigeron bonariensis
Cynodon dactylon
Crypsis schoenoides
Cotula coronopifolia
Convolvulus arvensis
Chenopodium murale
Carduus pycnocephalus
Capsella bursa-pastoris
Bromus hordeaceus
Bromus catharticus
Brassica nigra
Brachypodium distachyon
Avena fatua
Atriplex semibaccata
Atriplex rosea
Atriplex prostrata
Amaranthus albus
Aegilops cylindrica
Plant Species or Other Cover
2018
2019
2020
2021
2022
2023
2024
year
presence
FALSE
TRUE


Sand Flat
Stipa miliacea
Spergularia
Pseudognaphalium luteoalbum
Polypogon monliensis
Polypogon interruptus
Polygonum aviculare depressum
Plantago coronopus
Parapholis incurva
Melilotus indicus
Melilotus albus
Lythrum hyssopifolia
Crypsis schoenoides
Cotula coronopifolia
Chenopodium murale
Chenopodium album
Atriplex prostrata
Plant Species or Other Cover
2018
2019
2020
2021
2022
2023
2024
year
presence
FALSE
TRUE


Sandy Annuals
Vicia villosa
Vicia sativa
Sonchus sp
Polypogon monliensis
Plantago lanceolata
Melilotus indicus
Melilotus albus
Medicago polymorpha
Lysimachia arvensis
Logfia gallica
Hypochaeris glabra
Hordeum marinum
Geranium dissectum
Festuca perennis
Festuca myuros
Erodium cicutarium
Erodium botrys
Erigeron bonariensis
Bromus hordeaceus
Bromus diandrus
Brassica nigra
Brachypodium distachyon
Avena fatua
Avena barbata
Plant Species or Other Cover
2018
2019
2020
2021
2022
2023
2024
year
presence
FALSE
TRUE


Seasonal Brackish Marsh
Trifolium repens
Trifolium hirtum
Spergularia sp
Spergularia
Sonchus sp
Sonchus ar
Rumex cris
Pseudognaphalium luteoalbum
Polypogon monliensis
Polygonum aviculare depressum
Plantago coronopus
Melilotus indicus
Medicago polymorpha
Lythrum hyssopifolia
Hordeum murinum
Hordeum marinum
Helminthotheca echioides
Festuca perennis
Festuca myuros
Festuca bromoides
Cynodon dactylon
Crypsis schoenoides
Cotula coronopifolia
Chenopodium album
Centaurium tenuiflorum
Centaurium
Bromus hordeaceus
Bromus diandrus
Bromus catharticus
Avena fatua
Atriplex prostrata
Araujia sericifera
Plant Species or Other Cover
2018
2019
2020
2021
2022
2023
2024
year
presence
FALSE
TRUE


Seasonal Freshwater Pond
Spergularia sp
Spergularia
Sonchus oleraceus
Rumex cris
Plantago lanceolata
Plantago coronopus
Parapholis incurva
Festuca perennis
Crypsis schoenoides
Chenopodium murale
Atriplex prostrata
Plant Species or Other Cover
2018
2019
2020
2021
2022
2023
2024
year
presence
FALSE
TRUE


Vernal Pool
Plant Species or Other Cover
Vicia villosa
Vicia sativa
Urormum piciroides
Trifolium repens
Trifolium hirtum
Tamarix ramosissima
Stipa miliacea
Spergularia villosa
Spergularia sp
Spergularia bocconi
Spergularia
Spergula arvensis
Sorghum
Sonchus sp
Sonchus oleraceus
Sonchus ar
Sonchus
Silene gallica
Salsola tragus
Rumex cris
Pseudognaphalium luteoalbum
Polypogon viridis
Polypogon monliensis
Polypogon interruptus
Polygonum aviculare depressum
Poa annua
Plantago lanceolata
Plantago coronopus
Phalaris aquatica
Parapholis incurva
Oxalis pes-caprae
Melilotus indicus
Melilotus albus
Medicago polymorpha
Medicago lupulina
Malva parviflora
Lythrum hyssopifolia
Lysimachia arvensis
Logfia gallica
Lepidium didymum
Lactuca serriola
Lactuca saligna
Hypochaeris glabra
Hordeum murinum
Hordeum marinum
Helminthotheca echioides
Hedypnois cretica
Geranium dissectum
Foeniculum vulgare
Festuca perennis
Festuca myuros
Festuca bromoides
Euphorbia serpens
Euphorbia peplus
Erodium cicutarium
Erodium botrys
Erigeron bonariensis
Crypsis schoenoides
Cotula coronopifolia
Convolvulus arvensis
Centaurium tenuiflorum
Carduus pycnocephalus
Bromus hordeaceus
Bromus diandrus
Bromus catharticus
Brassica nigra
Brachypodium distachyon
Avena fatua
Avena barbata
Atriplex prostrata
Aegilops cylindrica
2018
2019
2020
2021
2022
2023
2024
year
presence
FALSE
TRUE

APPENDIX 3 – BIRD SURVEY SPECIES LISTS

Table A3.1. Bird species and the average number of each species observed in monthly bird surveys at the North Campus Open Space. Each Survey Year begins in September and ends in August. The species are grouped by guild, and by eBird Clements v2018 integrated checklist (August 2018).

Guild & Common Name	Year 1 2018	Year 2 2019	Year 3 2020	Year 4 2021	Year 5 2022	Year 6 2023	Year 7 2024
Cormorants and Anhingas	**1**	**3**	**5**	**8**	**6**	**8**	**10**
Double-crested Cormorant	1	3	5	8	6	8	10
Gulls, Terns, and Skimmers	**13**	**28**	**27**	**13**	**28**	**29**	**26**
California Gull	2	4	5	1	9	5	3
Caspian Tern			2		1	1	7
Mew Gull		3	1			1	2
Ring-billed Gull	3	6	4	4	5	7	5
Western Gull	8	15	15	8	13	15	9
Herons, Egrets, and Ibis	**34**	**43**	**78**	**45**	**65**	**63**	**88**
Black-crowned Night-Heron	2	2	15	20	23	17	16
Great Blue Heron	14	5	17	6	9	13	16
Great Egret	6	13	20	11	17	15	24
Green Heron	7	3	2	1	3	2	2
Snowy Egret	4	19	24	7	12	16	29
White-faced Ibis	1	1			1		1
Hummingbirds	**88**	**84**	**104**	**135**	**150**	**140**	**79**
Allen's Hummingbird	5	5	9	13	19	11	17
Anna's Hummingbird	81	78	94	117	124	116	50
Black-chinned Hummingbird			1	1		1	1
Rufous Hummingbird	2	1				1	2
Selasphorus sp				4	7	12	9
Insectivores	**429**	**670**	**765**	**815**	**795**	**896**	**727**
Blackbirds	***37***	***50***	***35***	***33***	***50***	***44***	***39***
Bullock's Oriole	1		1		1	1	
Great-tailed Grackle	1		3	1			5
Hooded Oriole	4	7	10	4	3	2	2

Guild & Common Name	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Red-winged Blackbird	12	22	7	12	32	22	23
Western Meadowlark	19	20	13	15	14	19	9
Yellow-headed Blackbird		1	1	1	0		
Cardinals, Gros-beaks, and Allies		***2***		***1***	***0***		
Western Tanager		2		1	0		
Catbirds, Mockingbirds, and Thrashers	***2***		***3***	***1***	***1***	***2***	***6***
California Thrasher	2		3	1	1	2	6
Gnatcatchers	***8***	***25***	***48***	***66***	***32***	***24***	***15***
Blue-gray Gnatcatcher	8	25	48	66	32	24	15
Kinglets	***5***	***15***	***16***	***32***	***33***	***17***	***7***
Ruby-crowned Kinglet	5	15	16	32	33	17	7
Martins and Swallows	***46***	***39***	***40***	***31***	***26***	***37***	***55***
Barn Swallow	6	8	6	2	3	4	10
Cliff Swallow	26	25	27	22	18	30	36
Northern Rough-winged Swallow	10	3	2	3	2	2	4
Tree Swallow	4	2	4	4	3		5
Violet-green Swallow		1	1		0	1	
New World Sparrows	***117***	***212***	***271***	***292***	***308***	***399***	***355***
Fox Sparrow	1						
Golden-crowned Sparrow	1		1		3	1	2
Lincoln's Sparrow		5	9	17	8	18	4
Savannah Sparrow	1	10	17	9	34	58	26
Savannah Sparrow (Belding's)	8	8	5	8			14
Song Sparrow	69	121	154	183	166	208	229
White-crowned Sparrow	37	68	85	75	97	114	80

Guild & Common Name	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Nuthatches		***3***	***8***	***7***	***5***	***3***	***1***
Red-breasted Nuthatch			8	5			***1***
White-breasted Nuthatch		3		2	5	3	
Parrotbills, Wrentit, and Allies		***3***	***3***	***5***	***2***	***10***	***8***
Wrentit		3	3	5	2	10	8
Penduline-Tits & Long-tailed Tits	***9***	***21***	***31***	***24***	***31***	***34***	***18***
Bushtit	9	21	31	24	31	34	18
Starlings and Mynas	***6***	***11***	***14***	***7***	***19***	***4***	***6***
European Starling	6	11	14	7	19	4	6
Swifts	***1***	***1***			***1***		
Vaux's Swift	1	1			1		
Thrushes	***28***	***31***	***32***	***38***	***30***	***36***	***21***
Hermit Thrush		1	1	1	2	3	1
Western Bluebird	28	30	31	37	28	33	20
Tits, Chickadees, and Titmice		***5***	***4***	***11***	***9***	***12***	***3***
Oak Titmouse		5	4	11	9	12	3
Tyrant Fly-catchers: Pewees, Kingbirds, & Allies	***121***	***193***	***184***	***173***	***182***	***179***	***146***
Ash-throated Flycatcher		3			4	2	
Black Phoebe	65	112	89	86	92	90	65
Cassin's Kingbird	11	28	30	20	27	30	33
Pacific-slope Flycatcher	1	1	3			3	2
Say's Phoebe	42	47	51	59	52	42	38
Tropical Kingbird		1	3	2	2	5	3
Western Kingbird	1		7	6	4	6	5
Western Wood-Pewee	1	1				1	
Willow Flycatcher			1		1		
Wagtails & Pipits	***24***	***19***	***8***	***9***	***23***	***19***	***11***
American Pipit	24	19	8	9	23	19	11

Guild & Common Name	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Woodpeckers	***6***	***11***	***15***	***12***	***11***	***19***	***11***
Acorn Woodpecker	2		1		3	3	5
Downy Woodpecker	2	2	6	5	1	7	3
Hairy Woodpecker	2		6	1	1		1
Northern Flicker		3	1	2		2	
Nuttall's Woodpecker		6	1	4	6	7	2
Wrens	***19***	***29***	***53***	***73***	***34***	***57***	***25***
Bewick's Wren	13	14	17	21	17	41	11
House Wren	4	9	26	33	12	11	13
Marsh Wren		3	10	19	5	5	1
Rock Wren	2	3					
Kingfishers		**5**	**4**	**1**	**4**	**5**	**2**
Belted Kingfisher		5	4	1	4	5	2
Omnivores	**152**	**140**	**144**	**156**	**159**	**189**	**149**
Blackbirds		***1***				**1**	
Brewer's Blackbird		1				***1***	
Catbirds, Mockingbirds, and Thrashers	***6***	***18***	***15***	***7***	***6***	***9***	***3***
Northern Mockingbird	6	18	15	7	6	9	3
Jays, Magpies, Crows, & Ravens	***53***	***47***	***72***	***77***	***75***	***67***	***59***
American Crow	53	46	72	75	74	64	59
Common Raven				1			
California Scrub Jay		1		1	1	3	
New World Sparrows	***79***	***57***	***47***	***62***	***61***	***87***	***70***
California Towhee	78	56	47	57	57	83	66
Spotted Towhee	1	1		5	4	4	4
Old World Sparrows	***14***	***17***	***10***	***13***	***17***	***25***	***17***
House Sparrow	14	17	10	13	17	25	17
Raptors	**64**	**79**	**86**	**98**	**97**	**55**	**69**
Falcons & Caracaras	***5***	***6***	***5***	***8***	***12***	***6***	***1***
American Kestrel	5	5	4	7	6	5	

Guild & Common Name	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Peregrine Falcon				1	3		
Merlin		1	1	1	3	1	1
Owls		***7***	***6***	***10***	***2***	***2***	
Burrowing Owl		6	3	9			
Great Horned Owl		1	3	1	2	2	
Shrikes	***9***	***9***	***11***	***5***	***1***	***1***	***3***
Loggerhead Shrike	9	9	11	5	1	1	3
Vultures, Hawks, & Allies	***50***	***57***	***64***	***74***	***82***	***46***	***65***
Cooper's Hawk	11	16	19	23	23	11	8
Accipiter sp.				1			
Northern Harrier			2	4	3	1	
Osprey		1		1			
Red-shouldered Hawk	8	8	15	8	17	5	19
Red-tailed Hawk	17	19	15	16	25	11	19
Turkey Vulture	7	7	9	12	13	18	19
White-tailed Kite	7	6	4	9	1		
Seed & Fruit Eaters	**174**	**205**	**201**	**245**	**255**	**287**	**166**
Blackbirds	***1***	***1***	***2***	***1***	***1***	***2***	***1***
Brown-headed Cowbird	1	1	2	1	1	2	1
Cardinals, Grosbeaks, & Allies	***1***	***1***	***1***			**1**	
Black-headed Grosbeak			1			1	
Blue Grosbeak	1	1					
Estrildids	***23***	***33***	***28***	***27***	***40***	***22***	***17***
Scaly-breasted Munia	23	33	28	27	40	22	17
Finches, Euphonias, & Allies	***85***	***99***	***95***	***61***	***145***	***205***	***84***
House Finch	72	76	73	16	88	146	61
Lesser Goldfinch	13	22	20	43	56	49	21
American Goldfinch				1	1		1
Purple Finch		1	2	1		1	1

Guild & Common Name	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Grouse, Quail, & Allies		***1***					
California Quail		1					
New World Sparrows	***3***	***16***	***20***	***10***	***15***	***12***	***18***
Chipping Sparrow		2	1				
Clay-colored Sparrow		1					
Dark-eyed Junco	1			1	5	6	9
Lark Sparrow	2	13	19	9	10	6	9
Pigeons & Doves	***61***	***54***	***55***	***46***	***54***	***45***	***46***
Eurasian Collared-Dove	9	2	5	5	1	5	6
Mourning Dove	23	19	18	13	23	16	20
Rock Pigeon (Feral Pigeon)	29	33	32	28	30	24	20
Shorebirds	**224**	**189**	**175**	**99**	**112**	**114**	**153**
American Avocet			2		1	1	
Black-necked Stilt	5	11	23	4	12	3	32
Dunlin	1	1			1		
Greater Yellowlegs	18	14	18	12	11	18	7
Killdeer	94	93	71	45	36	51	66
Least Sandpiper	45	30	17	18	28	15	23
Lesser Yellowlegs			1	1	1		1
Long-billed Curlew	2	3	2		2	5	1
Long-billed Dowitcher		2	5	1	2		
Pectoral Sandpiper		1	1				
Red-necked Phalarope	2	3	5		3	1	
Sanderling		1					
Semipalmated Plover	16	7	7	4	4	6	7
Solitary Sandpiper		1				1	
Spotted Sandpiper	1	1	5		1		2
Western Sandpiper	36	17	11	10	5	12	12
Western Snowy Plover	1	2	4		4		
Whimbrel		1			1		1

Guild & Common Name	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Willet	1						
peep sp.				1			1
Wilson's Snipe	2	1	3	3		1	
Warblers	**56**	**114**	**193**	**185**	**188**	**216**	**150**
Common Yellowthroat	16	41	77	107	93	117	85
Orange-crowned Warbler	3	3	11	6	12	15	10
Yellow Warbler	1	4	4		3	8	2
Yellow-rumped Warbler	36	66	101	72	80	76	53
Waterfowl & ALLIES	**104**	**202**	**262**	**136**	**219**	**170**	**159**
Grebes	***2***	***10***	***21***	***8***	***7***	***3***	***7***
Clark's Grebe			5				
Eared Grebe	2	6	4		2	2	
Pied-billed Grebe		2	11	8	5	1	7
Western Grebe		2	1				
Rails, Gallinules, & Allies	***7***	***59***	***48***	***23***	***31***	***24***	***24***
American Coot	5	45	39	16	29	18	9
Sora	2	14	7	4	2	4	14
Virginia Rail			2	3		2	1
Waterfowl	***95***	***133***	***193***	***105***	***181***	***143***	***128***
American Wigeon	3		8	10	16	6	3
Blue-winged Teal	1	2	2				
Bufflehead	2	4	2		3	1	
Cackling Goose (Aleutian)	5	1		1	1		
Canada Goose	16	22	21	17	25	18	26
Canvasback			1				
Cinnamon Teal	7	8	17	5	1	7	4
Cinnamon Teal x Northern Shoveler (hybrid)		1					
Gadwall	7	10	21	11	25	16	18
Greater White-fronted Goose	7	2	4	2	2	1	3
Green-winged Teal		3	5	1	4	4	7

Guild & Common Name	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Hooded Merganser	1	2	1	2	2	1	4
Mallard	35	53	62	40	63	66	49
Mute Swan		1			2		
Northern Pintail	2		6		2	2	
Northern Shoveler	3	14	17	6	20	15	6
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	5	6
Snow Goose		2	1	2	2	1	2
Grand Total	**1339**	**1763**	**2044**	**1936**	**2080**	**2172**	**1778**

Table A3.2. Number of observations of breeding behavior recorded during monthly bird surveys at NCOS (highlighted in green) and reported to the Santa Barbara Audubon Society's Breeding Bird Study (highlighted in pink) in 2018-2024. Note that some of the NCOS bird survey observations are also reported to the Breeding Bird Study.

	NCOS Monthly Bird Survey Observations (in green), Santa Barbara breeding bird survey (in pink)						
Species Common Name	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
American Crow			2 3	1 1	2 1		1
Allen's Hummingbird					1		1
Anna's Hummingbird		1			1		1
Ash-throated Flycatcher					1		
Barn Swallow			1	1			
Bewick's Wren			1				
Black-necked Stilt					1		11 3
Black Phoebe	3	2 1	1 3	2	2 3		
Bushtit	1			1			
California Towhee	2 1		1 2	1 1		2	1 1
Canada Goose		2 1	2 1	3	1	1	2 1
Cassin's Kingbird		1			1		
Cliff Swallow	5 3	4 3	1 3	3 2	1 1		1 1
Common Yellowthroat					1	5	1 1
Cooper's Hawk	1		2 1			1	
Dark-eyed Junco				1			1
Downy Woodpecker							1
European Starling		1	1		2		1 1
Gadwall		2 3	1	2			2 1
Great Egret		1					
Great Horned Owl	1		1	1			

Hooded Oriole												1								
House Finch	2	2	3	4	3	3	3	5	1	1					2					
House Sparrow	2	2	1						1				1				1	2		
House wren																	1	2		
Killdeer	4	5	3	6	2	2	2		2	3			2				6	2		
Lark Sparrow			2		1	1	2		3				1							
Lesser Goldfinch			1	1	1	1	1		2											
Mallard	1	2	2	2	2	2	2						3	4			2	6		
Mourning Dove							1													
Northern Mockingbird							1	1												
Northern Rough-winged Swallow							1										1			
Nuttall’s Woodpecker							1													
Red-shouldered Hawk	1				1		1		2				1				1	3		
Red-tailed Hawk			1																	
Rock Pigeon (Feral Pigeon)	1	1																		
Savannah Sparrow (Belding's)					3	4	1	2												
Say's Phoebe	1		1				2	1	1	2			1	1			2	1		
Selasphorus sp.																	1			
Scaly-breasted Munia													1							
Song Sparrow			2	7	1	1	4	2	1				2	1			15	4		
Western Bluebird	1	1					1		2				1	1			1			
Western Kingbird							1	1												
Western Sandpiper	1																			
Western Snowy Plover	2		1		1	1			2	2										
White-tailed Kite							2													
White-breasted Nuthatch							1													

Wrentit			1				

APPENDIX 4 – JUNE 2024 AQUATIC SPECIES SURVEY REPORT

Technical Memorandum

Date:	June 20, 2024
To:	Chris Dellith (chris_dellith@fws.gov)
CC:	Lisa Stratton (stratton@ccber.ucsb.edu)
From:	Hannah Donaghe (hdonaghe@ce.solutions)
RE:	**Devereux Slough and UCSB North Campus Open Space 2024 Post-Construction Tidewater Goby 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 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.

Pre-construction surveys of Devereux Creek and Phelps Creek conducted in 2016, and post-construction surveys conducted in the fall of 2017, 2018, 2020, 2021, and 2022 found no tidewater gobies (*Eucyclogobius newberryi*) 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. During the previous survey conducted on June 21, 2023, tidewater gobies were observed in Devereux Slough at the mouth and pier sites as well as further upstream at the Phelps Bridge site. The 20182023 surveys also found no southwestern pond turtles or California red-legged frogs.

On June 11, 2024, a post-construction survey was conducted in Devereux Slough, the restored channels, and lower Phelps Creek by Catalyst Environmental Solutions (Catalyst) biologist Hannah Donaghe (Federal Recovery Permit 14532C-2) with assistance from CCBER staff (Lisa Stratton, Darwin Richardson, Alison Rickard, Jeremiah Bender, and Chris Berry). Ms. Donaghe was approved by the U.S. Fish and Wildlife Service (USFWS) to conduct surveys for tidewater goby under the Biological Opinion for the UCSB Devereux Slough

Restoration Project (08EVEN00-2016-F-0484). During the 2024 survey, tidewater gobies were observed at all sampling sites, with the exception of Phelps Creek. Tidewater gobies were observed throughout Devereux Slough at the mouth and pier sites as well as further upstream in the NCOS restored channels and at the Phelps Bridge site.

Due to the initial discovery of the invasive New Zealand mudsnail (*Potamopyrgus antipodarum*) in the Phelps Creek area by CCBER staff in 2023, sampling at that site was completed last and the sampling gear was decontaminated following completion of work in an attempt to limit any spread of the invasive species. CCBER staff identified the presence of New Zealand mudsnail using aquatic eDNA sampling which was then verified with hand sampling and identification by a local expert. New Zealand mudsnails were also observed by CCBER staff in Phelps Creek during the 2024 survey.

The methods used and results of the surveys are described in the sections below.

Methodology

Fish Sampling

Sampling sites were selected in the field based on access, water depth, density of widgeon grass (*Ruppia maritima*; aquatic plant) and *Ulva intestinalis* algae, and proximity to sampling sites from previous years (Figure 2). Sample sites included three locations in Devereux Slough and three locations in the restored channels consisting of one site near Venoco Road, one site in the East Channel, and one site near the West Arm of the Main Channel at Phelps Bridge. Photographs of the sampling sites are provided in Attachment A.

Sampling was conducted between 8:00 AM and 12:30 PM. Weather conditions were overcast with minimal wind and temperatures between 59 degrees Fahrenheit (°F) and 66°F. 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 approximately 20 to 30 feet. The seine was pulled across the channel perpendicular to the shore 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. Fish were immediately removed from the net, identified, and counted. After counting, all species were released back into the water. At sites where the substrate was too rocky to conduct an effective seine haul (Phelps Creek, Phelps Bridge, and south of Venoco Bridge), dip net sweeps were completed to sample the area. Many sweeps were made using fine-mesh dip nets wherever open water occurred with minimal obstructions. All captured organisms were identified and released.

Water Quality

Water quality parameters (temperature in degrees Celsius [°C], dissolved oxygen in milligrams per liter [mg/L], and salinity in parts per thousand [ppt]) were measured by CCBER staff with a YSI Pro 2030 at each sampling location.

Results and Discussion

Table 1 summarizes the fish captured at each sampling site. Native fish species captured included tidewater goby, topsmelt (*Atherinops affinis*), and California killifish (*Fundulus parvipinnis*). Two non-native fish species were captured, mosquitofish (*Gambusia affinis*) and Mississippi silversides (*Menidia audens*). Mosquitofish, which can tolerate a wide range of salinity, were only captured at the Phelps Bridge and Phelps Creek sites, and Mississippi silversides were captured at the Venoco Bridge North, East Channel, and Phelps Bridge sites.

Tidewater gobies were captured at the Devereux Slough mouth and pier sample sites, Venoco Bridge South site, and in the NCOS restored channels north of Venoco Bridge, the East Channel, and the Phelps Bridge site. A total of 94 tidewater gobies were captured during the survey, with the majority captured at the Devereux Slough mouth site (66 individuals). A total of 7 tidewater gobies were captured at the Devereux Slough pier site, 4 were captured at the Venoco Bridge South site, 3 were captured at the Venoco Bridge North site, 6 were captured in the East Channel, and 8 were captured at the Phelps Bridge site (Table 1). Tidewater goby has been reported in Phelps Creek in the past but were not captured in the creek upstream of Phelps Bridge in 2024. Removal of the weir at the Venoco Road crossing has allowed fish access to upstream areas. Tidewater gobies in Devereux Slough have expanded into NCOS aquatic habitats further upstream, as they were observed north of Venoco Bridge upstream to the Phelps Bridge site and the East Channel. Tidewater gobies generally only live one year (Swift et al. 1989, Moyle 2002).

Several dragonfly nymphs were captured at the upstream sites, including Venoco Bridge North, East Channel, Phelps Bridge, and Phelps Creek. The non-native red swamp crayfish continues to occur in Phelps Creek, with several individuals captured during dip net sampling. Several crayfish were also found at the Phelps Bridge site. Its spread into the restored channels will likely be limited by its intolerance of high salinity. CCBER staff observed the invasive New Zealand mudsnail on submerged portions of rocks at the Phelps Creek site.

Widgeon grass, an aquatic plant, was abundant at the Devereux Slough sampling sites and upstream into the NCOS restored channels at lower density and algal mats were present throughout. Dense emergent vegetation was present at the Phelps Bridge site and upstream in Phelps Creek, consisting of cattails (*Typha* spp.) and southern bulrush (*Schoenoplectus californicus*) and arroyo willow (*Salix lasiolepis*) was prominent along the banks of Phelps Creek.

Table 2 provides the results of the water quality sampling completed at each site. Tidewater gobies can withstand a wide range of habitat conditions, including temperature and dissolved oxygen levels. They have been documented in waters with salinity levels from 0 to 42 parts per thousand and can live and breed at temperatures of 8 to 25°C (46 to 77°F) (Swift et al. 1989, Moyle 2002, USFWS 2005). Dissolved oxygen ranged from 2.5 to 13.3 at the sampling sites. Two sites where tidewater goby were captured had low dissolved oxygen levels, 3.1 and 2.5 mg/L at the Devereux Slough mouth and Phelps Bridge sites, respectively. Salinity was highest at the lower Devereux Slough sites (approximately 19.1 to 19.8 ppt) and decreased moving upstream to the restored channels and upstream to Phelps Creek (2.2 ppt). Temperatures were lowest at the most upstream sample sites at Phelps Creek and bridge (17.2 and 17.4°C, respectively). The lower estuary sites ranged from 21.2 to 22.1°C. The Venoco Bridge sites had the highest temperatures recorded at approximately 25°C. All sampling sites had temperatures within the known range for tidewater goby.

Water depths at the lower estuary sampling sites were generally 2.5 to 3.5 feet, and other sites were generally shallower, ranging from 1 to 2.5 feet. The water depth in Phelps Creek ranged from 6 inches to 2 feet. Storm events and high rainfall occurred during the winter preceding the 2024 survey, and a late rainfall event in May which did not breach the estuary, contributed to the water levels in the NCOS channels and Devereux Slough. Tidewater gobies were observed at all sampling sites from Devereux Slough upstream to Phelps Bridge, including the restored NCOS channels. At the time of sampling, the berm was closed.

Table 1: Fish Captured during 2024 Survey – June 11, 2024

Site	Common Name	Scientific Name	Number		Method
Phelps Creek[1]	Mosquitofish	*Gambusia affinis*	2		Dip net
Phelps Bridge[2]	**Tidewater goby**	***Eucyclogobius newberryi***	**8**		Dip net
	Mississippi silverside	*Menidia audens*	3		
	Mosquitofish	*Gambusia affinis*	2		
East Channel	**Tidewater goby**	***Eucyclogobius newberryi***	**6**		Seine
	Topsmelt	*Atherinops affinis*	44		
	California killifish	*Fundulus parvipinnis*	3		
	Mississippi silverside	*Menidia audens*	18		
Venoco Bridge North	**Tidewater goby**	***Eucyclogobius newberryi***	**3**		Seine
	Topsmelt	*Atherinops affinis*	9		
	California killifish	*Fundulus parvipinnis*	1		
Venoco Bridge South[3]	**Tidewater goby**	***Eucyclogobius newberryi***	**2**	**2**	Seine, Dip net
	Topsmelt	*Atherinops affinis*	30	18	
	Mississippi silverside	*Menidia audens*	19	0	
Devereux Slough-Pier	**Tidewater goby**	***Eucyclogobius newberryi***	**2**	**5**	Seine (2 hauls)
	Topsmelt	*Atherinops affinis*	12	212	
	California killifish	*Fundulus parvipinnis*	0	1	
Devereux Slough-Mouth	**Tidewater goby**	***Eucyclogobius newberryi***	**23**	**43**	Seine (2 hauls)
	Topsmelt	*Atherinops affinis*	0	111	
	California killifish	*Fundulus parvipinnis*	0	2	

Table Notes:

[1] Area sampled was approximately 1,200 square feet.

[2] Area sampled was approximately 800 square feet.

[3] Dip nets sweeps were performed just south of the Venoco Bridge (approximately 600 square feet) due to rock riprap present. Further downstream, where the substrate consisted of sand and silt, one seine haul was performed.

Table 2: Water Quality at Fish Sampling Sites – June 11, 2024

Location	Approx. Latitude	Approx. Longitude	Temperature (°C)	Salinity (ppt)	Dissolved Oxygen (mg/L)
Phelps Creek	34.422760	-119.879539	17.2	2.2	4.9
Phelps Bridge	34.421387	-119.878841	17.4	2.2	2.5
East Channel	34.420399	-119.874420	20.7	10.0	8.3
North of Venoco Bridge	34.417780	-119.873950	24.8	12.4	6.0
South of Venoco Bridge	34.417350	-119.874013	25.0	14.8	13.3
Devereux Slough-Pier	34.411891	-119.876993	22.1	19.1	4.8
Devereux SloughMouth	34.409815	-119.879349	21.2	19.8	3.1

Figure 1. Creeks and Channels at North Campus Open Space

Figure 2. Fish Sampling Sites and Water Quality Sites

References

Moyle, P. B. 2002. Inland Fishes of California. University of California Press, Berkeley and Los Angeles. Pp 431434.

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.

U.S. Fish and Wildlife Service. 2005. Recovery Plan for the Tidewater Goby (*Eucyclogobius newberryi*). Pacific Region, U. S. Fish and Wildlife Service, Portland, Oregon.

ATTACHMENT A

SAMPLE SITE PHOTOGRAPHS

Seining at Devereux Slough mouth site, tidewater goby present (6/11/24).

Devereux Slough pier site, tidewater goby present (6/11/24).

Venoco Bridge South site, looking downstream. Dip net sampling completed just downstream of bridge and seine haul completed further downstream where no rip rap was present. Tidewater gobies captured by seine and dip net (6/11/24).

Seining at NCOS restored East Channel site, looking north. Tidewater goby present (6/11/24).

Dip netting conducted at Phelps Bridge site, tidewater goby present. Dense emergent vegetation present including cattails and southern bulrush (6/11/24).

Phelps Creek sample site upstream of bridge, no tidewater goby present (6/11/24).

APPENDIX 5 – NCOS Cultural Burn

NCOS Mesa Controlled Burn Year 1

Report N. Saglimbeni

August 12, 2024

Executive Summary

A controlled burn was conducted at UCSB's North Campus Open Space in September of 2023. Controlled burning was used with the ecological goals of 1) promoting native bunchgrass and wildflower species and 2) reducing nonnative annual grass cover. A plot-based study was designed to explore the effectiveness of the fire on meeting these goals. Overall, native bunchgrass cover was reduced, but this is likely due to the consumption of aboveground biomass rather than the death of individual plants from the fire. Native forb species richness increased as a result of seeding efforts. The fire had mixed effects on nonnative annual grasses, as their cover decreased in some areas and increased in others. Findings also show that burning did not reduce nonnative plant cover and may have caused a release of the nonnative forb *Melilotus indicus.* Overall, results from this study suggest controlled fire in a restored coastal grassland can be successful in reducing annual grass cover in some cases, but managers must be aware of the risk of conversion from grassland to forb-land.

Introduction

Santa Barbara's coastal grasslands have experienced frequent fires as a result of thousands of years of indigenous land management by the Chumash (Timbrook et al. 1982). Natives likely used fire in these systems for a variety of reasons, including the cultivation of important plant resources and the removal of dense, shrubby vegetation to improve hunting, visibility and travel near village sights (Timbrook et al. 1982). Coastal grassland plant species of Santa Barbara are therefore well adapted to fire, and should respond well to controlled burns for management of these systems. Some "fire-following" species grow incredibly well in response to fire (Timbrook et al. 1982). A critical factor that the Chumash did not face is the presence of nonnative annual grasses and other invasive forbs that tend to dominate the majority of coastal grasslands today (Heady, n.d.). As a result, the use of controlled burning to promote native species and reduce nonnative species has shown mixed results (Heady, n.d., Keeley et al 2023). Understanding the interplay of fire with native and nonnative grassland species is critical to furthering our ability to effectively use fire as a management tool.

UCSB's North Campus Open Space (NCOS) is part of 130+ acres of restoration of the upper arm of Devereux Slough and surrounding open spaces. 14+ acres of native perennial grasslands dominated by the bunchgrass, *Stipa pulchra*, were restored as a part of this project. Since the creation of this grassland, nonnative grasses

have progressively invaded the site. A controlled burn was implemented in September of 2023 with the goals of reducing the presence of these nonnative grasses and promoting *S. pulchra* and other native grassland species. Many of these other native forb species are culturally important plants for the local Chumash people, such as wildflowers (e.g. *Calyndrinia menzesii*) or bulb forming plants (e.g. *Brodiaea spp.* and *Bloomeria spp*.).

It was predicted that this controlled burn would reduce nonnative annual grass cover as has been shown in previous studies (DiTomaso et al. 2006). It was also predicted to promote the growth and germination of native fire adapted species. *S. pulchra* was predicted to respond well to the fire, but likely over a multi-year time period (Keeley et al 2023).

Methods and Design

Vegetation Data:

65 1m x 1m experimental plots were placed within the burn area (Fig. 1). An additional 10 1m x 1m plots were placed just outside of the burn to represent unburned controls (Fig. 1). All plots had their GPS coordinates taken with a sub-1 ft accurate Geode GNS3S Receiver (Juniper Systems) so they could be reliably relocated after the burn. Percent cover data was collected in each plot by ocularly identifying each species within the plot and estimating its absolute percent cover of the plot. To date, the plots have all been surveyed twice; first in the summer before the burn (July 2023) and then in the spring following the burn (May 2024). The 65 experimental plots were chosen to represent a few different variables.

32 “Grass Cover” plots were haphazardly chosen based on the dominant grass species at each plot. 16 plots were dominated by *S. pulchra*, and 16 were dominated by a nonnative European annual grass, usually *Festuca perennis*. Each of those clusters were further divided into areas where native bulb species were known to have been planted the season before the fire and areas where bulb plantings likely did not occur. This resulted in 8 plots for each grass cover x bulb planting combination. Unfortunately, no bulb plants were found in our post burn vegetation surveys, although they were found on site outside of the monitoring plots.

30 “Seed Treatment” plots were randomly placed within the two predominant soil textures found within the burn site. 15 plots were placed in a sandy zone and 15 plots were placed in a heavy clay zone. Of the 15 plots in each soil zone, 5 were left unseeded, 5 had all species seeded after the fire (“Post Only”), and 5 had select species seeded before the fire with the rest of the species being seeded after the fire (“Pre+Post”). The species palettes were different between soil zones, but consistent between seeding treatments within each zone (Table S1). Overall, 21 species were seeded at a rate of 100 seeds / m^2. *Sisyrinchium bellum* was seeded at a rate of 200 seeds / m^2 due to having a thick seed coat and potentially reduced germination rate.

The remaining 3 plots were located in an area where salvaged soil containing native bulb species was placed in 2017.

Fire Data:

In addition to vegetation cover, maximum burn temperature at the soil surface, temperature at a depth of 5 cm, and pre-burn biomass were recorded on a subset of the experimental plots. Maximum soil surface temperature was recorded using Tempilaq Advanced Temperature Liquid

Temperature Indicators (LA-CO Industries). 6 indicators, with melting points of 149C, 177C,

204C, 232C, 260C, and 343C, were painted on a copper tag and placed on the soil surface at 60 of the plots. These tags were collected after the burn and examined to determine approximately how hot the fire got at each plot. For example, if 4 of the 6 paints melted, we would know the fire reached a temperature between 232C and 260C. Subsurface soil temperatures were monitored at 32 plots by burying a temperature-sensitive iButton 5 cm below the soil surface. These iButtons recorded temperature every minute throughout the entirety of the burn. Biomass samples were collected on 0.25m x 0.25m plots directly adjacent to the plots where iButtons were placed in September 2023 before the fire occurred. These samples were dried at 60C for 72 hours before being weighed.

Statistical analysis:

All statistics should be considered preliminary, especially where sample sizes are small. Significance values were calculated using Welch's t-test where "ns" indicates no significant difference * indicates $p<0.05$, ** indicates $p<0.01$, *** indicates $p<0.001$, and **** indicates $p<0.0001$. Significance of regression lines was calculated using Spearman's Correlation Coefficient.

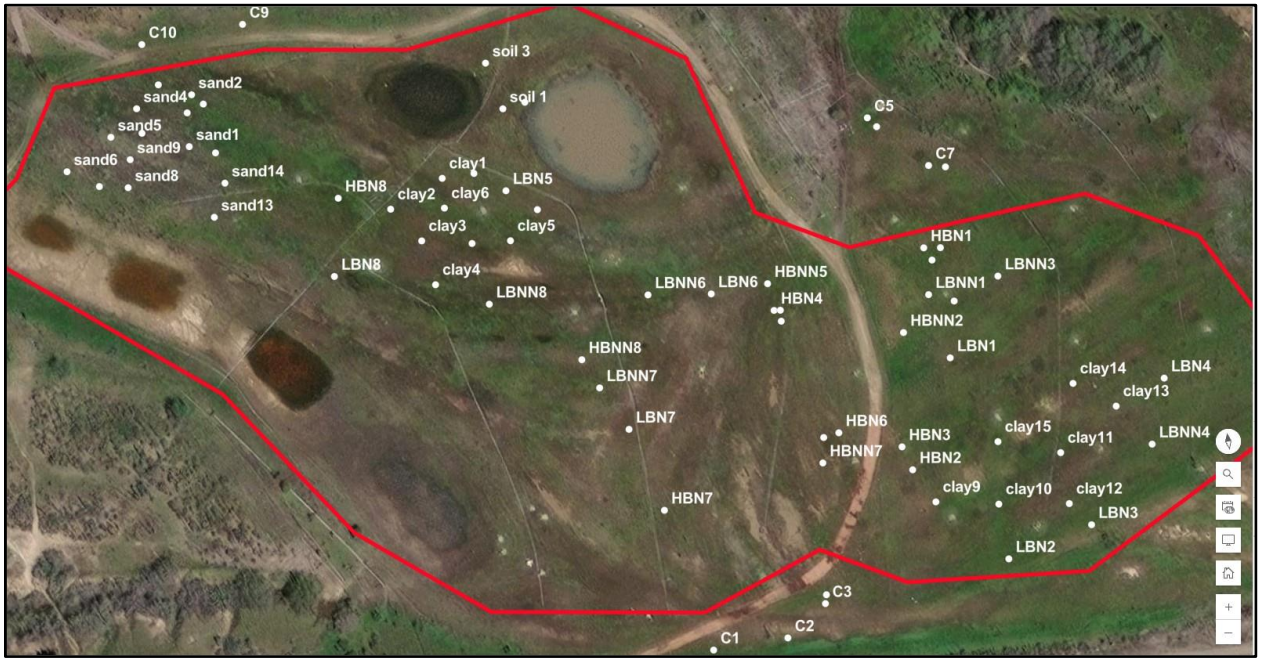


Figure 1: 75 1m x 1m experimental monitoring plots (white dots) were established before burning. The red polygon indicates the area burned. C1-C10 are control plots and did not burn (n=10 for control plots). Sand1 - Sand15 and Clay1 - Clay15 are plots where native wildflower seeds were spread in sand and clay dominated soils respectively (n=30 for seeded plots). Soil1Soil3 are plots where soil known to contain native wildflowers was placed in 2017 (n=3 for soil addition plots). HB or LB naming represent high or low effort of native bulb planting respectively. High effort means bulbs were certainly planted nearby. Low effort means likely no bulbs were planted nearby. N or NN naming represents whether native or nonnative grasses respectively accounted for the majority of vegetation cover before the fire occurred (n=8 for HBN, HBNN, LBN, and LBNN plots). Note: not all plot labels are visible in this figure.

Results Grass Cover:

In burned plots where *S. pulchra* was dominant before the fire, its cover was reduced from ~80% to ~15% in the first year after the burn (Fig. 2A). In plots where exotic annual grasses were dominant before the fire, *S. pulchra* cover remained constant between years after being burned (Fig. 2A). European annual grass cover was reduced from ~90% to ~60% in plots where they were dominant before the burn occurred (Fig. 2B). Their cover rose from ~10% to ~40% in burned plots dominated by *S. pulchra* prior to fire (Fig. 2B). No significant changes in cover were detected in unburned plots (Fig. 2).

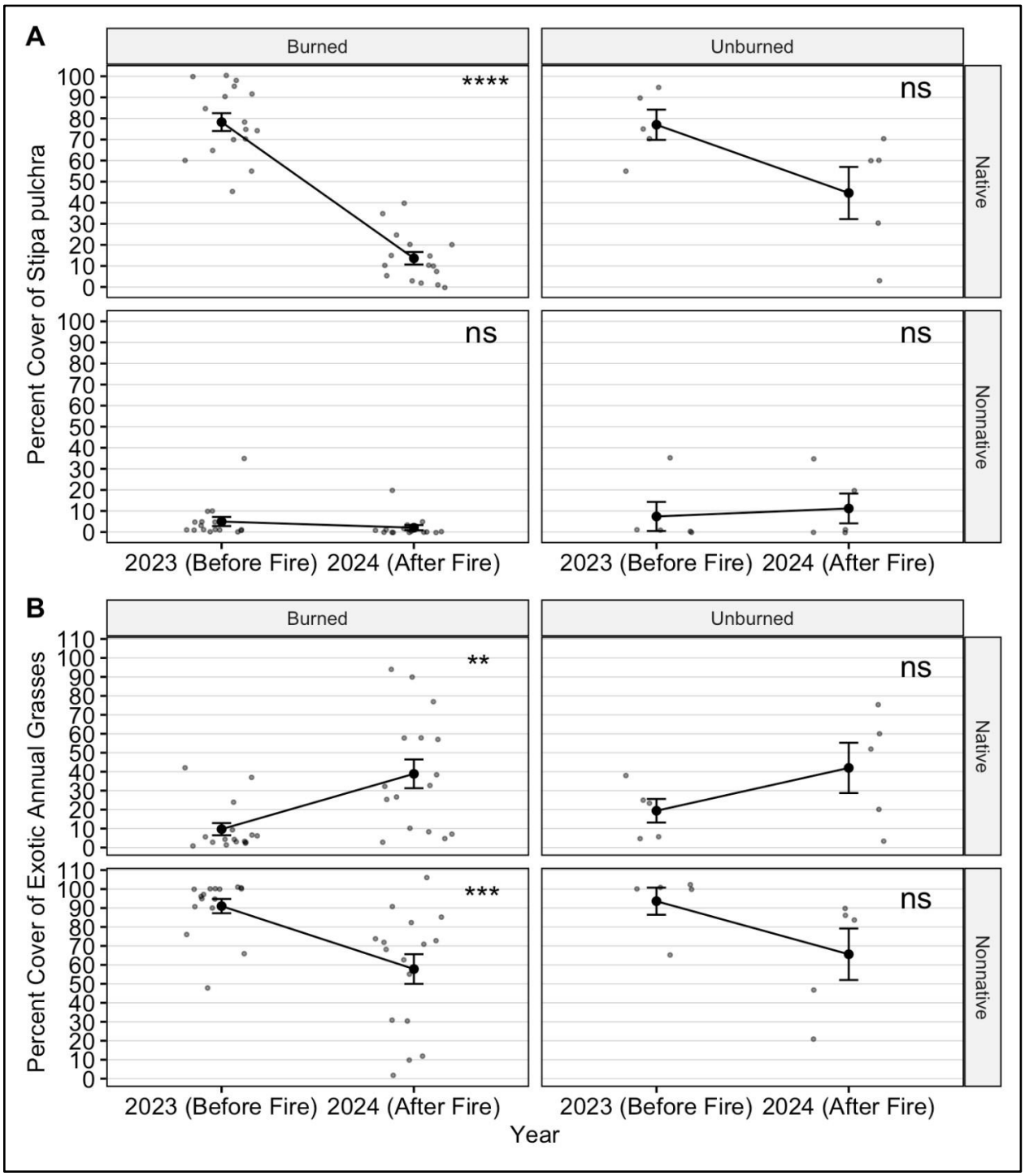


Figure 2: Percent cover of *S. pulchra* (A) and exotic annual grasses (B) before and after fire. Panels delineate whether plots were burned or not (columns) and whether the dominant species in each plot in 2023 was native or nonnative (rows). Native means the plot was dominated by *S. pulchra* and nonnative means the plot was dominated by exotic annual grasses.

Forb Cover:

Native forb cover was unchanged and remained very low regardless of being burned or not (Fig. 3A). Nonnative forb cover increased from <5% to ~55% and <5% to ~30% in burned and unburned plots respectively (Fig. 3B).

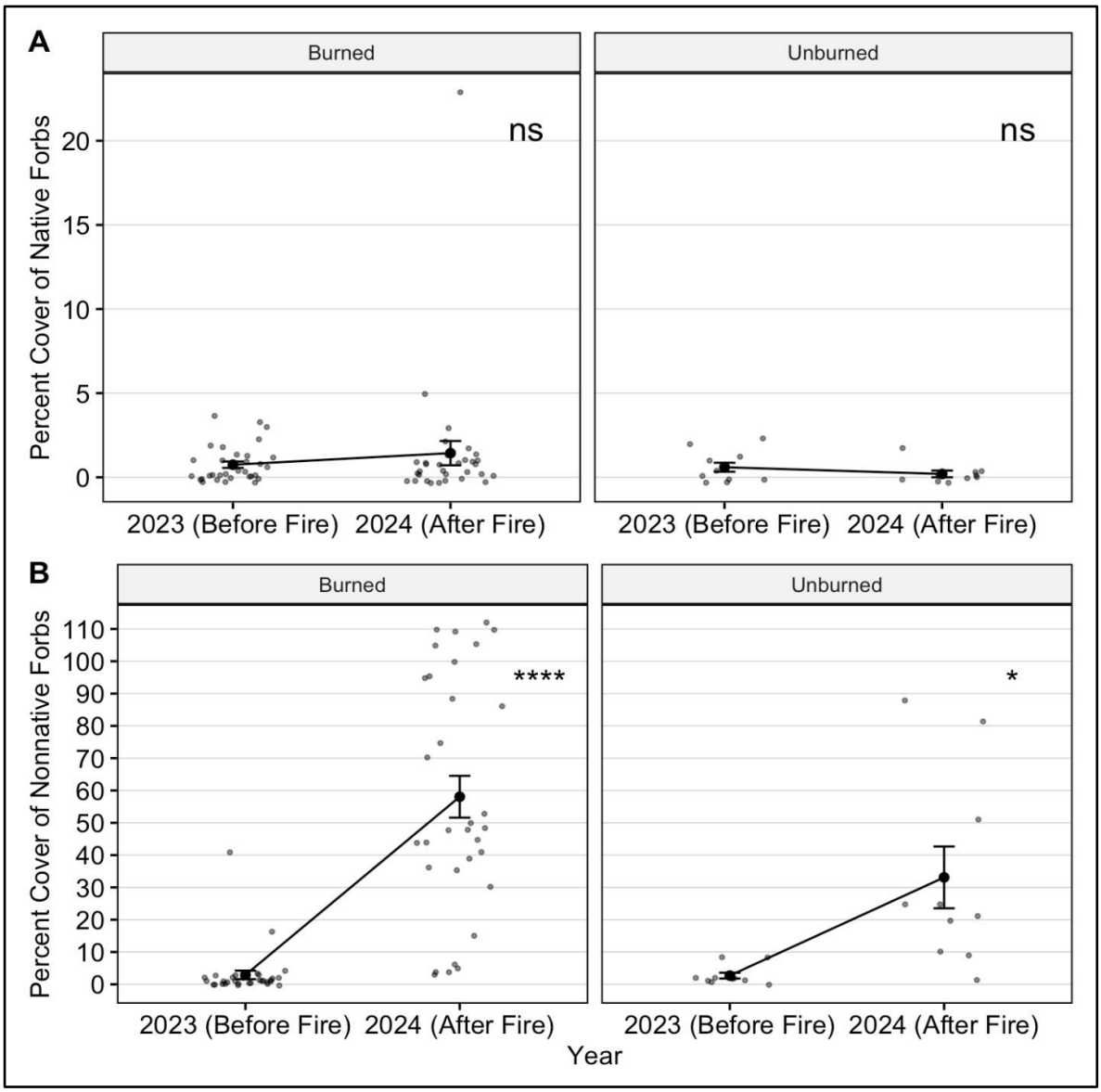


Figure 3: Combined percent cover of all native (A) and nonnative (B) forb species before and after fire in burned and unburned plots.

Two species, *Melilotus indicus* and *Medicago polymorpha*, accounted for the vast majority of nonnative forb cover in 2024. *M. indicus* increased from <5% to ~30% in burned plots (Fig. 4A). Cover of *M. indicus* did not change in unburned plots (Fig. 4A). *M. polymorpha* cover increased from <5% to ~20% and from <5% to ~30% in burned and unburned plots respectively (Fig. 4B).

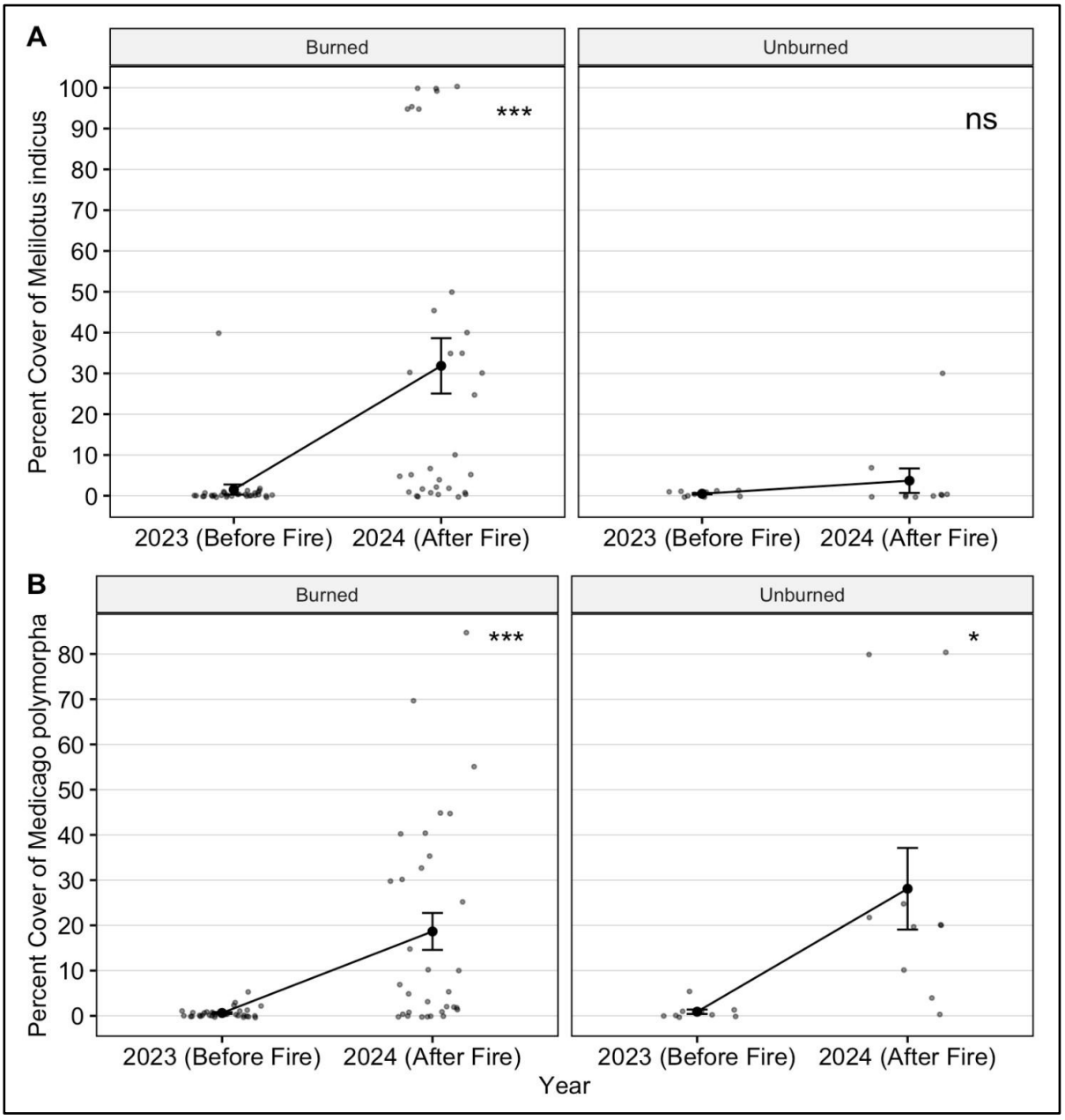


Figure 4: Percent cover of *M. indicus* (A) and *M. polymorpha* (B) before and after fire in burned and unburned plots.

Overall, change in nonnative forb cover from 2023 to 2024 was significantly greater in the sand plots than in clay plots (Fig. 5). *M. polymorpha* similarly showed a much greater increase in cover in the sand soil plots than in the clay ones (Fig. 5). Soil did not affect changes in *M. indicus* cover (Fig. 5).

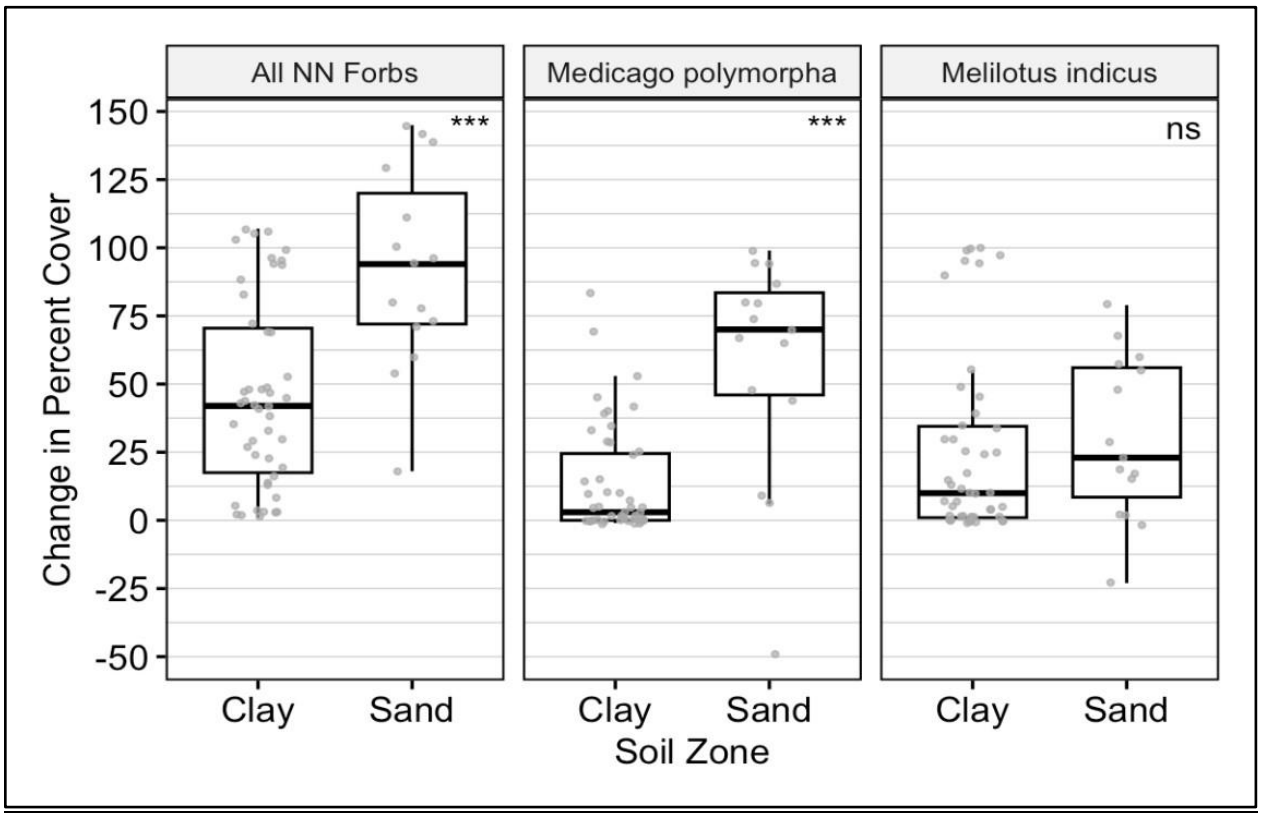


Figure 5: Boxplots of the change in percent cover of all nonnative forbs, *M. polymorpha*, and *M. indicus* from 2023 to 2024 in Clay and Sand soil zones. Change was calculated as the difference in cover in a given plot from 2023 to 2024. For clay and sand plots n = 47 and n = 15 respectively.

Seeding trials:

Of the 21 species seeded, 9 were found growing in 2024 (Table S2). Of the species seeded before the fire, only *Acmispon americanus* was found in 2024. It was found in both "Pre+Post" and "Post Only" seed plots. Therefore, we concluded that our "Pre+Post" treatment did not differ from our "Post Only" treatment. As a result, the below figures display "Seeded" plots as both treatments combined and do not delineate between seeding treatments.

Overall, in seeded plots, native forb richness was 3.5x higher in 2024 than in 2023 ($p<0.0001$), while richness remained roughly the same between years in unseeded plots ($p=0.46$, Fig. 6A). When looking at the average change in richness between years, seeded plots had significantly greater increases in richness (Fig. 6B). When separating by soil zone, clay plots saw significant increases in richness in both seeded ($p<0.0001$) and unseeded ($p<0.05$) plots (Fig. 6C). These relationships only grow stronger when including all "Grass Cover" plots as "Not

Seeded" clay plots (Fig. S1). Sand plots showed no significant changes in richness regardless of being seeded (p=0.19) or not (p=0.16, Fig. 6C). However, the change in richness across years in sand plots is significantly different as the seeded plots slightly increased while the unseeded plots slightly decreased in richness (Fig. 6D).

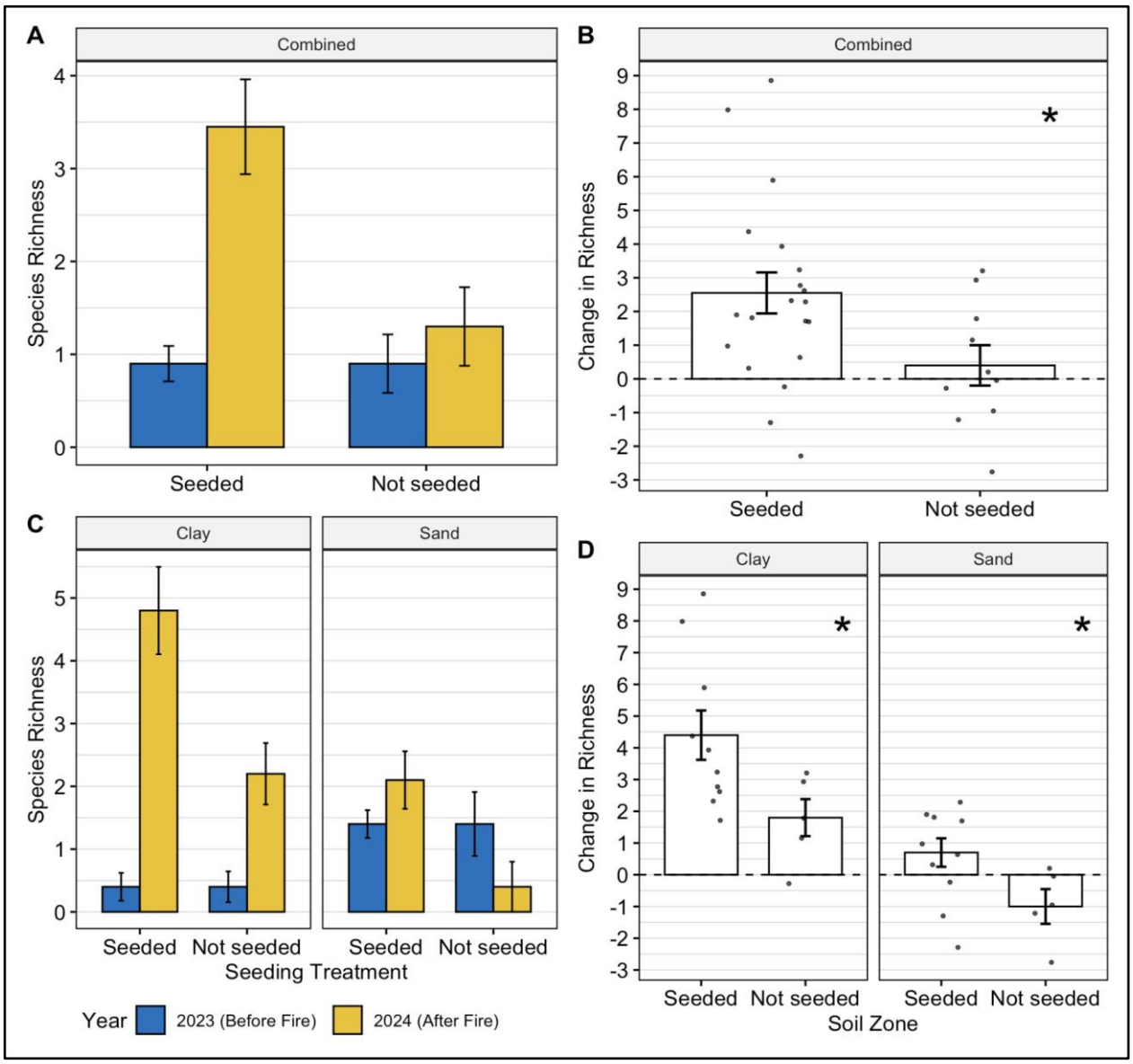


Figure 6: Average native forb species richness (A, C) and change in richness from 2023 to 2024 (B, D) in seed treatment plots regardless of soil (A, B) and split by soil zone (C, D). For panels A and B, n = 20 and n = 10 for "Seeded" and "Not seeded" plots respectively. For panels C and D, n = 10 and n = 5 for "Seeded" and "Not seeded" plots for each soil zone. Significance values indicate differences in the change of richness between seeded and unseeded plots (C, D).

Fire Data:

Soil surface temperatures varied across the burn site (Fig S3) but had no effect on the cover of exotic annual grasses (Fig. 7A), nonnative forb cover (Fig. 7B), or native forb richness (Fig. 7C). Changes in cover for *M. indicus* and *M. polymorpha* were similarly unaffected by max soil surface temperatures (Fig. S4). Subsurface temperatures did not correlate with change in native forb richess (Fig S6). Pre-fire biomass did not significantly correlate with belowground burn temperatures, but did correlate significantly with temperatures at soil surface (Fig. S7).

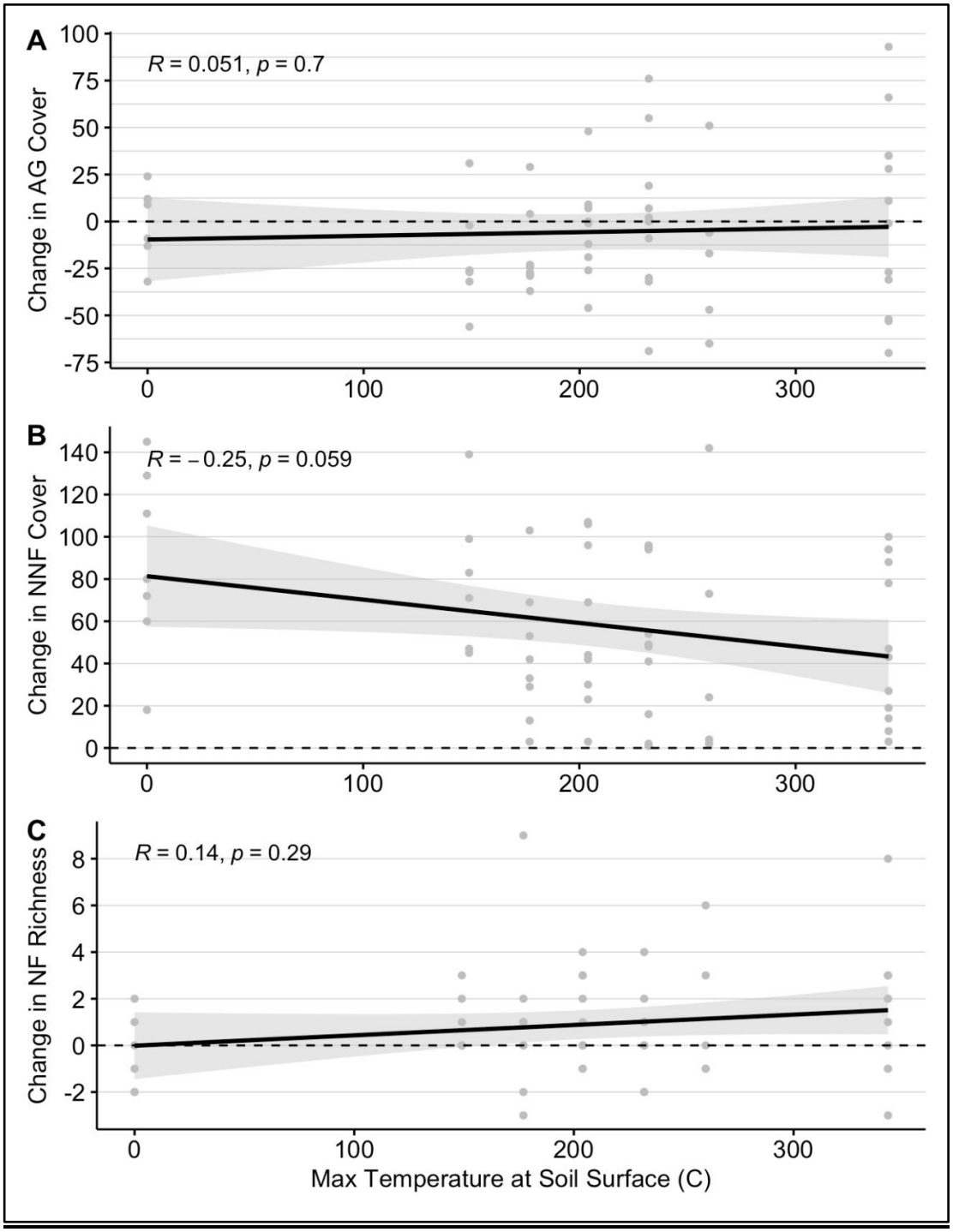


Figure 7: Influence of maximum recorded temperature at the soil surface on the change in A) cover of exotic annual grasses, B) cover of nonnative forbs, and C) species richness of native forbs.

Discussion

Vegetation Cover:

Unsurprisingly, *S. pulchra* cover was significantly lower after the burn because, as a perennial bunchgrass, most of its aboveground biomass was consumed by the fire. Studies suggest that *S. pulchra* will recover well after a few growing seasons post fire (Keeley et al. 2023). Future rounds of monitoring will be important to capture *S. pulchra* recovery.

The fire seemed to have a stabilizing effect on the cover or exotic annual grasses as their cover dropped where it was previously high and rose where it was previously low. This supports the idea that a quick, low intensity fire will not completely wipe out annual grasses, but can be used to knockback their populations. In our case, cover dropped by about 30% where annual grasses were previously dominant.

The expansion of nonnative forbs was the most concerning finding from this controlled burn. A conversion from grassland (native or otherwise) to forb-land could reduce the ecosystem services grasslands are known to provide (Veldman et al., 2015). *M. indicus* appears to have been released by the fire due to its larger increase in cover in burned plots compared to unburned plots. On the other hand, *M. polymorpha* increased across both burned and unburned plots, so this increase may not be directly linked to the fire. The sandier soils seem to be especially prone to invasion by nonnative forbs and are therefore most vulnerable to potential conversion.

While not statistically significant, *S. pulchra* cover appears to have been reduced in unburned plots which is likely, at least in part, due to increased competition from expanding nonnative forbs such as *M. polymorpha.* A similar explanation may be true for the apparent, yet not significant, decrease in exotic annual grass cover in unburned plots. Lack of statistical power makes it difficult to determine whether or not these trends are legitimate, but nonetheless, managers should continue to consider invasion from forb species like *M. polymorpha* a serious threat to grassland systems.

Seeding trials:

Lack of germination of the majority of seeded species was likely due to low seeding rates (Table S2). It is also possible some seeds were removed by seed predators or the seed was no longer viable due to being older. Seeding was successful and essential to increasing native forb richness across the site. This is likely due to the lack of a robust native seedbank due salvaged, degraded soils constituting the majority of the grassland site. Seeding success was largely driven by plots in the clay soil zone. This may be a result of the different species palettes seeded in the clay and sand zone due to the readiness of certain species to germinate, the freshness of the seeds, or something else unaccounted for. It is also possible that seed movement and removal was more prominent in the sandy zone where gopher activity was anecdotally more widespread. Alternatively, it is also

possible that the clay zone was more conducive to seed germination as 2 of the 6 species seeded into both zones and found in 2024 were only found in clay plots (Table S2).

Fire Data:

Controlled burning has been shown to eliminate annual grasses of certain species (DiTomaso et al, 2006). While annual grass cover was significantly reduced in some circumstances, it was far from completely removed. Multiple burns may be necessary to completely removing annual grasses as has been shown for certain annual grass species (DiTomaso et al. 2001, Miller et al. 1999). Higher fire temperatures at the soil surface had no effect on annual grass cover. While it could be the case that more seeds were killed by higher burn temperatures, there is likely a robust seedbank that allowed annual grasses to recruit regardless. Sub-surface temperature data show that temperatures did not reach the threshold (~150C) required to cause seedbank mortality for annual grasses (Levine et al., unpublished data). In fact, recorded subsurface temperatures positively correlated with annual grass cover (Fig. S5). Supplemental fuel additions and increased fire residence time are likely necessary to reach this threshold (Levine et al., unpublished data). Above and below ground temperatures also had no effect on native forb richness despite some native forbs being known “fire-followers”.

Conclusions

This study provides important information for the use of controlled burning in the management of California’s coastal grasslands. 1) Continued monitoring is required to assess the response of *S. pulchra*, the dominant native species on the site. 2) This burn effectively reduced the cover on nonnative annual grasses in areas where those grasses were dominant, but likely released them from competition where native grass previously dominated. This suggests a single controlled burn of this type should be only utilized in areas dominated by nonnative annual grasses. Multiple years of burning may be more appropriate for areas of high *S. pulchra* cover. 3) This fire released nonnative forbs which could pose a threat of converting away from a grassland system altogether. 4) Supplemental seeding, even at low rates, can be effective in increasing overall biodiversity by increasing native species richness. 5) Burn temperatures are likely ineffective in predicting plant species assemblages because of robust seedbanks that were likely unaffected by the quick, flashy fire behavior of a grassland setting.

Supplementary Tables and Figures

Table S1: Seeding trials and associated species

Species	Seed Collection Date	Soil Zone Seeded	Seeding Timing	Seeding Rate (#seeds/plot)
Acmispon americanus	NA	Both	Pre+Post	100
Acmispon glaber	2016	Sand	Pre+Post	100
Acmispon strigosis	2018	Both	Post Only	100
Calandrinia menziesii	2023	Both	Post Only	100
Cammisoniopsis micrantha	NA	Sand	Post Only	100
Clarkia purpurea	NA	Both	Post Only	100
Crypthantha clevlandii	2019	Sand	Post Only	100
Datura wrightii	NA	Clay	Post Only	100
Deinandra fasciculata	2023	Both	Post Only	100
Eschscholzia californica	2018	Both	Post Only	100
Lepidium nitidum	2017	Clay	Post Only	100
Lupinus bicolor	NA	Both	Pre+Post	100
Lupinus succulentus	NA	Both	Pre+Post	100
Madia sativa	2023	Both	Post Only	100
Navarettia squarrosa	2023	Clay	Post Only	100
Nuttallanthus texanus	2018	Sand	Post Only	100
Plantago erecta	2016	Clay	Post Only	100
Sanicula arguta	NA	Clay	Post Only	100
Sisyrinchium bellum	2019	Both	Pre+Post	200
Stebbinsoseris heterocarpa	2023	Clay	Post Only	100
Verbena lasiostachys	2020	Clay	Post Only	100

Table S2: Native forb species list. C = Clay soil zone, S = Sand soil zone, and B = Both soil zones. Count = number of plots in which a given species was observed. This table includes all burned plots (seed treatment and grass cover plots). *D. fasciculata* was the only seeded species found in both seeded and unseeded plots.

Species	Observations 2023 (Soil Zone - Count)	Observations 2024 (Soil Zone - Count)	Location Seeded
Acmispon americanus	NA	C - 8	Both
Ambrosia psilostachya	C - 1 S - 3	C - 1 S - 2	NA
Calandrinia menziesii	NA	C - 1	Both
Clarkia purpurea	NA	C - 5 S - 7	Both
Deinandra fasciculata	C - 5 S - 1	C - 6 S - 2	Both
Epilobium brachycarpum	C - 2 S - 1	C - 6 S - 1	NA
Erigeron canadensis	C - 9 S - 11	C - 14 S - 4	NA
Eschscholzia californica	NA	S - 1	Both
Lupinus succulentus	S - 1	NA	Both
Madia sativa	NA	C - 9 S - 6	Both
Navarretia squarrosa	NA	C - 5	Clay
Plantago erecta	NA	C - 5	Clay
Pseudognaphalium stramineum	S - 2	NA	NA
Sisyrinchium bellum	C - 1	NA	Both
Stebbinsoseris heterocarpa	NA	C - 10	Clay
Symphyotrichum subulatum var. parviflorum	C - 10 S - 2	C - 12	NA

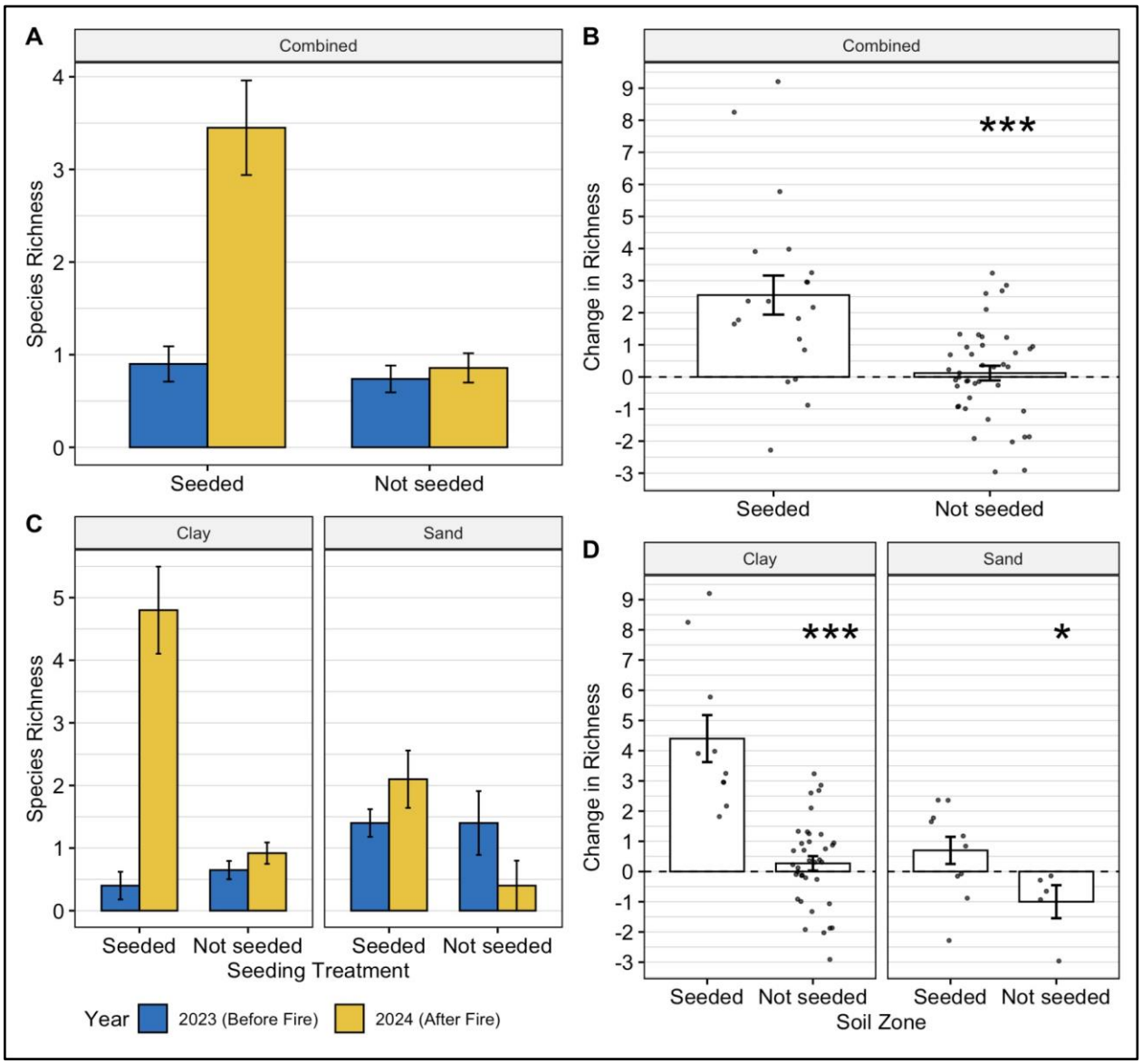


Figure S1: Average native forb species richness in seeded and unseeded plots in 2023 and 2024 across all seed treatment plots (A) and split by soil zone (B). This figure includes both seed treatment plots and grass cover plots. Therefore, in panels A and B, n = 20 for "Seeded" and n = 42 for "Not seeded." For panels C and D, n = 10 for "Seeded" in each soil zone, n = 5 for "Not seeded" x Sand, and n = 37 for "Not seeded x Clay"

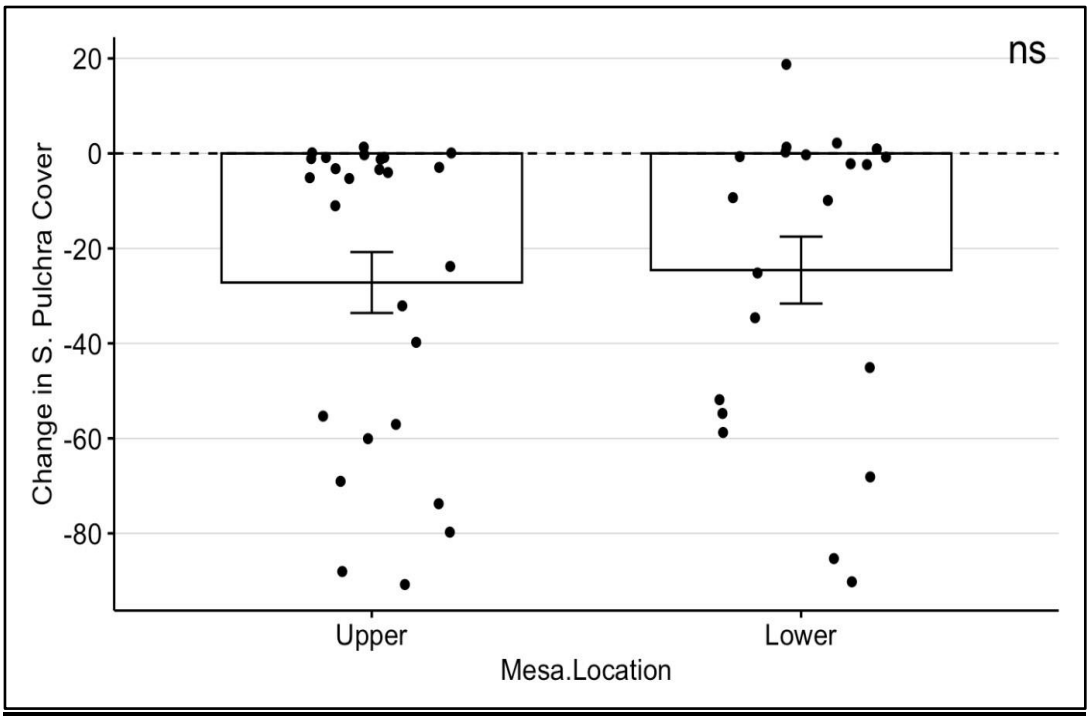


Figure S2: Change in *S. pulchra* cover from 2023 to 2024 by location on NCOS Mesa. The upper mesa experienced a flood in the winter of January of 2023.

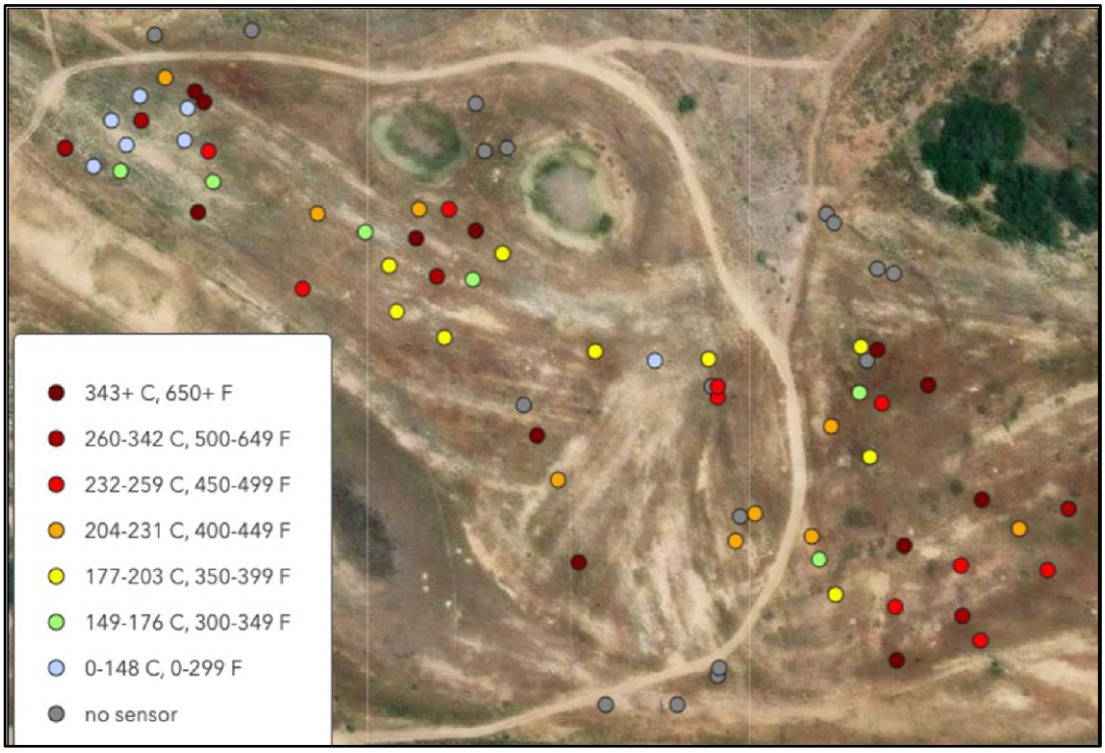


Figure S3: Soil surface temperatures at experimental plots across burn area

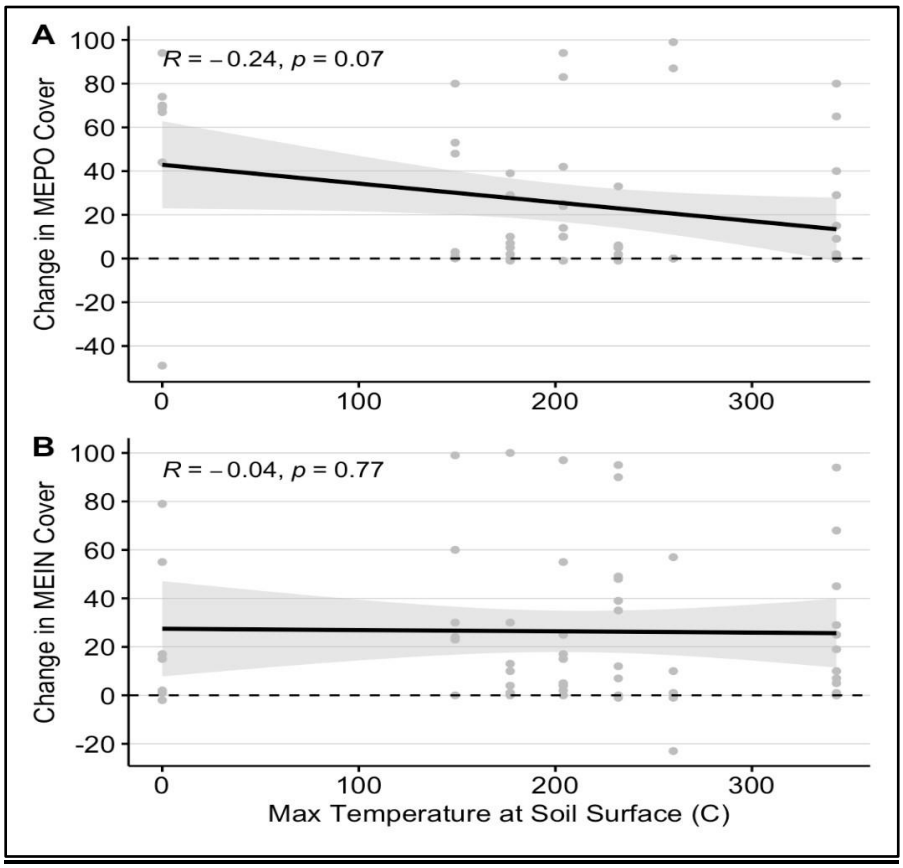


Figure S4: Change in cover of *M. polymorpha* (A) and *M. indicus* (B) by soil surface temperature during the fire.

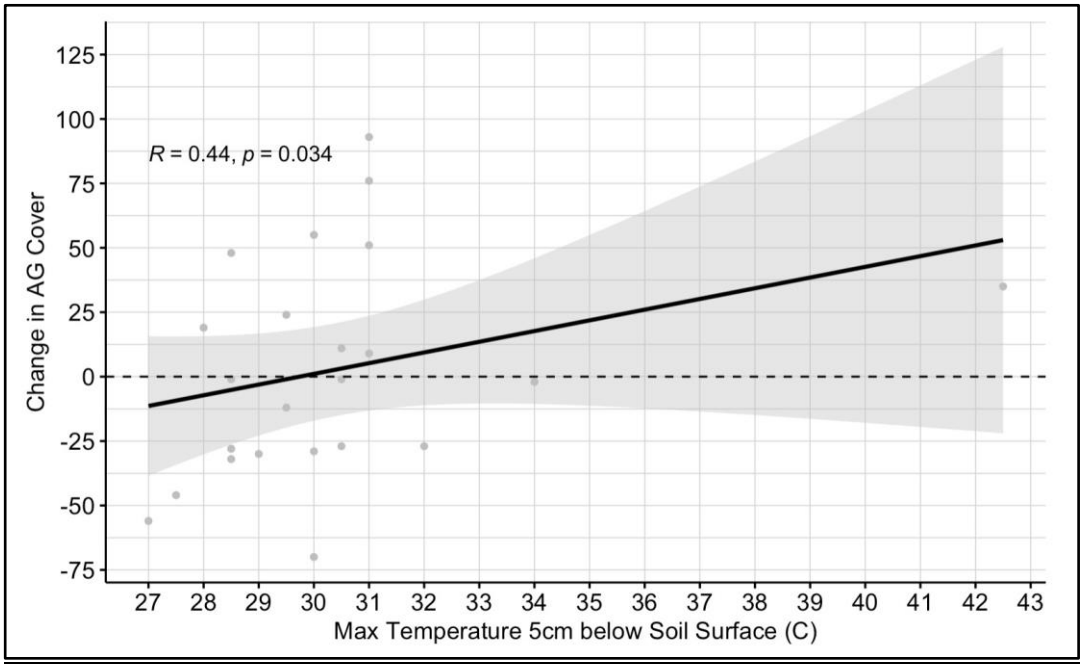


Figure S5: Change in exotic annual grass cover by soil temperature at 5 cm depth increase.

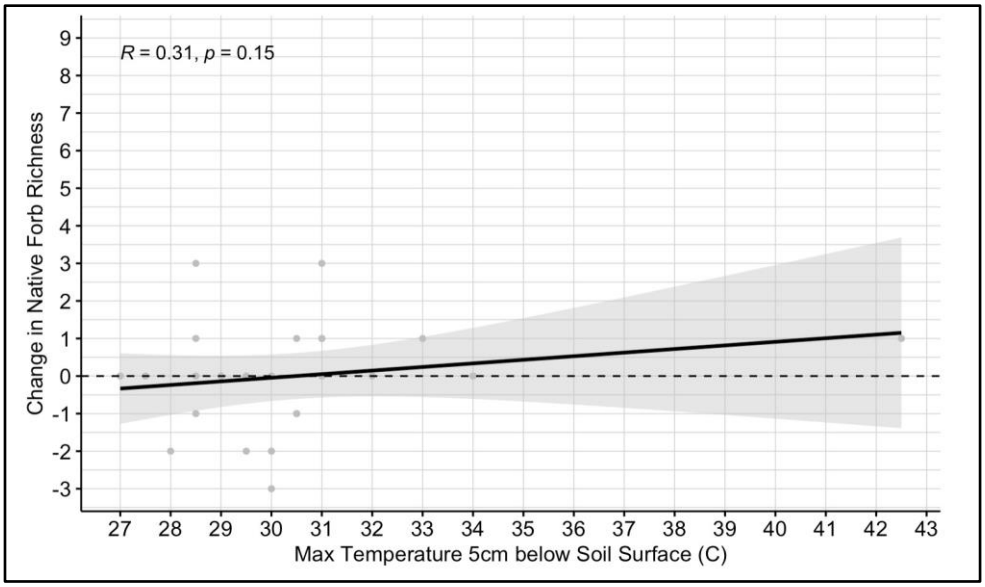


Figure S6: Change in native forb richness by soil temperature at 5 cm depth increase.

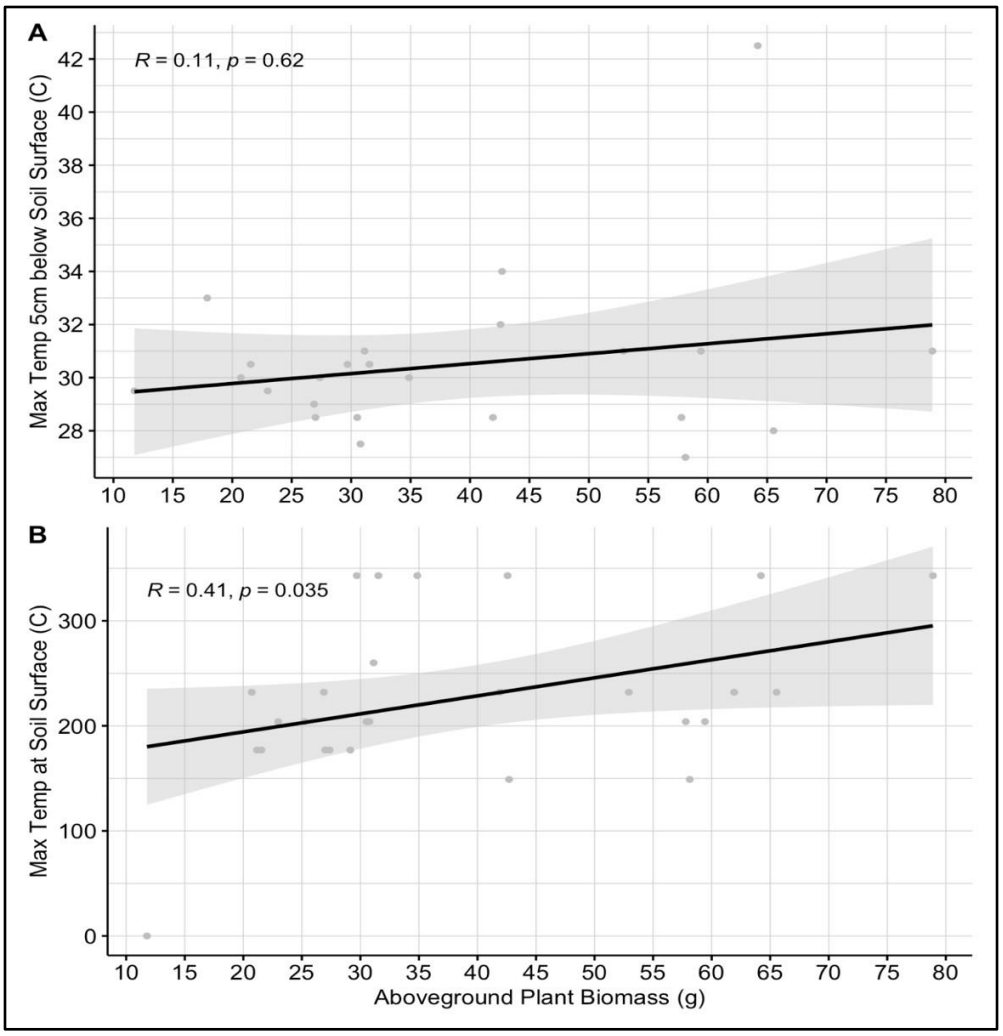


Figure S7: Pre-burn biomass and recorded fire temperatures below (A) and at (B) soil surface.

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