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Environmental baseline conditions of a five-pond restoration wetland during the first year in Moro Cojo Slough, California

GEOL 460 Spring 2022:
Andria Greene (Instructor)
Bibiana Carrazco
Andrea Cihasky
Mayra Cuevas-Cardenas
Katherine Day
Brian Eichel
Joshua Ewell
Kaitlynn Funsch
Valerie Li
Arioch M'Greené
Katherine Melchor
Jesse Rodriguez
Alyssa Schaer
Ryan Wells
Gretchen Wichman

Contact:
andipaigegreene@gmail.com

Executive Summary

Tottino II is a five-pond restored wetland in the Moro Cojo Slough that aims to improve water quality, native plant and animal diversity, and erosion in the agriculturally significant Salinas Valley watershed. The purpose of our research was to establish environmental baseline conditions on water chemistry, biologic communities (plants and invertebrates), and hydrology/morphology during the first year water was present. We classified all ponds at Tottino II as brackish (0.5-30 ppt) and recorded the highest average salinity at Pond 5 (15.34 ppt ± 7.02) and the lowest at Pond 3 (3.04 ppt ± 0.39). To understand nutrient dynamics inside and outside of the restoration site, we separated water quality samples into two categories: "Ponds" and "Inputs". We analyzed the highest nitrate+nitrite and ammonium levels in Moro Cojo (Input D) at 57.50 mg/L and 3.06 mg/L, respectively. Drainage from an agricultural sump-pump into the site (Input C) resulted in the highest phosphate recorded at 1.11 mg/L. Our team found the lowest average nutrient levels in the ponds, yet Pond 4 contained the highest average nitrate+nitrite concentration at 14.58 mg/L ± 2.7. In the ponds, our team measured average ammonium, phosphate, and urea levels ≤ 0.5 mg/L. Among nutrient species analyzed, we found average urea to be of least concern (Ponds: 0.12 mg/L ± 0.13, Inputs: 0.03 mg/L ± 0.02). From the 21 plant species identified, we found that 11 species are not listed on the National Wetland Plant List and that 29% of species identified are "Obligate" or "Facultative Wetland" (i.e., occurring in wetlands 67-99% of the time). Six of the identified plants fall under "Limited" or "Moderate" ranking under the California Invasive Plant Council with the remaining 26 plants lacking a rating. We found that open water had the greatest area coverage of 29.06% and *Salicornia pacifica* had the greatest vegetation coverage of 18.0%. Of 237 invertebrates sampled in the water column and in benthic mud, taxa known to occur on the site are *Cenocorixa, Chironomus, Daphniidae, Olivaceus,* and *Servilia.* We found no invertebrates in benthic samples. Pond 5 produced the highest count of invertebrates but the lowest species diversity. We found that taxa showed no preference between deep and shallow depths. Our team created the first elevation product for the site by combining drone and RTK-GNSS grid surveys. We found high bathymetric variation between the five ponds: Pond 3 is the shallowest with an average depth of 6 cm ± 8 and a surface area of 20,150 m^2 while Pond 2 is the deepest at 38 cm ± 43 and a surface area of 2,740 m^2, respectively. We observed that ponds with greater depth also have the smallest surface area and vice versa. Finally, we created a rating curve for the system. Since Tottino II underwent anthropogenic alteration from years of farming prior to restoration completion in 2019, we recommend seasonal monitoring (i.e., wet winter and dry summer) of the site for the standard monitoring duration of ten years to determine if anticipated ecosystem services prevail.

Acknowledgments

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1. Introduction

1.1. Challenges to the Salinas Valley Watershed and Near-Shore Environment

Located in Monterey County is a regionally significant agroecosystem– the Salinas Valley. Fertile floodplains bordering the Salinas River have undergone sweeping land use transformation from wetland to farmland in the last ~180 years (City of Salinas 2018), resulting in contemporary challenges to the surrounding watershed and near-shore environment:

Challenge 1: Water quality impairment

Within the Salinas Valley watershed lies the Moro Cojo Slough, a tidal creek that undergoes mixing of marine water from the Monterey Bay and runoff from two adjacent systems, the Old Salinas River and the Elkhorn Slough. Consequently, Moro Cojo faces water quality impairment ranging from nutrient pollution to high salinity. Hypoxic conditions and harmful algal blooms have persisted from nutrient loading (Khan and Muhammad 2014, Sánchez-Carrillo et al. 2010), where bright-green mats of *Ulva* sp. can be observed in both estuaries from California State Route 1. Sedimentation from tillage practices binds with pre-existing pollutants and fertilizers, further degrading water quality (e.g., DDT, PCBs, N, and P; Burton 2003, CRWQCB 2013, Lintern et al. 2020, Manuel 2014, Paerl et al. 2014). Increased tidal influence from the presence and maintenance of the Moss Landing Harbor opening, paired with evaporation has resulted in high concentration of salts that simplify local terrestrial-aquatic food webs (Mitsch and Gosselink 1986, Tweedley 2019).

Challenge 2: Community diversity

Tidal wetlands provide ecological connectivity between land and sea, supporting species diversity across complex trophic hierarchies (Valiela, Rutecki, and Fox 2004). Whether restored or native, wetlands have the potential to host rich communities composed of primary producers and consumers, making monitoring of organism abundance and diversity— especially those occupying low trophic levels— imperative. Aquatic invertebrates play a key role in the circulation of material and energy flow in wetlands and act as a food source to higher trophic organisms (e.g., avian and fish communities). A decrease in invertebrate abundance may create trophic cascades and impact the overall biodiversity and ecology of entire ecosystems, like wetlands (Li et. al 2021, Stephenson et al. 2020).

Challenge 3: Harbor-induced erosion

Construction of the Moss Landing Harbor seventy-five years ago led to a permanent connection between the Elkhorn Slough and the Pacific Ocean, allowing year-round tidal influence into a historically slow-meandering and seasonally connected “slough” (Caffrey 2002). This permanent

opening has increased the tidal prism (i.e., total volume of water exchanged over a 24-hr tidal cycle), decreased residence times of hydrologically connected waters, and led to increased erosion of vegetated marshes and mudflats (Elkhorn Slough Tidal Wetland Project Team 2007). Broenkow and Breaker (2019) quantified a variable plume of sediment originating from the muddy banks of present inland wetlands extending as far out as three kilometers offshore. Efforts to reduce sediment loss and facilitate brackish-to-freshwater habitats within the Elkhorn and Moro Cojo sloughs include the development of water impoundments that spread polluted runoff across multiple hectares of permanent and seasonal wetlands and ponds (Burton 2003, CCWG 2018).

1.2. Goals of Restoration at Tottino II in the Moro Cojo Slough

In January 2017, Coastal Conservation and Research, Inc. (CCR) and the Central Coast Wetlands Group (CCWG) received funding to restore a 35-acre reclaimed wetland in the Moro Cojo Slough along the Southern Pacific rail tracks (Fig. 1). Designs of the Hugo Tottino Wetland Restoration Project (Tottino II) were completed by Water Ways Consulting Inc. in September 2019, while major earth moving was completed by Durden Construction in August 2021. The restored wetland filled with water from precipitation in January 2021. Under the Ocean Protection Council grant, the project followed three primary goals (CCWG 2018):

Goal 1: Water quality improvement

The site acts as a treatment wetland from three main sources– the project has reestablished hydrologic connectivity with the Moro Cojo Slough at two points (Fig. 1. Inputs A and C) and captures point-source irrigation drainage from adjacent agricultural fields (Fig. 1. Inputs B and D). By February 2023, CCWG plans to install and disperse all of the 17,584 plants and 104.5 pounds of native seed to the restoration site (A-1; Mason 2022). Wetland plants improve water chemistry by absorbing nutrients, metals, and other contaminants (Dybiec et al. 2021). Nutrients will be absorbed as plant biomass increases and phosphorus-bound-sediment will be captured in the series of ponds and channels (Fisher and Acreman 2004). Furthermore, microbes in anaerobic wetland soil will facilitate nitrogen removal via biogeochemical pathways (denitrification and anammox) to reduce nitrogen loads (Diaz et al. 2012, Poe et al. 2003). Diversity in hydrologic flow, the establishment of new plant communities, and wetland soil formation at Tottino II will mediate eutrophic conditions endemic to the Moro Cojo Slough.

Goal 2: Habitat enhancement

Habitat creation and enhancement (i.e., brackish-to-fresh marsh) provides a space for more biota to thrive, increasing Tottino II's ecosystem services (CCWG 2018). The reintroduction of native plant species and development of adequate conditions for aquatic invertebrates will contribute to restoring a biologically functional wetland (Galatowitsch et. al 2021). Since wetland plants

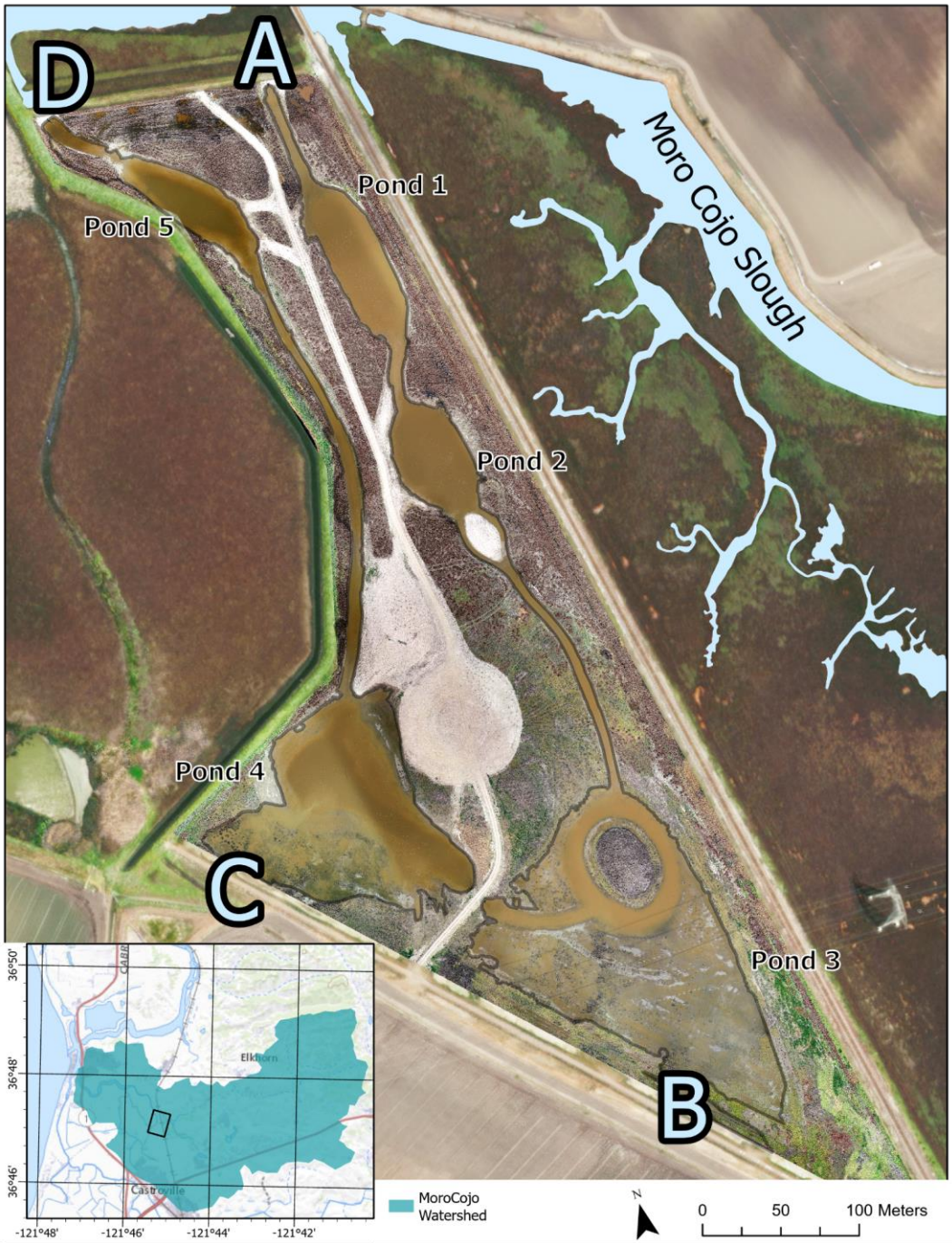


Figure 1. Tottino II in Moro Cojo Slough, California, is a five-pond constructed wetland system with the goal of providing a brackish-to-freshwater refuge within the Moro Cojo Slough watershed. This orthomosaic was created using drone imagery captured on February 11, 2022 (see Section 2.2). Surface water inputs may enter the site during flood events from the Moro Cojo (A), via sump-pump activation from adjacent agricultural ditches (B and C), and/or from flood tides in the Moro Cojo Slough (D).

provide critical habitat to other taxonomic groups (e.g., bacteria, invertebrates, fish, and birds), the composition of a native plant community influences the overall diversity of the wetland (Cronk and Fennessy 2009). If present conditions (i.e., low salinity, high nutrient concentration) persist at Tottino II, the potential for microbial growth is maximized and a positive relationship may form between microbial health and total dissolved nitrogen (Batanero et all 2019). As low-trophic communities are established and consecutively surveyed, habitat complexity may flourish from the soil upwards.

Goal 3: Flood water retention

The five-pond system was designed as a reservoir for episodic flood events that, over time, may reduce the magnitude of flood events through increased floodplain access by flood waters (CCWG 2018). Input A (Fig. 1) was designed to allow freshwater to spill in from the Moro Cojo Slough during precipitation events, Inputs B and C allow the addition of water from agricultural sump pumps (located at Ponds 3 and 4, respectively), and Input D is in constant connection with the Moro Cojo Slough. Situated in topographic lows, wetlands buffer against hydrologic events (i.e., rainfall, tidal storm surges, anthropogenic inputs, sea level rise).

The purpose of our study is to assemble environmental baseline data on the goals previously outlined and to monitor the progress of the Tottino II Restoration Project in the first year after reaching hydrologic capacity (i.e., constructed ponds and channels are full of surface water). To do this, our team focused data collection efforts on *Water Quality*, *Biology (Vegetation and Invertebrates)*, and *Morphology and Hydrology*.

2. Methods

Our team collected data during four field visits in spring 2022 on February 11th and 25th and on March 4th and 25th. The field team consisted of 15 people and each visit was approximately four hours.

2.1. Water Quality

In situ parameters at 45 locations

Our team collected in-situ water quality parameters (salinity, electrical conductivity [EC], temperature, and dissolved oxygen [DO]) with a YSI multiprobe at 45 locations previously sampled by CCWG in winter 2022.

Surface water nutrient collection and analysis

We collected nutrient samples from various water sources inside and outside of the site: each of the five ponds, the Moro Cojo Slough channel, sump-pump ditches, and irrigation water from sump-pump ditches when the culverts were flowing. To collect each nutrient sample, we filled a 100 mL acid-washed syringe from the surface water (five ponds and Moro Cojo channel) and from a ~1 L sample container at the flowing culverts. Next, we filtered the syringe water into a 50 mL acid-washed falcon tube using a syringe-attachable PES filter disk (0.2 µm). We then stored filtered water samples in a cooler with ice for transport until freezing at 0°C. We targeted NO_3^- + NO_2^- (nitrate + nitrite), NH_4^+ (ammonium), CH_4N_2O (urea), and PO_4 (phosphate) species to detect nutrient runoff from fertilizer application in the surrounding watershed. Our team analyzed these nutrient species using a Lachat Flow Injection Analyzer (Wendt 2000) at Moss Landing Marine Laboratory.

2.2. Biology: Vegetation and Invertebrates

Identifying and classifying vegetation

We conducted qualitative field surveys to identify vegetative communities at the site, omitting new and/or experimental woody plantings on upland berms (i.e., *Quercus agrifolia*). To classify plant species according to wetland indicator status, we used the National Wetland Plant List (NWPL 2021). Additionally, we classified plants according to their potential threat to native California wildlands using the invasive species inventory created by the California Invasive Plant Council (Cal-IPC 2022).

Calculating percent cover with Imagery Analyst

Our team used the digital surface model (DSM) from drone photogrammetry (see Section 2.3 *Producing drone photogrammetry*) to ground-truth plants in areas with high plant diversity and

abundance. To estimate percent cover of seven common plants, we used a red-blue-green (RGB) raster paired with the Classification Tools in ArcGIS Pro (v.2.9.2). First, we created a classification schema using the ground-truthing data. Next, we created training samples for machine learning to yield a classified raster. Then, the "Summarize Categorical Raster" tool was used to obtain pixel count per plant species and major features (i.e., dirt roads and water bodies). We multiplied pixel count by pixel cell size squared to find the area of each feature and summed all feature areas to find the total area. To calculate percent cover, we divided the area of each feature by the total area and multiplied it by 100.

Collecting free-swimming and benthic invertebrates

At each pond, we collected free swimming invertebrates at ten random locations (n = 50) and benthic invertebrates at four random locations (n = 20). We divided the sampled groups– free swimming and benthic– into "deep" and "shallow" locations qualitatively, with respect to each pond's depth (Fig. 2). For free swimming samples, we used dip nets to capture invertebrates along a 1 m sweep near the pond bottom. We carefully removed living invertebrates with tweezers and placed them into labeled 500 mL containers with in situ water. To collect benthic samples, we used a shovel to excavate approximately 100 cm^3 of mud from the pond bottom and placed the sample into a label Ziplock bag. We stored samples in a 4.5°C refrigerator after collection and until processing.

Processing and identifying invertebrates

We processed free swimming invertebrate samples by transferring organisms into a labeled 500 mL container using tweezers and/or a pipette and adding 70% ethanol. Due to the high number of *Daphniidae*, these organisms were discarded to permit analysis during the limited duration of this study. We processed benthic invertebrates by rinsing out fine clay particles using water over a set of sieves (150 µm-25 mm). If invertebrates were found, we stored the organisms in a labeled 500 mL container with 70% ethanol. Finally, we sorted– identified to taxonomic order (Fitzpatrick 1983, Chu and Cutkomp 1992) and counted– invertebrate samples under a Nikon SMX645 stereo microscope.

Ecological statistics on invertebrates

To assess invertebrate abundance, richness, and diversity, we applied the Shannon-Weiner Diversity and Simpson Diversity indices in R Studio (R Studio 2020). The Shannon-Weiner index has been used to estimate genetic diversity through counts of species and other taxonomic levels (Konopinski 2020).

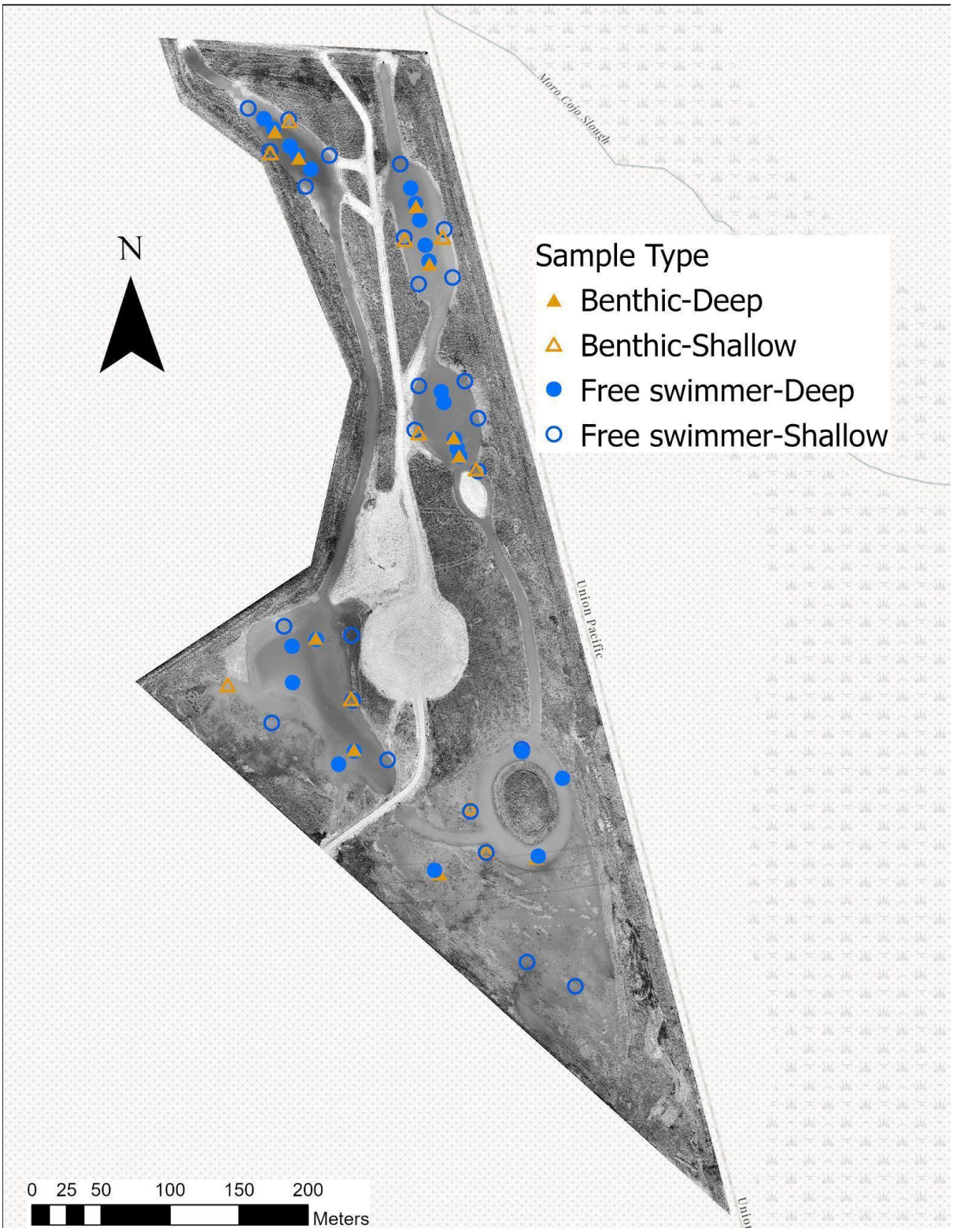


Figure 2. Invertebrate sampling locations for benthic and free-swimmer samples.

2.3. Morphology and Hydrology

Producing drone photogrammetry

On February 11, 2022, we conducted an aerial survey of the site using a DJI Phantom 4 with a Real Time Kinematics (RTK) Global Positioning System (GPS) at an altitude of 65 m above ground level. At this altitude, the drone's 20-megapixel camera yielded imagery with a Ground Sampling Distance of 2.00 cm. The pilot designed the flight line spacing, aircraft speed, and camera trigger rate to produce images with 80% fore-aft and 70% side overlap for use in Structure from Motion photogrammetry processing. We used six benchmarks as checkpoints, each shot with an Emlid Reach RS2 RTK Global Navigation Satellite System (GNSS) capable of 0.02 m spatial accuracy. Of the six benchmarks surveyed, we utilized five as checkpoints to assess the spatial accuracy of the processed imagery. We recorded all shots using the North American Datum (NAD) 1983 (2011) Universal Transverse Mercator (UTM) Zone 10N and North American Vertical Datum (NAVD) 1988 (Meters) Height Geoid based on the GEOID12B model. The California State University Monterey Bay's GNSS base station (15 km from the study site) provided RTK corrections via Networked Transport of RTCM via Internet Protocol (NTRIP) for both the drone and the Emlid Reach RS2 GNSS units. We processed drone imagery using Pix4D software and imported the XYZ coordinates for the benchmark target centers into Pix4D, manually marking pixels for the target centers in eight images.

Developing a 10 x 10 m survey grid

We used drone photogrammetry to capture elevation change across the unsubmerged portions of the site. To capture submerged topography, we used a grid-style survey technique to measure equal distance bathymetry. Using the computed orthomosaic in ArcGIS Pro, we traced surface water features using a polygon feature class and generated a 10 square meter grid inside the polygon. We computed center points for each grid square. Next, we published these feature layers into ArcGIS Online, where they could be accessed in the field using ArcGIS Field Maps (A-2).

Collecting data using "Emelid Rods"

To capture changes in elevation across the submerged landscape (i.e., areas that cannot be measured by drone), we collected XYZ coordinate data using Emlid Reach RS2 RTK GNSS receivers using the datum outline in Section 2.2. Our team built "Emelid Rods" by mounting receivers onto the top of a two meter long (graduated in centimeters) 1-inch diameter PVC pipe, with a 6-inch diameter, rigid, perforated plastic screen attached to the bottom to prevent the instrument from sinking into the unconsolidated muddy ponds. We used the ArcGIS Field Maps application on a tablet and the Emlid Rods to navigate within 10 cm of each grid center point. At the center point, we collected GNSS data using the Emlid ReachView3 application. Each shot was taken over a five second interval and averaged to generate position. During this time, we measured water depth

from the Emelid Rod. Additionally, our team took GNSS shots at five culverts (inside, bottom, on both sides) located at Pond 1, Pond 5, and the channel between Ponds 4 and 5. We also took GNSS shots at each of the site's three water level loggers located in Ponds 1, 4, and 5.

Post-processing bathymetric and topographic data

Our team imported coordinate data recorded in the field into ArcGis Pro and displayed it as X, Y, Z points projected using the datum outlined in Section 2.2. We applied Inverse Distance Weighted (IDW) interpolation to find elevation across the entire site and re-sampled the elevation raster into 0.02 m grids to match the higher spatial accuracy of the drone acquired Digital Surface Model (DSM). Next, we mosaicked the interpolated elevation raster (i.e., representing the bathymetry of the submerged ponds) on top of the DSM (i.e., representing the land topography), giving us total topographic coverage across the site.

Using the mosaicked elevation product, we produced a hillshade to visualize site-wide topographic range. In ArcGIS Pro Model Builder, we ran the geoprocessing tool "Surface Volume" multiple times to calculate volume under measured spill-point and fixed integer elevations of 0.12 m. These elevations represent stage calculated above base bathymetry.

Modeling system volume using a rating curve

We imported water surface elevations (i.e., stage, m) and volumes (m^3) generated by the ArcGIS "Surface Volume" model into Microsoft Excel. To create a rating curve of the system we applied linear and polynomial regressions, respectively, to relate water surface elevation (i.e., stage) and volume using a sample size of thirty (n = 30). Additionally, we used the elevation product raster as an "Elevation Source" in ArcGIS Pro to extrapolate longitudinal elevation profiles for pond morphologic analysis.

Exploring water level at three locations

Staff from CCWG downloaded water level data from three Rugged TROLL 100 Data Loggers at Ponds 1, 4, and 5. We imported water level (m) and date-time into R Studio to create a timeseries of the water level at each pond from January 21 to April 28.

Creating a 3D model using GPS data

We used R Studio and the "Plotly" package (Sievert 2020) to generate a 3D scatter plot using the Master GPS file containing location data– easting, northing, and elevation set to X, Y, and Z respectively– taken with the Emelid Rods. We plotted the data as a "scattered" trace where we constrained the ranges of the X and Y axes to display the full range of the data without excess (i.e., x-axis [611000, 611390], y-axis [40715000, 4072200]) and we expanded the z axis [-4, 4]) to better reflect the elevation to area ratio (A-3).

3. Results

3.1. Water Quality

In-situ parameters

We found similar average salinity between winter and spring at 8.5 ± 6.7 ppt and 8.2 ± 5.9 ppt, respectively (Fig. 3). Of the 45 points collected, we recorded the highest salinity values closest to the Moro Cojo Slough at Ponds 1 and 5 (Fig. 4). All measured water quality parameters (salinity, DO, EC, and temperature) for ponds and inputs are presented in Figure 5, followed by coefficient of variations for each parameter (CV; Table 1).

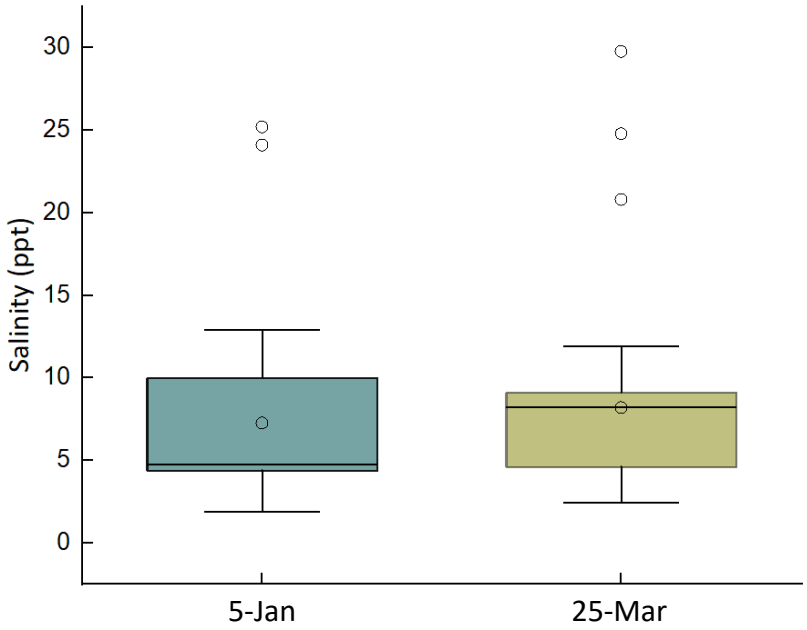


Figure 3. Average salinity in winter (Jan 5: median 4.83 ppt) and spring (Mar 25: median 8.2 ppt) at 45 locations. Mason Cole of CCWG collected data in winter.

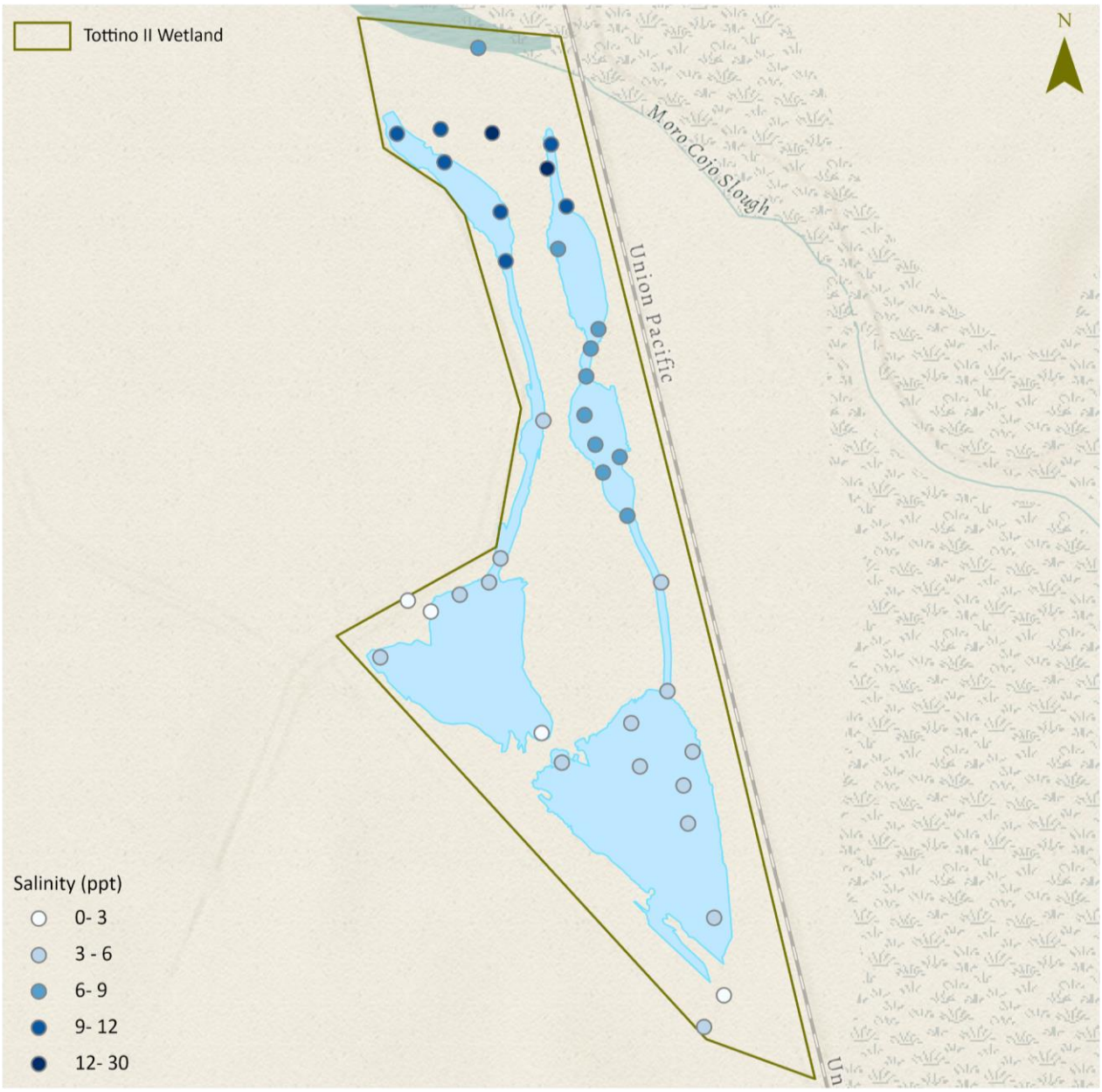


Figure 4. Salinity concentrations at 45 sampling locations across Tottino II in spring 2022.

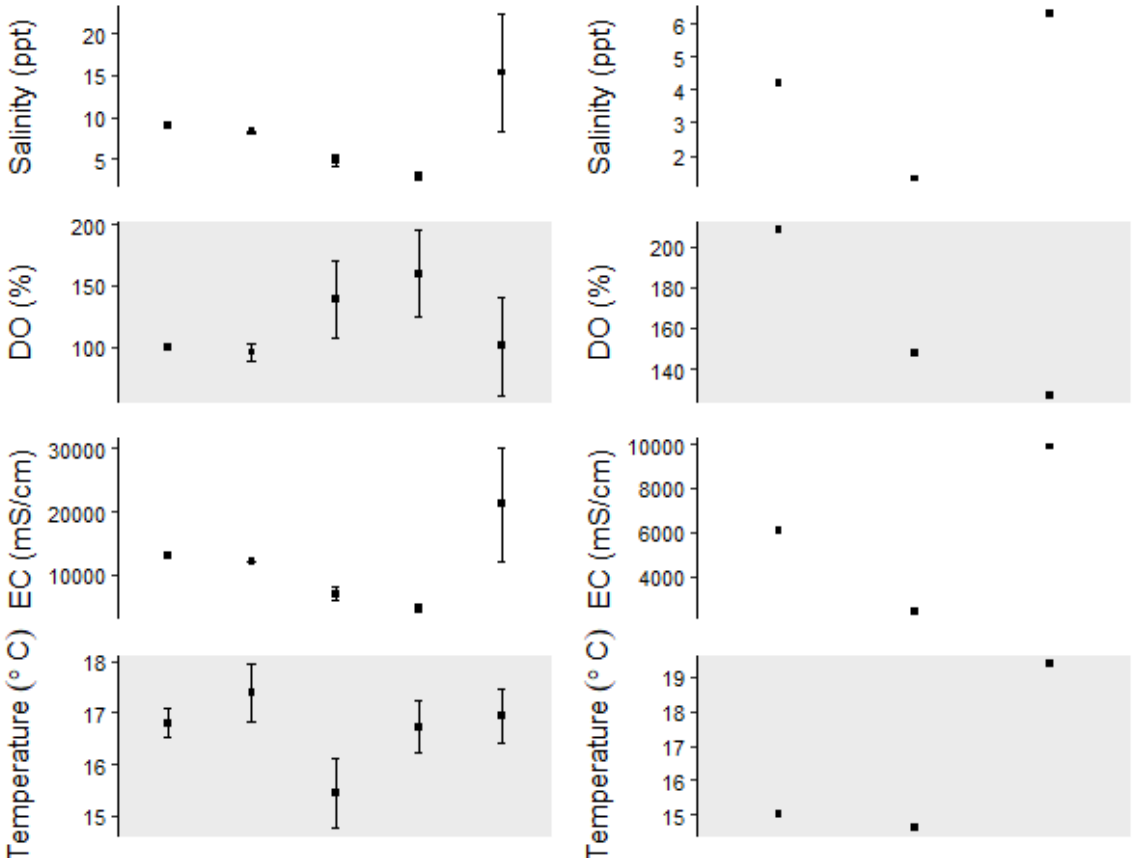


Figure 5. Water quality parameter results of ponds (left) and inputs (right) at the 45 sampling locations. Error bars represent standard deviation. Input B corresponds to Figure 1 and Ag. Ditch represents the source of Input B.

Table 1. Coefficient of variation (%) for water quality parameters of ponds and inputs. Input B corresponds to Figure 1 and Ag. Ditch represents the source of Input B.

Location	Salinity (ppt)	DO (mg/L)	EC (µs/cm)	Temperature (°C)
		Ponds		
Pond 1	1	1	0	2
Pond 2	1	11	1	3
Pond 3	14	21	17	4
Pond 4	13	21	13	3
Pond 5	46	45	43	3
		Inputs		
Input B	10	0	10	10
Moro Cojo	30	20	10	20
Ag. Ditch	20	30	30	0

Nutrients

Three days of nutrient results for ponds are presented in Figure 6 and inputs are presented in Figure 7, alongside a precipitation event of 2.4 mm on March 4. Among ponds, we measured the highest concentrations of nitrate+nitrite and ammonium at Pond 4 (17.6 mg/L) and at Pond 3 (1.43 mg/L), respectively (Fig. 6). Our team recorded the highest nitrate+nitrite concentration of 65.04 mg/L at Input B, followed by 57.5 mg/L at Input D (Fig. 7). We found that some inputs yielded the highest average nitrate+nitrite, ammonium, and phosphate concentrations over ponds (Fig. 8), but urea values were highest at ponds (see Pond 4 in Fig. 8).

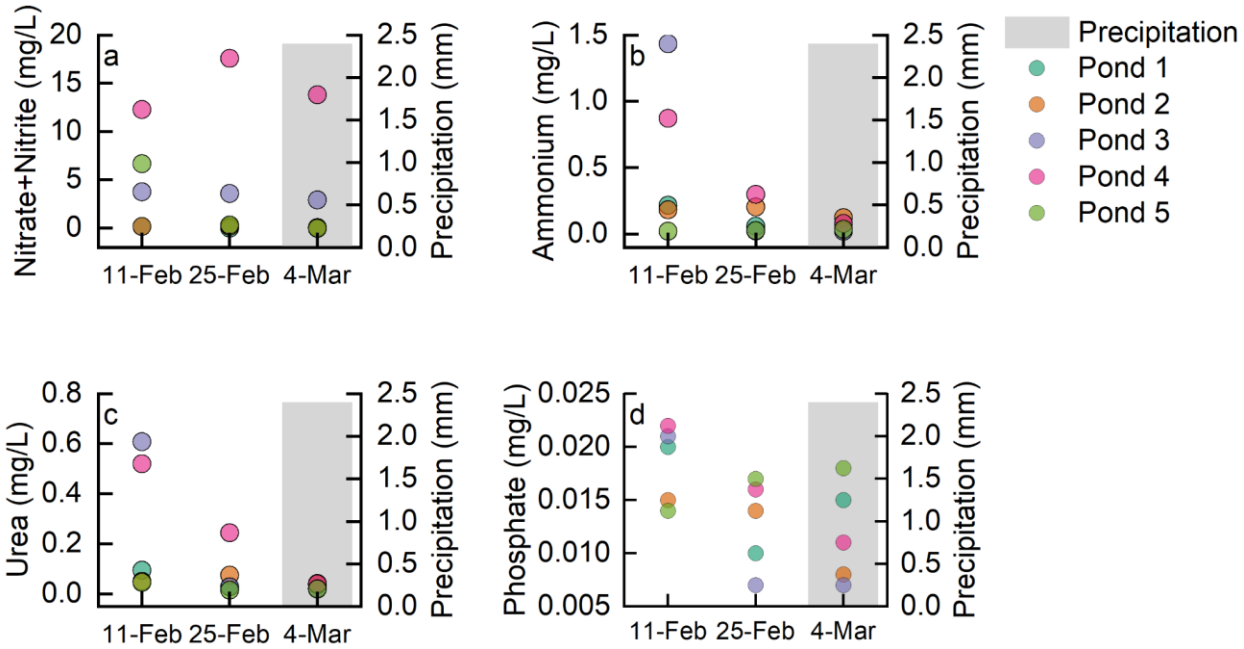


Figure 6. Pond water nutrient concentrations for combined nitrate and nitrite, ammonium, urea, and phosphate across three sampling dates in February and March 2022.

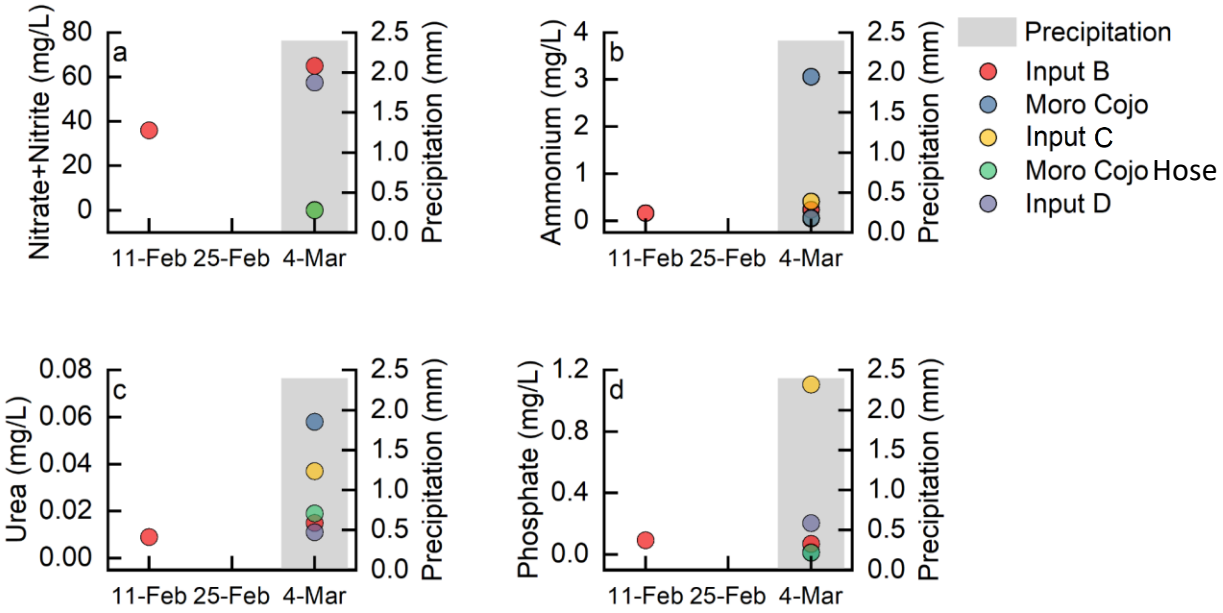


Figure 7. Input water nutrient concentrations for combined nitrate and nitrite, ammonium, urea, and phosphate across three sampling dates in February and March 2022. Input samples were collected when water was flowing into the site. N.b. Inputs B, C, and D corresponds to Figure 1 while Moro Cojo Hose was an additional sample taken near Pond 5 and Input D.

Table 2. Averages and standard deviations for nutrients of ponds and inputs. N.b. Inputs B, C, and D correspond to Figure 1 while Moro Cojo Culvert was an additional sample taken near Pond 5 and Input D.

Location	Nitrite+Nitrite (mg/L)	Ammonium (mg/L)	Urea (mg/L)	Phosphate (mg/L)
		Ponds		
Pond 1	0.07 ± 0.10	0.12 ± 0.09	0.05 ± 0.04	0.02 ± 0.01
Pond 2	0.16 ± 0.07	0.17 ± 0.04	0.06 ± 0.02	0.01 ± 0.00
Pond 3	3.45 ± 0.44	0.50 ± 0.81	0.22 ± 0.34	0.01 ± 0.01
Pond 4	14.58 ± 2.73	0.42 ± 0.41	0.27 ± 0.24	0.02 ± 0.01
Pond 5	2.35 ± 3.77	0.03 ± 0.01	0.03 ± 0.02	0.02 ± 0.00
		Inputs		
Input B	50.52 ± 20.53	0.20 ± 0.05	0.01 ± 0.00	0.08 ± 0.02
Moro Cojo*	0.12	3.06	0.06	0.02
Input C*	0.06	0.41	0.04	1.11
Moro Cojo Hose*	0.00	0.05	0.02	0.01
Input D*	57.50	0.06	0.01	0.20

*Sampling occurred on March 4, only.

3.2. Biology: Vegetation and Invertebrates

Vegetation

Of the 21 plant species identified at the site, we found that 48% were classified by their USACE-designated occurrence in wetlands (Tables 3 and 4). We identified two obligate wetland species – or those occurring in wetlands 99% of time – *Cotula coronopifolia* (brass buttons) and *Spergularia marina* (sand spurry; Table 3). We found that 29% of plant species identified pose a limited to moderate threat to California's natural areas (Table 3 and 5). The two moderately rated species included *Conium maculatum* (poison hemlock) and *Brassica nigra* (black mustard; Table 3).

Table 3. Plant species identified at the site by scientific name, USACE wetland indicator rating, and CAL-IPC rating.

Scientific Name	USACE Wetland Indicator Code	CAL-IPC Rating
Salicornia pacifica	N/A	N/A
Distichlis spicata	FACW	N/A
Atriplex prostrata	FAC	N/A
Polypogon monspeliensis	FACW	Limited
Rumex crispus	FAC	Limited
Frankenia salina	FACW	N/A
Conium maculatum	FAC	Moderate
Cotula coronopifolia	OBL	Limited
Trifolium microdon	N/A	N/A
Raphanus sativus	N/A	Limited
Spergularia marina	OBL	N/A
Brassica nigra	FACU	Moderate
Baccharis pilularis	N/A	N/A
Grindelia hirsutula	FACW	N/A
Limonium californica	N/A	N/A
Artemisia californica	N/A	N/A
Extriplex californica	N/A	N/A
Typha latifolia	N/A	N/A
Diplacus aurantiacus	N/A	N/A
Melilotus indicus	N/A	N/A
Lemnoideae sp.	N/A	N/A

Table 4. Explanation of USACE Wetland Indicator Codes.

Code	Rating	Occurrence in Wetlands (%)
OBL	Obligate Wetland	99
FACW	Facultative Wetland	67-99
FAC	Facultative	34-66
FACU	Facultative Upland	1-33
UPL	Upland	1

Table 5. Explanation of CAL-IPC Ratings.

Rating	Explanation
High	Severe ecological impact
Moderate	Substantial and apparent, but generally not severe ecological impact
Limited	Invasive, but ecological impacts are minor (not enough information)
Alert	High to moderate impact (limited distribution in California)
Watch	Pose a high risk of becoming invasive in the future

The total area of Tottino II is 35 acres, where water covered 29% of the total area and living vegetation covered 48% in spring 2022 (Table 6). The most distinguished features from a bird's eye view are illustrated in Figure 8. We found that *Salicornia pacifica* (common pickleweed) was the second most prominent feature and open ground the third at 18% and 15% cover, respectively (Table 6). Plant species with 10 percent cover or less included *Atriplex prostrata* (fat hen), *Conium maculatum* (posion hemlock), *Cotula coronopifolia* (brass buttoms), *Trifolium microdon* (thimble clover), *Spergularia marina* (sand spurry), and *Extriplex californica* (saltbush; Table 6).

Table 6. List of common features (water, open ground, vegetative), areas, and percent covers at the site.

Feature	Area (ac.)	Cover (%)
Water	10.2	29.06
Open ground	5.5	15.81
Senesced vegetation	2.4	6.77
Salicornia pacifica	6.3	18.00
Atriplex prostrata	3.6	10.38
Conium maculatum	1.3	3.83
Cotula coronopifolia	1.3	3.80
Trifolium microdon	0.9	2.49
Spergularia marina	1.0	2.82
Extriplex californica	2.5	7.04
Total	35	100

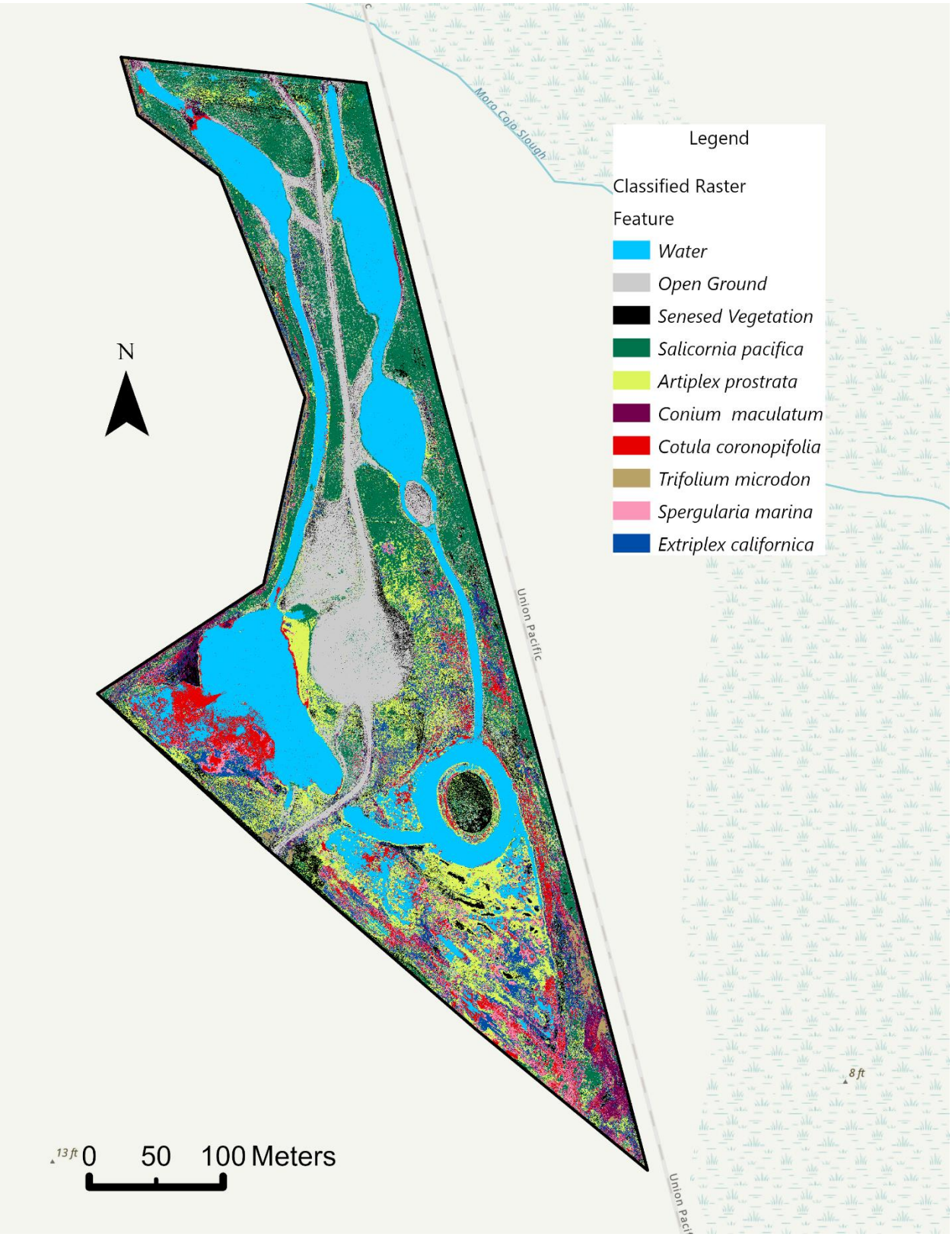


Figure 8. Supervised pixel-based classified raster representative of common features (water, open ground, vegetative) at Tottino II.

Invertebrates

We found no invertebrates in the benthic mud samples; so, free-swimming invertebrates became the focus of our identification. Our team found five families across three animal classes: brachiopoda, insecta, and gastropoda (Table 7). We grouped 237 invertebrates according to a final identification, two of which included genus and species (Fig. 9 and 10). *Cenocorixa* accounted for 38% of all invertebrates identified and only 5% belonged to *Melampus olivaceus* (Fig. 10). Grouped by sample location in Figure 11 and 12, we found *Melampus olivaceus* exclusively in Pond 1 and *Crocothemis servilia* exclusively in Pond 2 and that Pond 5 contained the greatest number of invertebrates at the site.

Table 7. Invertebrate identification grouped by class, order, family, genus, species, and final identification.

Class	Order	Family	Genus	Species	Final Identification
Brachiopoda	Anomopoda	Daphniidae			*Daphniidae*
Gastropoda	Ellobiida	Ellobiidae	Melampus	Olivaceus	*Melampus olivaceus*
Insecta	Diptera	Chironomidae	Chironomus		*Chironomus*
	Hemiptera	Corixidae	Cenocorixa		*Cenocorixa*
	Odonata	Libelluidae	Crocothemis	Servilia	*Crocothemis servilia*

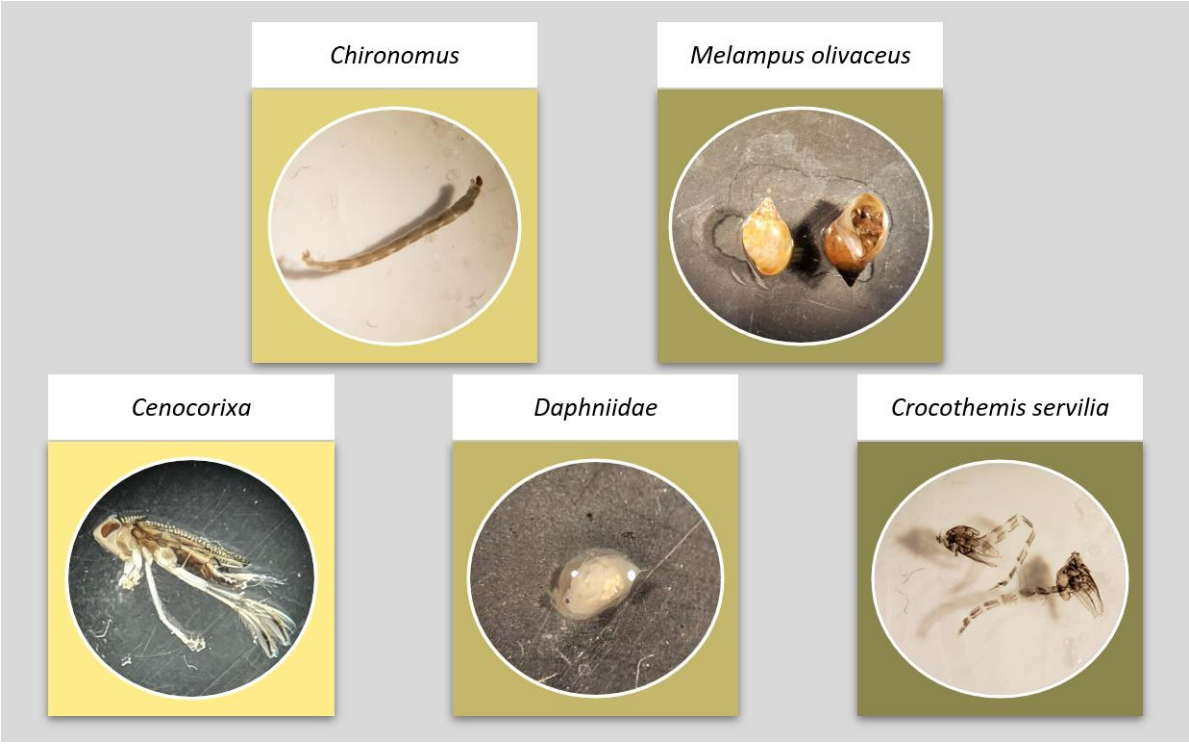


Figure 9. Microscope photographs of the five invertebrate taxa identified at Tottino II.

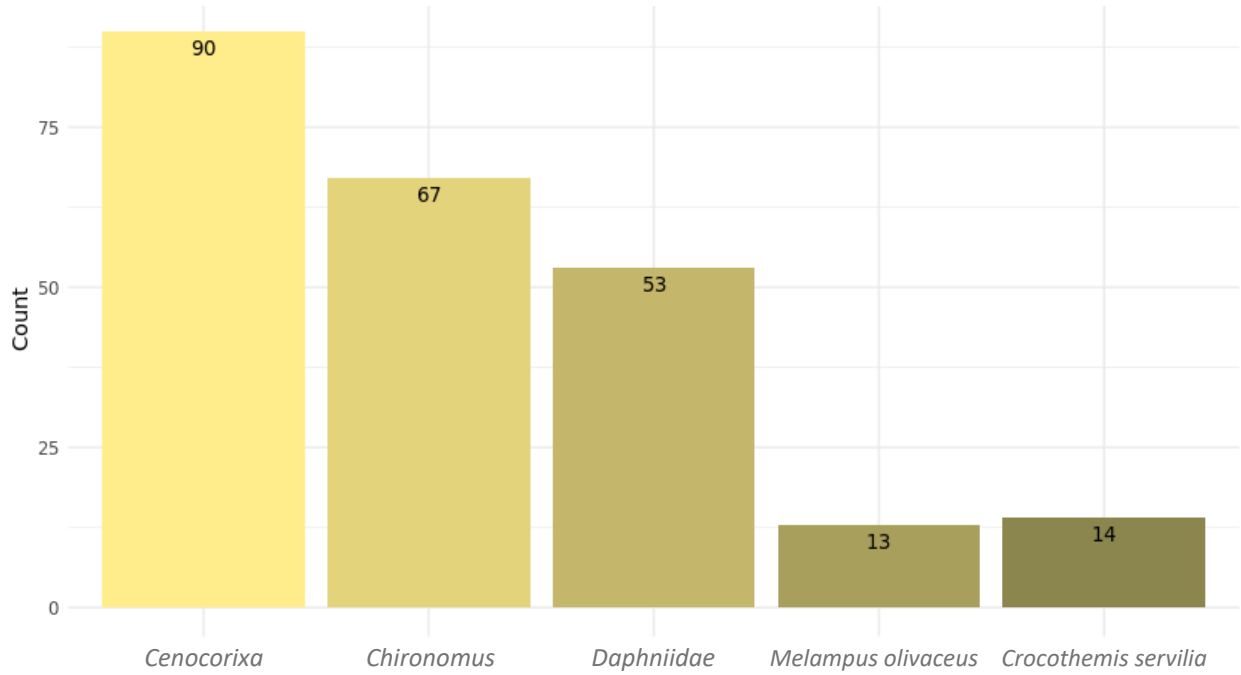


Figure 10. Invertebrate count (n = 237) categorized by final identification.

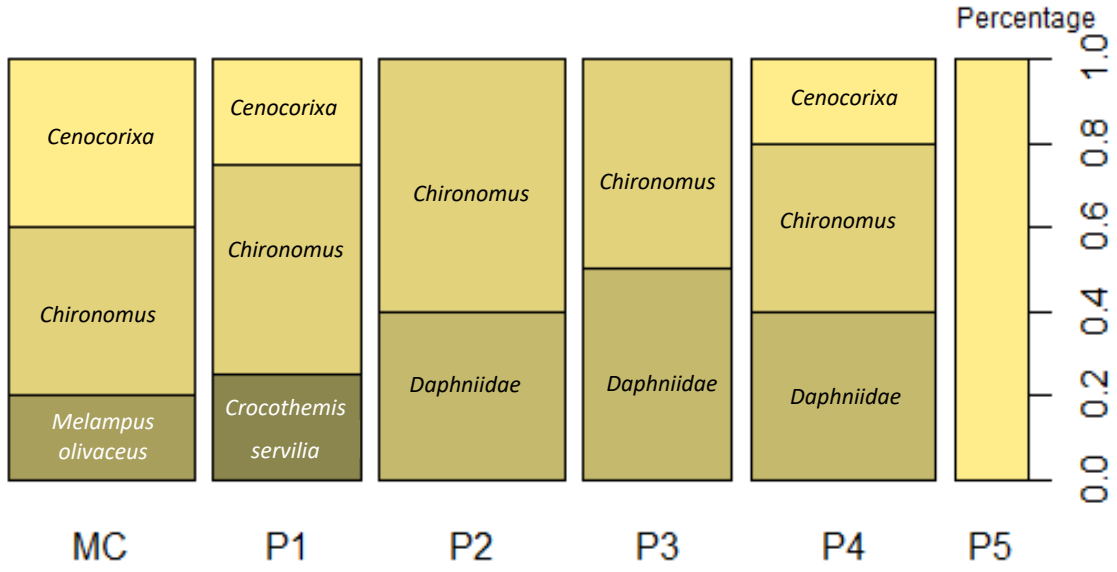


Figure 11. Percentage occurrence of taxa in the Moro Cojo (MC) and in each pond (P1-P5).

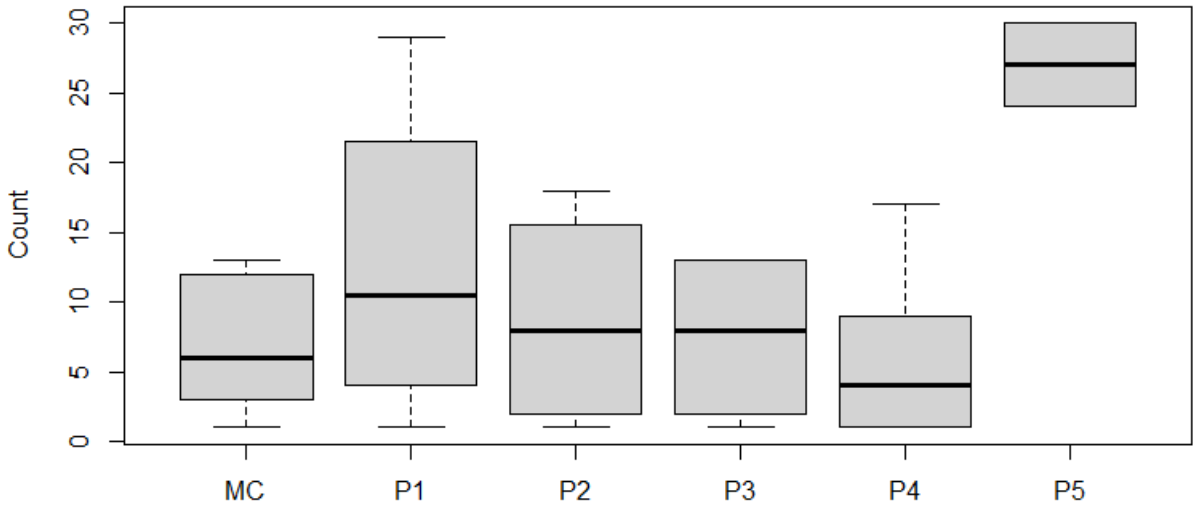


Figure 12. Invertebrate counts in the Moro Cojo (MC) and in each pond (P1-P5). The median is indicated by the horizontal black line across each box, gray boxes represent the interquartile range between Q1 (bottom) and Q3 (top), and the whiskers show extreme data points. There are no outliers.

We applied the chi-squared test for independence (Table 8) and found a significant difference among depths ($\chi^2 = 77.72$, df = 4, $p < 0.001$; Fig. 13), where 56% percent of invertebrates collected were located in deep depths (Fig. 14). Furthermore, 83% of collected *Chironomus* occupied deep depths.

Table 8. Contingency table used for chi-squared test for independence.

Taxa	Shallow	Deep
Cenocorixa	41	33
Chironomus	12	71
Daphniidae	38	15
Crocothemis servilia	14	0
Melampus olivaceus	0	13

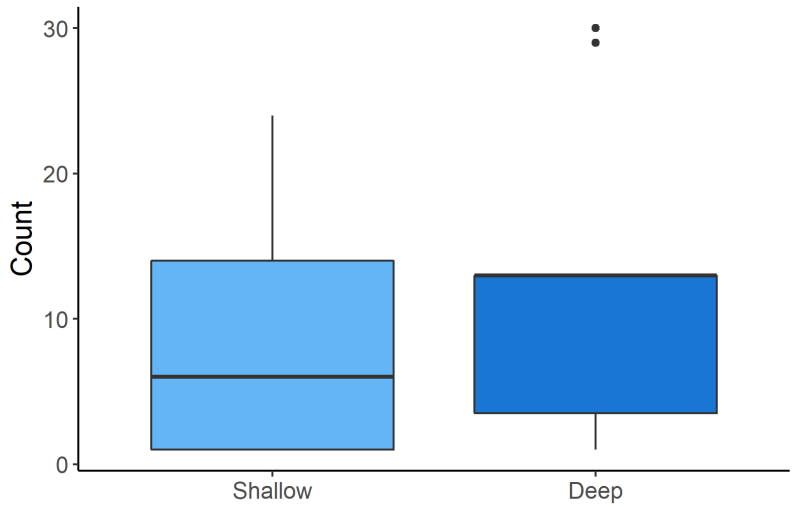


Figure 13. Invertebrate counts in respective depths. The median is indicated by the horizontal black line across each box, blue boxes represent the interquartile range between Q1 (bottom) and Q3 (top), and the whiskers show extreme data points. Dots represent outliers.

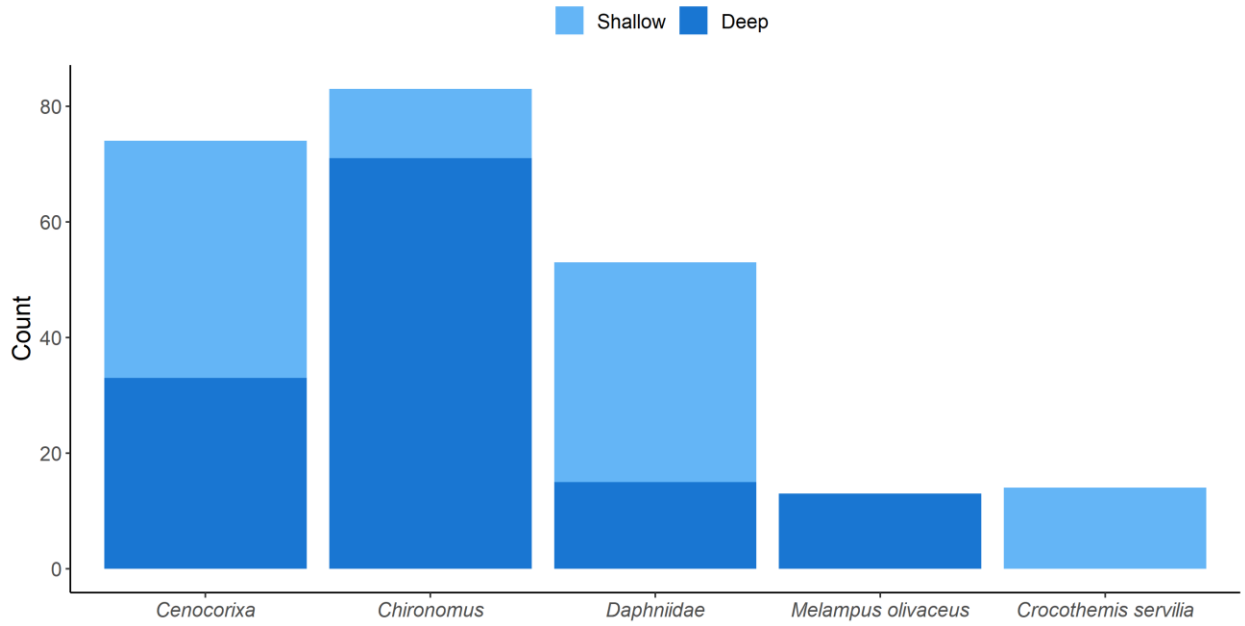


Figure 14. Invertebrate count across respective depths.

We applied the Shannon-Weiner and Simpson's diversity indices (Fig. 15 and Table 9) to all sampling locations and included final values for Tottino II (Shannon: 1.39, Simpson: 0.72). We found Pond 5 had the lowest species diversity, richness, and evenness with one species observed (*Cenocorixa*).

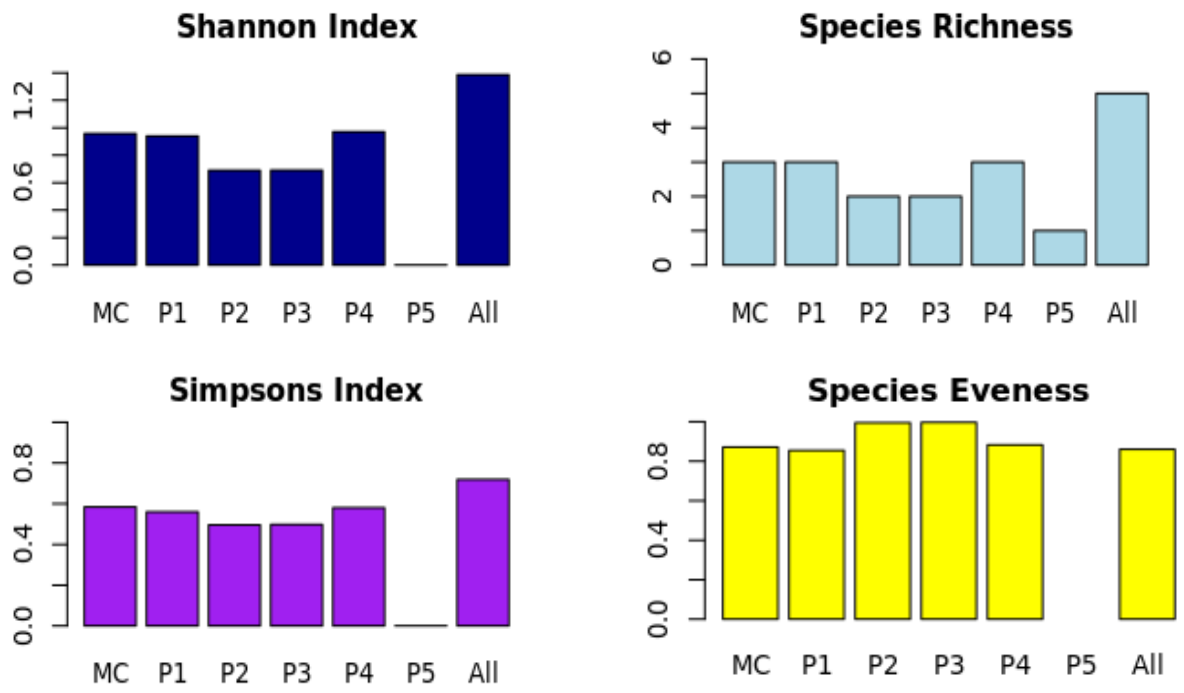


Figure 15. Invertebrate diversity indices in the Moro Cojo (MC), in each pond (P1-P5), and combined for Tottino II (All).

Table 9. Invertebrate diversity indices in the Moro Cojo (MC), in each pond (P1-P5), and combined for Tottino II (All).

Location	Shannon	Richness	Simpson	Evenness	Count
Moro Cojo	0.96	3	0.58	0.88	35
Pond 1	0.94	3	0.57	0.86	51
Pond 2	0.69	2	0.50	0.99	35
Pond 3	0.69	2	0.50	1.00	30
Pond 4	0.97	3	0.58	0.87	32
Pond 5	0.00	1	0.00	N/A	54
All	1.39	5	0.72	0.86	237

3.3. Morphology and Hydrology

Drone photogrammetry

We used a total of 585 calibrated and geolocated images with an average of 53,663 keypoints per image. A small closing error for our drone survey was represented by a 0.4% relative difference between initial and optimized internal camera parameters. The primary photogrammetric output products were a 0.02 m resolution stitched orthomosaic image (Fig. 1) and a DSM. The estimated spatial accuracy RMS error of these products was ± 0.02 m, ± 0.05 m, and ± 0.06 m in X, Y, and Z, respectively.

Elevation product, key elevations, and system rating curve

We combined the drone acquired DSM with our interpolated DEM to make a bathymetric map (Fig. 16). Subsequently, we collected key elevation points during our surveys (e.g., culverts connecting the Moro Cojo Slough and Tottino II or Inputs A and D; Table 8). We created a rating curve of the system (Fig. 17) where two equations are used to predict volume at a given stage. Volumes were estimated from the high-resolution DSM (Fig. 16). Combining Figures 16 and Equation 2 of Figure 17, we found the total water volume of the site after calculating the average elevation of the wetted perimeter (0.409 m): 10,090 m^3 (8.2 ac-ft).

Table 8. Key elevations at Tottino II. We measured elevation at each culvert end (i.e., North lies closest to the Moro Cojo Slough, while south lies within the site).

Location	Elevation (m)	Minimum Elevation (m)	Maximum Elevation (m)	Water Level Recorder Elevation (m)
Pond 1	0.00864 ± 0.34	-0.754	0.427	-0.07
Pond 2	-0.00349 ± 0.50	-0.837	1.621	NA
Pond 3	0.33640 ± 0.13	0.012	1.276	NA
Pond 4	0.18176 ± 0.28	-0.776	0.493	-0.6
Pond 5	0.09098 ± 0.26	-0.796	0.495	-0.301
Input A (North)	0.6955 ± 0.01	NA	NA	NA
Input A (South)	0.3475 ± 0.00	NA	NA	NA
Input D (North)	0.235	NA	NA	NA
Input D (South)	0.369	NA	NA	NA

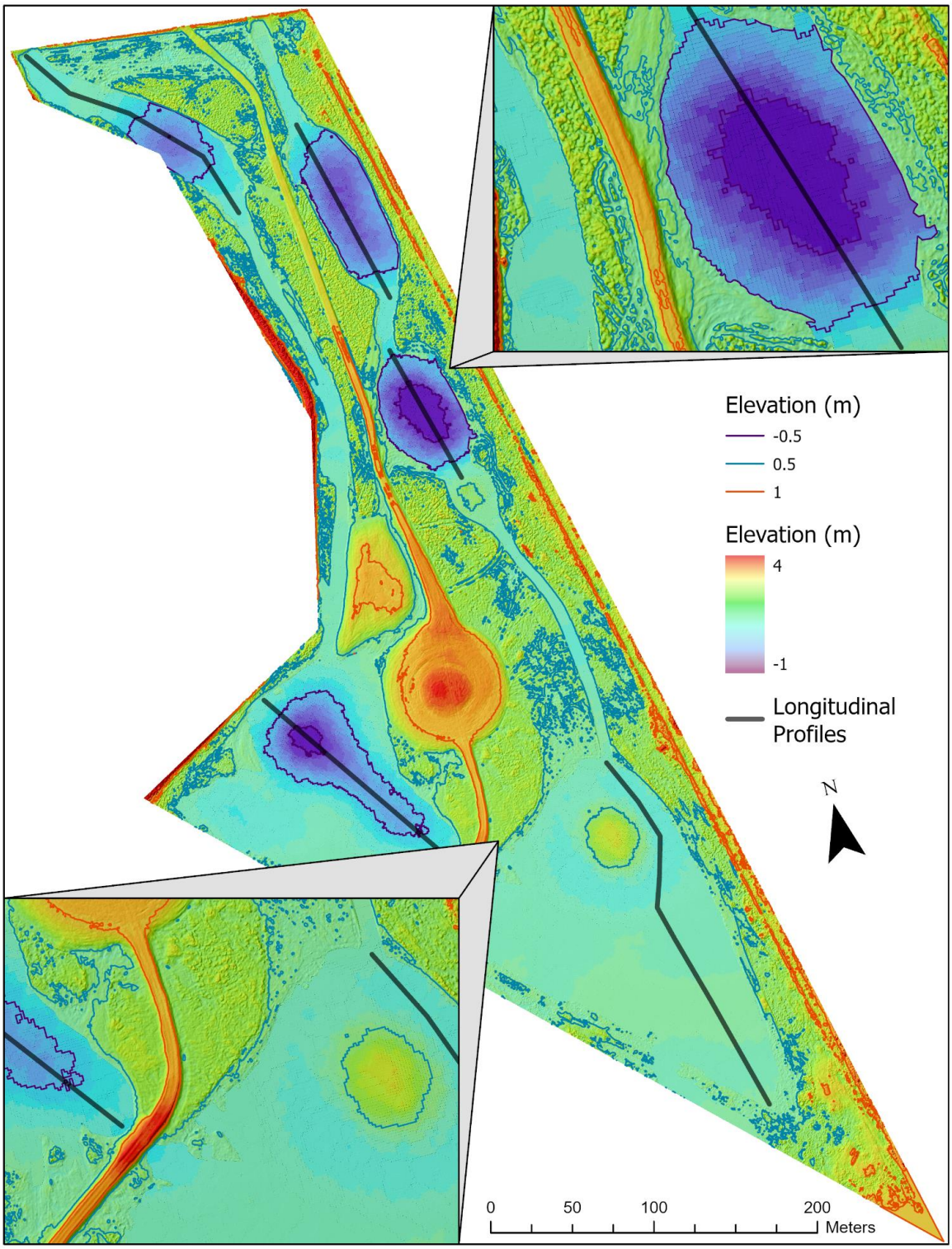


Figure 16. A DSM-DEM combined elevation product showing bathymetry of Tottino II.

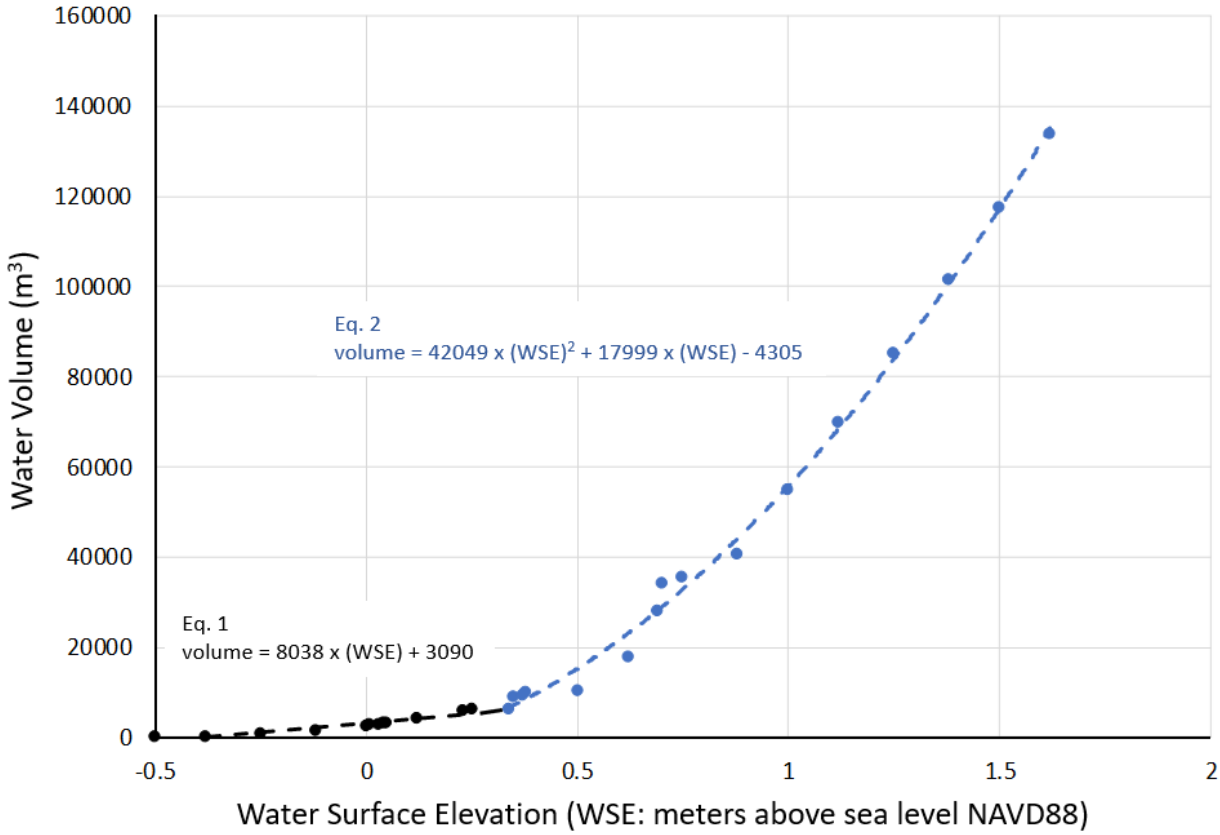


Figure 17. Water volume in Tottino II as a function of water surface elevation above sea level (i.e., stage). Equation 1 is used for water elevations below 0.34 m. Equation 2 is used for water elevations between 0.34 m and 1.62 m.

Longitudinal profiles

Using the bathymetric map (Fig. 16) as an elevation source, we created digital longitudinal profiles of each pond excluding connecting channels (Fig. 18). Pond 2 had the highest slope across its longitudinal profile, extending to the deepest point in the wetland at 0.76 m below sea level. Conversely, Pond 3 had the lowest slope and remains shallow across its entire longitudinal profile. Average depths and calculated surface areas are outlined in Table 9.

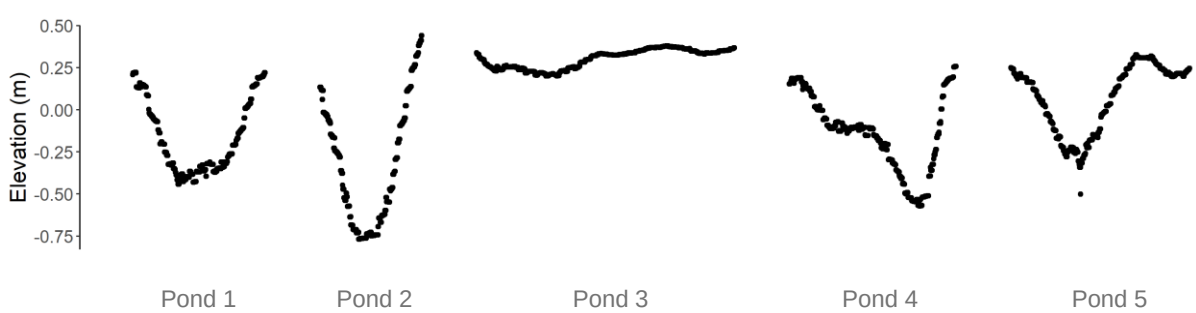


Figure 18. Longitudinal profiles of ponds.

Table 9. Average depth and surface areas of ponds.

Location	Average Depth (cm)	Surface Area (m²)	Surface Area (ac)
Pond 1	32 ± 32	3,690	0.91
Pond 2	38 ± 43	2,740	0.68
Pond 3	6 ± 8	20,150	4.98
Pond 4	22 ± 28	12,650	3.13
Pond 5	28 ± 26	3,407	0.84

Water level time series

Figure 19 represents surface water level in Ponds 1, 4, and 5 during spring 2022. The time series data shows consistent patterns among each pond, with a decrease in water level by 0.3 m from January to April.

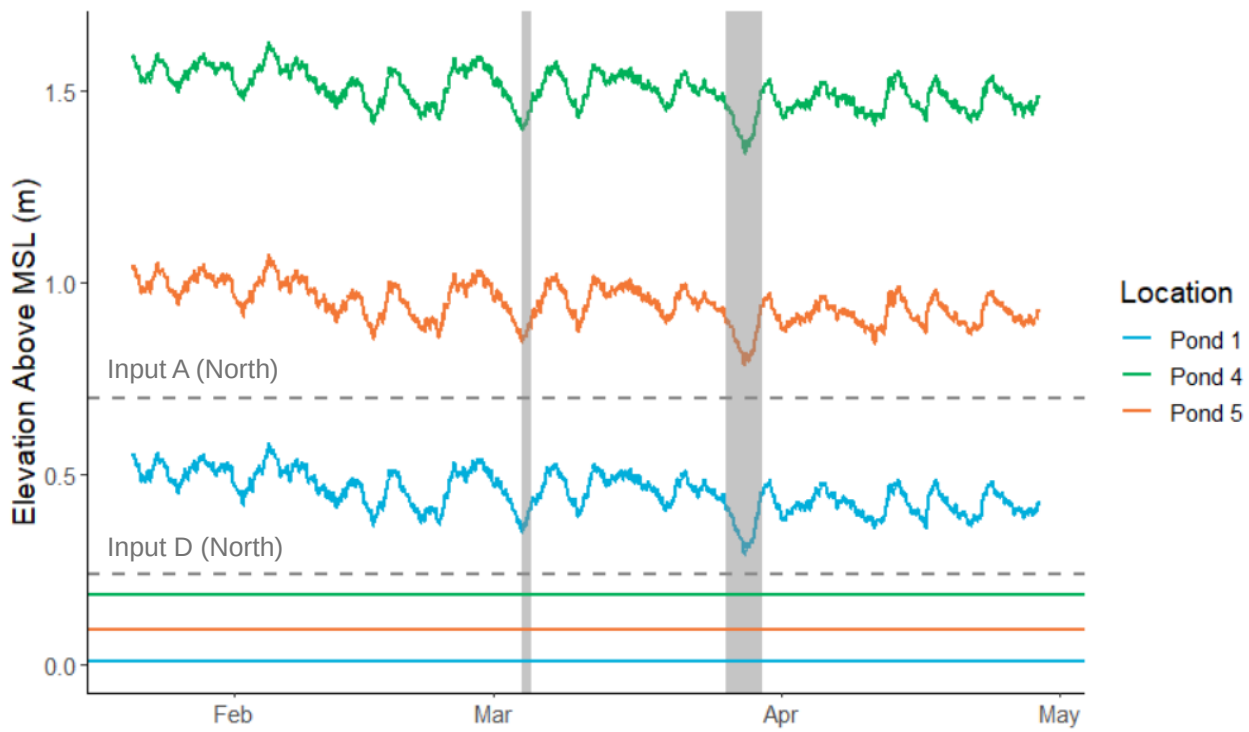


Figure 19. Water level in three ponds at Tottino II between January and April of 2022. The vertical gray bars represent two precipitation events: 2.4 mm on March 4 and 18.4 mm from March 26 - March 30. Horizontal lines show elevations of inputs (A and D [North]) and ponds, respectively.

4. Discussion

4.1. Water Quality

Site is brackish with small variability in salinity between winter and spring

Figure 4 depicts the pond system as a brackish-to-freshwater refuge during spring (fresh: 0-0.5 ppt, brackish: 0.5-30 ppt; Hartog 1974). In spring 2022 the site is classified as brackish, with average salinity for ponds at 7.7 ppt ± 5.5 (range: 3.0 and 15.3 ppt). Winter and spring salinity remained consistent (0.4 ppt difference in average salinity between seasons; Fig. 3) during the ~80-day period, emphasizing that future efforts on measuring water quality parameters at the 45 locations be focused during seasonal hydrologic extremes (wet winter v. dry summer). We observed the greatest variability in salinity, DO, and EC at Pond 5 (average CV of 44.7 ± 1.5; Table 1) likely the result of its near-constant surface water connection through Input D with the Moro Cojo (Fig. 4 and Fig. 1).

High concentrations of nitrate+nitrite from adjacent inputs mediated by wetland

Inputs B and D acted as point sources of nitrate+nitrite during spring (average: 54.0 ± 4.9 mg/L; Table 2). Furthermore, we observed the highest sampled nitrate+nitrite concentrations at these locations (Input B: 65.0 mg/L, Input D: 57.5 mg/L; Fig. 7a). Inputs B and D exceeded the combined EPA maximum contaminant level of 11 mg/L (Nitrate: 10 mg/L + Nitrite: 1 mg/L; California Water Boards 2020) by 490% and 423%, respectively. Despite high concentrations on nitrate+nitrite from adjacent inputs, Pond 4 was the only other location to exceed this standard at 14.6 mg/L ± 2.7 (Table 2). High nutrients concentrations in Ponds 3 and 4 may be anticipated, due to their point source connection with agricultural ditches (Fig. 1 Inputs B and C). Although Input D was designed to allow water into Tottino II from the Moro Cojo Slough during flood tides (Fig. 1), no surface water connection was observed (i.e., south end of the culvert greater in elevation than north end; see Table 8). This stagnant water may have led to the high concentration of nitratie+nitrite measured at Input D; we recommend adjusting the elevation of the culvert to achieve a daily tidal connection between the Moro Cojo Slough and Tottino II.

4.2. Biology: Vegetation and Invertebrates

Moderately invasive Conium maculatum covers 1.3 acres

Conium maculatum (poison hemlock) is a moderately invasive occupant of compacted berms at the site center and edges (Tables 3-5, Fig. 8). Although chemical control is the status-quo for noxious weeds in the United States, alternative management strategies may be explored: limiting chemical application to only during spring when plants are in the rosette stage, mowing, controlled burn, tillage, and/or adopting a long-term invasive species management plan as depletion of energy reserves and the underlying seedbank may take years (Woodard 2008).

Ponds 3 and 4 marked a contrast between native or naturalized communities and potential invaders (Fig. 8), highlighting a unique need for vegetative management in these areas. This is likely due to seed bank dispersal from upland inputs (Inputs B and C; Fig. 1).

Vegetation accounted for 55% cover of the restored wetland

Despite limitations from ArcGIS percent-cover aided analyses (i.e., least abundant plants not recognized; Table 3, Table 6, and Fig. 8), we found plant species *Salicornia pacifica* (18%)*, Atriplex prostrata* (10.38%), and *Extriplex californica* (7.04%) had the most coverage at Tottino II and all other species occupied less than 4% cover (Table 6). Vegetation covered 55.13% and bare ground covered 15.81% of the restored wetland, serving as a baseline for plant and seed installation efforts over time (Table 6, A-1).

Young site age may play a role in low invertebrate abundance and diversity

We collected only free-swimming invertebrates belonging to five taxonomic groups (Table 7) as none existed in the benthic mud samples. A significant ($p < 0.001$) distinction was made among average invertebrate counts across depths (Table 8, Fig. 13 - 14). Pond 5 was the least diverse with only *Cenocorixa* (Fig. 15 and Table 9), but it contained the greatest number of invertebrates among all locations (Fig. 12 n = 54). Moro Cojo Slough, Pond 1, and Pond 4 contained three different species, or the greatest number of species found among all locations (Fig. 11). Since invertebrates adapt to specific abiotic and biotic factors spatially within wetlands (O'Rear 2007), the evolution of Tottino II into a biologically functional site for aquatic organisms will take time.

4.3. Morphology and Hydrology

Monitoring wetland erosion and accretion with remote sensing technology

Combining a drone survey product (DSM) for exposed land with an "Emelid Rod" survey (DEM) for submerged land lends to an elevation product (Fig. 16) that can be used to measure wetland erosion and accretion over time using elevation averages and longitudinal profiles as a baseline (Table 8 and Fig. 18). A remote sensing-based monitoring campaign may be more efficient than traditional, manual wetland-monitoring (Bhatnagar 2021). Furthermore, tracking microtopographic changes within the system will aid in an enhanced understanding of hydrology as it related to the intended function of the restored site. A higher-resolution grid may be required, as we interpolated longitudinal profiles (Fig. 18) at 10 m spacing.

Future expansion of hydrologic datasets

While not explored in this study, preliminary time series analyses (Fig. 19) show a cyclic signal between the ponds and Moro Cojo and/or the pumping of irrigation from surrounding agricultural fields into the ponds. For a complete understanding of pond water level to outside

sources, data logging should continue through the dry season. Furthermore, the installation of shallow groundwater wells (i.e., piezometers) would elucidate subsurface flow.

5. References

Berezina NA. 2003. Tolerance of Freshwater Invertebrates to Changes in Water Salinity. Russian Journal of Ecology. 34(4):261–266. doi:10.1023/a:1024597832095.

Bhatnagar S, Gill L, Regan S, Waldren S, Ghosh B. 2021. A nested drone-satellite approach to monitoring the ecological conditions of wetlands. ISPRS Journal of Photogrammetry and Remote Sensing. 174:151–165. doi:10.1016/j.isprsjprs.2021.01.012.

Broenkow WW, Breaker LC. 2019. A 30-Year History of the Tides and Currents in Elkhorn Slough, California. IntechOpen. https://www.intechopen.com/chapters/69606.

Burton RK. 2003. Moro Cojo Slough NPS Implementation Project. Moss Landing, California: Creative Environmental Conservation INC.

Caffrey M, Brown J, Tyler M, Silverstein WB. 2002. Changes in a California Estuary A Profile of Elkhorn Slough. 1st ed. Elkhorn Slough Foundation.

(CALIPC) California Invasive Plants Council. The Cal-IPC Inventory. Available from: https://www.cal-ipc.org/plants/inventory/

California Water Boards. 2020. Nitrates and Nitrites in Drinking Water. Available from: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/Nitrate

(CCWG) Central Coast Wetlands Group. 2018. Hugo Tottino Wetland Restoration, Construction and Maintenance Plan. https://mlml.sjsu.edu/ccwg/wp-content/uploads/sites/23/2020/03/HugoTottinoWetland_ConstructionMaintenancePlan.pdf.

Cole M. 2022. Personal Communication. Central Coast Wetlands Group.

Cronk JK, Fennessy MS. 2009. Wetland Plants. Earth Systems and Environmental Science.:590–598. doi:10.1016/B978-012370626-3.00060-0. https://www.sciencedirect.com/science/article/pii/B9780123706263000600.

Díaz FJ, O'Geen AT, Dahlgren RA. 2012. Agricultural pollutant removal by constructed wetlands: Implications for water management and design. Agricultural Water Management. 104:171–183. doi:10.1016/j.agwat.2011.12.012.

Dybiec JM, Danz NP, Learman DR, Uzarski DG. 2021. Evaluating relationships between plants, water chemistry, and denitrification potential in palustrine freshwater marshes. Ecological Indicators. 131:108163. doi:10.1016/j.ecolind.2021.108163.

Elkhorn Slough Tidal Wetland Project Team. 2007. Elkhorn Slough Tidal Wetland Strategic Plan.

Fisher J, Acreman MC. 2004. Wetland nutrient removal: a review of the evidence. Hydrology and Earth System Sciences. 8(4):673–685. doi:10.5194/hess-8-673-2004.

Fitzpatrick JF. 1983. How to Know the Freshwater Crustacea. McGraw-Hill Science, Engineering & Mathematics.

Galatowitsch S, Bohnen J. 2021. Long-Term Recovery of a Restored Palustrine Wetland: the Role of Monitoring and Adaptive Management. Wetlands. 41(6). doi:10.1007/s13157-021-01478-7.

Hartog C. 1974. Brackish-water classification, its development and problems. Hydrobiological Bulletin. 8(1-2):15–29. doi:10.1007/bf02254902.

Khan MN, Mohammad F. 2013 Nov 19. Eutrophication: Challenges and Solutions. Eutrophication: Causes, Consequences and Control.:1–15. doi:10.1007/978-94-007-7814-6_1.

Konopiński MK. 2020. Shannon diversity index: a call to replace the original Shannon's formula with unbiased estimator in the population genetics studies. PeerJ. 8:e9391. doi:10.7717/peerj.9391.

Lintern A, McPhillips L, Winfrey B, Duncan J, Grady C. 2020. Best Management Practices for Diffuse Nutrient Pollution: Wicked Problems Across Urban and Agricultural Watersheds. Environmental Science & Technology. 54(15):9159–9174. doi:10.1021/acs.est.9b07511.

Manuel J. 2014. Nutrient Pollution: A Persistent Threat to Waterways. Environmental Health Perspectives. 122(11). doi:10.1289/ehp.122-a304. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4216153/.

Mason C. 2022. Personal communication, February, 15.

Mathers K. 2019 Frequently-Asked Questions about Anhydrous Ammonia. Tfiorg. https://www.tfi.org/content/frequently-asked-questions-about-anhydrous-ammonia

O'Rear T. 2007. The Distribution and Abundance of Invertebrates in the Grande Ronde River, Oregon, U.S.A. Education at the Center for Watershed Sciences UC Davis. https://cwseducation.ucdavis.edu/class/41/distribution-and-abundance-invertebrates-grande-ronde-river-oregon-u-s.

Osmolovsky P, Harlan L, Hamilton, Worcester K, Keeling M, Paradies DM, Hammer P, Barricarte M, Saiz S. 2013. Total Maximum Daily Loads for Nitrogen Compounds and Orthophosphate for the Lower Salinas River and Reclamation Canal Basin, and the Moro Cojo Slough Watershed, Monterey County, California. California Regional Water Quality Control Board Central Coast Region. https://www.waterboards.ca.gov/centralcoast/water_issues/programs/tmdl/docs/salinas/nutrients/index.html.

Paerl HW, Hall NS, Peierls BL, Rossignol KL. 2014. Evolving Paradigms and Challenges in Estuarine and Coastal Eutrophication Dynamics in a Culturally and Climatically Stressed World. Estuaries and Coasts. 37(2):243–258. doi:10.1007/s12237-014-9773-x.

Poe AC, Piehler MF, Thompson SP, Paerl HW. 2003. Denitrification in a constructed wetland receiving agricultural runoff. Wetlands. 23(4):817–826. doi:10.1672/0277-5212(2003)023[0817:diacwr]2.0.co;2.

Potter IC, Chuwen BM, Hoeksema SD, Elliott M. 2010. The concept of an estuary: A definition that incorporates systems which can become closed to the ocean and hypersaline. Estuarine, Coastal and Shelf Science. 87(3):497–500. doi:10.1016/j.ecss.2010.01.021.

Salinas History. 2017. City of Salinas. Available from: https://www.cityofsalinas.org/visitors/salinas-history.

Sánchez-Carrillo S, Angeler DG, Álvarez-Cobelas M, Sánchez-Andrés R. 2010. Freshwater Wetland Eutrophication. Eutrophication: causes, consequences and control.:195–210. doi:10.1007/978-90-481-9625-8_9.

Sievert C. 2020. Interactive Web-Based Data Visualization with R, plotly, and shiny. 1st ed. Chapman and Hall/CRC.

Stephenson PJ, Ntiamoa-Baidu Y, Simaika JP. 2020. The Use of Traditional and Modern Tools for Monitoring Wetlands Biodiversity in Africa: Challenges and Opportunities. Frontiers in Environmental Science. 8(61). doi:10.3389/fenvs.2020.00061.

Tweedley JR, Dittmann SR, Whitfield AK, Withers K, Hoeksema SD, Potter IC. 2019. Hypersalinity: Global Distribution, Causes, and Present and Future Effects on the Biota of Estuaries and Lagoons. Coasts and Estuaries.:523–546. doi:10.1016/b978-0-12-814003-1.00030-7.

(USACE) United States Army Corps of Engineers. National Wetland Plant List, version 3.5. 2020. unblockfederalregistergov. https://wetland-plants.sec.usace.army.mil/nwpl_static/data/DOC/lists_2020/National/National_2020v1.pdf.

Valiela I, Rutecki D, Fox S. 2004. Salt marshes: biological controls of food webs in a diminishing environment. Journal of Experimental Marine Biology and Ecology. 300(1-2):131–159. doi:10.1016/j.jembe.2003.12.023.

Wendt K. 2000. Determination of Nitrate/Nitrite in Surface and Wastewaters by Flow Injection Analysis. Milwaukee, WI: Lachat Instruments. https://www.uvm.edu/bwrl/lab_docs/protocols/Nitrate_water_lachat.pdf.

Woodard CA. 2008. POISON HEMLOCK (Conium maculatum L.): BIOLOGY, IMPLICATIONS FOR PASTURES AND RESPONSE TO HERBICIDES. https://mospace.umsystem.edu/xmlui/bitstream/handle/10355/5674/research.pdf?sequence=3.

6. Appendix

A-1. CCWG restoration plants (A) and seeds (B) to be installed by Coastal Conservation and Research (CC&R; Mason 2022).

(A) Plants List

Species	Size	Quantity
Achillea millefolium	Rose Pot	200
Artemisia californica	Gallon	30
Artemisia douglasiana	Gallon	200
Baccharis glutinosa	Rose Pot	50
Baccharis pilularis	Gallon	200
Bolboschoenus maritimus	Gallon	132
Bolboschoenus maritimus	Rose Pot	68
Bromus carinatus	Deep Pot	75
Bromus carinatus	Rose Pot	97
Carex barbarae	Rose Pot	400
Ceanothus thyrsiflorus	Gallon	20
Distichlis spicata	Rose Pot	1600
Eleocharis macrostachya	Gallon	200
Elymus glaucus	Rose Pot	371
Elymus triticoides	Gallon	1261
Elymus triticoides	Rose Pot	639
Epilobium canum	Gallon	5
Eriophyllum staechadifolium	Gallon	300
Euthamia occidentalis	Gallon	50
Festuca rubra	Rose Pot	700
Frangula californica	Gallon	30
Frankenia salina	Rose Pot	2500
Grindelia stricta	Rose Pot	1100
Iris douglasiana	Small Tree Pot	10

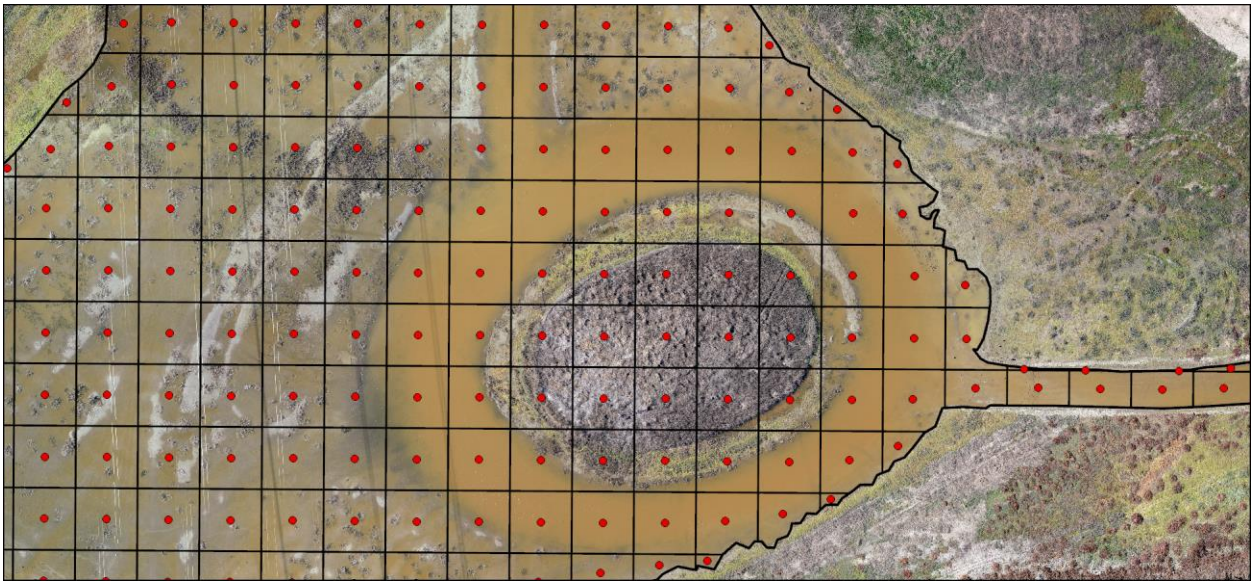
Jaumea carnosa	Cone	2600
Juncus mexicanus	Cone	2000
Juncus mexicanus	Rose Pot	400
Juncus patens	Cone	500
Juncus patens	Rose Pot	200
Juncus xiphioides	Cone	800
Lupinus arboreus	Gallon	50
Morella californica	5 Gallon	2
Oenothera elata	Rose Pot	200
Persicaria punctata	Rose Pot	40
Populus trichocarpa	5 Gallon	17
Potentilla anserina	Gallon	50
Quercus agrifolia	Gallon	23
Ribes sanguineum	Gallon	20
Rosa californica	Gallon	5
Rubus ursinus	Gallon	30
Salix exigua	5 Gallon	23
Salvia mellifera	Gallon	30
Scrophularia californica	Gallon	200
Sisyrinchium bellum	Rose Pot	50
Stipa pulchra	Smal Tree Pot	20
Symphiotrichum chilense	Gallon	50
Total		17,548

(B) Seed Lists

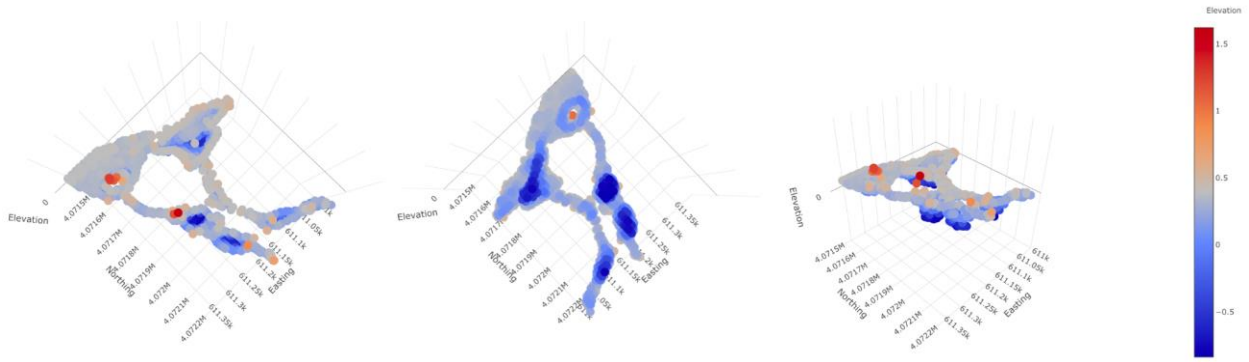
Wetland (3.5 acres)	Quantity (lbs)
Bolboschoenus maritimus	8
Juncus mexicanus	0.5
Eleocharis macrostachya	0.5
Salicornia pacifica	0.5
Total	11.5

Transitional (15 acres)	Quantity (lbs)
Elymus triticoides	12
Hordeum brachyantherum	42
Distichlis spicata	9
Artemisia douglasiana	4
Total	67

Upland (4 acres)	Quantity (lbs)
Bromus carinatus	7
Elymus glaucus	5
Artemisia californica	1
Eriogonum fasciculatum foliolosum	4
Eschscholzia californica	2
Saliva mellifera	2
Oenothera elata ssp Hookeri	5
Total	26



A-2. Example view of 10x10 meter survey grid used to sample evenly spaced points for elevation.



A-3. 3D Elevation Model of Tottino II with an elevation color gradient.