Biomonitoring of the California Department of Water Resources Delta Levees Program Habitat Restoration Sites

2021 Annual Report

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Biomonitoring of the California Department of Water Resources Delta Levees Program Habitat Restoration Sites:

2021 Annual Report

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December 2021

Cover photo: Bobcat visiting a camera trap station in the Tall Forest at Cosumnes River Preserve. (All photos in this report were taken at our sites unless otherwise specified)

Acknowledgements

On behalf of the UC Davis Museum of Wildlife and Fish Biology (MWFB) and Bohart Museum of Entomology, we wish to thank everyone involved in the 2021 Biomonitoring of the California Department of Water Resources (CA DWR) Delta Levees Program Habitat Restoration Sites survey season. We would especially like to thank all of the site managers who provided access to our study areas, including Bryan Brock (DWR West Delta Program Manager), Joel McElroy (Sherman Island Superintendent), Juan Mercado (Board President for both Sherman and Twitchell Island Reclamation District boards), Katherine Bandy (Program Manager of Dutch Slough Tidal Marsh Restoration Project), Mark Ackerman (Cosumnes River Preserve Manager), and Ricky Carter (Twitchell Island Superintendent). Additionally, our work at Cosumnes River Preserve, McCormack-Williamson Tract, and Grizzly Slough would not have been possible without the assistance of Sara Sweet (Cosumnes River Preserve Restoration Ecologist) and Anitra Pawley (CA DWR North Delta Program Manager). Lastly but certainly not least, this project would not be possible without the dedication of our field teams and museum staff. Many thanks to our hard-working 2021 field crews, including DWR's Beth Hendrickson and Grayson Sandy who performed the vegetation/habitat surveys, Bohart's Brennen Dyer and Steven Heydon who conducted field surveys, Socrates Letana, Jeff Smith and John DeBenedictis who made invertebrate species identifications, MWFB's Hanika Cook, Irene Engilis and John Trochet who helped conduct vertebrate field surveys, and to our interns, Karen Torres Reyes and Doris Wu who helped conduct small mammal surveys and sort through camera trap photos.

Executive Summary

- The University of California, Davis Museum of Wildlife and Fish Biology and Bohart Museum of Entomology are contracted to collect baseline inventory of multiple taxa (amphibians, bats, birds, invertebrates, mammals, and reptiles) in and near six California Department of Water Resources habitat management and restoration sites (Cosumnes River Preserve, Grizzly Slough, McCormack-Williamson Tract, Twitchell Island, Sherman Island, and Dutch Slough).

- These data are being used to correlate wildlife response to restored habitat versus surrounding land use across the Delta and provide vital information for habitat management and restoration designs.

- We established 279 herpetofauna (amphibian and reptile) coverboards, 152 avian (bird) point count stations, 35 acoustic bat monitoring stations and camera trap locations, 35 small mammal trap lines, and 11 invertebrate survey stations across 35 microsites where data on species presence/absence, abundance, and diversity are being collected.

- Small mammal mark-recapture surveys were conducted during fall (September and October) 2020 and 2021. We captured a total of 704 individuals in 2020 and 405 individuals in 2021 of five species including the California native species Deer Mouse, Western Harvest Mouse, and California Meadow Vole, and the introduced species House Mouse, and Black Rat. These mark-recapture data were used to calculate relative abundance of small mammal species across our study sites. Western Harvest Mouse was more abundant in riparian and wetland habitat than in pasture sites. Black Rat was most abundant in riparian habitat ($p < 0.001$), and House Mouse was most abundant in wetland habitat ($P < 0.005$).

- Camera trap surveys were conducted April-September 2021. Total camera trap effort was 945 trap days or about 22,680 trap hours (through September 2021). We observed a total of 18 species of mammalian mesocarnivores and herbivores at the six macrosite locations, including 15 California native species and 3 introduced species. Average mammalian mesocarnivore and herbivore species richness increased at microsites with increasing tree cover and open water cover but is negatively correlated with bare ground cover. Richness also decreased as percent cover of pasture increased. We observed Coyotes and Raccoons in the greatest number of microsites.

- Passive bat acoustic surveys were conducted April-September 2021. We recorded calls from seven bat species (Free-tailed Bat, California Myotis, Hoary Bat, Little Brown Bat, Silver-haired Bat, Western Red Bat, and Yuma Myotis). Free-tailed Bat had the highest predicted occupancy across our study sites. However, we found no statistical effect of habitat type on Free-tailed Bat occupancy. Little Brown Bat and Yuma Myotis occupancy was significantly higher in riparian forests than other habitat types.

- Avian point count surveys were conducted during the breeding season (April, May, and June) of 2020 and 2021 (175 surveys in total). Avian transect surveys were conducted during winter (January and February) and breeding season (May and June) 2021 (69 surveys in total). We identified a total of 121 bird species using the study sites during the breeding surveys. Total avian species richness was highest in riparian sites. Passerine species richness was also highest in riparian sites, being significantly higher than in pasture or wetland. Average avian species richness increased at microsites with increasing tree cover and open water cover. Passerine richness was most strongly positively associated with percent tree cover. During the breeding season, passerines had a significantly higher species richness than during the winter season, however overall avian species richness was not significantly different between the two seasons.

- Herpetological coverboard surveys were conducted at all 35 sites using 279 coverboards. We observed a total of 11 herpetofauna species, including 2 amphibians, 9 reptiles and 2 introduced species. The most common reptile species encountered by far was the Western Fence Lizard, and the most common amphibian was the Sierran Treefrog. Average herpetofauna species richness was significantly higher in riparian and wetlands sites than in sites with pasture habitat. Herpetofauna species richness decreased as percent cover of herbaceous vegetation increased and as percent cover of pasture habitat increased.

- Invertebrates were surveyed across 11 sites in the Sacramento-San Joaquin Delta using Malaise, pitfall, and blue vane traps. To date we have collected roughly 200,000 specimens, with huge series of some common species. We have identified and databased 336 species of insects in 8 orders, including 2 cockroaches, 21 flies, 247 bees and wasps, 1 mantis, 46 moths and butterflies, 2 earwigs, 5 true bugs and plant bugs, and 11 beetles. Roughly 5% of the species we've identified to date are introduced.

- Habitat and vegetation surveys were conducted at each avian point count station. Survey methodologies used elements from existing protocols of the California Native Plant Society (CNPS) and the California Department of Fish and Wildlife's Wildlife Habitat Relationships system (CWHR). To date we have identified 191 species of plants across 44 families at our survey sites. Of these, 54% are introduced species.

- We observed a total of 11 CDFW Species of Special Concern at our study sites during the 2020 and 2021 survey seasons. These included 9 bird species (Least Bittern, Northern Harrier, Swainson's Hawk, Burrowing Owl, Loggerhead Shrike, Yellow-breasted Chat, Yellow-headed Blackbird, Tricolored Blackbird, and Yellow Warbler), Western Pond Turtle, and Western Red Bat.

Introduction

The California Department of Water Resources has funded development of habitat mitigation and enhancement sites in the Sacramento-San Joaquin Delta in accordance with Delta Levees Program provisions that mandate no net loss of habitat as well as net long-term habitat improvement (Water Code §12314(c-d) and §12987(c-d)). Ongoing management activities of habitat sites are required to restore and maintain sites in good condition. Monitoring is an important facet of all DWR operations and is integral to the adaptive management that is required to be consistent with the Delta Plan (California Water Code §85308(f) and §85052). This effort will inform habitat management decisions and restoration planning under the goals and direction of the California Water Plan and EcoRestore.

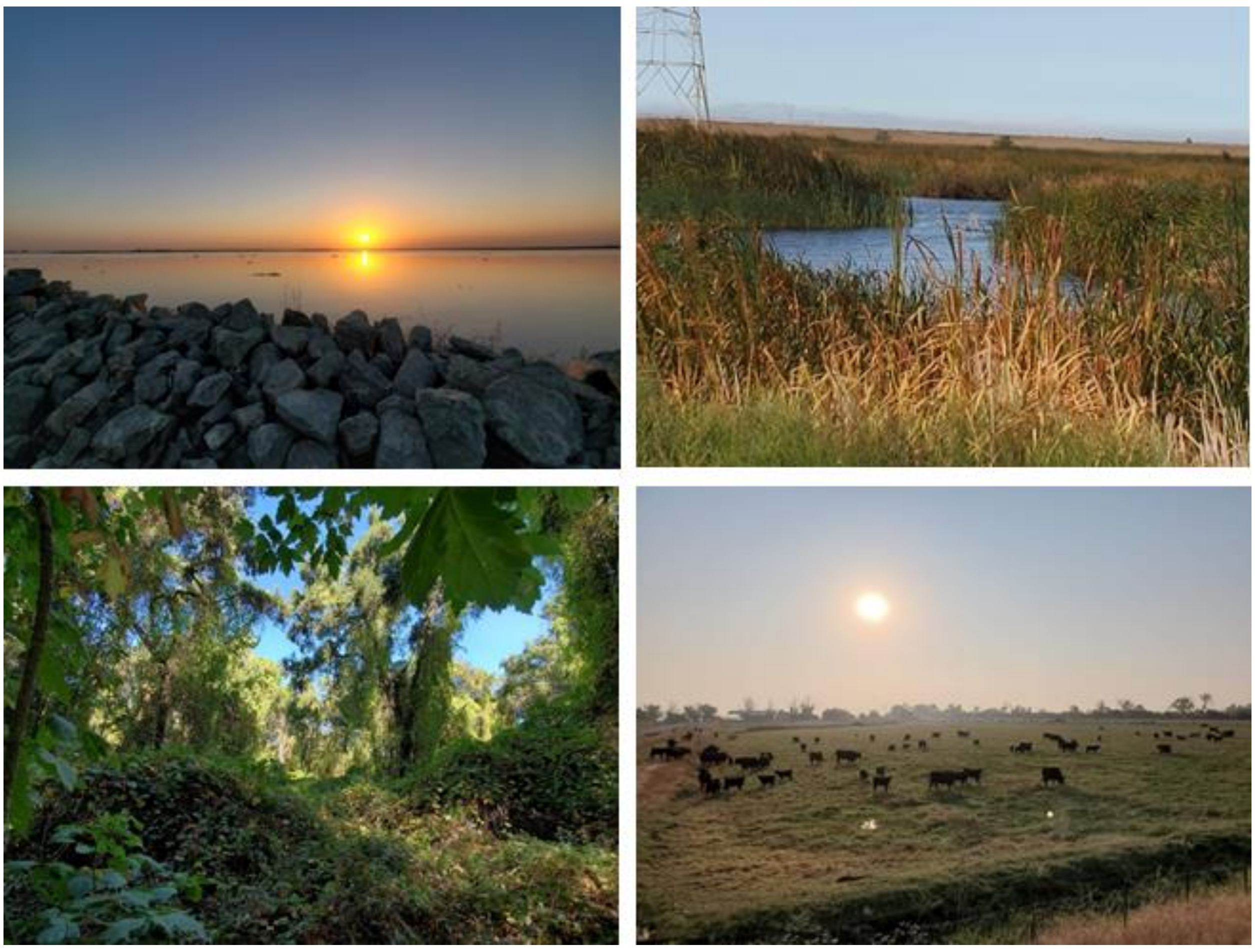

Figure 1: Various microsites in our study around the Sacramento-San Joaquin Delta. Rip rap levee on Twitchell Island (upper left), subsidence reversal freshwater marsh on Sherman Island (upper right), mature riparian forest at Cosumnes River Preserve (bottom left), and cattle pasture at Dutch Slough (bottom right).

The University of California, Davis Museum of Wildlife and Fish Biology and Bohart Museum of Entomology are contracted to collect baseline inventory of multiple taxa (amphibians, bats, birds, invertebrates, mammals, and reptiles) in and near six DWR habitat macrosites (Cosumnes River Preserve, Grizzly Slough, McCormack-Williamson Tract, Twitchell Island, Sherman Island,

and Dutch Slough; Figure 1). We established 279 herpetofauna (amphibian and reptile) coverboards, 152 avian (bird) point count stations, 35 acoustic bat monitoring stations and camera trap locations, 35 small mammal trap lines, and 11 invertebrate survey stations across 35 microsites where data on species presence/absence, abundance, and diversity are being collected (see Appendix A for detailed maps of survey locations within microsites, and Appendix B for a list of sites and survey effort). These data are being used to correlate wildlife response to restored habitat versus surrounding land use across the Delta and provide vital information for habitat management and restoration designs. Each restored habitat site is paired with a non-restored reference site to compare the effect of habitat management and restoration in the Delta to a pre-restored condition.

This initial effort will yield baseline data and be the foundation for a long-term biomonitoring program in the Delta. Understanding species responses to habitat management activities, climate change events, vegetation structure, and habitat design can improve DWR's adaptive management strategies. This information can also be used to help restore and conserve habitats that are providing resilient ecosystem services such as biological diversity, nutrient cycling, and flood protection.

Surveys include mammal, bat, avian, herpetofauna, invertebrate and vegetation during varying times and durations throughout this 2-year period of baseline data collection (Table 1). Generally, the sample sites for this survey were based on DWR Delta Knowledge Improvement Program bird surveys that began in 2011 and continued intermittently through 2019. Some of the point locations have shifted due to land use changes.

While we have managed to avoid some of the disruption from the ongoing pandemic, the project has nonetheless been impacted. We established field protocols for limiting COVID-19 risk including having fixed field crews from UC Davis working together, using proper personal protective equipment, and adhering to strict disinfecting guidelines. DWR Delta Levees Program wildlife monitoring fell under the category of research for which discontinuation would generate data and sample loss that would be effectively irreplaceable. We argued that it was critical that we get the field study sites set up and data gathered during these initial seasons. Many of these sites underwent extensive habitat restoration in 2020 and 2021 and losing pre- and post-restoration data would render the study useless and jeopardize long-term funding and stated research goals. Thus, UC Davis allowed us a variance to carry out work in the Delta while maintaining the safety of our biologists.

Table 1: Survey methods and timing of monitoring for various taxa across the DWR Delta Levees Program habitat restoration sites.

Taxa	Survey Method	Months	# of visits/site	Time of day
Small mammal	Sherman Live Trap	September - October	3 consecutive nights per site	Sunset (open traps) and following sunrise (check traps)
Mammalian Mesocarnivore & Herbivore	Camera Trap & Visual Encounter	January – December (Monthly)	4 consecutive nights per site per month	24 hours
Bat	Passive Acoustic Monitoring	January – December (Monthly)	4 consecutive nights per site per month	Sunset to sunrise
Avian (Breeding)	Point Count	April, May & June	1x per month	Sunrise – 10am
Avian (Breeding)	Transect	May - June	1x per season	Sunrise – 10am
Avian (Winter)	Transect	January - February	1x per season	Sunrise – 10am
Herpetofauna	Coverboard & Visual Encounter	January – December (Monthly)	Each bat and camera trap survey visit	Same as bat and camera trap
Invertebrate	Malaise, Pitfall and Blue Vane Traps	April - November	2-4x per month	24 hours
Habitat/Vegetation	CNPS & CWHR Circle Plot	March - October	One time only (2020)	Varied

Small Mammal Trapping Survey

Methodology

Field

Small mammal surveys were conducted during fall (September and October) 2020 and 2021 (see Appendix C for survey schedule) at six Delta Levees Program locations (Cosumnes River Preserve, Grizzly Slough, McCormack-Williamson Tract, Twitchell Island, Sherman Island, and Dutch Slough) across 35 sites in the Sacramento-San Joaquin Delta (Figure 2). We surveyed small mammals at different locations within each site in 2020 versus 2021 to increase sampling effort across the California Delta. All sites were surveyed during 2020, but we were unable to survey Grizzly Slough before the end of the 2021 survey period due to early rains.

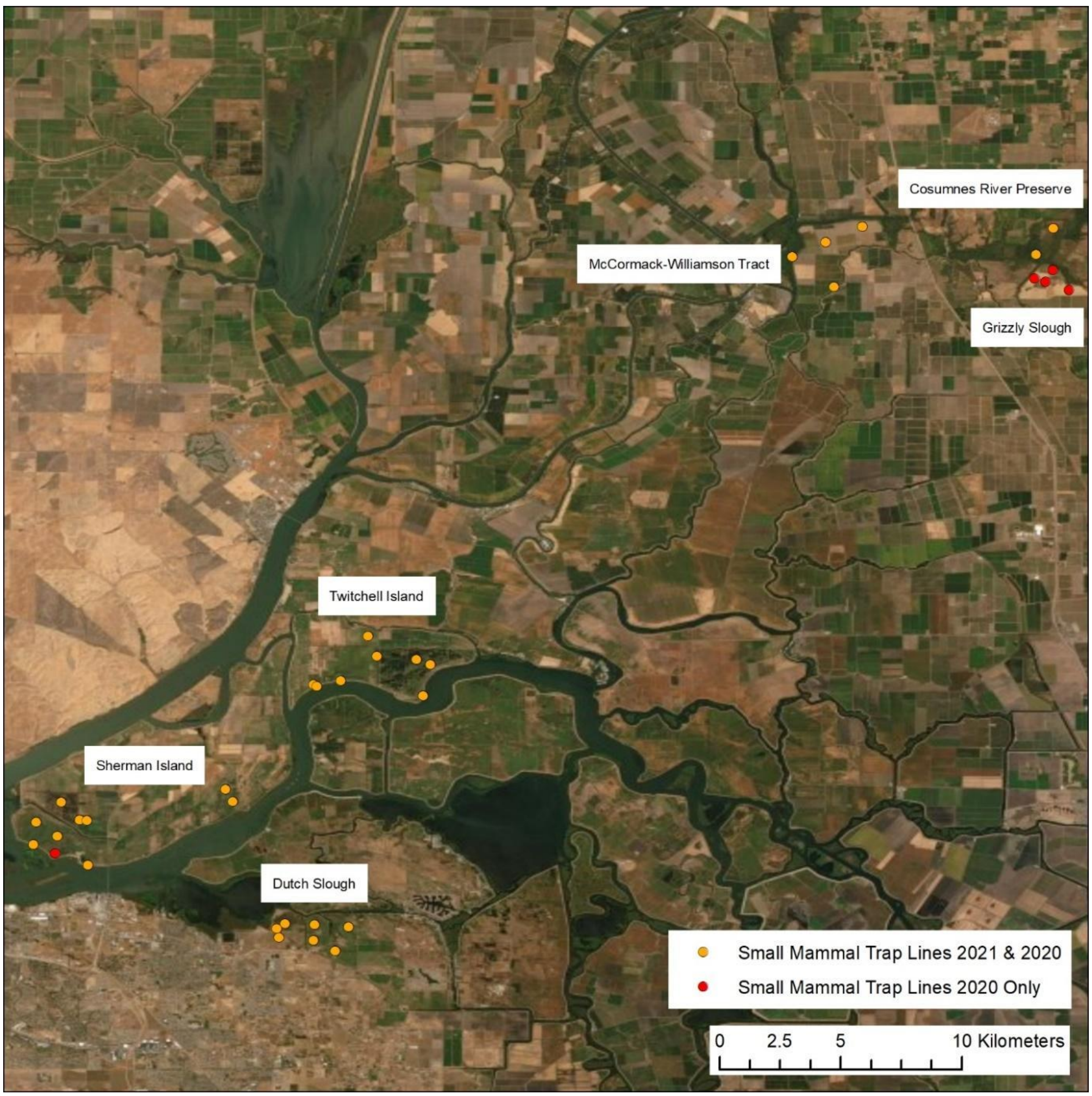

Figure 2: Overview map of small mammal trap line locations (35 in total) across the study area.

We live-trapped small mammals (<200 g) using Sherman traps (7.62x8.89x22.86 cm). Depending on the site, we placed the Sherman traps using one of two spatial layouts. At linear sites, such as along levees or roads, we arranged 50 traps 5 meters apart in a 250-meter line across the site. In all other sites we employed a nodal trapping protocol. For nodal trapping, traps were arranged in lines of ten trap nodes, each node separated by 20 meters. Each node consisted of five Sherman live traps placed within 5 meters of the node's center, with a total of 50 traps per 200-meter long trap line (Figure 3).

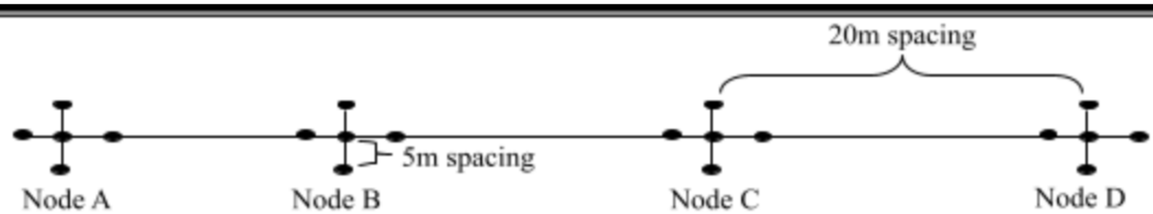

Figure 3. Schematic of small mammal trapping nodes employed by MWFB protocol.

We marked each trap location with plastic flagging tied to vegetation or a fence (Figure 4). When the temperature was forecasted to drop below 10 °C (50 °F), we added polyester batting to the traps for insulation/bedding. Each site was surveyed over three consecutive nights. We opened traps at sunset, baiting them with rolled oats, and returned to check them beginning at sunrise the next morning.

Figure 4: An example of a linear small mammal trap line in a pasture site at the Dutch Slough Burroughs parcel.

When we captured an animal, we identified it to species and noted its age, sex, weight, and reproductive status (Figure 5). We marked each captured animal by trimming a small area of fur from their rear to indicate if an animal was recaptured on a following night. Additionally, we conducted visual encounter surveys, recording all incidental observations of mammals including under coverboards, or via the presence of scat, tracks, and other physical signs (gnawing, runs, etc.) at each site, however incidentals were not used in our analysis of relative abundance for small mammals.

Figure 5: MWFB Delta team hard at work marking House Mice at Dutch Slough that were captured in Sherman live traps (upper left). Michelle weighing a Black Rat (upper right). Danielle checking the reproductive status of a California Meadow Vole (lower left). Michelle training our intern, Karen, in handling small mammals (lower right).

Small mammals were surveyed using mark-recapture methods in fall (September and October) 2020 for 105 nights of trapping, which totaled 5,250 trap nights (35 sites x 50 traps at each site x 3 survey nights), and in fall 2021 for 93 nights of trapping, totaling 4,500 trap nights (30 sites x 50 traps at each site x 3 survey nights). Grizzly Slough and Sherman Island Unit 2 were not surveyed in 2021 due to rain.

There was concern from DWR and CDFW scientists about capturing the endangered Salt Marsh Harvest Mouse (*Reithrodontomys raviventris)* at Dutch Slough, Sherman Island, and Twitchell Island, as they can be difficult to distinguish from the more widespread Western Harvest Mouse (*Reithrodontomys megalotis* - REME). Laureen Thompson of CDFW visited these sites during sampling on October 7, 2020, to assess the habitats and provide a genetic test kit. She determined that the habitats were likely not suitable for Salt Marsh Harvest Mice, and that the trapped Western Harvest Mice did not display the physical traits and behaviors associated with Salt Marsh Harvest Mice.

Analysis

We examined effects of habitat on small mammal relative abundance with data from 2020 and 2021 using generalized linear mixed models for each species and for three sets of predictor habitat variables. The first set of variables included categorical habitat classifications for each site (pasture, riparian, and wetland). The second set of variables were derived from the California Department of Fish and Wildlife's Delta Vegetation and Land Use 2011 land cover classification (CDFW 2011). We reclassified the California Wildlife Habitat Relationship categories into three classes (pasture, riparian, and wetland), and calculated the percent cover of each habitat type within a 50-meter radius of each point count station. The third set of variables were measured at each site by DWR scientists (see the Vegetation section). We used percent bare ground, herbaceous vegetation, litter, marsh, shrub, tree, and water cover as predictors. Finally, we used day of year as a fixed effect in each model as we expected capture rates to decline later in the year. To account for interannual variability and spatial autocorrelation, we included random effects of year and 'macrosite'. As small mammal trapping often results in zero catches per unit effort, we built models using a Tweedie distribution with a log link function (Shono 2008). We checked for multicollinearity of predictor variables and no model resulted in variable inflation factor values greater than 10. Thus, all fixed effects were retained in global models. We ensured goodness-of-fit of each model by using diagnostic tests for uniformity, dispersion, outliers, quantiles, and zero-inflation.

We created all possible subsets of the fixed effects in the global model and ranked them by Akaike Information Criterion (AIC). We then ran model averaging (Grueber et al., 2011) on the subset of models that were within 2.0 AIC of the top scoring model (Burnham and Anderson, 2002) and reported subset (i.e., conditional) averages for coefficient values. For the set of categorical habitat variables, we ran pairwise Tukey HSD tests. All statistical analyses were conducted in R version 4.0.5 (R Core Team, 2021) using the "DHARMa" (Hartig 2021), "emmeans" (Length et al. 2021), "glmmTMB" (Brooks et al., 2017), "MuMIn" (Barton, 2020), and "performance" (Lüdecke et al., 2020) packages.

Small Mammal Results 2020-2021

Small mammals captured across the six macrosites during fall (September and October) 2020 and 2021 survey seasons included California native species Deer Mouse, Western Harvest Mouse, and California Meadow Vole, and introduced species House Mouse, and Black Rat (Figure 6; Table 2). Additional small mammal species that we observed directly or indirectly at the sites but not captured in our trapping effort include Ornate Shrew, Broad-footed Mole, and Botta's Pocket Gopher (Table 2). We captured a total of 704 individuals in 2020 and 405 individuals in 2021 (0.13 individuals per trap night in 2020 and 0.09 individuals per trap night in 2021) during each two-month trapping period (Table 3).

Table 2: Small mammal species (<200g) identified in our 2020 and 2021 surveys from small mammal trapping (marked by "X"s), or coverboard surveys and incidental sightings (marked by "*"s) in the Sacramento-San Joaquin Delta. Macrosite locations include Cosumnes River Preserve (CR), Grizzly Slough (GS), McCormack-Williamson Tract (MW), Twitchell Island (TW), Sherman Island (SH), and Dutch Slough (DS). (I) indicates introduced species.

Family	**Species**		**Macrosite**					
	(Common Name)	(Scientific Name)	CR	GS	MW	TW	SH	DS
Shrews (Soricidae)	Ornate Shrew	*Sorex ornatus*	*					
Moles (Talpidae)	Broad-footed Mole	*Scapanus latimanus*				*		
Pocket Gophers (Geomyidae)	Botta's Pocket Gopher	*Thomomys bottae*					*	*
New World Rats, Mice & Voles (Cricetidae)	Deer Mouse	*Peromyscus maniculatus*		X	X			X
	Western Harvest Mouse	*Reithrodontomys megalotis*	X	X	X	X	X	X
	California Meadow Vole	*Microtus californicus*	X	X	X	X	X	X
Old World Rats & Mice (Muridae)	House Mouse **(I)**	*Mus musculus* **(I)**	X	X	X	X	X	X
	Black Rat **(I)**	*Rattus rattus* **(I)**	X	X	X	X	X	X

Figure 6: Examples of small mammal species captured during our 2020 fall survey season. House Mouse (Dutch Slough; upper left), Western Harvest Mouse (Dutch Slough; upper right), Deer Mouse (McCormack-Williamson Tract; bottom left), and California Meadow Vole (Dutch Slough; bottom right).

Table 3: Number of individuals of small mammal species captured at each macrosite during the September - October 2020 and 2021 trapping periods. Note: Grizzly Slough and Sherman Island Unit 2 (refer to Appendix C) were not surveyed in 2021 due to early-season rains.

Macrosite	Species	Number of Individuals Captured 2020	Number of Individuals Captured 2021
Cosumnes River Preserve (CR)			
	Deer Mouse	0	0
	Western Harvest Mouse	2	0
	California Meadow Vole	3	0
	House Mouse	7	2
	Black Rat	8	5
Grizzly Slough (GS)			
	Deer Mouse	13	NA
	Western Harvest Mouse	5	NA
	California Meadow Vole	42	NA
	House Mouse	35	NA
	Black Rat	8	NA
McCormack-Williamson Tract (MW)			
	Deer Mouse	4	43
	Western Harvest Mouse	27	11
	California Meadow Vole	3	0
	House Mouse	19	5
	Black Rat	1	1
Twitchell Island (TW)			
	Deer Mouse	0	0
	Western Harvest Mouse	22	10
	California Meadow Vole	6	4
	House Mouse	40	66
	Black Rat	2	3
Sherman Island (SH)			
	Deer Mouse	0	0
	Western Harvest Mouse	3	1
	California Meadow Vole	4	1
	House Mouse	295	65
	Black Rat	9	4
Dutch Slough (DS)			
	Deer Mouse	35	5
	Western Harvest Mouse	5	44
	California Meadow Vole	12	9
	House Mouse	94	125
	Black Rat	0	1
Total		**704**	**405**

Deer Mouse abundance had no statistically significant relationship to categorical habitat type in our study area (Figure 7). Percent bare ground cover (p = 0.02) and water cover (p = 0.009) both had a positive relationship with Deer Mouse abundance. In addition, we found that a higher percentage of shrub cover (p = 0.01) resulted in lower Deer Mouse abundance. Deer Mice are found to adapt to many environments and tend to prefer herbaceous, scrubland, woodland forest, desert, and fire prone areas (Bonds, 1977). Populations of Deer Mice can vary seasonally (as we saw in our highly variable capture rates: Table 3) and high densities result in population expansions into other habitat types (Millus and Stapp, 2008).

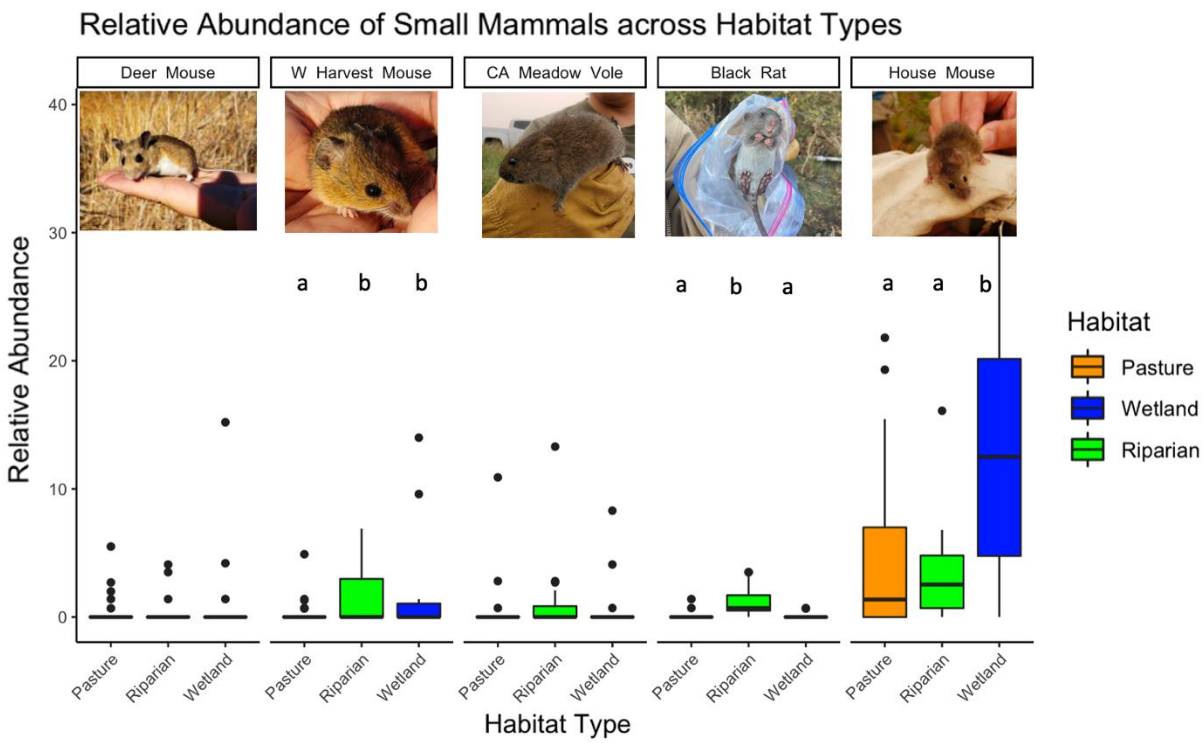

Figure 7: Effect of categorical habitat type on relative abundance (number of captures per 100 trap nights) of small mammals in the California Delta. Letters represent groupings of significant difference between habitat types.

We found no evidence of any vegetation type or habitat covariate affecting California Meadow Vole relative abundance (Figure 7). However, previous studies found voles prefer habitat with large shrubs and woody debris (Bias and Morrison, 2006). This may be due to a low sample size from the 2021 season. Additional data will aid in determining factors affecting relative abundance of California Meadow Voles.

Western Harvest Mouse relative abundance was highest in riparian forests (p = 0.03; Figure 7) and was found to be negatively associated with percent pasture cover (p = 0.009; Figure 8).

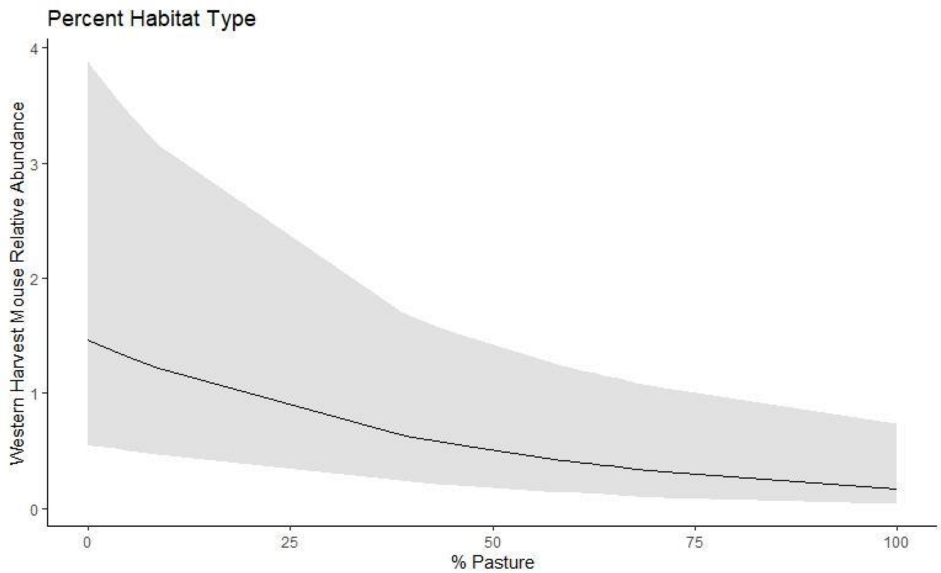

Figure 8: Effect of percent pasture cover on Western Harvest Mouse relative abundance (number of captures per 100 trap nights).

Black Rat abundance was significantly higher in riparian forests than in any other habitat type ($p < 0.001$; Figure 7) and percent tree cover was significantly positively associated with Black Rat abundance across our survey sites ($p < 0.005$; Figure 9). Our results are consistent with other studies that found Black Rats favor habitat which provides dense foliage cover (particularly Himalayan Blackberry (*Rubus discolor*), leaf litter, and vertical understory to provide adequate climbing substrates) (Cox, Dickman and Cox, 2001; Whisson et al., 2004; Whisson et al., 2007). Black Rats are highly adaptable to many environments (Elton, 1942) and have successfully spread all over the world with the unintended help from humans for thousands of years (Watts and Aslin, 1981).

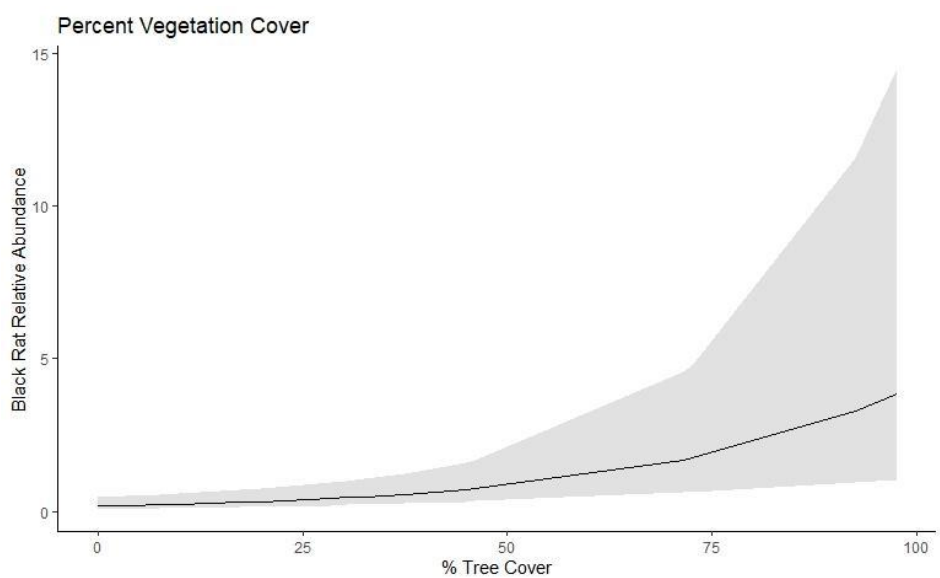

Figure 9: Effect of tree cover on Black Rat relative abundance (number of captures per 100 trap nights).

Wetlands had significantly higher abundance of House Mouse than riparian forest (p < 0.001) and pasture (p = 0.002; Figure 7) and House Mouse relative abundance was greater in areas with higher herbaceous cover (p = 0.009), marsh cover (p < 0.001; Figure 10) and open water (p = 0.004). Furthermore, House Mouse abundance was negatively associated with percent riparian cover (p <0.001; Figure 11). In tidal marshes, invasive species like Black Rats and House Mice have been known to outcompete native species such as Harvest Mice and Meadow Voles and tend to do better in highly disturbed tidal marshes near human development (Padgett-Flohr and Isakson, 2003). House Mice prefer patchy, fragmented habitat, while homogeneous habitats are preferred by the native Salt Marsh Harvest Mouse (Bias and Morrison, 2006). Reducing habitat fragmentation may favor Harvest Mouse abundance, while concurrently reducing House Mouse populations (Bias and Morrison, 2006).

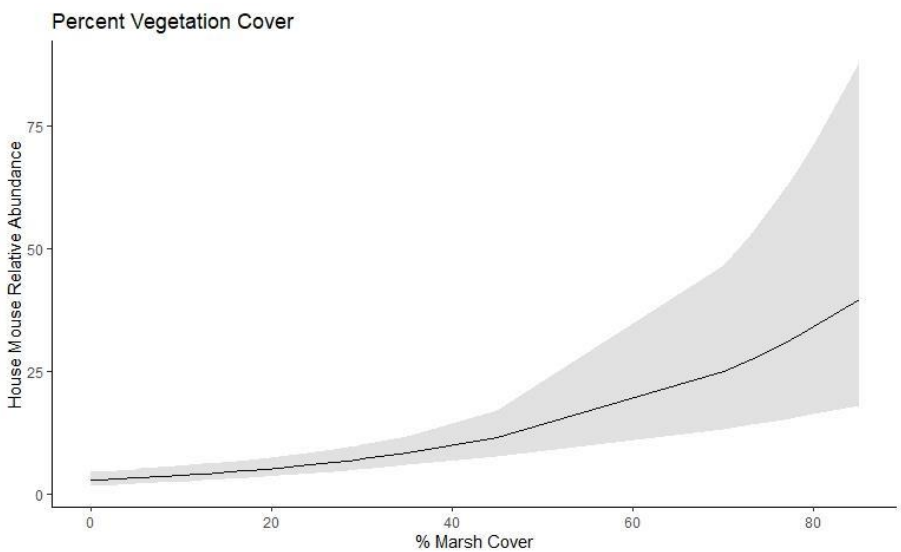

Figure 10: Effect of marsh vegetation cover on House Mouse relative abundance (number of captures per 100 trap nights).

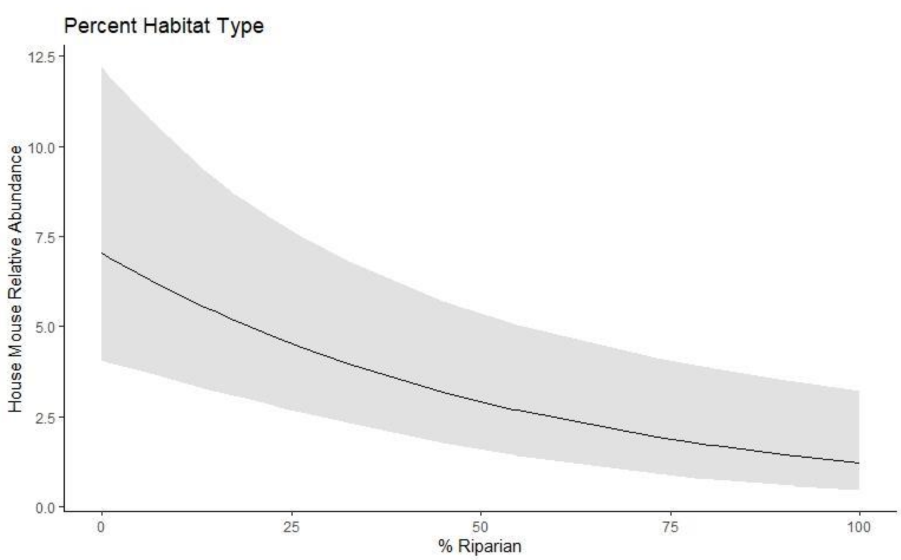

Figure 11: Effect of riparian habitat on House Mouse relative abundance (number of captures per 100 trap nights).

Mammalian Mesocarnivore & Herbivore Camera Trap Surveys

Methodology

Field

Camera trap surveys were conducted in September-October of 2020 and from April of 2021 to present, at six Delta Levees Program locations across 35 points (Figure 12).

Figure 12: Overview map of camera trap and bat detector locations (35 in total) across the study area.

We established one camera trap station at each of the 35 microsites, equipped with a Bushnell Trophy Cam HD Low-Glow trail camera attached to a T-stake a half-meter above the ground

(Figure 12). Each camera trap station was baited with an aluminum screw-top tin with holes drilled into the top, attached to the top of a T-stake with a nut and bolt, and filled with a ~1 ounce of fish-based cat food. This design allowed the scent of the cat food to attract mesocarnivores while not allowing them access to the food inside. We trapped for 3 consecutive days (~72 hours total) at each site once in 2020, and for 4 consecutive days (~96 hours total) at each site per month in 2021, beginning in April. Total camera trap effort was 945 trap days or about 22,680 trap hours (through September 2021). In addition, we conducted visual encounter surveys, recording all incidental observations of mammals or their physical signs (e.g., scat or tracks) at each site. Analysis of camera trap and incidental data was used to determine mammalian mesocarnivore and herbivore species diversity and occupancy at each site, across categorical, remotely sensed, and ground-surveyed habitat and cover types.

Figure 13: (Top) An example of a complete camera trap set up on Dutch Slough (top). An aluminum bait can secured to a T-stake with a nut and bolt (bottom left). Trail camera secured to T-stake with nylon strap and rubber gear tie and locked to the bat detector box with a python cable (bottom right).

Analysis
We examined effects of habitat on mammalian mesocarnivores and herbivore species richness using generalized linear mixed models for three sets of predictor habitat variables. The first set of variables included categorical habitat classifications for each site (pasture, riparian, and wetland). The second set of variables were derived from the California Department of Fish and Wildlife's Delta Vegetation and Land Use 2011 land cover classification (CDFW 2011). We reclassified the California Wildlife Habitat Relationship categories into three classes (pasture, riparian, and wetland), and calculated the percent cover of each habitat type within a 50-meter radius of each point count station. The third set of variables were measured at each site by DWR scientists (see the Vegetation section). We used percent bare ground, herbaceous vegetation, litter, marsh, shrub, tree, and water cover as predictors. To account for spatial autocorrelation, we included the random effect of 'macrosite.' We checked for multicollinearity of predictor variables and no model resulted in variable inflation factor values greater than 10. Thus, all fixed effects were retained in global models. We ensured goodness-of-fit of each model by using diagnostic tests for uniformity, dispersion, outliers, quantiles, and zero-inflation.

We created all possible subsets of the fixed effects in the global model and ranked them by Akaike Information Criterion (AIC). We then ran model averaging (Grueber et al., 2011) on the subset of models that were within 2.0 AIC of the top scoring model (Burnham and Anderson, 2002) and reported subset (i.e., conditional) averages for coefficient values. For the set of categorical habitat variables, we ran pairwise Tukey HSD tests. All statistical analyses were conducted in R version 4.0.5 (R Core Team, 2021) using the "DHARMa" (Hartig 2021), "emmeans" (Length et al. 2021), "glmmTMB" (Brooks et al., 2017), "MuMIn" (Barton, 2020), and "performance" (Lüdecke et al., 2020) packages.

Mammalian Mesocarnivore & Herbivore Results

We observed a total of 18 species of mammalian mesocarnivores and herbivores at the six macrosite locations, including 15 California native species and 3 introduced species (Table 4).

Table 4: Mammal species (excluding those targeted in trapping efforts) identified in our 2020-21 surveys from camera traps and incidental sightings in the Sacramento-San Joaquin Delta. Macrosite locations include Cosumnes River Preserve (CR), Grizzly Slough (GS), McCormack-Williamson Tract (MW), Twitchell Island (TW), Sherman Island (SH), and Dutch Slough (DS). (I) indicates introduced species. *Introduction status unknown.

Family	**Species**		**Macrosite**					
	(Common Name)	(Scientific Name)	CR	GS	MW	TW	SH	DS
Opossums (Didelphidae)	Virginia Opossum **(I)**	*Didelphis virginiana* **(I)**				X	X	X
Rabbits (Leporidae)	Black-tailed Jackrabbit	*Lepus californicus*		X		X	X	X
	Desert Cottontail	*Sylvilagus audubonii*	X	X	X	X		X
Squirrels (Sciuridae)	Fox Squirrel **(I)**	*Sciurus niger* **(I)**	X	X	X			X
	California Ground Squirrel	*Otospermophilus beecheyi*		X	X	X	X	X
Beavers (Castoridae)	North American Beaver	*Castor canadensis*		X		X	X	
Cats (Felidae)	Bobcat	*Lynx rufus*	X	X	X			
Canids (Canidae)	Coyote	*Canis latrans*		X	X	X	X	X
	Red Fox*	*Vulpes vulpes**					X	
Skunks (Mephitidae)	Western Striped Skunk	*Mephitis mephitis*	X			X	X	X
Raccoons (Procyonidae)	Raccoon	*Procyon lotor*	X	X	X	X	X	X
Mustelids (Mustelidae)	River Otter	*Lontra canadensis*	X		X	X	X	X
	American Mink	*Neogale vison*		X		X	X	X
	Long-tailed Weasel	*Neogale frenata*						X
Deer (Cervidae)	Black-tailed Deer	*Odocoileus hemionus*	X	X	X			X

It is possible that the Red Foxes observed in the Delta may be the native Sacramento Valley Red Fox (*Vulpes vulpes patwin*) and not the introduced European Red Fox (*Vulpes vulpes crucigera*). Both subspecies' ranges extend into the north Delta (Sacks et al., 2010), and the distribution has not been clarified, so the Red Fox was given an introduction status of unknown.

Figure 14: Camera trap photos of a Virginia Opossum climbing a bait stake (SH; upper left), a Black-tailed Jackrabbit sniffing out the bait (TW; upper right), a Coyote pup exploring the marsh (SH; bottom left), and a Raccoon by the creek (DS; bottom right).

We found little variation in species richness between macrosites for mammalian mesocarnivores and herbivores observed through camera trap photos and incidental sightings or signs (Figure 15). Dutch Slough had the most mammalian mesocarnivore and herbivore species observed (12) while Cosumnes River Preserve had the least (7).

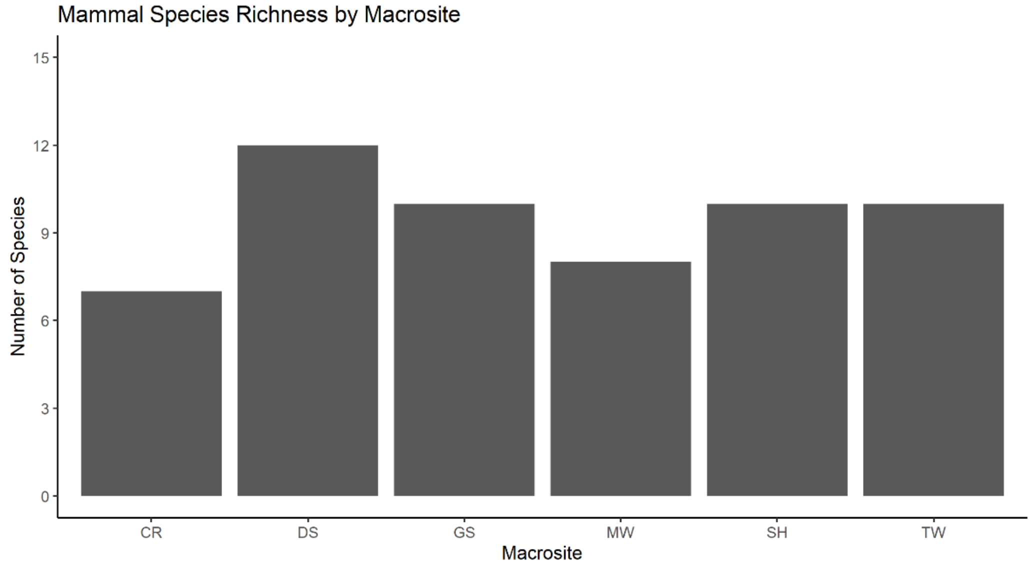

Figure 15: Total mammal species richness by macrosite yields similar results across macrosites.

Mammalian mesocarnivore and herbivore species richness was lowest in pasture habitat, but the differences were not significant (Figure 16).

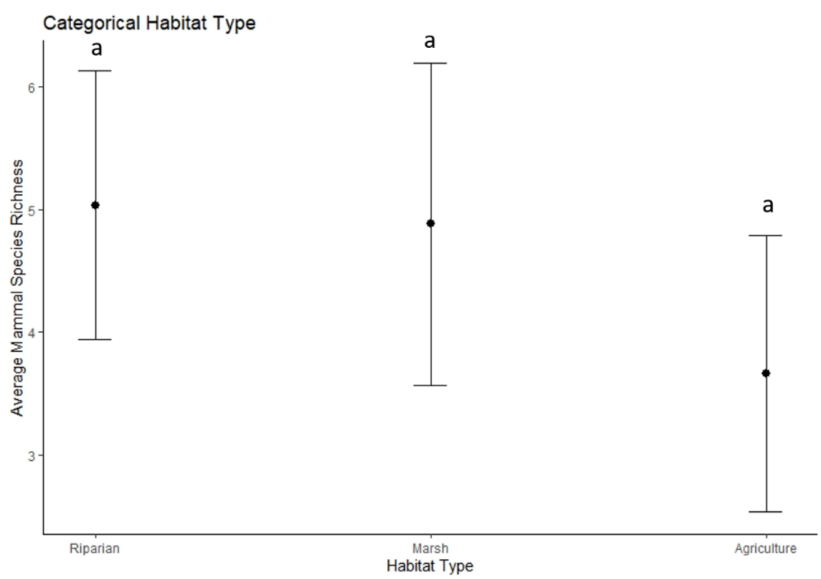

Figure 16: Average mammal species richness observed at microsites as predicted by categorical habitat type.

Average mammalian mesocarnivore and herbivore species richness increased at microsites with increasing tree cover ($p = 0.045$; Figure 17) and open water cover ($p < 0.0001$), but is negatively correlated with bare ground cover ($p = 0.04$). Forest cover provides natural food and shelter resources for Striped Skunks (Amspacher et al., 2020; Rodriguez et al. 2021) and for Bobcats (Anderson et al., 1987; Rodriguez et al. 2021), and is associated with River Otter (Torgerson et al. 2014) habitat selection.

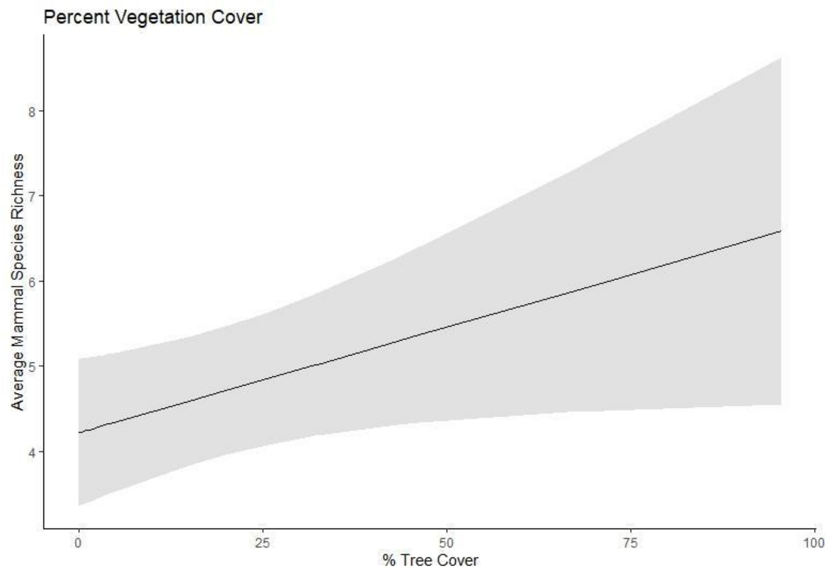

Figure 17: Average mammal species richness observed at microsites as predicted by percent vegetation cover.

Conversely, average mammal species richness decreased as percent cover of pasture increased (p = 0.02; Figure 18). Areas with high pasture cover tend to lack year-round ground cover and support lower prey density, causing mammalian mesocarnivores to avoid large patches of agriculture (McDonald et al., 2008).

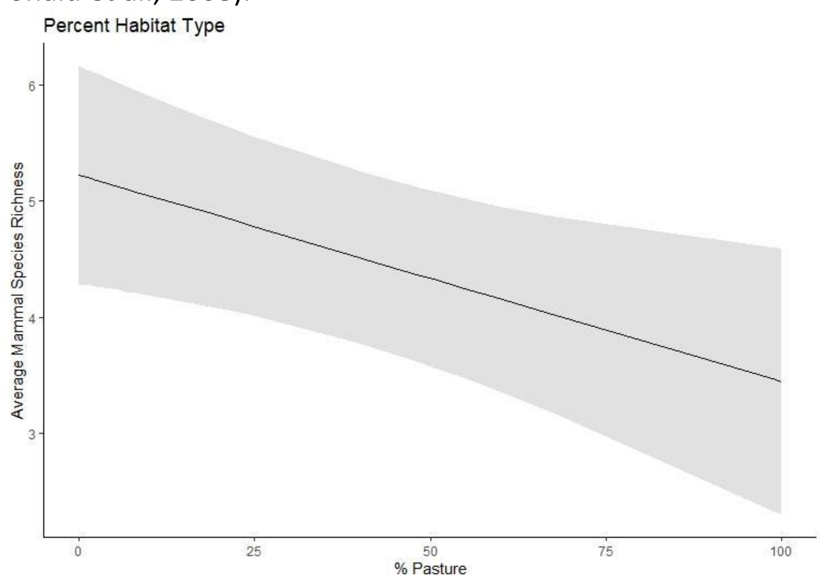

Figure 18: Average mammal species richness observed at microsites as predicted by percent habitat type.

Coyote and Raccoon, both habitat generalists with diverse diets, occupied the most microsites (Figure 19). The most common herbivores were the Desert Cottontail and Black-tailed Jackrabbit. River Otter actively used the restored wetland sites at Dutch Slough and the subsidence reversal sites on Sherman Island, but not the Twitchell Island subsidence reversal wetland site. A possible explanation could be that the restored wetland and subsidence reversal sites on Dutch Slough and Sherman Island have significantly more open water than Twitchell Island. Otters also occupied other sites with visible open water such as Twitchell Meadow & Canal (TWMC), Twitchell Setback Levee (TWSB), and Sherman Setback Levee Reference (SHSR). Open water provides areas for foraging, which would make open freshwater wetlands more suitable Otter habitat (Anderson and Woolf 1987). Camera traps showed Bobcats present in just the north Delta, occurring only in mature riparian forest on Grizzly Slough and at Cosumnes River Preserve (Table 4). Compared to Coyotes, Bobcats are not as successful in urbanized or fragmented habitats (Riley et al. 2003). This observation may explain why Bobcats are not present in the south Delta, where dispersal would require crossing urban development and bridges, with only fragmented, newly restored riparian forest areas available to them.

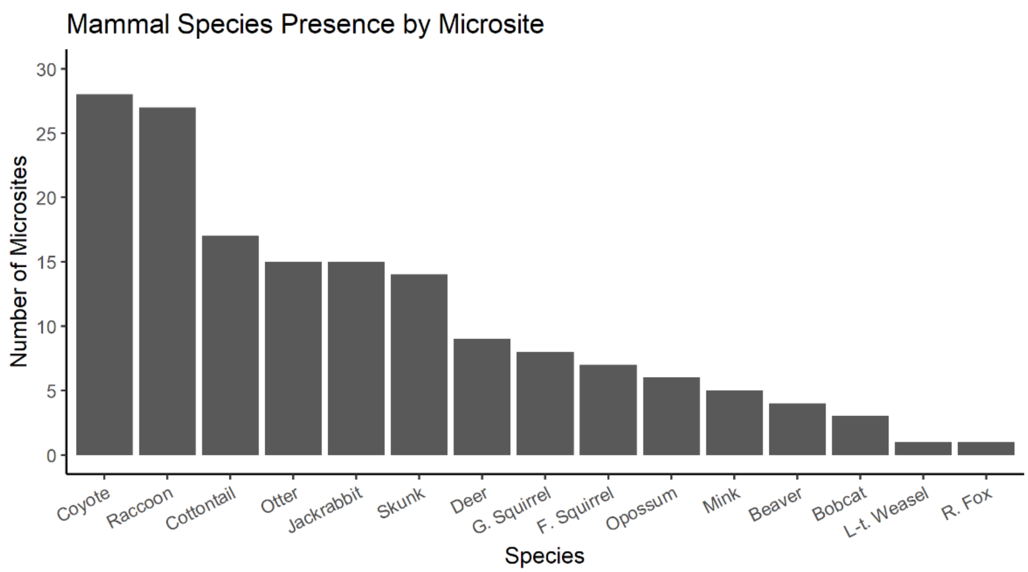

Figure 19: Mammal species presence across all the microsites, displayed from most- to least-widely observed.

Figure 20: Camera trap photos of an American Mink carrying a fresh-caught crayfish (TW; top left), a Striped Skunk visiting the camera station at night (SH; top right), a River Otter emerging from the creek (DS; bottom left), and a Bobcat resting in front of the bait station (MW; bottom right).

Bat Passive Acoustic Survey

Methodology

Field

Passive bat acoustic surveys were conducted in September and October 2020 and from April through December 2021 (Figure 21) at six Delta Levees Program locations (Cosumnes River Preserve, Grizzly Slough, McCormack-Williamson Tract, Twitchell Island, Sherman Island, and Dutch Slough) (Figure 22). We surveyed bats for a total of 210 survey nights in fall 2020 and 1,224 survey nights in 2021. At each of the 35 sites, we established a passive acoustic survey station equipped with a Pettersson Model D500X full-spectrum ultrasonic detector that was deployed for four consecutive nights as per the North American Bat Monitoring Program (NA Bat) protocols. We established a fixed location to mount the detectors by driving a stake into the ground and connected the microphone to a 4-meter tall pole and angled them towards flight corridors. Detectors were turned on 15 minutes prior to sunset and left on until 15 minutes after sunrise. Microphones were oriented horizontally to maximize the amount of detectable airspace and minimize the amount of vegetative clutter that would generate noise within the sample space. We used the high-pass filter on each detector to reduce undesired low frequency signals below 15 kHz. We customized the recording modes (gain, trigger level, and interval) for each detector depending on the density of vegetation surrounding the microphone at the detector location. The recording settings would be set to 60/120/0 for cluttered habitat, while detectors in non-cluttered habitat would have settings that read 45/160/0.

Figure 21: Photos of the MWFB Delta team setting up passive bat acoustic stations at Dutch Slough.

Figure 22: Overview map of bat acoustic station locations (35 in total) across the study area.

Analysis

We used SonoBat bat call analysis software (version 4) to identify recorded bat calls to species and used the maximum likelihood estimator to determine bat presence (>50%). We only used bat data collected from April-September 2021 in these models. Bat presence was converted to binary data (zero for <50% and one for >= 50%). We first used single-species, single-season occupancy models to investigate the effects of habitat type for bat species occupancy across the entire study area. Day of year and wind speed were included as detection covariates. We expected bat detection to decrease later in the season and with higher wind speeds. These models used presence/absence data to determine the occupancy of a species across our survey sites. We reclassified the California Wildlife Habitat Relationship categories into three classes (pasture, riparian, and wetland), and calculated the percent cover of each habitat type within a 50-meter radius of each bat acoustic station for environmental predictors of bat occupancy. We created all possible subsets of the fixed effects in the global model and ranked them by Akaike Information Criterion (AIC). We then ran model averaging (Grueber et al., 2011) on the subset of models that were within 2.0 AIC of the top scoring model (Burnham and Anderson, 2002) and reported subset (i.e., conditional) averages for coefficient values.

In addition, we examined the effect of season on bat occupancy using dynamic occupancy models. Dynamic occupancy models work well for mapping spatiotemporal occupancy patterns and account for imperfect detection probability. We used season as a random effect in the model as we expected occupancy to change over the seasons (increasing in the spring with warming temperatures and/or migration, peaking in the summer breeding season, and decreasing in fall with cooling temperatures and/or migration). We created all possible subsets of the fixed effects in the global model and ranked them by Akaike Information Criterion (AIC). All statistical analyses were conducted in R version 4.0.5 (R Core Team, 2021) using the "unmarked" (Chandler et al., 2021), "bbmle" (Bolker et al., 2013), "AICcmodavg" (Mazerolle, 2020), "ggplot2" (Wickham et al., 2021) packages.

Bat Results

We detected seven bat species across the six macrosites during our 2020 and 2021 survey seasons (Table 5; Figure 23).

Table 5: Bat calls identified to species in our 2020 and 2021 surveys in the Sacramento-San Joaquin Delta are listed below. Macrosite locations include Cosumnes River Preserve (CR), Grizzly Slough (GS), McCormack-Williamson Tract (MW), Twitchell Island (TW), Sherman Island (SH), and Dutch Slough (DS). "X's" represent bat species presence where SonoBat's maximum likelihood estimator was greater than 50% for auto-classified calls.

Species			**Macrosite**					
(Common Name)	(Scientific Name)	Bat Codes	CR	GS	MW	TW	SH	DS
Molossidae								
Free-tailed Bat	*Tadarida brasilliensis*	TABR	X	X	X	X	X	X
Vespertilionidae								
California Myotis	*Myotis californicus*	MYCA	X	X				
Hoary Bat	*Lasiurus cinereus*	LACI				X		
Little Brown Bat	*Myotis lucifugus*	MYLU	X	X				
Silver-haired Bat	*Lasionycteris noctivagans*	LANO	X	X	X	X	X	X
Western Red Bat	*Lasiurus blossevillii*	LABL	X	X	X	X	X	X
Yuma Myotis	*Myotis yumanensis*	MYYU	X			X		X

Figure 23: Photos of bat species that we found to occupy the California Delta. Photos are labeled with each bat species code. Free-tailed Bat (top left), Hoary Bat (top right), Little Brown Bat (middle left), California Myotis (middle center), Silver-haired Bat (middle right), Western Red Bat (bottom left), and Yuma Myotis (bottom right).

We detected 10 bat species across our study area in 2021 (seven species had enough detections to include in the models; Figure 24). Free-tailed Bat had the highest predicted occupancy across our study sites. Free-tailed Bat is a resident species that has become highly adaptable to human modified environments and does well foraging in open landscapes (Smith, 2021). We found no statistical effect of habitat type on Free-tailed Bat occupancy. Little Brown Bat ($p = 0.003$) and Yuma Myotis ($p = 0.03$) were positively associated with riparian forest habitat. Our results are consistent with other studies showing that Little Brown Bats typically forage and roost in forested habitat near water (Coleman et al., 2014).

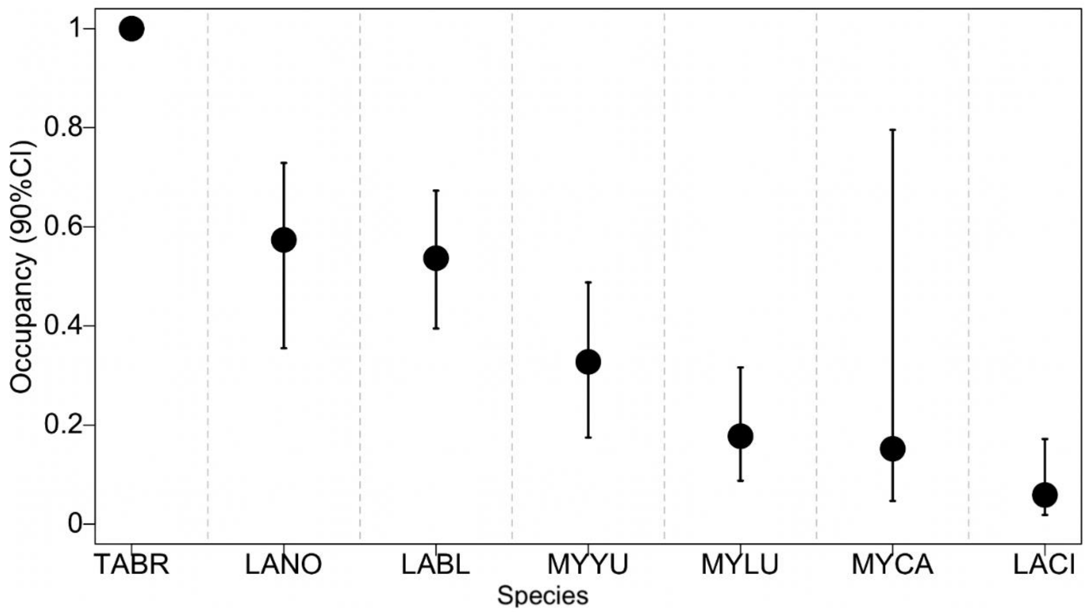

Figure 24: Bat species occupancy across the entire study area, predicted across a single breeding season (April to September 2021).

Detection probability was highest for Free-tailed Bat (Figure 25). Both Western Red Bat and California Myotis detection increased later in the year ($p < 0.05$), suggesting that it's easier to detect species later in the season potentially due to the increased number of individuals after the breeding season. Detection probability for nearly all species was significantly negatively associated with high winds ($p < 0.05$), as predicted.

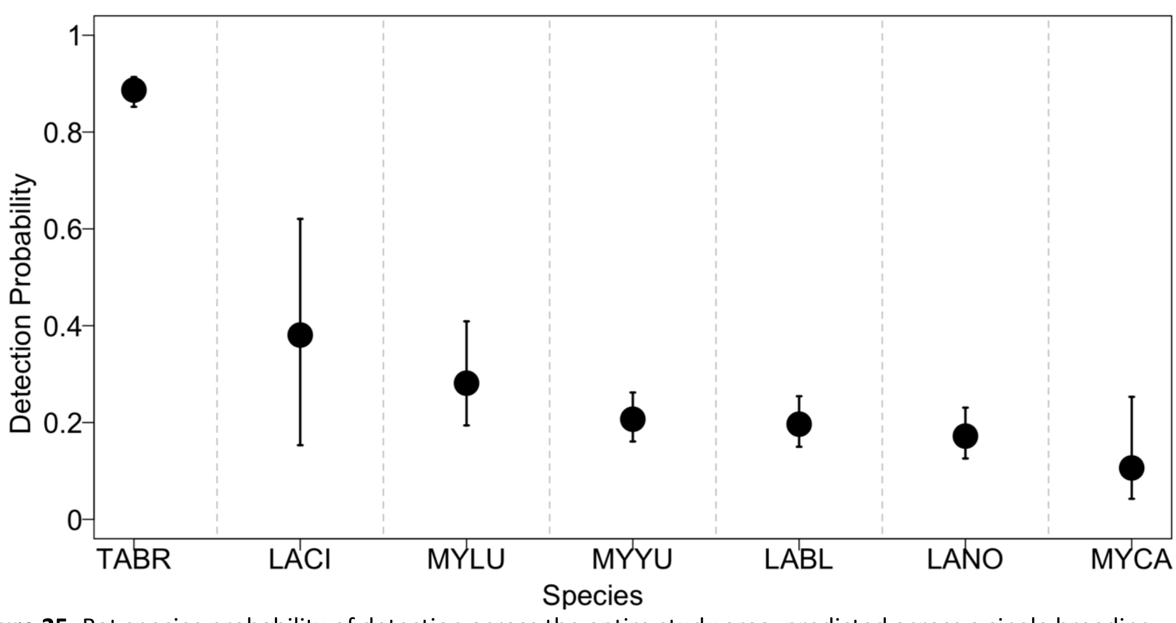

Figure 25: Bat species probability of detection across the entire study area, predicted across a single breeding season (April to September 2021).

Predicted Yuma Myotis occupancy is highest in the summer (Figure 26) when they are breeding and lowest in fall when they likely begin reducing activity levels prior to hibernation (Weller and Stricker, 2012). Yuma Myotis is known to summer in forested habitat across northern California and are less frequently found in the winter months (Weller and Stricker, 2012).

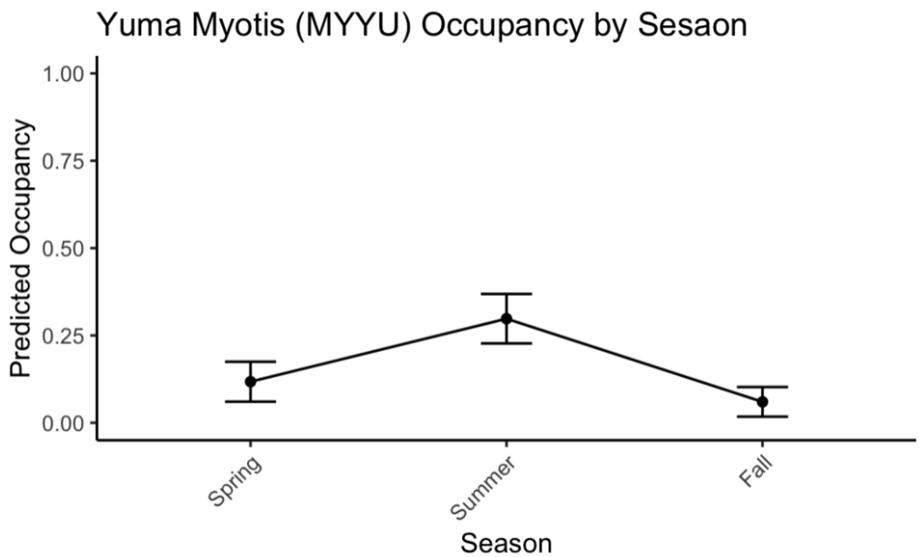

Figure 26: Effect of season on predicted bat occupancy for Yuma Myotis (MYYU).

Western Red Bats are a resident species in the California Central Valley and predicted occupancy does not change our spring-summer-fall model (Figure 27). Our study mirrors other studies in the Central Valley, which have found consistent occupancy across the seasons for Western Red Bat (Smith et al., 2021; Solick et al., 2020).

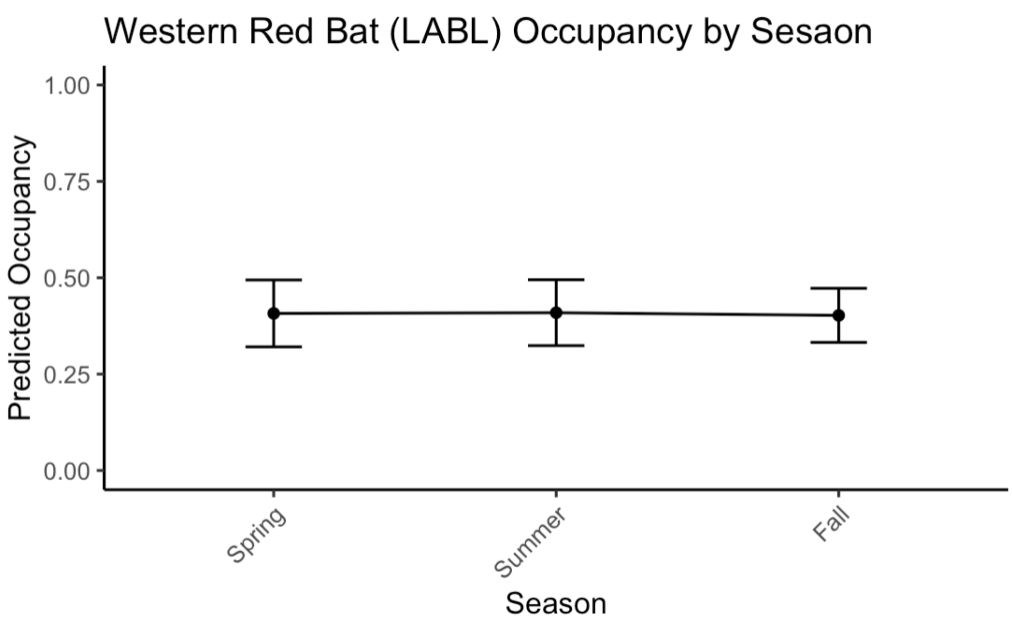

Figure 27: Effect of season on predicted bat occupancy for Western Red Bat (LABL).

As management activities restore and maintain sites, continuation of bat monitoring in the California Delta is crucial. Food web studies linking bats to their insect prey may illuminate vital connections between habitat restoration and management efforts and Delta-wide ecosystem services. Insectivorous bats provide opportunities as bioindicators to evaluate ecosystem health and to provide ecosystem services such as agriculture pest control (Willaims-Gullén et al., 2015) and mosquito pest management (Jones, et al., 2009). Bat and insect bioindicators are correlated in their assessment of habitat quality, and studies from bat diets can provide information on contaminants (such as mercury) brought on by bioaccumulation (Jones, et al., 2009). Assessing bat diets and their interactions with their prey will be an important next step in understanding the impact of habitat restoration and management in the California Delta.

Avian Point Count and Transect Surveys

Point Count Methodology

Field

Avian variable circle point counts were conducted during the 2020 and 2021 breeding seasons at six Delta Levees Program locations across 35 microsites and 152 stations (Figure 28).

Figure 28: Overview map of avian point count stations and coverboard locations (152 in total) across the study area.

Point counts were performed at each site during the breeding season, twice in 2020 (once each in May and June), and thrice during 2021 (once a month in April, May, and June), for a total of 175 surveys. We followed standard variable circle point count survey protocols (Ralph et al., 1993). Repeated surveys at each site were spaced a minimum of 14 days apart. These surveys began no later than 30 minutes after sunrise and were completed by 10:00 am with a maximum of 10 points surveyed by a single surveyor in a morning. Point count sample sites included between 2-6 points, spaced at least 200 meters apart.

Each point was surveyed for 10 minutes, broken into two contiguous 5-minute count periods. For every survey, we recorded surveyor, site, date and time, temperature, wind speed, percent cloud cover, and any weather conditions (rain, drizzle, fog, haze, or smoke). Kestrel 2000 Pocket Wind and Temperature Meters were used to measure initial temperature in Celsius and average wind speed in kph. Every species detected at a point was recorded, regardless of the distance from the observer. For each detection, we estimated the distance in meters from the point to the bird(s) using a Nikon Prostaff 1000 Laser Rangefinder. Flying birds not using the habitat within the count circle and birds observed greater than 100 meters from the point were noted separately and excluded from the analysis. We recorded how each bird was detected (e.g., visually or by song), and if we observed any evidence of breeding (e.g., courtship, nest building, or feeding young). Analysis of avian point count data was used to determine species diversity and density at each site, across categorical, remotely sensed, and ground-surveyed habitat and cover types.

Transect Methodology

Field

Avian transect surveys were conducted once at each site during the 2021 winter season (January and February) and once during the 2021 breeding season (May and June) for 34 of the 35 sites. Lack of access to site MWTN during the breeding season caused it to be skipped, making a total of 69 surveys.

The transect survey protocol outlined in Bird Census Techniques 2nd Edition (Bibby et al., 2000) was used for all transect surveys. Survey timeframes had the same limitations as with the point count surveys, with a maximum of 10 transect segments surveyed by a single surveyor on any morning, and a minimum of 14 days between repeated surveys at any site. Transect lines consisted of between 2-5 consecutive segments, each 100 meters in length. Segments were surveyed consecutively for 10 minutes each. For every survey, we recorded surveyor, site, date and time, temperature, wind speed, percent cloud cover, and any weather conditions (rain, drizzle, fog, haze, or smoke). Kestrel 2000 Pocket Wind and Temperature Meters were used to measure initial temperature in Celsius and average wind speed on the Beaufort scale. Every species detected from the transect line was recorded, along with whether it was first observed within or beyond 30 meters from the line. Flying birds not using the habitat were noted separately and excluded from the analysis. If we observed any evidence of breeding, this was also noted with the observation. Analysis of avian transect data was used to determine species diversity and density at each site, comparing winter and breeding seasons.

Figure 29: Overview map of avian transect lines (35 in total) across the study area.

Figure 30: Some of the bird species we observed in the Delta. Spotted Towhee (top left) and American Kestrel (top right) utilizing riparian habitat. One of the many Sora we saw and heard within the restored marshes (bottom left). Red-winged Blackbird singing on a fence in pasture habitat (bottom right). Photo credit: Andrew Engilis, Jr.

Point Count and Transect Analysis

We examined the effects of habitat on avian species richness using generalized linear mixed models for three sets of predictor habitat variables. The first set of variables included categorical habitat classifications for each site (pasture, riparian, and wetland). The second set of variables were derived from the California Department of Fish and Wildlife's Delta Vegetation and Land Use 2011 land cover classification (CDFW 2011). We reclassified the California Wildlife Habitat Relationship categories into three classes (pasture, riparian, and wetland), and calculated the percent cover of each habitat type within a 50-meter radius of each point count station. The third set of variables were measured at each site by DWR scientists (see the Vegetation section). We used percent bare ground, herbaceous vegetation, litter, marsh, shrub, tree, and water cover as predictors. To account for spatial autocorrelation, we included the random effect of 'macrosite.' For transect analyses, we also included a categorical season variable (winter or breeding). We checked for multicollinearity of predictor variables and no model resulted in variable inflation factor values greater than 10. Thus, all fixed effects were retained in global models. We ensured goodness-of-fit of each model by using diagnostic tests for uniformity, dispersion, outliers, quantiles, and zero-inflation.

We created all possible subsets of the fixed effects in the global model and ranked them by Akaike Information Criterion (AIC). We then ran model averaging (Grueber et al., 2011) on the subset of models that were within 2.0 AIC of the top scoring model (Burnham and Anderson, 2002) and reported subset (i.e., conditional) averages for coefficient values. For the set of categorical habitat variables, we ran pairwise Tukey HSD tests. All statistical analyses were conducted in R version 4.0.5 (R Core Team, 2021) using the “DHARMa” (Hartig 2021), “emmeans” (Length et al. 2021), “glmmTMB” (Brooks et al., 2017), “MuMIn” (Barton, 2020), and “performance” (Lüdecke et al., 2020) packages.

Avian Survey Results

During the 2020 and 2021 avian point count and transect surveys, we identified 121 avian species (60 passerine) across the 152 stations and 35 lines located within the 6 macrosites (Figures 28 and 29). Total avian species richness was highest in riparian sites, significantly higher than in pasture sites ($p < 0.0001$) and marginally greater than in wetland sites ($p = 0.07$; Figure 31). Riparian habitats tend to support greater avian species diversity and density (Szaro et al., 1980). Passerine species richness was also highest in riparian sites, being significantly higher than in pasture or wetland ($p < 0.0001$; Figure 31). There was no significant difference in passerine species richness between pasture and wetland sites. Our total avian species composition included several non-passerine wetland specialists from the families *Podicipedidae*, *Rallidae*, and *Ardeidae*, as well as aerial predators from *Accipitridae*, which could explain the difference in richness at wetland habitats.

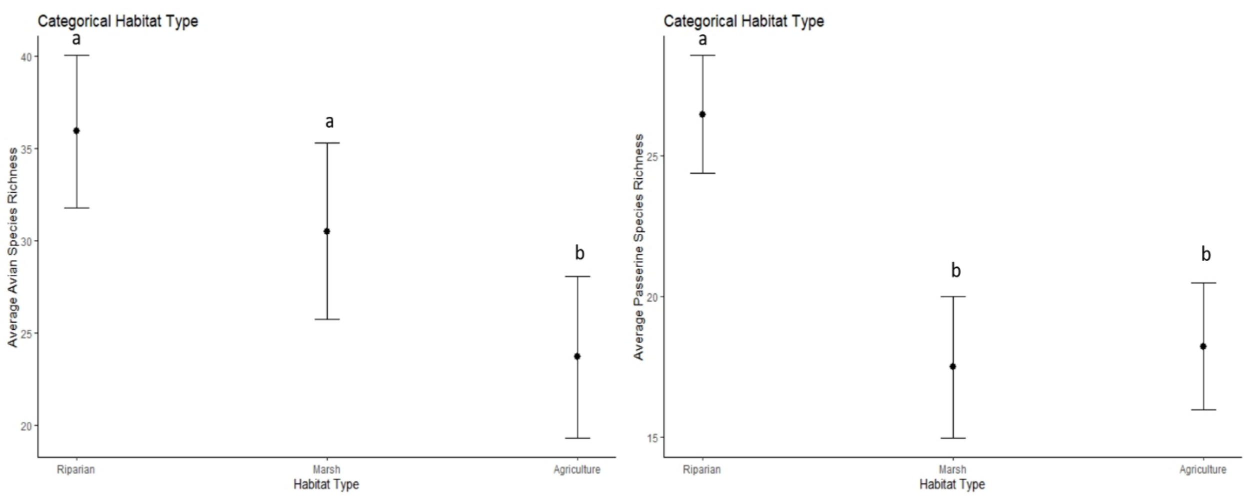

Figure 31: Average number of all avian species (left) and only passerine species (right) at microsites found during breeding season point count surveys as predicted by categorical habitat type.

Average avian species richness increased at microsites with increasing tree cover ($p < 0.0001$) and open water cover ($p = 0.02$; Figure 32). Open water is an important resource for both breeding shorebirds and wintering waterfowl (Kahara et al., 2021). Passerine richness was most strongly positively associated with percent tree cover ($p < 0.0001$; Figure 32). Similarly, tree density has a direct correlation to breeding bird diversity in Arizonan riparian woodlands (Carothers et al. 1974). Passerine richness was negatively correlated with marsh vegetation cover ($p = 0.01$) and litter cover ($p = 0.008$).

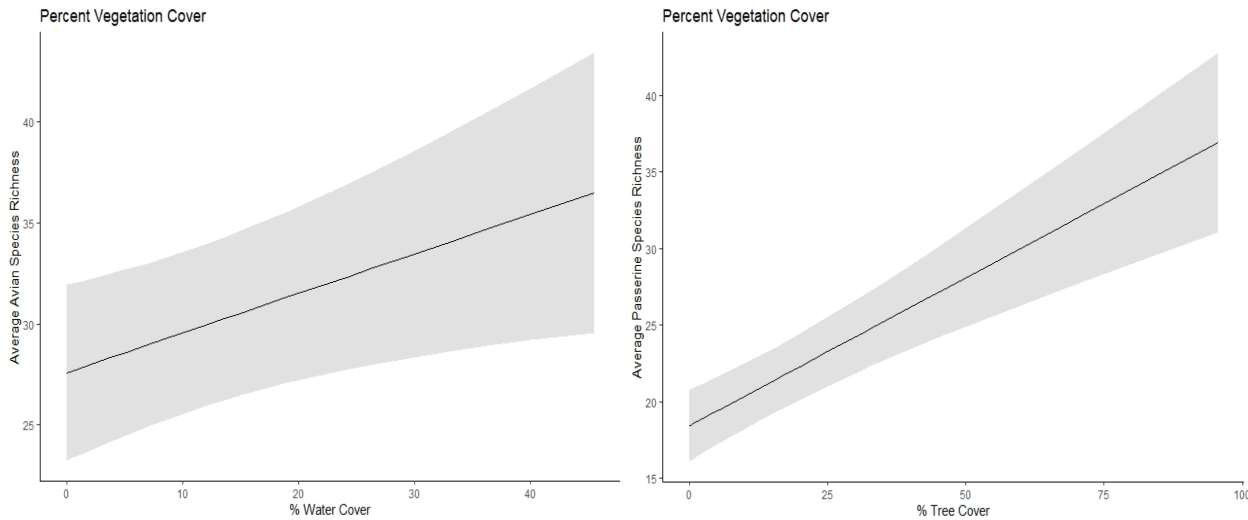

Figure 32: Average number of all avian species (left) and only passerine species (right) at microsites found during breeding season point count surveys as predicted by percent vegetation cover.

During the breeding season, passerines had a significantly higher species richness than during the winter season ($p = 0.02$; Figure 33), however overall avian species richness was not significantly different between the two seasons (Figure 33). This could be due to the exclusion of waterfowl migrants that appear in the winter and counterbalance the lower passerine richness.

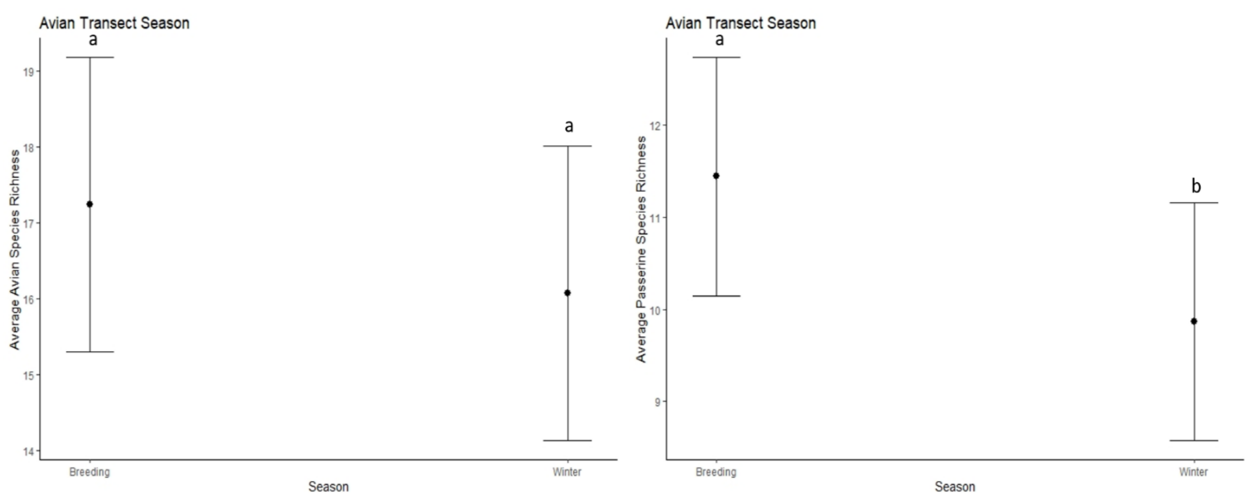

Figure 33: Average number of all avian species (left) and only passerine species (right) at microsites found during transect surveys as predicted by season.

Figure 34: Examples of birds seen at the various habitat types. White-tailed Kites (top left) were observed around marsh, riparian, and grassland habitats. Marsh Wrens (top right) and American Bitterns (bottom left) were found in and around the Delta marshes. Nuttall's Woodpeckers (bottom right) were seen in riparian forest habitat. Photo credit: Andrew Engilis, Jr.

Herpetofauna Coverboard Surveys

Methodology

Field

Herpetological coverboard surveys were conducted whenever a site was surveyed for birds, bats, or small mammals across 35 sites and 152 stations in the Sacramento-San Joaquin Delta (Figure 28). We placed two 2 x 4’ coverboards, one wood and one corrugated metal, at the center of each avian point count station (Figure 35). At sites with cows, we used only a single wood coverboard as the metal boards were prone to being trampled, resulting in a total of 279 coverboards. On both Sherman Island Whale’s Belly microsites (SHBN and SHBS), and at Dutch Slough, we removed select coverboards for the duration of construction efforts.


Figure 35: Coverboards at avian point count locations.

For each coverboard survey, we noted the board material, location, species observed, and number of individuals of each species. Additionally, we conducted visual encounter surveys, recording all incidental observations of amphibians and reptiles or their physical signs (e.g., shed skins) at each site. Analysis of coverboard survey and incidental data was used to determine herpetofauna species diversity and occupancy at each site across categorical, remotely sensed, and ground-surveyed habitat and cover types.

Analysis

We examined effects of habitat on herpetofauna species richness using generalized linear mixed models for three sets of predictor habitat variables. The first set of variables included categorical habitat classifications for each site (pasture, riparian, and wetland). The second set of variables were derived from the California Department of Fish and Wildlife’s Delta Vegetation and Land Use 2011 land cover classification (CDFW 2011). We reclassified the California Wildlife Habitat Relationship categories into three classes (pasture, riparian, and wetland), and calculated the percent cover of each habitat type within a 50-meter radius of each point count station. The third set of variables were measured at each site by DWR scientists (see the Vegetation section). We used percent bare ground, herbaceous vegetation, litter, marsh, shrub, tree, and water cover as predictors. To account for spatial autocorrelation, we included the random effect of 'macrosite.' We checked for multicollinearity of predictor variables and no model resulted in variable inflation factor values greater than 10. Thus, all fixed effects were retained in global models. We ensured goodness-of-fit of each model by using diagnostic tests for uniformity, dispersion, outliers, quantiles, and zero-inflation.

We created all possible subsets of the fixed effects in the global model and ranked them by Akaike Information Criterion (AIC). We then ran model averaging (Grueber et al., 2011) on the subset of models that were within 2.0 AIC of the top scoring model (Burnham and Anderson, 2002) and reported subset (i.e., conditional) averages for coefficient values. For the set of categorical habitat variables, we ran pairwise Tukey HSD tests. All statistical analyses were conducted in R version 4.0.5 (R Core Team, 2021) using the "DHARMa" (Hartig 2021), "emmeans" (Length et al. 2021), "glmmTMB" (Brooks et al., 2017), "MuMIn" (Barton, 2020), and "performance" (Lüdecke et al., 2020) packages.

Herpetofauna Results

We observed a total of 11 herpetofauna species at our six macrosite study areas, including 2 amphibians and 9 reptiles, 2 of which are introduced species (Table 6).

Table 6: Herpetofauna species identified from coverboard surveys and incidental sightings in the Sacramento-San Joaquin Delta during 2020 and 2021. Macrosite locations include Cosumnes River Preserve (CR), Grizzly Slough (GS), McCormack-Williamson Tract (MW), Twitchell Island (TW), Sherman Island (SH), and Dutch Slough (DS). (I) indicates introduced species.

Family	**Species**		**Macrosite**					
	(Common Name)	(Scientific Name)	CR	GS	MW	TW	SH	DS
Treefrogs (Hylidae)	Sierran Treefrog	*Pseudacris sierra*	X	X	X	X	X	X
True Frogs (Ranidae)	American Bullfrog **(I)**	*Lithobates catesbeianus* **(I)**	X			X	X	X
Alligator Lizards (Anguidae)	Southern Alligator Lizard	*Elgaria multicarinata*	X		X	X	X	X
Spiny Lizards (Phrynosomatidae)	Western Fence Lizard	*Sceloporus occidentalis*	X	X	X	X	X	X
Colubrids (Colubridae)	Western Yellow-bellied Racer	*Coluber constrictor mormon*					X	
	Sharp-tailed Snake	*Contia tenuis*				X		
	California Kingsnake	*Lampropeltis californiae*				X		
	Pacific Gopher Snake	*Pituophis catenifer catenifer*				X	X	X
	Valley Garter Snake	*Thamnophis sirtalis fitchi*				X	X	X
Basking Turtles (Emydidae)	Western Pond Turtle	*Actinemys marmorata*			X			X
	Red-eared Slider **(I)**	*Trachemys scripta elegans* **(I)**	X		X		X	X

Figure 36: A juvenile Southern Alligator Lizard found under a coverboard (GSPW; upper left); Sierran Treefrogs were the most observed amphibian (SH; upper right); a Red-eared Pond Slider sunning (bottom left); a Western Pond Turtle sunning (bottom right).

We observed little variation in herpetofauna species richness between macrosites (Figure 37). Twitchell Island (TW), Sherman Island (SH), and Dutch Slough (DS) all had the greatest number of herpetofauna species observed (8), while Grizzly Slough (GS) only had Western Fence Lizard and Sierran Treefrog.

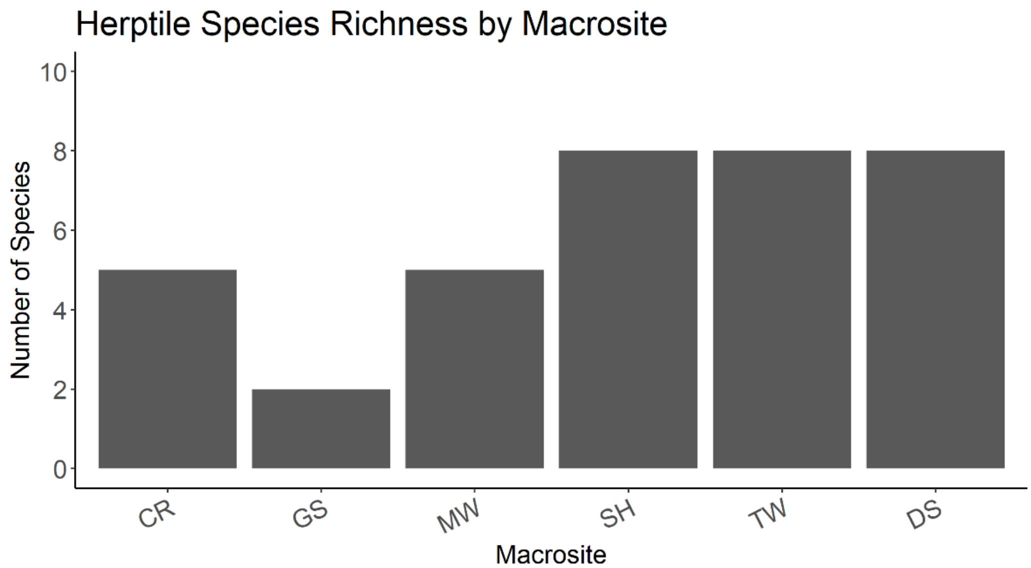

Figure 37: Herpetofauna species richness by macrosite yields mostly similar results across macrosites.

The most common reptile species encountered was the Western Fence Lizard, which occurred at 24 of 35 microsites, and the most common amphibian was the Sierran Treefrog (*Pseudacris sierra*), occupying 23 of 35 microsites (Figure 38). The Pacific Gopher Snake (*Pituophis catenifer catenifer*), which has been documented using marsh, woodland, and grassland areas in Central California, was observed at the most microsites (9) of all snake species and was observed at all three habitat types during our study (Rodríguez-Robles and Lannoo 2003).

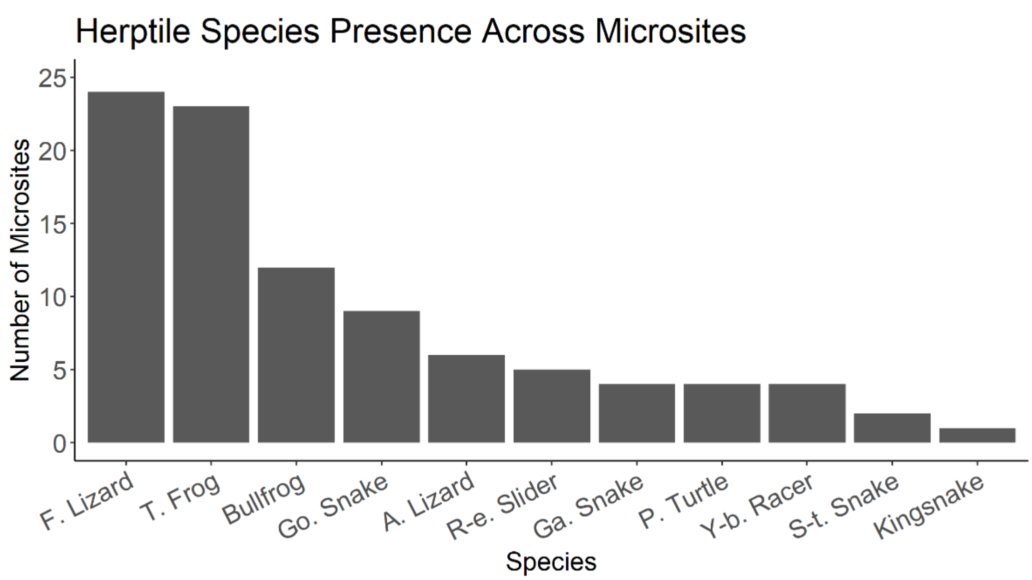

Figure 38: Herpetofauna species presence across all the microsites displayed from most widely observed to least widely observed.

Figure 39: Valley Garter Snake (top left) found near coverboards at DS. California Kingsnake (top right) from a small mammal trapping incidental capture. Western Fence Lizard (bottom left) was the most observed reptile species, while Pacific Gopher Snakes were the most observed snake (bottom right).

Average herpetofauna species richness was lowest in sites with pasture habitat. Richness was significantly higher in riparian habitat than in pasture habitat (p = 0.04), which is consistent with another study showing that the complexity of riparian habitat is of high quality for reptiles and amphibians (Bateman et al., 2020). Species richness was also marginally significantly higher in wetland habitat compared to pasture habitat (p = 0.06). There was no significant difference between herpetofauna species richness in wetland versus riparian habitats. (Figure 40).

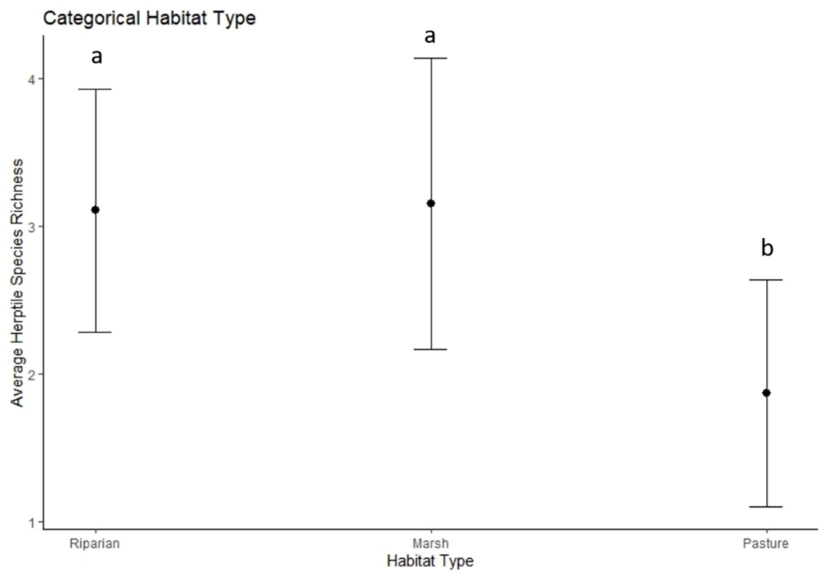

Figure 40: Average herpetofauna species richness observed at microsites as predicted by categorical habitat type.

Herpetofauna species richness decreased as percent cover of herbaceous vegetation increased (p = 0.002) and as percent cover of pasture habitat increased (p = 0.009; Figure 41). One study found that gopher snakes are associated with bare ground cover (Harings et al., 2014). Lack of vegetation cover results in larger ground surface area and thus higher thermoregulation opportunity for reptiles (Moseley et al., 2003). Some studies show that amphibians favor more vegetation cover, which increases moisture and assists with dermal respiratory ability (Moseley et al., 2003). Our study area had more reptile species than amphibians, which may have disproportionately affected our results for total herpetofauna species richness.

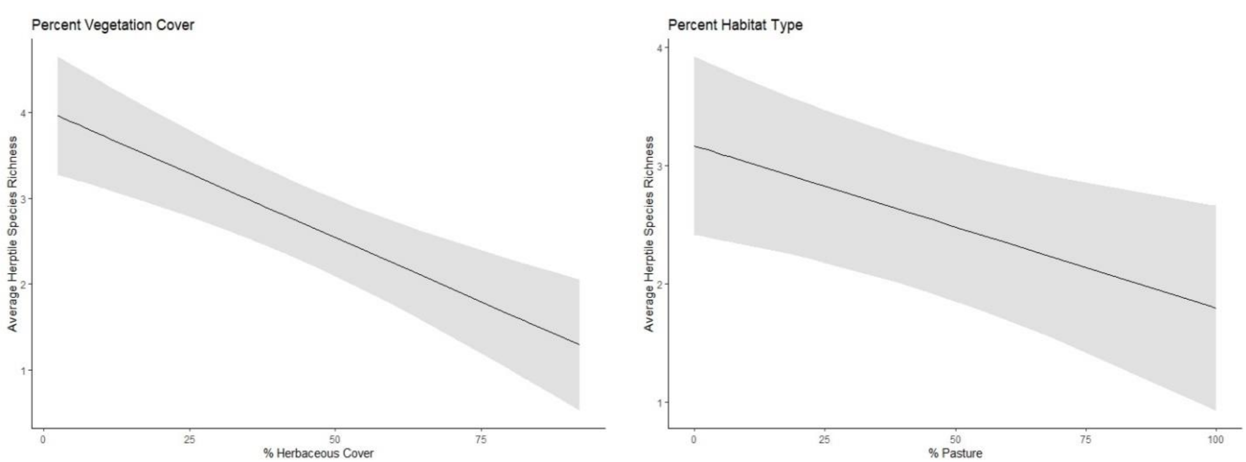

Figure 41: Average herpetofauna species richness observed at microsites as predicted by percent vegetation cover (left) and percent habitat type (right).

Invertebrate Trapping Survey

Methodology

The insect fauna of the Sacramento-San Joaquin Delta has never been systematically surveyed, apart from the Antioch sand dunes. Our survey is the first of its kind and we are hoping to find some of the species thought to be endemic to the Antioch Dunes in other Delta sites, particularly Dutch Slough. Insect trapping was conducted at six Delta Levees Program locations across 11 sites in the Sacramento-San Joaquin Delta (Figure 42).

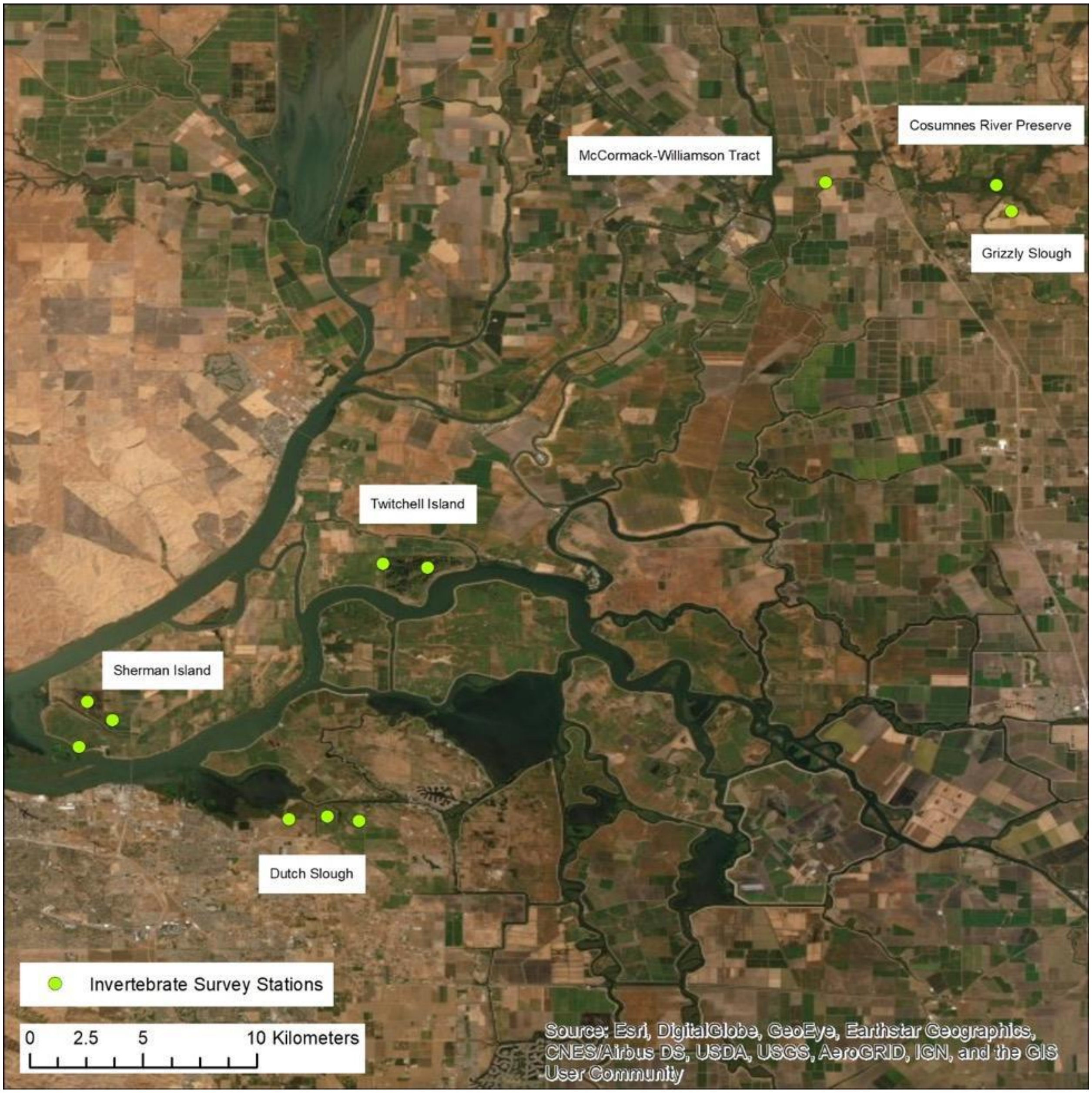

Figure 42: Overview map of invertebrate survey stations (11 in total) across the study area.

Figure 43: Malaise trap with blue vane trap in front on Sherman Island (top). Blue vane trap (bottom left). Contents of pitfall trap, black widow, and carrion beetles (bottom right).

At each site, we ran two Malaise traps, four pitfall traps, and four blue vane traps (Figures 43 and 44). Invertebrate survey stations were established in restored and non-restored habitats. The Malaise, blue vane, and pitfall traps ran 24/7 for the trapping period. They were emptied either weekly or every two weeks depending on the number of insects captured and levels of evaporation of the preservation fluid in the traps. Preservation fluid consisted of ethyl alcohol with propylene glycol added to slow evaporation. The Malaise traps continuously intercept flying insects, the pitfall traps sample ground-based insects and other arthropods, and the blue vane traps specifically sample bees. Because of concerns over potential capture of the federally threatened Valley Elderberry Long-horned Beetle, we put beetle excluders on our Malaise traps, which were the only traps likely to capture this beetle. Each trap yielded an 8 oz jar of alcohol preserved specimens. Trap samples brought back to the Bohart Museum of Entomology at UC Davis were stored in ethyl alcohol, curated, and sorted to taxon by trap number and sampling technique. Analysis of insect trapping data will be used to determine species diversity at each site, across habitat types.

Figure 44: Establishing an invertebrate survey station in remnant Antioch Dunes habitat at the Dutch Slough Emerson Vineyard (DSEV). A pitfall trap can be seen in the foreground with a Malaise trap in the center and blue vane trap off to the right.

Invertebrate Survey Preliminary Results

To date we have collected roughly 200,000 specimens, with huge series of some common species. We have identified and databased 336 species of insects in 8 orders, including 2 cockroaches, 21 flies, 247 bees and wasps, 1 mantis, 46 moths and butterflies, 2 earwigs, 5 true bugs and plant bugs, and 11 beetles (Figure 45; Appendix E). Roughly 5% of the species we've identified to date are introduced, either from Europe or western Asia. Compare this to the plant species where 54% are exotic (Appendix F). Interestingly, based on the species we've identified to date, about 40% of the insect species are parasites or predators of aphids and scale insects. Given the low numbers of species in otherwise abundant groups such as beetles, plant bugs and flies, we estimate that the insect fauna in the Delta is probably close to 1,000 species.

Chlorion aerarium female, family Sphecidae.

Oestris ovis, sheep bot, family Oestridae.

Cryptocephalus astaneus, family Chrysomelidae

Noctua pronuba, family Noctuidae

Figure 45: Photographs of four species collected in Delta survey traps.

Habitat and Vegetation Survey

Methodology

Survey methodologies used elements from existing protocols of the California Native Plant Society (CNPS) and the CDFW's Wildlife Habitat Relationships system (CWHR). At each avian point count station, three 10-meter radius circular vegetation plots were established linearly with the avian point count station being central, and the other two centered at 25 meters from the point count station, measured either perpendicular to the levee (many stations are located on levees) or on a north/south axis in non-levee areas. Plot center locations were captured using a Trimble GPS unit with an auxiliary antenna mounted on a 2 meter tall pole. This equipment is capable of sub-meter accuracy once data is post-processed.

Plots were surveyed once beginning in spring 2020 (Figure 46). Vegetation surveys captured percent cover of all plant species, habitat elements, and vegetative structure of each avian point count station. At each 314 square-meter plot, the following CWHR-related information was recorded:

- Percent cover of each plant species using the CNPS California Natural Community rapid assessment method
- CWHR Wooded Habitat Sampling data for each tree in the plot, including species, height, DBH of the stem (Diameter at Breast Height), and a count of all stems within the plot. Species identified as tree, shrub, liana/vine, or ground cover (herb/forb) were grouped into physiognomic classes by growth-form and height:
    - T1 – upper tree layer – trees > 10 m tall
    - T2 – lower tree layer – trees usually 5-10 m tall (includes tree species, seedlings, and saplings)
    - S1 – taller shrub layer – shrubs 2-5 m tall
    - S2 – lower shrub layer – shrubs 0-2 m tall (includes shrub spp. and seedlings)
    - V – liana/vine
    - HG – herb layer or graminoids
- Habitat elements recorded including percent cover/depth of leaf litter/duff, woody debris, bare ground, rocks, and open water
- An aerial sketch delineating trees, roads, and other habitat-related or notable features
- Photos taken from the plot's center facing North, East, South, and West
- An assigned trampling code:
    - 1 = Low: 0 to 10% of plot trampled
    - 2 = Moderate: more than 10 to 50% of plot trampled
    - 3 = Heavy: more than 50% of plot trampled

Figure 46: Conducting the vegetation surveys generally involved accessing the sites by foot (Cosumnes River Preserve Tall Forest; upper left), but sometimes required a boat (Twitchell Island Setback Levee; upper right). Surveys took place in a wide variety of habitat types including remnant Antioch sand dunes on Dutch Slough (bottom left) and riparian forest and shrub (bottom right).

Habitat and Vegetation Survey Preliminary Results

To date we have identified 191 species of plants across 44 families at our survey sites (Appendix F). Of these, 54% are introduced species.

Observations of CDFW Species of Special Concern

Avian Species

The Least Bittern (*Ixobrychus exilis*) is considered a Bird of Conservation Concern by the United States Fish and Wildlife Service (USFWS) and a Species of Special Concern by the California Department of Fish and Wildlife (CDFW). They nest in freshwater or brackish marshes, preferring areas with tall cattails interspersed with open patches of water and small stands of trees (Figure 47). Several individuals were calling on apparent territory in both May and June 2020 breeding season point counts at the Sherman Island Whale's Mouth subsidence reversal (SHSR) sites. We also had a single individual calling at Dutch Slough in the tidal marsh restoration site (DSGT) on the Gilbert Parcel in April 2021.

Figure 47: A Least Bittern in the reeds along the San Joaquin River near Sherman Island (photo credit: Chris Wills).

The Northern Harrier (*Circus hudsonius*) is a CDFW Species of Special Concern. They inhabit large wetland and grassland areas with low vegetation, and, in the western US populations, tend to breed in dry upland habitats (Figure 48). They were observed during the 2020 and 2021 spring breeding season point count surveys at Cosumnes River Preserve, McCormack-Williamson Tract, Twitchell Island, Sherman Island, and Dutch Slough. During the 2021 winter season transects, we observed Northern Harriers foraging over marsh sites at Twitchell Island, Sherman Island, and Dutch Slough.

Figure 48: An adult male Northern Harrier soaring over Sherman Island (photo credit: Max Brodie).

The Swainson's Hawk (*Buteo swainsoni*) is listed as Sensitive by the Bureau of Land Management (BLM), listed as Threatened by the California Endangered Species Act (CESA), and considered a Bird of Conservation Concern by USFWS. They favor open grasslands with scattered stands of trees but have also adapted to hunt in agricultural fields. Their breeding range is restricted primarily to western North America. We observed Swainson's Hawks during our spring breeding season survey at the McCormack-Williamson Tract, Twitchell Island, and Dutch Slough macrosites (Figure 49). One individual was spotted carrying a vole during the 2020 breeding season, flying 50 meters above the Twitchell Island TIMES (TWTM) microsite, and another individual was seen on a nest at the Twitchell Island Meadow and Canal (TWMC) site.

Figure 49: A Swainson's Hawk perching on a wire at Cosumnes River Preserve.

The Burrowing Owl (*Athene cunicularia*) is considered a Bird of Conservation Concern by USFWS, a Species of Special Concern by CDFW, and Sensitive by BLM. They live in open grasslands, deserts, and pastures, often where there are also high densities of burrowing mammals. We have not observed a burrowing owl during our survey efforts, but an individual was spotted on Twitchell Island in early November, perched on a fence post in the pasture across from the TWTM microsite (Figure 50).

Figure 50: Burrowing Owl perched on fence post in pasture across from the Twitchell TIMES (TWTM) microsite.

The Loggerhead Shrike (*Lanius ludovicianus*) is considered a Bird of Conservation Concern by USFWS and a Species of Special Concern by CDFW. They frequent agricultural fields, pastures, and riparian areas, often being found where there is low, thorny vegetation or along fence lines and utility poles. This species was seen in the cattle pasture on the Sherman Island Whale's Belly microsites (SHBN and SHBS) during the 2020 and 2021 breeding seasons. Individuals were seen regularly on Twitchell Island (Figure 51), Sherman Island, and Dutch Slough during our fall small mammal surveys.

Figure 51: A Loggerhead Shrike observed perching on a wire above the pasture on Twitchell Island.

The Yellow-breasted Chat (*Icteria virens*) is considered a Species of Special Concern by CDFW. They are frequently found along the edges of rivers or ponds, and they breed in areas with dense shrubbery, often blackberry bushes (Figure 52). One individual was observed singing on Twitchell Island during a 2020 breeding season point count (TWMC), and a second was observed incidentally singing on apparent territory on Lower Sherman Island.

Figure 52: A Yellow-breasted Chat singing on a wire on Bradford Island (photo credit: Robert Raffel).

The Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*) is a CDFW Species of Special Concern. They breed in wetlands and prairies, often nesting in cattails alongside Red-winged Blackbirds (*Agelaius phoeniceus*) and foraging in nearby grasslands or croplands. One was seen during the 2020 breeding season at the Sherman Island Whale's Mouth freshwater marsh. This species was also observed within mixed blackbird flocks on Grizzly Slough, Twitchell Island, and Sherman Island during fall 2020 (Figure 53).

Figure 53: Yellow-headed and Tricolored, and Red-winged Blackbirds captured mid-air on camera trap at the Twitchell TIMES (TWTM) microsite.

The Tricolored Blackbird (*Agelaius tricolor*) is considered both a Bird of Conservation Concern by USFWS and a Species of Special Concern by CDFW. BLM lists it as Sensitive, and on CESA it is ranked Threatened. It is on the North American Bird Conservation Initiative's (NABCI) Red Watch List for extremely high vulnerability as well as ranked Endangered by the IUCN. This species was seen in the spring 2020 breeding season foraging with mixed blackbird flocks in fall on the Twitchell Island TIMES microsite, indicating a possible nesting colony nearby (Figure 53).

The Yellow Warbler (*Setophaga petechia*) is listed as a CDFW Species of Special Concern and a USFWS Bird of Conservation Concern (Figure 54). They are often found among willows or in thickets, along streams and wetlands. This species was seen and heard singing on apparent territory at the Accidental Forest site at Cosumnes River Preserve (CRAF) in 2020 and 2021 and was also observed on Twitchell Island (TWMC and TWPK) in May 2020 and 2021.

Figure 54: A female Yellow Warbler observed on a migratory stopover during our fall small mammal surveys at Dutch Slough.

Herpetofauna Species

The Western Pond Turtle (*Actinemys marmorata*) is a CDFW Species of Special Concern, Bureau of Land Management and US Forest Service sensitive species, and is classified by the IUCN Red List of Threatened Species as Vulnerable. We observed Western Pond Turtles at four microsites—Dutch Slough Burroughs Riparian (DSBR), Dutch Slough Gilbert Managed Marsh (DSGM), Dutch Slough Gilbert Tidal Marsh (DSGT), and McCormack-Williamson Tract Riparian West (MWTW). At DSGM, we spotted 9 individuals in the slough from the top of the levee. The individual we encountered at DSGT was basking at the edge of the restored interior marsh. At MWTW, we saw 1 individual incidentally during a coverboard survey far from the slough in an apparent nesting attempt (Figure 55) in May, just before nesting season (Reese and Welsh 1997). Western Pond Turtles nest in upland areas up to 400 meters away from the water source, as well as leave the water source to overwinter on land (Reese and Welsh 1997). These behaviors indicate how managing terrestrial habitat to support the only extant California native turtle species is necessary for their success.

Figure 55: Western Pond Turtle spotted nesting at MWTW on high ground during spring surveys.

Mammal Species

The Western Red Bat (*Lasiurus blossevillii*) is a CDFW Species of Special Concern and a Western Bats Working Group (WBWG) High Priority Species. This species roosts in trees in forested and woodland areas and feeds over a variety of habitats (Figure 56). Our passive acoustic monitoring has picked up Western Red Bats in all sampling months (April through September) and at all macrosites across our study area.

Figure 56: Western Red Bat captured in Winters, CA (photo credit: Krysta Demere).

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Appendix A: Detailed Maps of Survey Sites

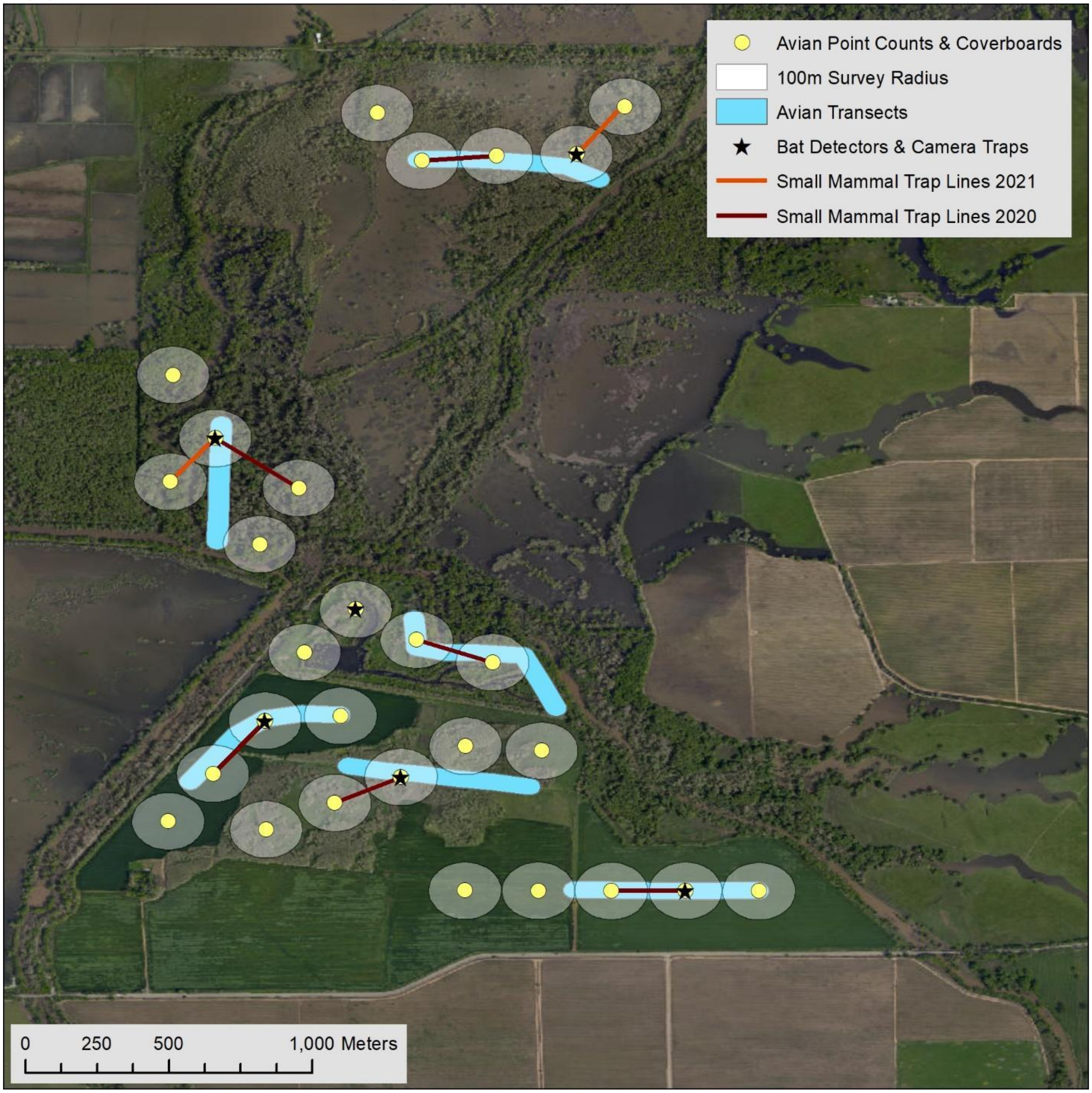

Figure A1: Detailed map of avian point count and transect, coverboard, bat detector, camera trap, and small mammal trap line locations across the Cosumnes River Preserve and Grizzly Slough macrosites.

Figure A2: Detailed map of avian point count and transect, coverboard, bat detector, camera trap, and small mammal trap line locations across the McCormack-Williamson Tract macrosite.

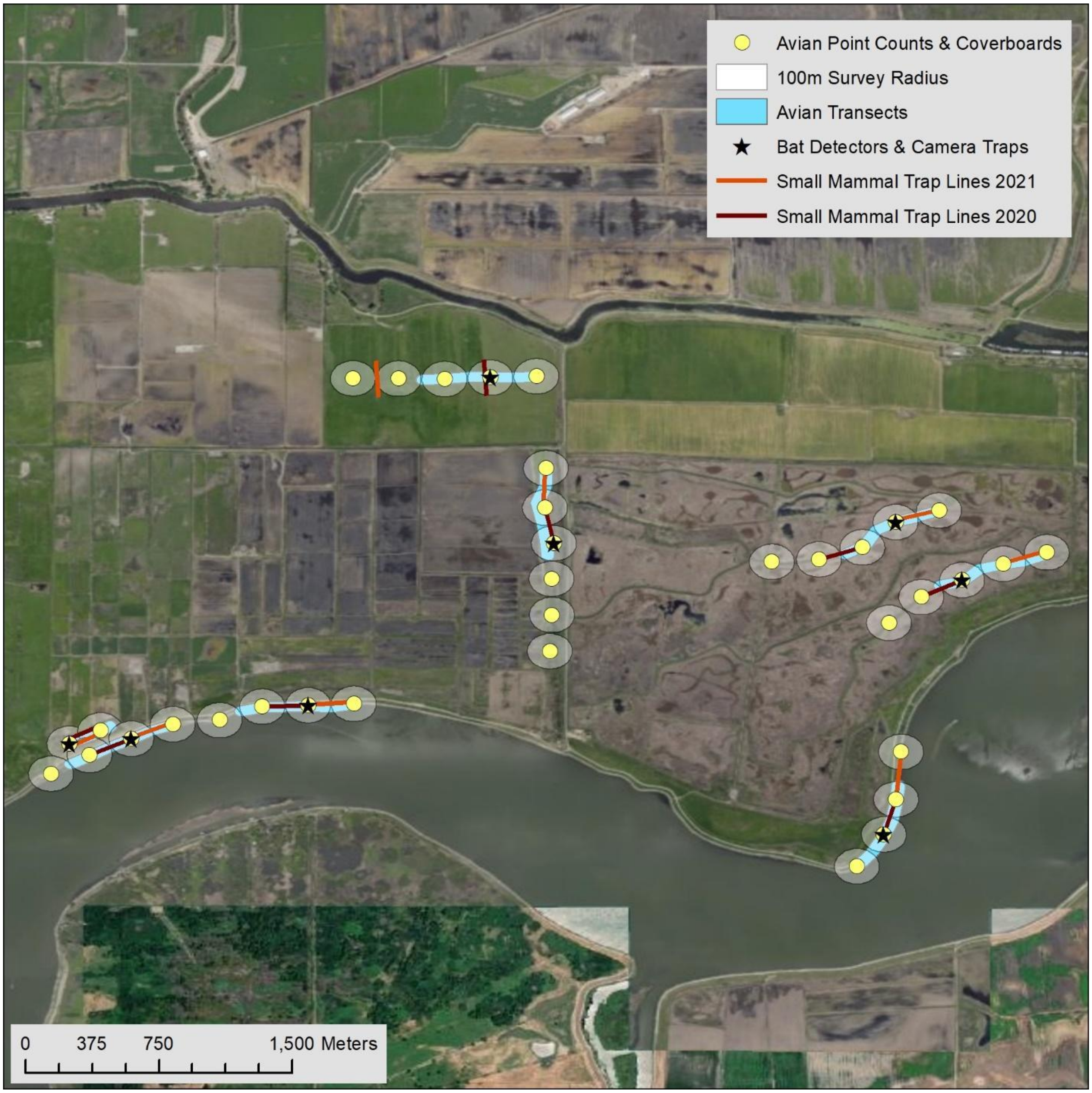

Figure A3: Detailed map of avian point count and transect, coverboard, bat detector, camera trap, and small mammal trap line locations across the Twitchell Island macrosite.

Figure A4: Detailed map of avian point count and transect, coverboard, bat detector, camera trap, and small mammal trap line locations across the Whale's Mouth and Mayberry Farms regions of the Sherman Island macrosite.

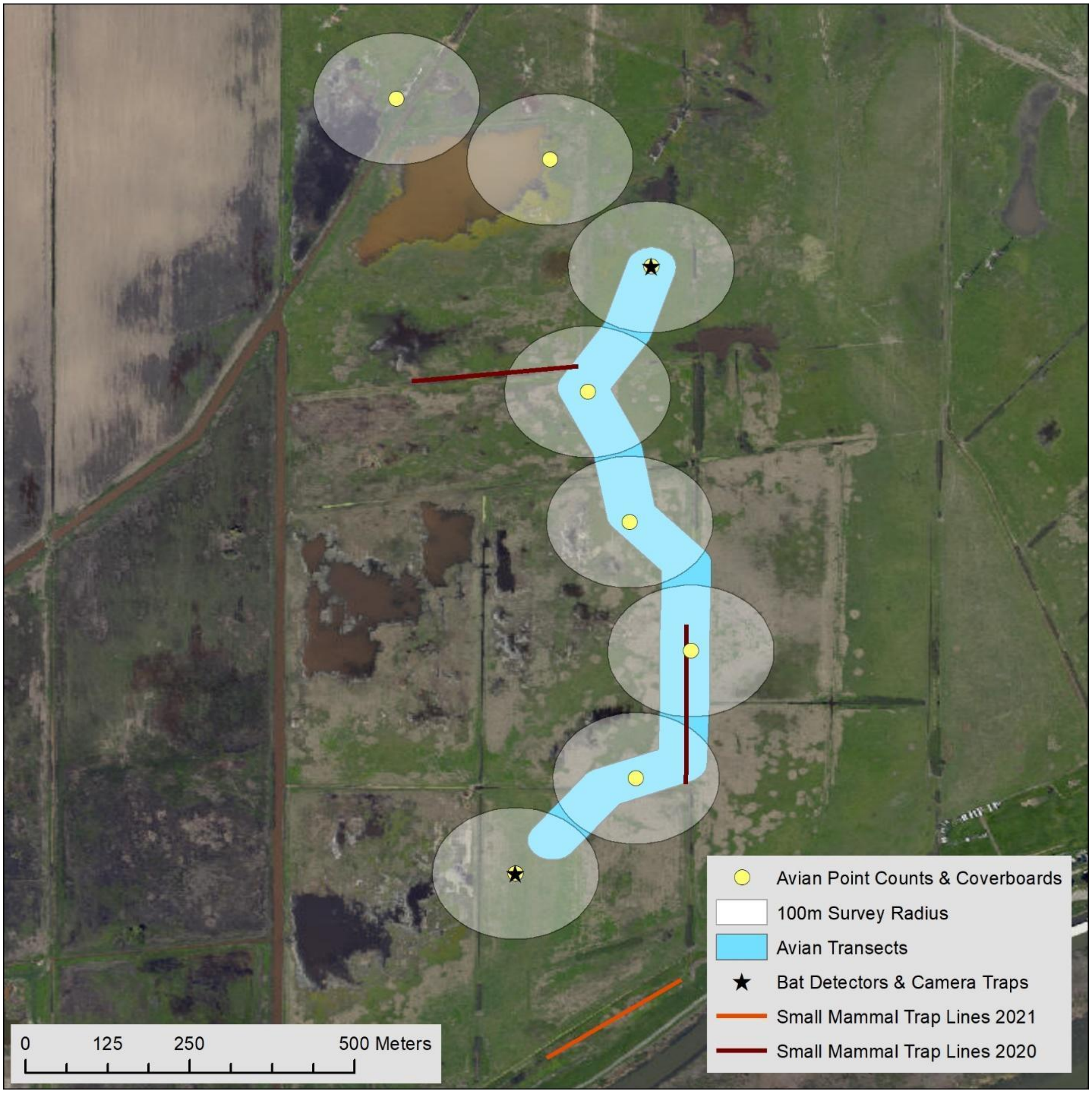

Figure A5: Detailed map of avian point count and transect, coverboard, bat detector, camera trap, and small mammal trap line locations across the Whale's Belly regions of the Sherman Island macrosite.

Figure A6: Detailed map of avian point count and transect, coverboard, bat detector, camera trap, and small mammal trap line locations across the Dutch Slough macrosite.

Appendix B: Summary of Survey Sites

Macrosite	Microsite	Site Code	Habitat Type	# Point Counts	# Avian Transects	# Coverboards	# Sherman Traps	# Bat Monitors	# Camera Traps
Cosumnes River Preserve	Tall Forest	CRTF	Riparian Forest	5	1	10	50	1	1
	Accidental/Intentional Forest	CRAF	Riparian Forest	5	1	10	50	1	1
Grizzly Slough	Phase 1	GSPO	Riparian Forest	4	1	8	50	1	1
	Phase 2	GSPW	Riparian Forest	5	1	10	50	1	1
	Phase 3	GSPT	Pasture	4	1	8	50	1	1
	Wildlife Friendly Agriculture	GSWA	Pasture	5	1	10	50	1	1
McCormack-Williamson	Ring Levee	MWTR	Pasture	5	1	10	50	1	1
	Riparian West	MWTW	Riparian Forest	5	1	10	50	1	1
	Floodplain North	MWTN	Pasture	5	1	10	50	1	1
	Riparian East	MWTE	Riparian Forest	5	1	10	50	1	1
Twitchell Island	TIMES	TWTM	Pasture	5	1	5	50	1	1
	East & West Pocket	TWPK	Riparian Forest	2	1	4	50	1	1
	TW Setback	TWSB	Riparian Forest	4	1	8	50	1	1
	TW Setback Reference	TWSR	Pasture	4	1	8	50	1	1
	East End Wetland North	TWEN	Freshwater Marsh	5	1	10	50	1	1
	East End Wetland South	TWES	Freshwater Marsh	5	1	10	50	1	1
	Meadow & Canal	TWMC	Riparian Forest	6	1	12	50	1	1
	Fish Friendly Levee	TWFL	Pasture	4	1	8	50	1	1
Sherman Island	Mayberry Farm	SHMF	Freshwater Marsh	5	1	10	50	1	1
	Parcel 11	SHPE	Riparian Forest	2	1	4	50	1	1
	Parcel 11 Extension	SHPX	Pasture	2	1	2	50	1	1
	Whale's Belly Phase C North	SHBN	Pasture	4	1	4	50	1	1
	Whale's Belly Phase C South	SHBS	Pasture	4	1	4	50	1	1
	Whale's Mouth West	SHWW	Freshwater Marsh	5	1	10	50	1	1
	Whale's Mouth East	SHWE	Freshwater Marsh	5	1	10	50	1	1
	SH Setback	SHSB	Riparian Forest	4	1	8	50	1	1
	SH Setback Reference	SHSR	Pasture	4	1	8	50	1	1
	Unit 2 (Upland)	SHUT	Freshwater Marsh	2	1	4	50	1	1
Dutch Slough	Emerson Marsh North	DSET	Freshwater Marsh	5	1	10	50	1	1
	Emerson Marsh South	DSEM	Freshwater Marsh	5	1	10	50	1	1
	Emerson Vineyard	DSEV	Mix	2	1	4	50	1	1
	Gilbert Marsh South	DSGT	Freshwater Marsh	5	1	10	50	1	1
	Gilbert Managed Marsh	DSGM	Freshwater Marsh	5	1	10	50	1	1
	Burroughs Riparian	DSBR	Mix	4	1	4	50	1	1
	Burroughs Pasture	DSBA	Agriculture/Pasture	6	1	6	50	1	1
			Total	**152**	**35**	**279**	**1750**	**35**	**35**

Appendix C: Small Mammal 2020 Survey Schedule

2020 Survey

Days	Region	Site	# Sherman Traps
Sept 8-11	Dutch Slough	Emerson Marsh North	50
		Emerson Marsh South	50
		Emerson Vineyard	50
		Total	**150**
Sept 15 - 18	Sherman Island	Whale's Mouth West	50
		Whale's Mouth East	50
		SH Setback	50
		SH Setback Reference	50
		Unit 2 (Upland)	50
		Total	**250**
Sept 22-25	Grizzly Slough	Phase 1	50
		Phase 2	50
		Phase 3	50
		Agriculture	50
	Cosumnes River Preserve	Accidental/Intentional Forest	50
		Total	**250**
Sept 29 - Oct 2	Twitchell Island	TIMES	50
		East & West Pocket	50
		TW Setback	50
		TW Setback Reference	50
		Total	**200**
Oct 5-8	Dutch Slough	Gilbert Marsh South	50
		Gilbert Managed Marsh	50
		Burroughs Riparian	50
		Burroughs Pasture	50
		Total	**200**
Oct 13 - 16	Sherman Island	Mayberry Farm	50
		Parcel 11	50
		Parcel 11 Extension	50
		Whale's Belly Phase C North	50
		Whale's Belly Phase C South	50
		Total	**250**
Oct 20 - 23	McCormack-Williamson Tract	Floodplain North	50
		Ring Levee	50
		Riparian West	50
		Riparian East	50
	Cosumnes River Preserve	Tall Forest	50
		Total	**250**

Oct 27 - 30	Twitchell Island	East End Wetland North	50
		East End Wetland South	50
		Meadow & Canal	50
		Fish Friendly Levee	50
		Total	**200**
		Total # of Traps	**1,750**

2021 Survey

Days	Region	Site	# Sherman Traps
Aug 31 – Sept 3	Cosumnes River Preserve	Accidental Forest/ Intentional Forest	50
		Tall Forest	50
		Total	**100**
Sept 7 - 10	Dutch Slough	Gilbert Marsh South	50
		Gilbert Managed Marsh	50
		Burroughs Riparian	50
		Burroughs Pasture	50
		Total	**200**
Sept 14 - 17	Twitchell Island	East End Wetland North	50
		East End Wetland South	50
		TIMES	50
		Fish Friendly Levee	50
		Total	**200**
Sept 21 - 24	Sherman Island	Whale's Belly Phase C North	50
		Whale's Belly Phase C South	50
		Mayberry Farm	50
		Parcel 11	55
		Parcel 11 Extension	50
		Total	**255**
Sept 28 – Oct 1	McCormack-Williamson Tract	Floodplain North	50
		Ring Levee	50
		Riparian West	50
		Riparian East	50
		Total	**200**
Oct 5 - 8	Dutch Slough	Emerson Marsh North	50
		Emerson Marsh South	50
		Emerson Vineyard	50
		Total	**150**

Oct 12 - 15	Twitchell Island	Meadow & Canal	50
		East & West Pocket	50
		TW Setback	50
		TW Setback Reference	50
		Total	**200**
Oct 19 - 22	Sherman Island	SH Setback	50
		SH Setback Reference	50
		Unit 2 (Upland)*	0
		Whale's Mouth West	50
		Whale's Mouth East	50
		Total	**200**
	Grizzly Slough*	Phase 1	0
		Phase 2	0
		Phase 3	0
		Agriculture	0
		Total	**0**
		Total # of Traps	**1505**

Note: *Grizzly Slough and Sherman Island Unit 2 (Upland) not surveyed due to early winter rains.

Appendix D: Avian species identified using the habitat during our 2020 and 2021 point count breeding surveys (121 species in total). Macrosite locations include Cosumnes River Preserve (CR), Grizzly Slough (GS), McCormack-Williamson Tract (MW), Twitchell Island (TW), Sherman Island (SH), and Dutch Slough (DS). (I) indicates introduced species.

Family	**Species**		**Macrosite**					
	(Common Name)	(Scientific Name)	CR	GS	MW	TW	SH	DS
Anatidae	Greater White-fronted Goose	*Anser albifrons*				X		X
	Canada Goose	*Branta canadensis*				X		X
	Mute Swan **(I)**	*Cygnus olor*					X	
	Wood Duck	*Aix sponsa*		X				
	Cinnamon Teal	*Spatula cyanoptera*						X
	Northern Shoveler	*Spatula clypeata*						X
	Gadwall	*Mareca strepera*					X	X
	Mallard	*Anas platyrhynchos*	X		X	X	X	X
	Green-winged Teal	*Anas carolinensis*						X
	Common Goldeneye	*Bucephala clangula*						X
	Common Merganser	*Mergus merganser*				X		
	Ruddy Duck	*Oxyura jamaicensis*						X
Odontophoridae	California Quail	*Callipepla californica*		X	X			X
Phasianidae	Ring-necked Pheasant **(I)**	*Phasianus colchicus* **(I)**	X			X	X	X
	Wild Turkey **(I)**	*Meleagris gallopavo* **(I)**	X	X				X
Podicipedidae	Pied-billed Grebe	*Podilymbus podiceps*				X	X	X
Columbidae	Rock Pigeon **(I)**	*Columba livia* **(I)**				X	X	X
	Eurasian Collared-Dove **(I)**	*Streptopelia decaocto* **(I)**			X			X
	Mourning Dove	*Zenaida macroura*	X	X	X	X	X	X
Apodidae	White-throated Swift	*Aeronautes saxatalis*				X		X
Trochilidae	Black-chinned Hummingbird	*Archilochus alexandri*	X					

	Anna's Hummingbird	*Calypte anna*	X	X	X	X	X	X
Rallidae	Virginia Rail	*Rallus limicola*						X
	Sora	*Porzana carolina*				X	X	X
	Common Gallinule	*Gallinula galeata*					X	X
	American Coot	*Fulica americana*				X	X	X
Recurvirostridae	Black-necked Stilt	*Himantopus mexicanus*					X	X
	American Avocet	*Recurvirostra americana*	X					X
Charadriidae	Killdeer	*Charadrius vociferus*			X	X	X	X
Scolopacidae	Long-billed Curlew	*Numenius americanus*					X	
	Least Sandpiper	*Calidris minutilla*					X	X
	Wilson’s Snipe	*Gallinago delicata*					X	X
	Greater Yellowlegs	*Tringa melanoleuca*				X	X	X
Laridae	Ring-billed Gull	*Larus delawarensis*						X
	California Gull	*Larus californicus*						X
	Caspian Tern	*Hydroprogne caspia*						X
	Forster’s Tern	*Sterna forsteri*					X	X
Phalacrocoracidae	Double-crested Cormorant	*Nannopterum auritum*				X		X
Pelecanidae	American White Pelican	*Pelecanus erythrorhynchos*					X	
Ardeidae	American Bittern	*Botaurus lentiginosus*				X	X	X
	Least Bittern	*Ixobrychus exilis*					X	X
	Great Blue Heron	*Ardea herodias*	X		X			X
	Great Egret	*Ardea alba*		X	X		X	X
	Snowy Egret	*Egretta thula*					X	X
	Green Heron	*Butorides virescens*				X		X
	Black-crowned Night-Heron	*Nycticorax nycticorax*				X	X	
Threskiornithidae	White-faced Ibis	*Plegadis chihi*				X		X
Cathartidae	Turkey Vulture	*Cathartes aura*	X	X	X	X	X	
Pandionidae	Osprey	*Pandion haliaetus*			X			
Accipitridae	White-tailed Kite	*Elanus leucurus*	X	X			X	X
	Northern Harrier	*Circus hudsonius*	X		X	X	X	X

	Cooper’s Hawk	*Accipiter cooperii*		X				
	Red-shouldered Hawk	*Buteo lineatus*	X			X		
	Swainson's Hawk	*Buteo swainsoni*			X	X		X
	Red-tailed Hawk	*Buteo jamaicensis*		X	X	X		X
Strigidae	Great Horned Owl	*Bubo virginianus*		X				X
Alcedinidae	Belted Kingfisher	*Megaceryle alcyon*		X		X	X	
Picidae	Downy Woodpecker	*Dryobates pubescens*	X	X	X	X	X	X
	Nuttall's Woodpecker	*Dryobates nuttallii*	X	X	X	X	X	X
	Northern Flicker	*Colaptes auratus*	X	X	X			
Falconidae	American Kestrel	*Falco sparverius*						X
Tyrannidae	Western Wood-Pewee	*Contopus sordidulus*	X	X				X
	Pacific-slope Flycatcher	*Empidonax difficilis*	X			X	X	
	Black Phoebe	*Sayornis nigricans*	X	X	X	X	X	X
	Say's Phoebe	*Sayornis saya*		X			X	
	Ash-throated Flycatcher	*Myiarchus cinerascens*	X	X	X	X		X
	Western Kingbird	*Tyrannus verticalis*		X	X	X	X	X
Vireonidae	Hutton's Vireo	*Vireo huttoni*	X	X				
	Warbling Vireo	*Vireo gilvus*	X	X	X	X		
Corvidae	California Scrub-Jay	*Aphelocoma californica*	X	X	X	X	X	X
	American Crow	*Corvus brachyrhynchos*		X		X	X	X
	Common Raven	*Corvus corax*	X			X		X
Paridae	Oak Titmouse	*Baeolophus inornatus*	X	X	X	X		
Alaudidae	Horned Lark	*Eremophila alpestris*			X	X	X	
Hirundinidae	Northern Rough-winged Swallow	*Stelgidopteryx serripennis*				X		X
	Tree Swallow	*Tachycineta bicolor*	X	X	X	X	X	X
	Barn Swallow	*Hirundo rustica*		X	X	X	X	X
	Cliff Swallow	*Petrochelidon pyrrhonota*		X	X	X	X	X

Aegithalidae	Bushtit	*Psaltriparus minimus*	X	X	X	X	X	X
Sylviidae	Wrentit	*Chamaea fasciata*	X	X	X	X	X	
Regulidae	Ruby-crowned Kinglet	*Corthylio calendula*	X	X	X	X	X	X
	Golden-crowned Kinglet	*Regulus satrapa*				X		
Sittidae	White-breasted Nuthatch	*Sitta carolinensis*	X	X	X			
Polioptilidae	Blue-gray Gnatcatcher	*Polioptila caerulea*	X					
Troglodytidae	House Wren	*Troglodytes aedon*	X	X	X	X	X	X
	Marsh Wren	*Cistothorus palustris*				X	X	X
	Bewick's Wren	*Thryomanes bewickii*	X	X	X	X		
Sturnidae	European Starling **(I)**	*Sturnus vulgaris* **(I)**	X	X	X	X	X	X
Mimidae	Northern Mockingbird	*Mimus polyglottos*		X	X	X	X	X
Turdidae	Western Bluebird	*Sialia mexicana*		X	X			
	Swainson's Thrush	*Catharus ustulatus*	X	X	X	X		
	American Robin	*Turdus migratorius*	X	X	X	X	X	X
Bombycillidae	Cedar Waxwing	*Bombycilla cedrorum*						X
Passeridae	House Sparrow **(I)**	*Passer domesticus* **(I)**			X			X
Motacillidae	American Pipit	*Anthus rubescens*					X	X
Fringillidae	House Finch	*Haemorhous mexicanus*	X	X	X	X	X	X
	Lesser Goldfinch	*Spinus psaltria*	X	X	X	X	X	
	American Goldfinch	*Spinus tristis*	X	X	X	X	X	X
Passerellidae	White-crowned Sparrow	*Zonotrichia leucophrys*			X	X	X	X
	Golden-crowned Sparrow	*Zonotrichia atricapilla*		X		X		X
	Savannah Sparrow	*Passerculus sandwichensis*		X	X	X	X	X
	Song Sparrow	*Melospiza melodia*	X	X	X	X	X	X
	Lincoln’s Sparrow	*Melospiza lincolnii*						X
	California Towhee	*Melozone crissalis*	X	X	X			X
	Spotted Towhee	*Pipilo maculatus*	X	X	X	X	X	X

Icteridae	Western Meadowlark	*Sturnella neglecta*			X	X	X	X
	Bullock's Oriole	*Icterus bullockii*	X	X	X	X		X
	Red-winged Blackbird	*Agelaius phoeniceus*	X	X	X	X	X	X
	Tricolored Blackbird	*Agelaius tricolor*				X		
	Brown-headed Cowbird	*Molothrus ater*	X	X	X	X	X	X
	Brewer's Blackbird	*Euphagus cyanocephalus*			X	X	X	X
	Great-tailed Grackle	*Quiscalus mexicanus*				X	X	X
Parulidae	Common Yellowthroat	*Geothlypis trichas*	X	X	X	X	X	X
	Hooded Warbler	*Setophaga citrina*	X					
	Yellow Warbler	*Setophaga petechia*	X			X		
	Yellow-rumped Warbler	*Setophaga coronata*	X			X		X
	Wilson's Warbler	*Cardellina pusilla*			X	X	X	
Cardinalidae	Western Tanager	*Piranga ludoviciana*	X		X	X	X	
	Black-headed Grosbeak	*Pheucticus melanocephalus*	X	X	X	X	X	
	Blue Grosbeak	*Passerina caerulea*				X	X	X
	Lazuli Bunting	*Passerina amoena*		X	X		X	

Appendix E: Insect taxa identified to date from survey samples taken during our 2020 and 2021 survey of the Delta.

Order	Families	No. of Genera	No. of Species	No. of Exotic Sp.	Traits
Blattodea	Corydiidae	1	1		cockroaches
	Ectobiidae	2	2		cockroaches
Coleoptera	Anobiidae	1	1		wood beetles
	Anthicidae	1	1		flower beetles
	Bostrichidae	3	3		wood beetles
	Buprestidae	2	2		wood beetles
	Carabidae	20	21		predators
	Cerambycidae	1	1		wood beetles
	Coccinellidae	8	133		predator
	Corylophidae	1	1		fungus beetles
	Cryptophagidae	1	2		fungus beetles
	Curculionidae	1	2		seed beetles
	Cybocephalidae	1	1		fungus beetles
	Dermestidae	2	2		Scavenger beetles
	Dytiscidae	1	1		diving beetles
	Elateridae	1	1		click beetles
	Erotylidae	1	1		fungus beetles
	Hydraenidae	1	1		diving beetles
	Hydrophilidae	3	3		diving beetles
	Laemophloeidae	1	2		wood beetles
	Lampyridae	1	1		fire flies
	Latridiidae	3	5		Scavenger beetles
	Leiodidae	1	1		fungus beetles
	Melyridae	2	3		flower beetles
	Monotomidae	1	1		root beetles
	Mordellidae	2	2		flower beetles
	Mycetophagidae	2	2		fungus beetles
	Phalacridae	1	1		flower beetles
	Ptiliidae	2	2		minute beetles
	Ptinidae	1	1		spider beetles
	Rhipiphoridae	1	1		parasitoid
	Scraptiidae	1	1		false flower beetles
	Scirtidae	1	2		carrion beetles
	Silphidae	1	1		scavenger
	Staphylinidae	2	2		rove beetles
	Tenebrionidae	9	10		darkling beetles

	Throscidae	1	1		false click beetles
Dermaptera	Anisolabidiidae	1	1	1	scavenger
	Forficulidae	1	1	1	scavenger
Diptera	Calliphoridae	1	1		blow flies
	Conopidae	3	3		thick headed flies
	Chloropidae	5	6		grass flies
	Empidiae	1	1		March flies
	Fanniidae	1	1		house flies
	Hybotidae	1	1		dance flies
	Muscidae	1	1	1	house flies
	Mythicomyiidae	1	1		hump backed flies
	Oestridae	1	1		parasites
	Polleniidae	1	1		cluster fly
	Psychodidae	1	1		drain flies
	Scatopsidae	1	1	0	scavenger flies
	Stratiomyidae	2	2		soldier flies
	Syrphidae	14	16		flower flies
	Therevidae	1	1		stiletto flies
	Ulidiidae	2	2		picture winged flies
Hemiptera	Aphididae	1	1		plant bugs
	Alydidae	1	1		plant bugs
	Berytidae	2	2		plant bugs
	Cicadellidae	1	1		plant bugs
	Cixiidae	2	2		plant bugs
	Miridae	3	4		plant bugs
	Psyllidae	1	1		plant bugs
Hymenoptera	Andrenidae	3	4		bees
	Aphelindiae	2	3		parasitoid
	Apidae	14	29	1	bees
	Bethylidae	1	1		parasitoid
	Braconidae	1	1		parasitoid
	Cephidae	1	1		herbivores
	Ceraphronidae	2	2		parasitoid
	Chalcididae	6	8		parasitoid
	Chrysididae	5	6		parasitoid
	Colletidae	3	6		bees
	Crabronidae	8	13		predators
	Cynipidae	1	1		parasitoid
	Dryinidae	1	1		parasitoid
	Encyrtidae	12	16		parasitoid
	Eulophidae	12	16		parasitoid
	Eupelmidae	2	3		parasitoid

	Eurytomidae	5	6		parasitoid
	Figitidae	4	5		parasitoid
	Gasteruptiidae	1	1		parasitoid
	Halictidae	6	23		bees
	Ichneumonidae	1	1		parasitoid
	Leucospidae	1	1		parasitoid
	Megachilidae	4	14	1	bees
	Megaspilidae	1	1		parasitoid
	Mutillidae	1	1		parasitoid
	Mymaridae	3	9		parasitoid
	Myrmosidae	1	1		parasitoid
	Ormyridae	1	1		parasitoid
	Perilampidae	1	1		parasitoid
	Platygasteridae	3	4		parasitoid
	Pompilidae	9	12		predators
	Proctotrupidae	1	1		parasitoid
	Pteromalidae	31	43		parasitoid
	Scelionidae	5	6		parasitoid
	Scoliidae	1	1		parasitoid
	Signiphoridae	1	1		parasitoid
	Sphecidae	5	5		predators
	Tenthredinidae	1	1		herbivores
	Torymidae	5	5		parasitoid
	Trichogrammatidae	5	5		parasitoid
	Vespidae	5	8	1	predators
Lepidoptera	Cosmopterygidae	1	1		herbivore
	Cossidae	12	14		herbivore
	Crambidae	12	12		herbivore
	Depressariidae	1	1		herbivore
	Erebidae	37	42		herbivore
	Erebidae/Arctiinae	3	3		herbivore
	Gelechiidae	6	14		herbivore
	Geometridae	5	6		herbivore
	Gracillariidae	1	2		herbivore
	Hesperiidae	6	6		herbivore
	Lycaenidae	4	4		herbivore
	Lasiocampidae	1	1		herbivore
	Momphidae	1	2		herbivore
	Noctuidae	35	46		herbivore
	Notodontidae	1	1		herbivore
	Papilionidae	2	2		herbivore
	Pieridae	3	3	2	herbivore

	Plutellidae	1	1		herbivore
	Pterophoridae	1	1		herbivore
	Pyralidae	2	2		herbivore
	Sphingidae	4	4		herbivore
	Tortricidae	9	9		herbivore
Mantodea	Mantidae	1	1	1	predator
Neuroptera	Chrysopidae	2	4		predator
	Hemerobiidae	3	5		predator
	Myrmeleontidae	2	3		predator
Odonata	Aeshnidae	2	2		predator
	Coenagrionidae	2	4		predator
	Libellulidae	3	3		predator
TOTAL	132	474	740	9	

Appendix F: Plant species identified to date from survey samples taken during our 2020 survey of the Delta. (I) indicates introduced species. Habit includes annual grass (AG), perennial grass (PG), annual herbaceous (AH), perennial herbaceous (PH), shrub (S) and tree (T).

Family	Common name	Scientific Name	Habit
Adoxaceae	Blue elderberry	Sambucus nigra ssp. caerulea	S
Alismataceae	Water plantain	Alisma triviale	PH
Amaranthaceae	Alligator weed	Alternanthera philoxeriodes (I)	PH
Amaranthaceae	Tumbleweed	Amaranthus albus (I)	AH
Amaranthaceae	Rough pigweed	Amaranthus retroflexus (I)	AH
Anacardiaceae	Poison oak	Toxicodendron diversilobum	S
Apiaceae	Poison hemlock	Conium maculatum (I)	PH
Apiaceae	Coyote thistle	Eryngium articulatum	AH
Apiaceae	Fennel	Foeniculum vulgare (I)	PH
Apiaceae	Hedge parsley	Torilis arvensis (I)	AH
Araliaceae	Marsh pennywort	Hydrocotyle ranunculoides	PH
Asteraceae	Yarrow	Achillea millefolium	PH
Asteraceae	Western ragweed	Ambrosia psilostachya	PH
Asteraceae	Dog fennel	Anthemis cotula (I)	AH
Asteraceae	Mugwort	Artemisia douglasiana	PH
Asteraceae	Marsh baccharis	Baccharis glutinosa	PH
Asteraceae	Coyote bush	Baccharis pilularis	S
Asteraceae	Mule fat	Baccharis salicifolia	S
Asteraceae	Sticktight	Bidens frondosa	AH
Asteraceae	Bur-marigold	Bidens laevis	PH
Asteraceae	Italian thistle	Carduus pycnocephalus (I)	AH
Asteraceae	Purple star thistle	Centaurea calcitrapa (I)	AH
Asteraceae	Tocalote	Centaurea melitensis (I)	AH
Asteraceae	Common spikeweed	Centromadia pungens	AH
Asteraceae	Yellow star thistle	Centaurea solstitialis (I)	AH
Asteraceae	Chicory	Cichorium intybus (I)	PH
Asteraceae	Bull thistle	Cirsium vulgare (I)	AH
Asteraceae	Brass buttons	Cotula coronopifolia (I)	PH
Asteraceae	Cardoon	Cynara cardunculus ssp. flavescens (I)	PH
Asteraceae	Stinkwort	Dittrichia graveolens (I)	AH
Asteraceae	Flax-leaved horseweed	Erigeron bonariensis (I)	AH
Asteraceae	Horseweed	Erigeron canadensis	AH
Asteraceae	Western goldenrod	Euthamia occidentalis	PH

Asteraceae	Valley gumplant	Grindelia camporum	PH
Asteraceae	Sunflower	Helianthus annuus	AH
Asteraceae	Bristley ox-tongue	Helminthotheca echioides (I)	AH
Asteraceae	Hayfield tarweed	Hemizonia congesta	AH
Asteraceae	Telegraph weed	Heterotheca grandiflora	AH
Asteraceae	Smooth cat's ear	Hypochaeris glabra (I)	AH
Asteraceae	Narrow-leaved lettuce	Lactuca saligna (I)	AH
Asteraceae	Prickly lettuce	Lactuca serriola (I)	AH
Asteraceae	Pineapple weed	Matricaria discoidea (I)	AH
Asteraceae	Saltmarsh fleabane	Pluchea odorata v. odorata	PH
Asteraceae	Everlasting	Pseudognaphalium luteoalbum (I)	AH
Asteraceae	Milk thistle	Silybum marianum (I)	AH
Asteraceae	Prickly sow thistle	Sonchus asper (I)	AH
Asteraceae	Common sow thistle	Sonchus oleraceus (I)	AH
Asteraceae	Suisun Marsh aster	Symphyotrichum lentum	PH
Asteraceae	Annual saltmarsh aster	Symphyotrichum subulatum	AH
Asteraceae	Dandelion	Taraxacum officinale (I)	AH
Asteraceae	Spiny cocklebur	Xanthium spinosum	AH
Asteraceae	Cocklebur	Xanthium strumarium	AH
Betulaceae	White alder	Alnus rhombifolia	T
Boraginaceae	Fiddleneck	Amsinckia menziesii	AH
Boraginaceae	Alkali heliotrope	Heliotropium curassavicum var. oculatum	PH
Brassicaceae	Black mustard	Brassica nigra (I)	AH
Brassicaceae	Field mustard	Brassica rapa (I)	AH
Brassicaceae	Shepard's purse	Capsella bursa-pastoris (I)	AH
Brassicaceae	Lesser swine cress	Lepidium didymum (I)	AH
Brassicaceae	Pepperweed	Lepidium latifolium (I)	PH
Brassicaceae	Wild radish	Raphanus sativus (I)	AH
Brassicaceae	Jointed charlock	Raphanus raphanistrum (I)	AH
Brassicaceae	Yellow watercress	Rorippa curvisiliqua	AH
Caryophyllaceae	Hairy sand spurrey	Spergularia villosa (I)	PH
Chenopodiaceae	Spear oracle	Atriplex patula	AH
Chenopodiaceae	Fat hen	Atriplex prostrata (I)	AH
Chenopodiaceae	Australian saltbush	Atriplex semibaccata (I)	PH
Chenopodiaceae	Five-hook bassia	Bassia hyssopifolia (I)	AH
Chenopodiaceae	Lambs quarters	Chenopodium album	AH
Chenopodiaceae	Mexican tea	Dysphania ambrosioides (I)	AH
Chenopodiaceae	Pickleweed	Salicornia pacifica	SS
Chenopodiaceae	Tumbleweed	Salsola tragus (I)	AH
Convolulaceae	Marsh morning glory	Calystegia sepium ssp. limnophila	PH
Convolulaceae	Bindweed	Convolulus arvensis (I)	PH

Cyperaceae	River bulrush	Bolboschoenus fluviatilis	PH
Cyperaceae	Alkali bulrush	Bolboschoenus maritimus ssp. paludosus	PH
Cyperaceae	Seacoast bulrush	Bolboschoenus robustus	PH
Cyperaceae	Barbara sedge	Carex barbarae	PH
Cyperaceae	Foothill sedge	Carex tumulicola	PH
Cyperaceae	Umbrella grass	Cyperus eragrostis	PH
Cyperaceae	Spike rush	Eleocharis macrostachya	PH
Cyperaceae	Common tule	Schoenoplectus acutus v. occidentalis	PH
Cyperaceae	California bulrush	Schoenoplectus californicus	PH
Dipsacaceae	Teasel	Dipsacus sativus (I)	AH
Euphorbiaceae	Thyme-leaved spurge	Chamaesyce serpillifolia	AH
Fabaceae	Spanish clover	Acmispon americanus var. americanus	AH
Fabaceae	Tule pea	Lathyrus jepsonii v. californicus	PH
Fabaceae	Bird's foot trefoil	Lotus corniculatus (I)	AH
Fabaceae	Miniature lupine	Lupinus bicolor	AH
Fabaceae	Burclover	Medicago minima (I)	AH
Fabaceae	California burclover	Medicago polymorpha (I)	AH
Fabaceae	Alfalfa	Medicago sativa (I)	PH
Fabaceae	White sweet clover	Melilotus albus (I)	AH
Fabaceae	Sour clover	Melilotus indicus (I)	AH
Fabaceae	Black locust	Robinia pseudoacacia (I)	T
Fabaceae	Scarlet sesban	Sesbania punicea (I)	S
Fabaceae	Strawberry clover	Trifolium fragiferum (I)	PH
Fabaceae	Rose clover	Trifolium hirtum (I)	AH
Fabaceae	White clover	Trifolium repens (I)	PH
Fagaceae	Live oak	Quercus agrifolia	T
Fagaceae	Valley oak	Quercus lobata	T
Geraniaceae	Filaree	Erodium cicutarium (I)	AH
Geraniaceae	Greenstem filaree	Erodium moschatum (I)	AH
Iridaceae	Flag iris	Iris pseudacorus (I)	PH
Juglandaceae	Black walnut	Juglans hindsii	T
Juncaceae	Common rush	Juncus effusus	PH
Juncaceae	Iris-leaved rush	Juncus xiphioides	PH
Lamiaceae	Pennyroyal	Mentha pulegium (I)	AH
Lamiaceae	Whitestem hedgenettle	Stachys albens	PH
Lamiaceae	Rigid hedgenettle	Stachys rigida	PH
Malvaceae	Velvet leaf	Abutilon theophrasti (I)	AH
Malvaceae	Alkali mallow	Malvella leprosa	AH
Malvaceae	Cheeseweed	Malva parviflora (I)	AH
Oleaceae	Oregon ash	Fraxinus latifolia	T
Onagraceae	Willow herb	Epilobium brachycarpum	AH

Onagraceae	Willow herb	Epilobium campestre	AH
Onagraceae	Fringed willowherb	Epilobium ciliatum	PH
Onagraceae	Floating water primrose	Ludwigia peploides (I)	PH
Onagraceae	Antioch dunes evening primrose	Oenothera deltoides ssp. howellii	PH
Onagraceae	Evening primrose	Oenothera elata ssp. hookeri	BH
Papaveraceae	California poppy	Eschscholzia californica	PH
Phyrmaceae	Seep monkeyflower	Eryanthe guttata	AH
Plantaginaceae	Sharp-leaved fluellin	Kicksia elatine (I)	AH
Plantaginaceae	English plantain	Plantago lanceolata (I)	PH
Plantaginaceae	Broad-leaved plantain	Plantago major (I)	AH
Platanaceae	Sycamore	Platanus racemosa	T
Poaceae	Spike bentgrass	Agrostis exarata	PG
Poaceae	Silver hairgrass	Aira caryophylla (I)	AG
Poaceae	Slender wild oat	Avena barbata (I)	AG
Poaceae	Wild oat	Avena fatua (I)	AG
Poaceae	California brome	Bromus carinatus	PG
Poaceae	Rescue grass	Bromus catharticus (I)	PG
Poaceae	Ripgut brome	Bromus diandrus (I)	AG
Poaceae	Soft chess	Bromus hordeaceus (I)	AG
Poaceae	Red brome	Bromus rubens (I)	AG
Poaceae	Swamp grass	Crypsis schoenoides (I)	AG
Poaceae	Bermuda grass	Cynodon dactylon (I)	PG
Poaceae	Barnyard grass	Echinochloa crus-galli (I)	PG
Poaceae	Medusa head	Elymus caputmedusae (I)	AG
Poaceae	Blue wild rye	Elymus glaucus	PG
Poaceae	Tall wheatgrass	Elymus ponticus (I)	PG
Poaceae	Creeping wild rye	Elymus triticoides	PG
Poaceae	Tall fescue	Festuca arundinacea (I)	PG
Poaceae	Rattail fescue	Festuca myuros (I)	AG
Poaceae	Rye grass	Festuca perennis (I)	AG
Poaceae	Meadow barley	Hordeum brachyantherum	PG
Poaceae	Mediterranean barley	Hordeum marinum ssp. gussoneanum (I)	AG
Poaceae	Foxtail	Hordeum murinum (I)	AG
Poaceae	Witchgrass	Panicum capillare	AG
Poaceae	Dallis grass	Paspalum dilatatum (I)	PG
Poaceae	Littleseed canary grass	Phalaris minor (I)	AG
Poaceae	Canary grass	Phalaris paradoxa (I)	AG
Poaceae	Common reed	Phragmites australis	PG
Poaceae	Rabbit's foot grass	Polypogon monspeliensis (I)	AG
Poaceae	Bristley foxtail	Setaria viridis (I)	AG

Poaceae	Johnson grassl	Sorghum halapense (I)	PG
Poaceae	Smutgrass	Sporobolus indicus (I)	PG
Polygonaceae	Water smartweed	Persicaria amphibia	PH
Polygonaceae	False waterpepper	Persicaria hydropiperoides	PH
Polygonaceae	Common smartweed	Persicaria lapathifolia	AH
Polygonaceae	Spotted lady's thumb	Persicaria maculosa (I)	AH
Polygonaceae	Prostrate knotweed	Polygonum arenastrum (I)	AH
Polygonaceae	Clustered dock	Rumex conglomeratus (I)	PH
Polygonaceae	Curly dock	Rumex crispus (I)	PH
Polygonaceae	Willow-leaved dock	Rumex salicifolius	PH
Pontederiaceae	Water hyacinth	Eichhornia crassipes (I)	PH
Portulacaceae	Purslane	Portulaca oleracea (I)	AH
Rosaceae	Wild rose	Rosa californica	S
Rosaceae	Himalayan blackberry	Rubus armeniacus (I)	V
Rosaceae	California blackberry	Rubus ursinus	V
Rubiaceae	Buttonbush	Cephalanthus occidentalis	S
Rubiaceae	Goose grass	Galium aparine (I)	AH
Salicaceae	Fremont cottonwood	Populus fremontii	T
Salicaceae	Weeping willow	Salix babylonica (I)	T
Salicaceae	Narrow-leaved willow	Salix exigua	T
Salicaceae	Gooding's black willow	Salix gooddingii	T
Salicaceae	Arroyo willow	Salix lasiolepis	T
Salicaceae	Red willow	Salix laevigata	T
Salicaceae	Pacific willow	Salix lasiandra ssp. lasiandra	T
Scrophulariaceae	Moth mullein	Verbascum blattaria (I)	AH
Scrophulariaceae	Woolly mullein	Verbascum thapsus (I)	AH
Solanaceae	Jimson weed	Datura stramonium (I)	AH
Solanaceae	Tree tobacco	Nicotiana glauca (I)	S
Solanaceae	Black nightshade	Solanum nigrum (I)	AH
Typhaceae	Narrow-leaf cattail	Typha angustifolia	PH
Urticaceae	Giant nettle	Urtica dioica	PH
Verbenaceae	Lippia	Phyla nodiflora	PH
Verbenaceae	Blue vervain	Verbena bonariensis (I)	AH
Viscaceae	Oak mistletoe	Phoradendron leucarpum ssp. tomentosum	PH
Vitaceae	California wild grape	Vitis californicus	V
Vitaceae	Wine grape	Vitis vinifera (I)	V