Kern Water Bank Ponds
Aquatic Ecology Monitoring & Assessment
CSU-Fresno Aquatic Ecology Lab (S. Blumenshine, Biology)

August-December 2017

PREPARED FOR: Kern Water Bank Authority

PREPARED BY: Steve Blumenshine
Professor of Biology
CSU-Fresno

PROJECT EXECUTION: CSU-Fresno Aquatic Ecology Lab
Crew Leaders: Karen Boortz, Elliana Rosenthal
Field & Lab Technicians: Kiana Cabasa, Guillermo Coronado, Efrain Jiminez, Emily Ramirez, Veronica Salcedo, Gabby Vang, Stephen Winsor, Jackson Xiong

Natural History Research: Gihad Mohsin

VEGETATION SURVEY: Kate Wazelkov and the Plant Anatomy Course

Table of Contents

OVERVIEW:

PURPOSE

The Kern Water Bank Authority (KWBA) initiated this project in order to inform ongoing and future goals including KWB management to foster the support of wildlife, especially waterbirds. Ongoing bird surveys and reports by Sterling Wildlife Biology are excellent for documentation, but there has been a lack of understanding and explanations for the observed distributions of waterbird species and abundances. This 'exploratory' project as well as subsequent iterations can help to refine the questions and sampling designs that can guide future KWB management, for example as outlined in the KWB Waterbird Management and the Habitat Conservation Plans.

Core goals of this project also included measuring and documenting ecological components of the KWB pond ecosystems, including physical-chemical variables, algae, riparian plants, and invertebrates. We also provide in-depth multivariate analyses of waterbird distributions to support broader KWBA management goals. Coupling analyses such as these with detailed pond morphological and hydrological information would increase the ability to understand and explain waterbird use of KWB ponds.

BACKGROUND & INTRODUCTION

Perhaps ironically, studies conjoining aquatic ecology and waterbird habitat are rare; researchers in these two disciplines operate as if the other did not exist. Despite this trend, I have led several projects which relate waterbirds with aquatic habitats (esp. as prey or energy sources) (Hodgens et al. 2004, Moss et al. 2009), which makes our research group particularly suited for this project.

Central Valley wetlands are among the most important wetlands for waterbirds in North America, especially given that 95% of historical wetland acreage in California has been lost (Dahl 1990). The remaining wetlands are therefore carefully managed to optimize their value to resident and migratory waterbirds. Wetland value relies upon the capacity to produce waterbird food resources, such as moist-soil plants and aquatic invertebrates. Invertebrates in particular are critical sources of energy and protein for both resident and migratory waterbirds (Taft & Haig 2005). Since invertebrates are so important to migratory and resident water birds, it is critical to understand the factors dictating invertebrate production in managed wetlands.

Invertebrates in particular are critical sources of energy and protein for both resident and migratory waterbirds. For example, chironomids (mostly adults and pupae) comprised 1% (Sept), 5% (Oct), 81% (Nov), 60% (Dec), 85% (Jan), and 65% (Feb) of the diet volumes of pintail ducks feeding in the Los Banos Wildlife Area (Connelly & Chesmore 1980). Invertebrate-derived energy and protein is used by waterbirds fuel over winter survival, continue migration, feather replacement (90% protein), and egg production. However, links between wetland flooding regimes, invertebrate production, and use of wetlands by waterbirds are poorly understood (de Szalay et al. 1999).

Factors affecting differential use of KWB ponds by waterbirds have not been previously investigated. If the ponds are used for foraging, most waterbirds are opportunistic and select feeding habitats that provide abundant food (Bellrose 1980, Austin and Miller 1995). Many of the common waterbirds in the KWB (i.e., dabbling ducks and shorebirds) prefer to forage in flooded habitats that are shallow (e.g. ~30 cm); enough for them to access invertebrates and other foods in the substrate (Safran et al. 1997, Isola et al. 2000). Managed flooded areas are vital as resting areas for migratory and nesting waterbirds as well as an energy source through foraging on plants and invertebrates. Invertebrates in particular are critical sources of energy and protein (Taft and Haig 2005) for both resident and migratory waterbirds (Euliss 1984, Miller 1987). Ducks feeding in marshes and evaporation ponds in Tulare Lake Basin for example rely heavily upon larval Chironomidae (Diptera) throughout the winter (Euliss and Harris 1987, Euliss et al. 1991). Chironomids (mostly adults and pupae) comprised as much as 85% of the diet volumes of pintail ducks feeding in the Los Banos Wildlife Area (Connelly and Chesemore 1980).

Waterbirds may also use the KWB ponds for refuge, nesting, or foraging on vertebrate prey such as fish and amphibians. We include a section (KWB Waterbird Habitats & Diets) on relevant natural history information of the very diverse array of waterbird species documented during the August 2017 survey by John Sterling. This information shows a remarkable variety on habitat use and aquatic food among most of the species, which suggests that the KWB provides an impressive array of habitat requirements for many waterbird species (e.g. 66 per Sterling 2012 report).

EXECUTIVE SUMMARY

This project was originated and designed to meet some general questions and goals regarding the composition and variation in broad attributes of the KWB pond ecosystems. As such, this is largely a survey project which can serve to: 1) document the basic physical/chemical and biological variables of the KWB ponds, and 2) explore the potential for non-random patterns in the measured variables, especially as they relate to waterbird assemblages based on the August 2017 survey. It is important to note the seasonality of waterbird use of the KWB ponds (KWB Waterbird Management Plan), and that the relationships of waterbird assemblages and habitat variables reported here may differ over time. In order to test the constancy of waterbird assemblages, we compared the August 2017 waterbird data with the prior survey conducted in May 2017. The average density (#/ha) of most abundant species varied little between months (Table 1), and pond waterbird densities were remarkably similar between these months. For example, of the seven ponds with the highest waterbird densities in the May and August surveys, five (C1, C4, C5, M4, M10) were common between these months. Also, the same nine ponds (C2, C7, CX, R6, S5, S6, S10, S11, SC) lacked waterbirds in both the May and August surveys.

Waterbird assemblages were very diverse across ponds, much more so than the measured environmental and biological variables, which largely differed more over time (months) than among ponds. The measured pond variables are less likely to diverge among ponds because they are hydrologically connected (at least in clusters) and are experiencing the same environmental influences (e.g. water source, chemical composition, climate). Given this, it was interesting to note the high variation (i.e. lack of precision) in measured variables during the same monthly sampling events. Evidence for this is the wide error bars or box and whisker plots.

Some of the notable aspects of the findings:

- Waterbird diversity is high, but very unevenly spaced among the KWB ponds. For comparison, a study of waterbird distributions in seasonal wetlands in Merced Co. found that water depth explained 84% of the variation in waterbird species distributions (Isola et al. 2000). Waterbird groups were found to differ in water depth preferences: small shore-birds (<5 cm); 2) large shorebirds (5-11 cm); 3) teal (10-15 cm); and large dabbling ducks (>20 cm)
- 68 riparian plant species were found along transects of the 10 study ponds during October 2017, but this diversity is relatively low for this type of ecosystem and likely does not reflect the seasonal diversity added by late-winter and spring species
- The ponds maintained adequate temperature ranges for algae, invertebrates, and fish; daytime oxygen concentrations were very high, suggesting very productive systems
- The pond water was generally clear, but some instances included Blue-Green algae (Cyanobacteria) as floating mats and in laboratory-processed water samples. This is of some concern because some cyanobacteria can produce toxins (cyanotoxins) under

certain conditions, and they are also affiliated with the bacteria that causes avian botulism. Fortunately the ponds are well-oxygenated which would preclude a botulism outbreak. Compared to BG algae, very palatable forms of green algae and diatoms were more common which constitute a productive base of the pond foodwebs.

- Low abundances and small body sizes of zooplankton in pond water columns. May be due to high predation by fish and/or birds. For example, 140,000 mosquitofish were stocked in the ponds during 2017.

TASKS

I. Assessment planning
   A. Scoping trip & mileage
   B. Review existing documentation (maps, reports, etc.)
   C. Communications (initial meeting, other biological consultants)
   D. Review & determine most appropriate sampling protocols, QA/QC

II. Biological & habitat sampling
   A. Develop sampling plan
   B. Field sampling
      1. Physical/Chemical measurements
      2. Biological sampling
   C. Laboratory processing of sample material
   D. Chain of command; QA/QC

III. Data organization & interpretation
   A. Record keeping (field notes, data from field & lab)
   B. Data organization & storage
   C. Statistical analyses of data

IV. Reporting (deliverables)
   A. Monthly progress reports
   B. Review of relevant literature & management materials
   C. Revise sampling; per seasonal dynamics
   D. Prospective planning for 2018
   E. Final report generation

SUMMARY POINTS OF PROJECT SAMPLING DESIGN

- Worked with John Sterling and his waterbird data from August 2017 as a basis for study site determination
- Ranked ponds based on calculated bird species richness (# spp/pond) and density (#/ha)
- Used rankings and pond proximities to establish five ‘High’ and ‘Low’ waterbird use ponds

- This sampling effort was based on a priori planning evaluation of monthly sampling effort requirements (staffing & time), which turned out to be just right based on field-based sampling tasks and laboratory processing of collected sample material
- Goal of evaluating ponds for homogeneity (or randomness) in water quality and biological attributes across ‘High’ and ‘Low’ designations.
- Measures of invertebrate composition & abundance can serve as indicators of aquatic habit health and condition
- Advanced multivariate analyses can be use to associate macroinvertebrates, water birds, and habitat measures to foster the management of high quality habitat

General Methods

This monitoring & assessment plan was produced to prioritize the efficiency producing the most information (data) per unit effort and cost.

Pond Sampling Strategy

Logistical and budget considerations led to the design of a monthly sampling strategy starting in August 2017 and continuing until most ponds were dewatered in December 2017. The monthly sampling design would allow for data and sample processing between site visits and constrain costs associated with staffing (~7-8 people/trip) and travel to the KWB (~200 mi RT). Monthly sampling intervals were also deemed suitable for detection of seasonal trends in the measured variables (water & biota).

Similar considerations were applied to the number of ponds targeted for monitoring. The established project budget was based on one-day sampling events, since each trip accumulated ~200 miles (@ $0.55/mi) on a university vehicle and ~28-32 person/hours in travel time alone. An a priori estimation of a minimum of 20 minutes to completely sample a pond (actual average was 19 minutes!) and additional travel time between ponds which was considerable in some cases given that the KWB covers 32mi^2. The objective was to solve how many ponds could be sampled in a period that ran from a 6:30-7:00am departure from CSU-Fresno and a return time by 5:00pm. The estimations of sampling time at each pond and travel to and within the KWB dictated that 10 ponds should be targeted.

The resulting selection of ponds for this study prioritized the ‘end points’ of waterbird use of the 50 ponds in John Sterling’s surveys. A secondary criterion was pond location & proximity. For example, if High/Low use ponds were respectively clustered in the very large KWBA complex, we would have no way of distinguishing an effect of region or location in waterbird pond use in contrast to spatially-adjacent pairs of ponds, which differed greatly in waterbird use.

Table 1. Comparison of average density differences of the most abundant waterbird species from John Sterling's May and August 2017 surveys.

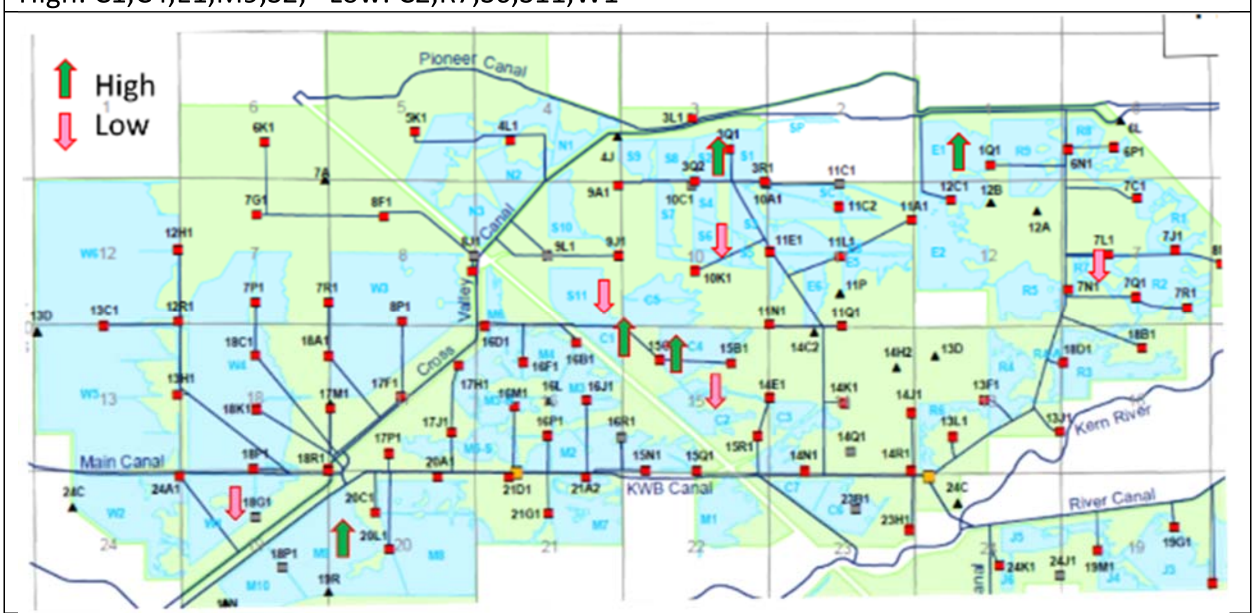
Bird Species	Average density (#/ha) difference across all ponds: August vs. May 2017 survey
AMERICAN COOT	1.76
BLACK-CROWNED NIGHT-HERON	0.02
BLACK-NECKED STILT	0.02
CASPIAN TERN	0.02
CATTLE EGRET	0.02
CINNAMON TEAL	0.04
CLARK'S GREBE	0.04
DOUBLE-CRESTED CORMORANT	0.05
GADWALL	0.08
GREAT BLUE HERON	0.03
GREAT EGRET	0.10
MALLARD	0.10
REDHEAD	0.02
RUDDY DUCK	0.04
SNOWY EGRET	0.03
WESTERN GREBE	0.01
WHITE-FACED IBIS	-0.54

Table 2. Waterbird data based on August 2017 survey.
'High' bird ponds=green shading; 'Low' bird ponds=pink shading.

Pond	Pair #	Area (acres)	Area (ha)	Surf Elev (ft ASL)	Bird Spp	Bird Density (#/ha)
C1	1	27	10.8	308	8	11.9
S11	1	88	35.8	308	0	0
C4	2	114	46.3	312	13	10.5
C2	2	51	20.5	311	0	0
E1	3	141	56.9	324	10	5.7
R7	3	46	18.6	328	0	0
M9	4	250	101	300	13	23.2
W1	4	144	58.2	296	10	1.1
S2	5	43	17.5	317	9	8.4
S6	5	33	13.3	314	0	0

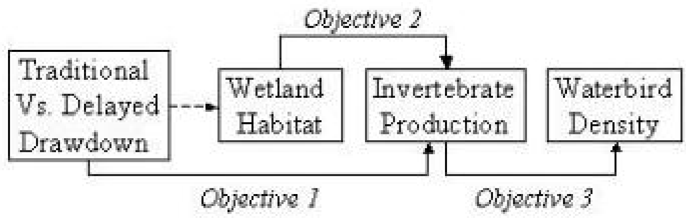
Paired (High,Low) ponds did not significantly differ in area (P=0.24) or elevation (P=0.60)(dependent t-test).

Figure 1. Map of KWB ponds highlighting ponds selected as 'High' and 'Low' waterbird use.
High: C1,C4,E1,M9,S2; Low: C2,R7,S6,S11,W1



SUGGESTED ADDITIONAL AND CONTINUING RESEARCH

- Further explore dynamic relationships among hydrology, habitat, invertebrates, and waterbirds per the conceptual model below. For example, the KWB Waterbird Management Plan notes that pond inundation occurs sporadically across years and with little planning time. Past data and relationships could be used to predict outcomes of future management options.



- Analysis of waterbird data over time
    - Are there consistent distributions of species and densities across ponds?
    - Would greatly help in understanding pond management options to foster waterbird pond use

- Impacts of pond inundation cycles on aquatic ecology (disturbance)
- Water residence time impacts on WQ & algae;
- Conditions fostering Blue-Green algal blooms
- Mammal use of ponds & riparian habitat
    - Currently doing such a study along the San Joaquin River restoration area

WATERBIRD DATA & PROJECT SAMPLE SITES

Waterbird distributions and the resulting assemblages on KWB ponds during John Sterling's August 2017 survey formed the basis of the SOW for this project and subsequent analyses of new data on pond habitats. Our overall goal includes documenting pond habitat conditions and how these might relate to the perceived value as waterbird habitat. The relationships of the waterbird species found in this survey with their use of aquatic habitats (food & otherwise) is provided in a table following this section. Nearly all species are remarkedly varied in their aquatic food sources.

We characterized the August 2017 survey information qualitatively and quantitatively. The overall goal of the data analysis and this study in general is to discern any non-random patterns in bird asseblages and/or pond attributes (abiotic & biotic) during the study period. Any non-random patterns can help to develop questions for further analyses that could aid in KWBA habitat management (e.g. KWB Waterbird Management Plan & KWBA Habitat Conservation Plan).

As expected based on basic community ecology theory, larger ponds support more species (Fig. 2a,b). However, bird density was invariant with pond area, suggesting that there is no evidence for a pond-size bias in the number of waterbirds using ponds across pond sizes. The management implication is that during water years of limited supply, larger ponds should be prioritized to maximize waterbird diversity in the KWB.

Figures 2a,b. Relationships of waterbird density (#/ha) and species richness (# spp/pond) with pond surface area from John Sterling's data on 50 KWBA ponds. Both August and May data were used to confirm general patterns.

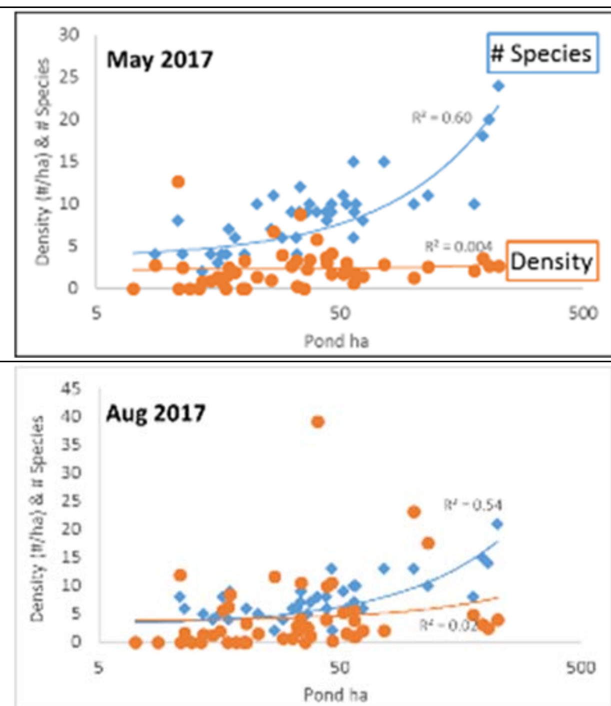
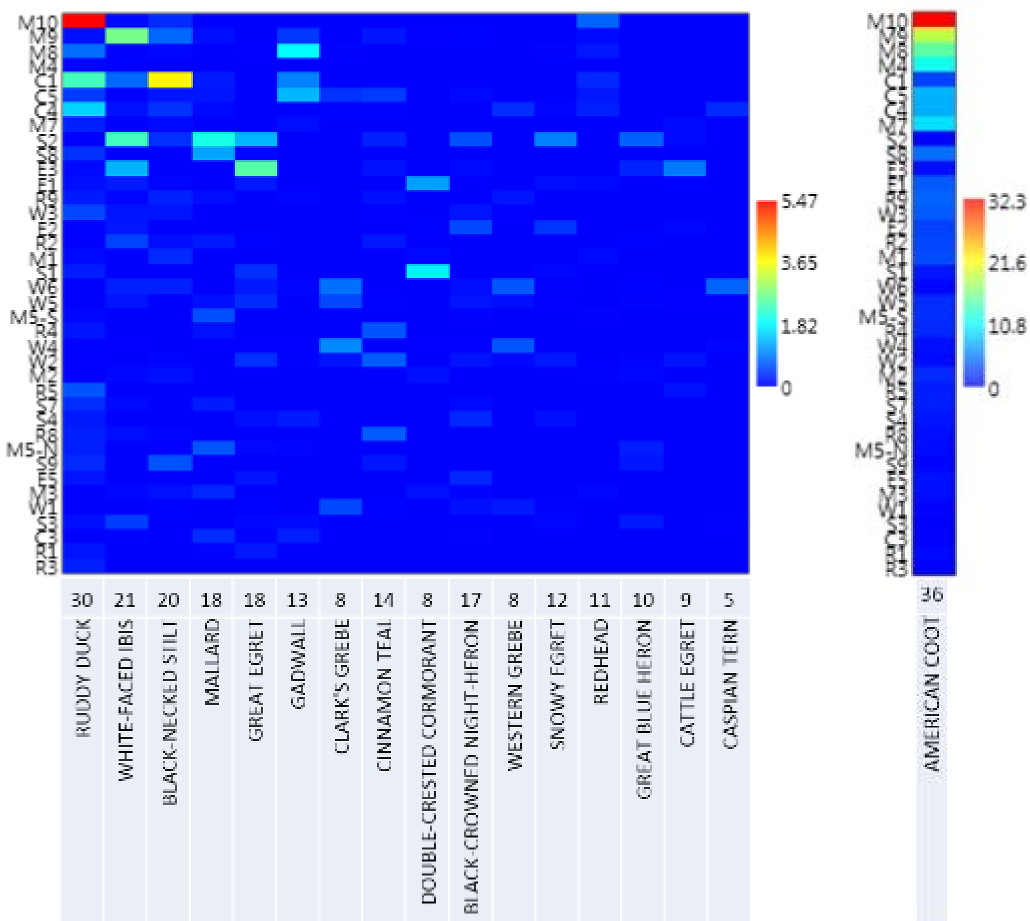


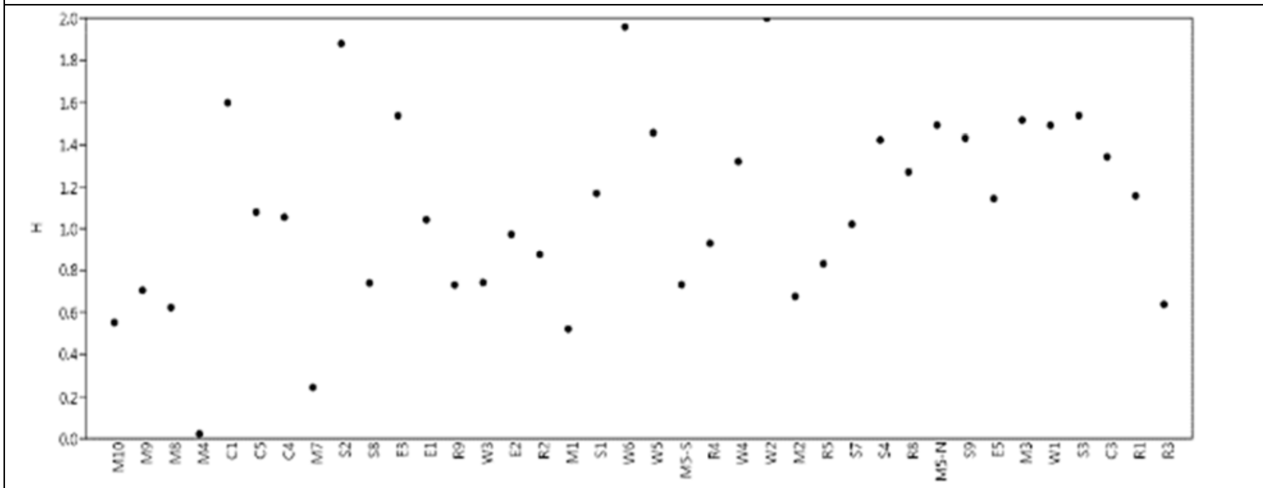
Figure 3. Density by species and pond (based on the waterbird species comprising ~98% of total abundance). The number of ponds occupied (of 50) by species in the August 2017 survey are above the species' labels. Note the relatively high densities and frequency of occurance of American Coot which is plotted seperately.



DIVERSITY

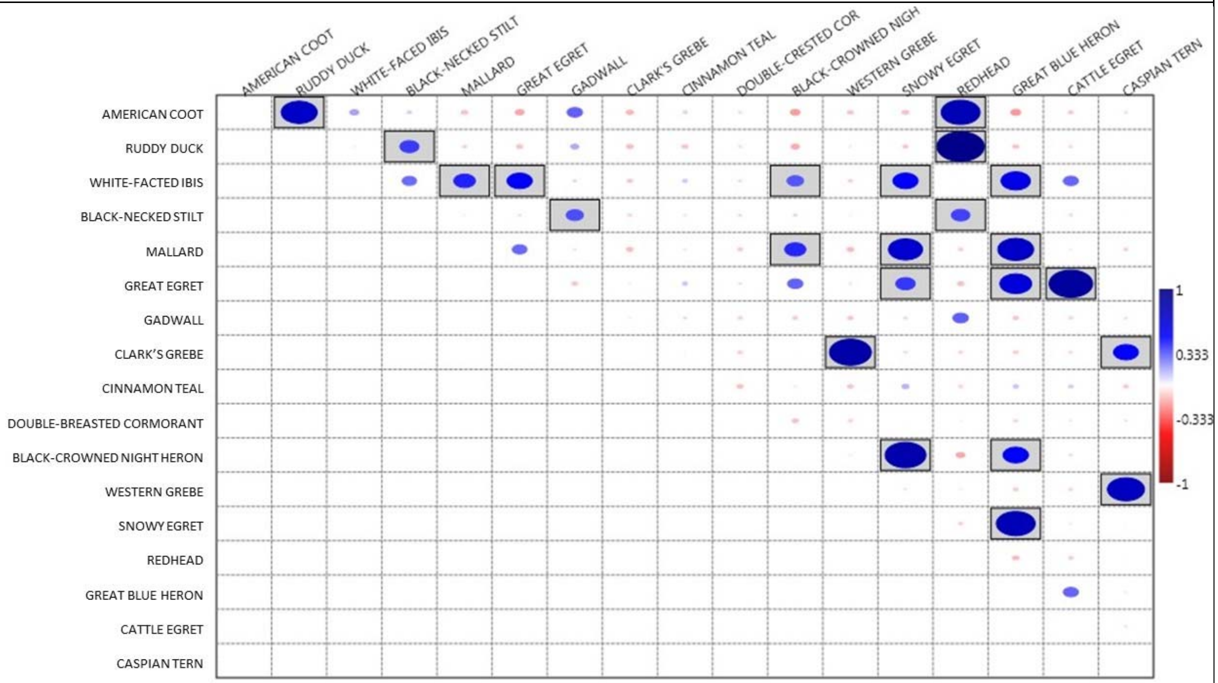
'Diversity' is a function of the number of species and their relative proportions in the assemblage, for example, pond M4 had very high waterbird density, but this was comprised of 220 American Coots and 1 Ruddy Duck. Diversity is highly variable among ponds, even in the same areas (e.g. ponds with same letter designation), and is slightly (negatively) correlated with waterbird density (r=-0.37, P=0.023).

Figure 4. Diversity (Shannon H) among ponds from Aug 2017 census, ordered from high to low waterbird densities in ponds (left to right).



The relationships of waterbird species, their densities, and distributions among ponds leads to questions about whether certain species are aggregated (or repellent), which may facilitate management of the ponds for particular species or diversity in general (Fig. 5). Waterbird species were primarily aggregative, with very few (if any) antagonistic interactions (negative correlations). This could greatly benefit management of waterbird density, and suggests a generalized, rather than a species or species-group approach would be best.

Figure 5. Cross-correlation plot of waterbird species based on correlations of their densities in common ponds. The size of the ellipse and depth of color (+blue; -red) indicates the degree of correlation between species pairs. Grey boxes indicate significant correlations. For example, densities of the two most abundant species in the August 2017 survey were American Coot and Ruddy Duck, which are very positively correlated (aggregated).



Multivariate Analyses of Waterbird Data

Multivariate analyses of the waterbird assemblage data (August 2017) allows for the examination of patterns in the assemblages among waterbird species and ponds. The abundance of zeros in the pond x species matrix suggests analyses by non-metric multidimentional scaling (NMDS) as opposed to other ordination methods such as principle components analysis (PCA). NMDS also does not assume linear relationships among variables, as with other ordination methods (Legendre & Legendre 1998).

Figure 6. NMDS plot based on waterbird species relationships among ponds. The spread of species in the plot is based on Euclidian distances which takes the absolute abundances of species into account. As supported in the prior analyses, American Coot and Ruddy Duck are the most abundant species and discerning of waterbird assemblages across ponds.

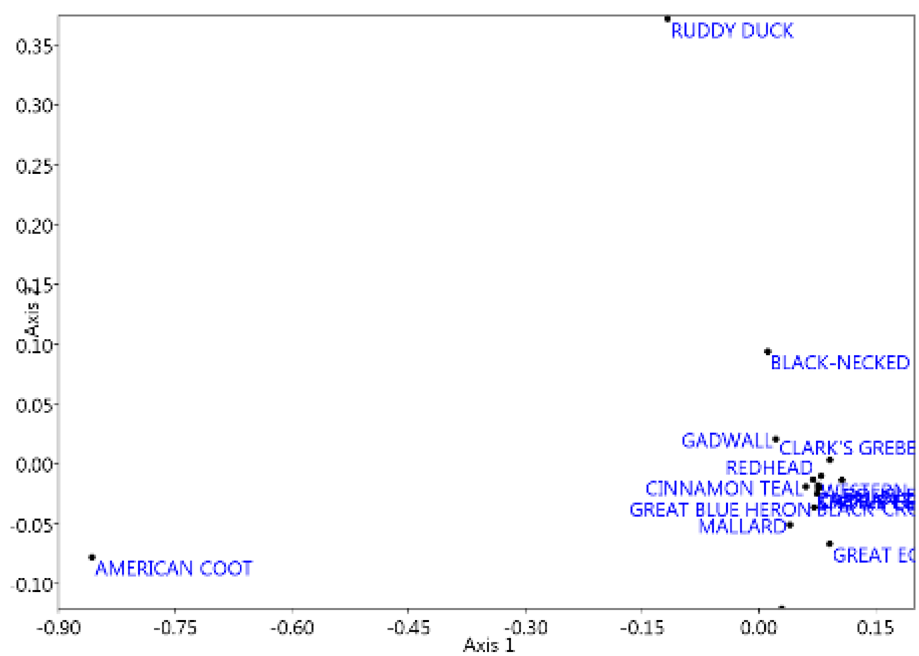


Figure 7. NMDS plot based on waterbird species relationships among ponds. The spread of species in the plot is based on correlations among species, which is based on relative and not absolute abundances. This analysis produces three clear species groupings, which partially suggest distinct body forms and/or foraging guilds (e.g. Grebes, ducks, Egrets/Herons)

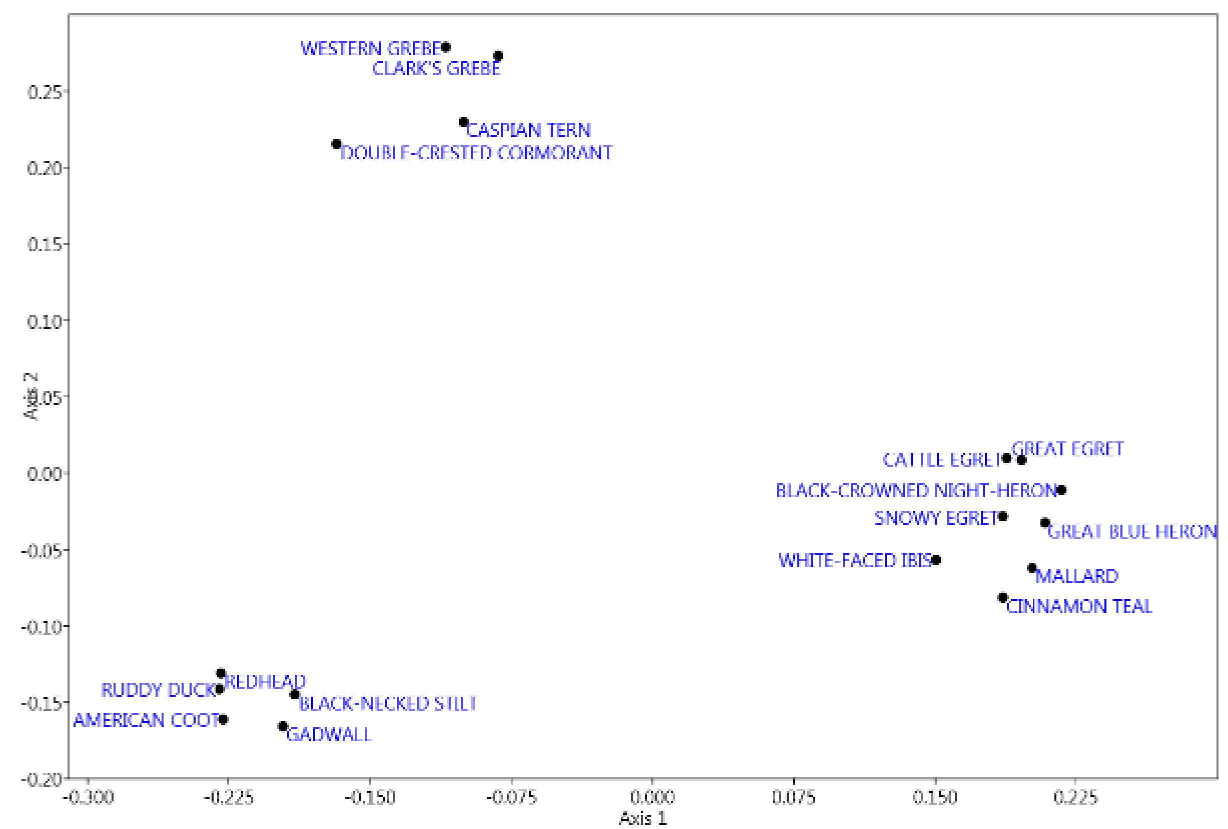
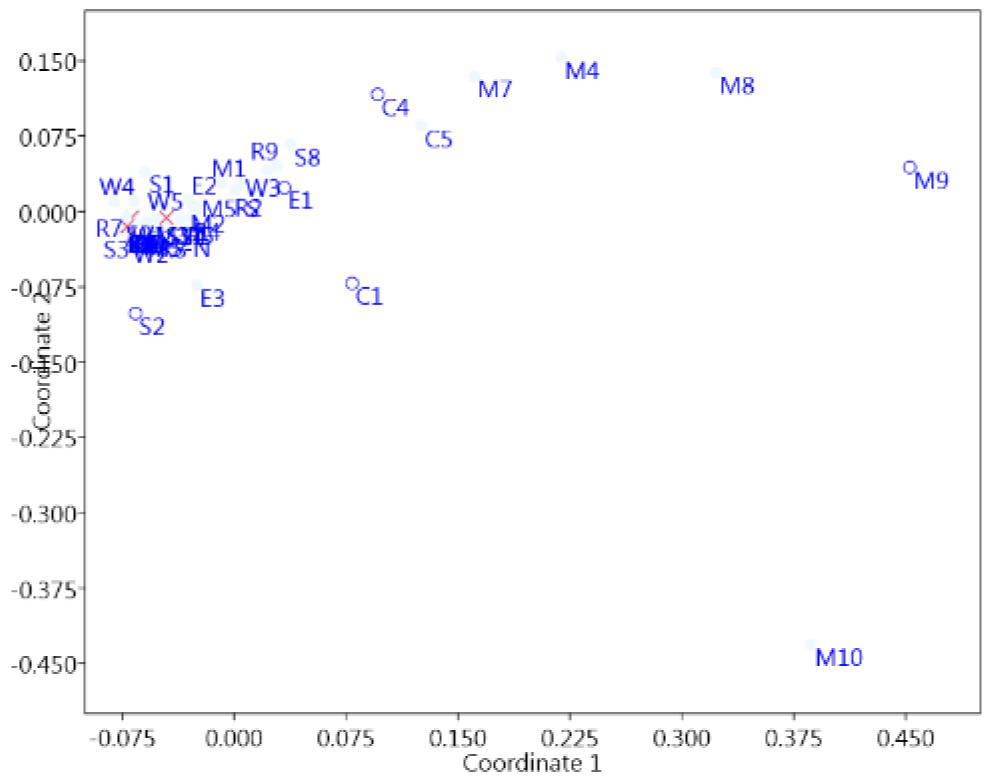
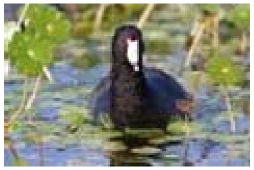
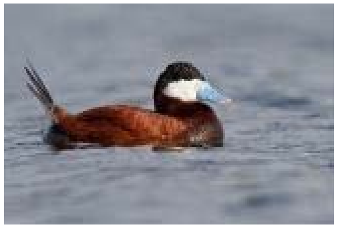
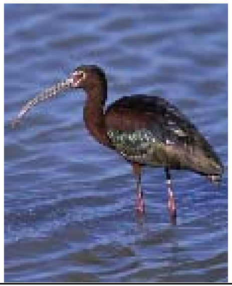


Figure 8. NMDS plot of ponds based on waterbird species assemblages; distances between sites calculated from Jaccard's similarity, which takes in to account species absolute abundances. 'High' waterbird status ponds are designated with open blue symbols. These sites are rather isolated in composition and abundance compared to the other 45 ponds, where as 'Low' waterbird ponds (red X) are clumped with the other ponds which had no or very sparse waterbird presence. The M ponds are isolated along the primary (=horizontal) ordination axis due to the influence of American Coot abundance at these sites.

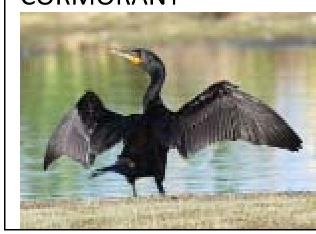


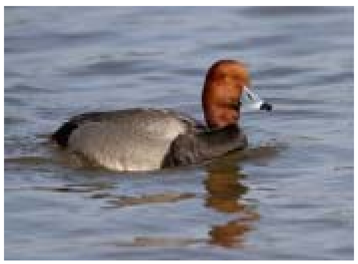
KWB Waterbird Habitats & Diets

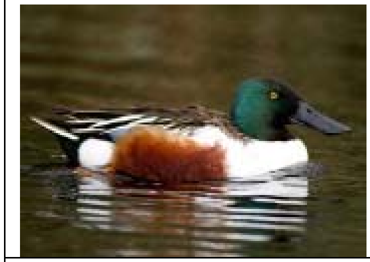
Species	**Habitat notes**	**Aquatic Food**	**Other Notes**
AMERICAN COOT 	Ponds, lakes, marshes Seasonal wetlands used during years of high water, while drought years cause breeding to be limited to permanent wetlands.	Omnivorous. Eats mostly plant material, including stems, leaves, and seeds of pondweeds, sedges, grasses, and many others, also much algae. Also eats insects, tadpoles, fish, worms, snails, crayfish, prawns, eggs of other birds.	For breeding season requires fairly shallow fresh water with much marsh vegetation.
RUDDY DUCK 	Fresh marshes, ponds, lakes; in winter, salt bays	Mostly seeds, roots, insects. Insects and their larvae may be main foods eaten in summer.	Breeds on fresh or alkaline lakes and ponds with extensive marshy borders and with areas of open water
WHITE-FACED IBIS 	Fresh marshes, irrigated land, tules. foraging, favors very shallow water, as in marshes, flooded pastures, irrigated fields.	Mostly insects, crustaceans, earthworms. Also eats frogs, snails, small fish, leeches, spiders.	Breeds in colonies. Colony sites often shift from year to year with changes in water levels.
CLARK'S GREBE 	Occur seasonally on large lakes and suitable wetlands throughout much of the western half of North America.	Mainly fish.	Until recently was considered a color morph of Western Grebe.

GADWALL 	On migration and in winter, look for Gadwall in reservoirs, ponds, fresh and salt water marshes, city parks, sewage ponds, or muddy edges of estuaries.	Eat mostly submerged aquatic vegetation such as algae, grasses, rushes, sedges, pondweed, widgeon grass, and water milfoil, including leaves, stems, roots, and seed and some invertebrates such as snails.	Gadwall breed mainly in the Great Plains and prairies
WESTERN GREBE 	Western Grebe breeds in lakes and ponds across the American West and winters primarily off the Pacific Coast.	Mainly fish and occasionally crustaceans and worms.	The very similar Clark's Grebe was long thought to be the same species. Both species have a dramatic, choreographed courtship display, in which the birds rush across the water with their long necks extended.
BLACK-NECKED STILT 	Found along the edges of shallow water in open country. flooded pastures are particularly suitable habitats for these birds, since such environments have some sparse vegetation without being too overgrown	Aquatic invertebrates and fish	Favor Human-maintained wetlands.

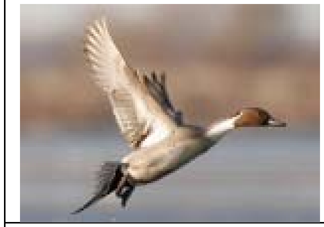
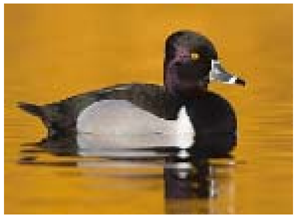
GREAT EGRET 	Lives in freshwater, brackish, and marine wetlands. During the breeding season they live in colonies in trees or shrubs with other waterbirds	Mainly small fish but also eats amphibians, reptiles, birds, small mammals and invertebrates such as crayfish, prawns, shrimp, polychaete worms, isopods, dragonflies and damselflies, whirligig beetles, giant water bugs, and grasshoppers.	
MALLARD 	Mallards prefer wetlands near water sources with an abundant supply of food and cover.	Omnivores. Aquatic vegetation, worms, insects, grain.	
CASPIAN TERN 	Breeds in wide variety of habitats along water, such as salt marshes, barrier islands, dredge spoil islands, freshwater lake islands, and river islands.	Almost entirely fish; occasionally crayfish and insects.	Nesting colonies occur on island beaches, often near colonies of other bird species.
FORSTER'S TERN 	Breeds in marshes, generally with lots of open water and large stands of island-like vegetation.	Small fish and arthropods	

CINNAMON TEAL 	Uses freshwater (including highly alkaline) seasonal and semipermanent wetlands of various sizes, including large marshes, reservoirs, sluggish streams, ditches, and stock ponds.	Seeds and aquatic vegetation, aquatic and semi-terrestrial insects, snails, and zooplankton.	Nesting--A depression on the ground, near water. Lined with grasses and down.
BLACK-CROWNED NIGHT-HERON 	Common in wetlands across North America, including saltmarshes, freshwater marshes, swamps, streams, rivers, lakes, ponds, lagoons, tidal mudflats, canals, reservoirs, and wet agricultural fields.	Black-crowned Night-Herons are opportunists feeders that eat many kinds of terrestrial, freshwater, and marine animals.	They require aquatic habitat for foraging and terrestrial vegetation for cover.
DOUBLE-CRESTED CORMORANT 	Colonial waterbirds that seek aquatic bodies big enough to support their mostly fish diet.	Diet is almost all fish, with just a few insects, crustaceans, or amphibians	They may roost and form breeding colonies on smaller lagoons or ponds, and then fly up to 40 miles to a feeding area.

CALIFORNIA GULL 	Breed on sparsely vegetated islands and levees in inland lakes and rivers, but they also breed in salt ponds in the San Francisco Bay, California	Omnivores that eat just about anything that will fit into their mouths, including fish, garbage, grasshoppers, mayflies, brine shrimp, earthworms, small mammals, cherries, bird eggs, grains, carrion	During the breeding season they may forage up to 40 miles away from the breeding colony in open areas including farm fields, garbage dumps, meadows, scrublands, yards, orchards, and pastures.
REDHEAD 	Breed mainly in the seasonal ponds and other wetlands of the Midwest's prairie pothole region, where emergent plants provide food and cover. Females often take their broods to a deeper marsh or permanent lake located near their nesting sites to raise them.	Eat submerged aquatic plants, including green algae, muskgrass, hardstem bulrush, pondweed, and widgeongrass.	Opportunistic in their choice of nesting sites, Redheads also nest on reservoirs, sewage ponds, streams, and cropland ponds, as well as on the large marshes of the Great Basin and Canada.
SNOWY EGRET 	Nest in colonies on thick vegetation in isolated places—such as barrier islands, dredge-spoil islands, salt marsh islands, swamps, and marshes.	Eats mostly aquatic prey, including fish, frogs, worms, crustaceans, and insects.	They winter in mangroves, saltwater lagoons, freshwater swamps, grassy ponds, and temporary pools, and forage on beaches, shallow reefs, and wet fields.

GREAT BLUE HERON 	Live in both freshwater and saltwater habitats, and also forage in grasslands and agricultural fields, where they stalk frogs and mammals.	Very broad diet, both aquatic and terrestrial prey including fish, amphibians, reptiles, small mammals, insects, and other birds.	Most breeding colonies are located within 2 to 4 miles of feeding areas, often in isolated swamps or on islands, and near lakes and ponds bordered by forests.
CATTLE EGRET 	Cattle Egrets breed in coastal barrier islands, marshes, reservoirs, lakes, quarries, swamps, riverside woodlands, and upland forests.	Cattle Egrets have broad, adaptable diets: primarily insects, plus other invertebrates, fish, frogs, mammals, and birds.	They usually nest in colonies already established by native herons and egrets, and forage in fields with grazing livestock.
NORTHERN SHOVELER 	Breeds in open, shallow wetlands. In winter, inhabits both freshwater and saline marshes.	Small swimming invertebrates. Forages in open water or dabbles in mud in shallow areas. Also consumes seeds.	
AMERICAN WHITE PELICAN 	American White Pelicans breed mainly on isolated islands in freshwater lakes or, in the northern Great Plains, on ephemeral islands in shallow wetlands.	Eat mostly small fish that occur in shallow wetlands, such as minnows, carp, and suckers.	They forage in shallow water on inland marshes, along lake or river edges, and in wetlands, commonly 30 miles or more from their nesting islands.

EARED GREBE 	Breeds in shallow lakes and ponds. In migration and in winter prefers salt water. Occurs in great numbers in super salty habitats, where fish are absent.	Aquatic invertebrates, especially brine shrimp and brine flies.	
PIED-BILLED GREBE 	Pied-billed Grebes live on bodies of flat or sluggish, fresh to slightly brackish water, at altitudes from sea level to about 8,000 feet	Eat mostly crustaceans (particularly crayfish) and small fish, which they capture and crush with their stout bills and strong jaws.	They forage in open water but construct their floating nests using materials and anchors of aquatic vegetation and/or dense stands of emergent vegetation—plants that root underwater with leaves and stems that extend into air.
LONG-BILLED DOWITCHER 	Found in wet, grassy meadows and ponds.	Consumes insects such as midge larvae, aquatic or moist soil worms, and small burrowing crustacea. Can also consume plant material.	Widely distributed and highly migratory.
CANADA GOOSE 	Canada Geese live in a great many habitats near water, grassy fields, and grain fields	In spring and summer, geese concentrate their feeding on grasses and sedges, including skunk cabbage leaves and eelgrass. During fall and winter, they rely more on berries and seeds, including agricultural grains, and seem especially fond of blueberries	

LONG-BILLED CURLEW 	Spend summers in areas of western North America with sparse, short grasses, including shortgrass and mixed-grass prairies as well as agricultural fields. n winter they migrate to the coasts where you can find them in wetlands	Eat insects, marine crustaceans, and bottom-dwelling marine invertebrates.	
NORTHERN PINTAIL 	Nests in open country with shallow, seasonal wetlands and low vegetation.	Grain, seeds, weeds, aquatic insects, crustaceans, and snails.	
GREATER YELLOWLEGS 	Breeds in muskeg, wet bogs with small wooded islands, and forests (usually coniferous) with abundant clearings. Winters in wide variety of shallow fresh and saltwater habitats.	Small aquatic and terrestrial invertebrates, small fish, frogs, and occasionally seeds and berries.	Wades in water and picks up prey it sees, sweeps bill side-to-side through water to catch prey by feel.
RING-NECKED DUCK 	Breed in freshwater marshes and bogs across the boreal forest of northern North America	Eat submerged plants and aquatic invertebrates. The plants they eat include leaves, stems, seeds, and tubers of pondweed, water lilies, wild celery, wild rice, millet, sedges, and arrowhead.	Although they're diving ducks, they're frequently seen in quite shallow waters (four feet deep or less), where patches of open water are fringed with aquatic or emergent vegetation such as sedges, lilies, and shrubs.

AMERICAN AVOCET 	Shallow fresh and saltwater wetlands.	Aquatic invertebrates.	Populations declined in the 1960s and 1970s, largely from the loss of wetlands from water diversion for human use.
HORNED GREBE 	Breeds on small to moderate-sized, shallow freshwater ponds and marshes. Winters along coasts and on large bodies of water.	Aquatic arthropods in summer, fish and crustaceans in winter.	Nesting-- An open bowl in a platform of floating vegetation or on a rock.
GREEN HERON 	Common breeders in coastal and inland wetlands. They nest along swamps, marshes, lakes, ponds, impoundments, and other wet habitats with trees and shrubs to provide secluded nest sites	Eat mainly small fish such as minnows, sunfish, catfish, pickerel, carp, perch, gobies, shad, silverside, eels, and goldfish. They also feeds on insects, spiders, crustaceans, snails, amphibians, reptiles, and rodents.	They hunt at all times of the day and night in the shallows of swamps, creeks, marshes, ditches, ponds, and mangroves. They usually forage among thick vegetation in water that is less than 4 inches deep, avoiding the deeper and more open areas frequented by longer-legged herons.

Citations & Sources
http://www.audubon.org/field-guide/bird/american-coot
http://www.audubon.org/field-guide/bird/ruddy-duck
https://www.allaboutbirds.org/guide/Gadwall/lifehistory#at_food
https://www.allaboutbirds.org/guide/Western_Grebe/lifehistory#at_food
https://www.allaboutbirds.org/guide/Black-necked_Stilt/lifehistory
https://www.allaboutbirds.org/guide/Great_Egret/id
https://americanexpedition.us/learn-about-wildlife/mallard-duck-facts-information/
https://www.allaboutbirds.org/guide/Caspian_Tern/
https://www.allaboutbirds.org/guide/Forsters_Tern/lifehistory
https://www.allaboutbirds.org/guide/Cinnamon_Teal/lifehistory
https://www.allaboutbirds.org/guide/Black-crowned_Night-Heron/lifehistory
https://www.allaboutbirds.org/guide/Double-crested_Cormorant/lifehistory
https://www.allaboutbirds.org/guide/California_Gull/lifehistory
https://www.allaboutbirds.org/guide/Redhead/lifehistory
https://www.allaboutbirds.org/guide/Snowy_Egret/lifehistory
https://www.allaboutbirds.org/guide/Great_Blue_Heron/lifehistory
https://www.allaboutbirds.org/guide/Cattle_Egret/lifehistory
https://www.allaboutbirds.org/guide/Northern_Shoveler/lifehistory
https://www.allaboutbirds.org/guide/American_White_Pelican/lifehistory
https://www.allaboutbirds.org/guide/Eared_Grebe/lifehistory

https://www.allaboutbirds.org/guide/Pied-billed_Grebe/lifehistory
https://www.allaboutbirds.org/guide/Long-billed_Dowitcher/lifehistory#at_habitat
https://www.allaboutbirds.org/guide/Canada_Goose/lifehistory
https://www.allaboutbirds.org/guide/Long-billed_Curlew/lifehistory
https://www.allaboutbirds.org/guide/Northern_Pintail/lifehistory
https://www.allaboutbirds.org/guide/Greater_Yellowlegs/id
https://www.allaboutbirds.org/guide/Ring-necked_Duck/lifehistory
https://www.allaboutbirds.org/guide/American_Avocet/lifehistory
https://www.allaboutbirds.org/guide/Horned_Grebe/lifehistory
https://www.allaboutbirds.org/guide/Green_Heron/lifehistory

PLANT SURVEY

Plant species growing on pond margins were surveyed in October 2017 by the CSU-Fresno Plant Anatomy course lead by Dr. Katherine Wazelkov. Approximately 30m of shoreline was surveyed at each of the 10 study ponds, which produced identifications of 68 species. According to professional botanist John Stebbins, it would not be unreasonable to expect ~200 species in a system like this. For example, Pollock et al. (1998) documented 233 plant species in a sample of riparian wetlands in southeast Alaska. Examples from the Central Valley include a range of 129-418 species (including upland plants) from the San Luis, Kesterson, San Joaquin, and Merced National Wildlife Refuges (F. Takahashi [USFWS] pers. comm.).

An important point is that the diversity and assemblages surveyed in KWB represent one time-point estimate that will not include diversity generated from high-value annuals that bloom in late winter and spring. Many common upland species and late summer and fall species were represented in this October survey. This section includes a comprehensive list of all KWB species recorded and the ponds where they occurred.

Table 3. Most common plant species among the 10 focal study ponds. 27 (this list) of the 68 species were found in at least 40% of the pond margins.

Common Name	Species	# Ponds
Canada horseweed	Erigeron canadensis	10
Floating primrose-willow	Ludwigia peploides	10
Narrowleaf dock	Rumex stenophyllus	10
Valley Redstem	Ammannia coccinea	9
False daisy	Eclipta prostrata	9
Sunflower	Helianthus annuus	9
Dotted smartweed	Persicaria punctata	8
Jungle rice	Echinochloa colona	7
Shortpod mustard	Hirschfeldia incana	6
Least duckweed	Lemna minuta	6
Turkey tangle fogfruit	Phyla nodiflora	6
Rabbitsfoot grass	Polypogon monspeliensis	6
Rough cockleburr	Xanthium strumarium	6
Russian knapweed	Acroptilon repens	5
Fragrant flatsedge	Cyperus odoratus	5
Prickly lettuce	Lactuca serriola	5
Mexican sprangletop	Leptochloa fusca ssp. uninervia	5
Gooding's willow	Salix gooddingii	5
Cattail	Typha sp.	5

Bermudagrass	Cynodon dactylon	4
Tall flatsedge	Cyperus eragrostis	4
Salt heliotrope	Heliotropium curassavicum	4
Coulter's horseweed	Laennecia coulteria	4
California loosestrife	Lythrum californicum	4
Silver sheath knotweed	Polygonum argyrocoleon	4
Prickly russian thistle	Salsola tragus	4
American black nightshade	Solanum americanum	4

Plant species diversity along pond margins was consistent, with no discernable differences among High & Low waterbird status or among pond pairs (Fig. 9). An ordination of ponds based on plant assemblages displays a lack of clustering of ponds based on these assemblages, suggesting that there is little about pond waterbird designation or location that would characterize these plant assemblages (Figs. 10,11).

Figure 9. Plant species diversity among the study ponds. 'High' and 'Low' waterfowl ponds are designated by the green and red bars respectively (along the x-axis). There was no significant difference in diversity between pond types (P=0.42, indep t-test)

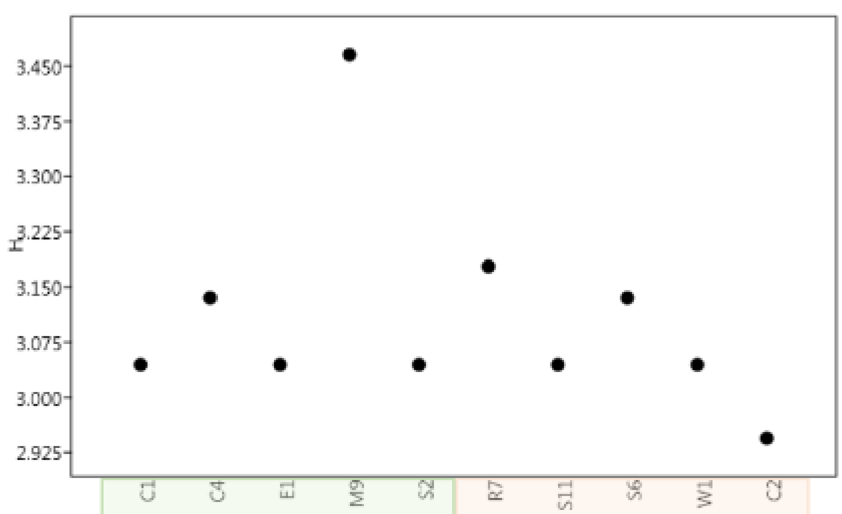


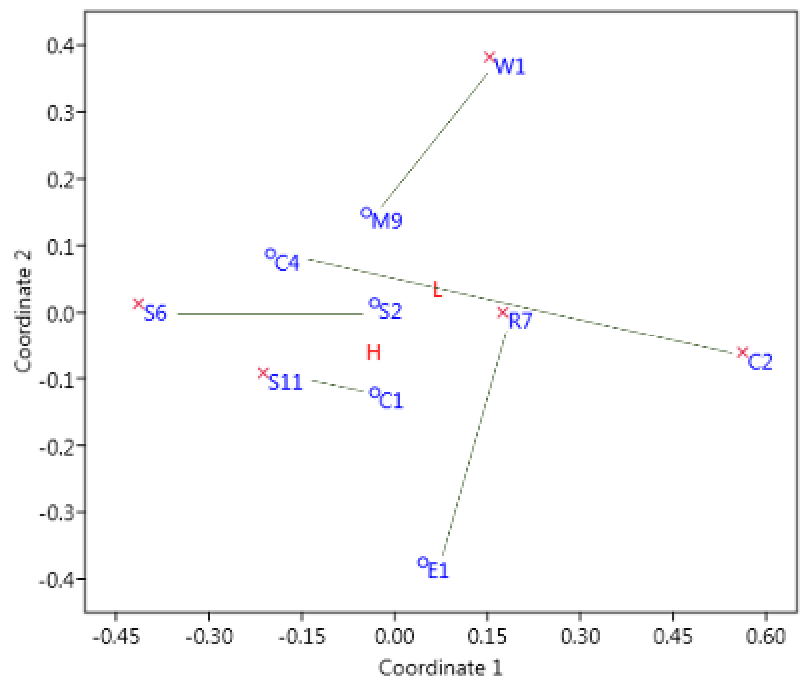
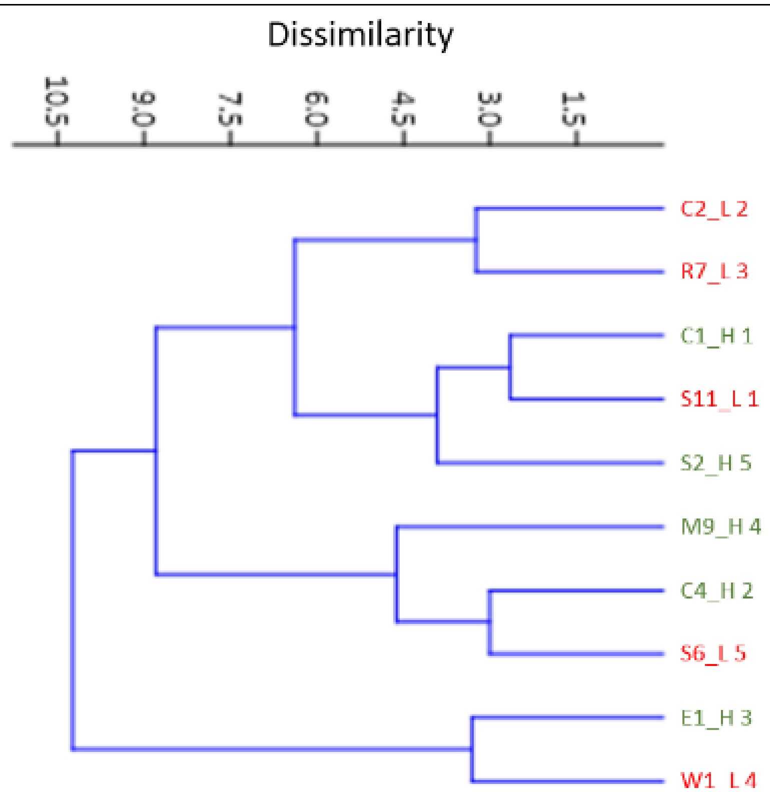
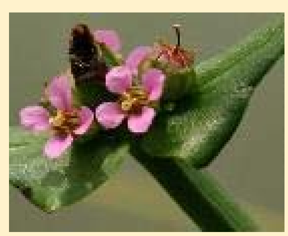
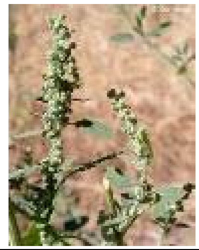
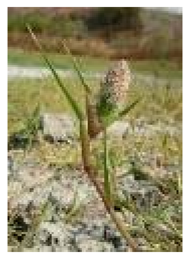
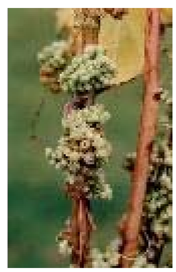
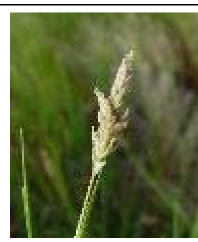
Figure 10. NMDS ordination w/ Jaccard's distance index (for pres/abs data). Open circles and red X are 'High' and 'Low' waterbird ponds respectivley. 'H' & 'L' are centers of the High & Low waterbird ponds. Green lines connect High and Low pond pairs.	
Figure 11. Cluster analysis of ponds based on plant assemblages. Labels are pond code, waterbird status, and pond pair number. This configuration confirms the ordination analysis; there is little grouping by waterbird status or proximity (i.e. pond pairs are not grouped together).	

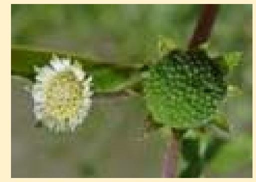
Table 4. Terrestrial Vegetation at Study Pond Margins

Common Name Scientific Name Growth Form / Habitat Study Ponds Source	**Kern Water Bank: Vegetation Inventory** **Oct 21, 2017** (C1, C2, C4, E1, M9, R7, S2, S11, W1) **(highlight = Found at ≥70% of these ponds)**
Russian knapweed Acroptilon repens (Rhaponticum repens) Forb/herb C1,S11,S6,M9,C4 https://www.cabi.org/isc	 
Pigweed (+ variants) Amaranthus albus Forb/herb W1, S2 http://southwestdesertflora.com	
Ragweed Ambrosia acanthicarpa Forb/herb R7 https://plants.usda.gov	
Valley redstem (+ variants) Ammannia coccinea Forb/herb, Subshrub W1,R7,C2,C1,S11,M9,E1,C4,S2 https://plants.usda.gov	 

Stinking orach Atriplex serenana var. serenana Forb/herb M9 https://www.calflora.org	
Peregrine saltbush Atriplex suberecta Forb/herb S11,C4,S2 https://www.calflora.org	
Mexican mosquito fern Azolla microphylla Forb/herb C2 https://www.calflora.org	 
*Same as above Azolla microphylla (or less likely A. filiculoides) (floating) W1	
Mule fat Baccharis salicifolia Shrub W1,M9,E1 https://www.calflora.org	
Fivehorn smotherweed (+ variants) Bassia hyssopifolia Forb/herb M9,C4 https://plants.usda.gov	 

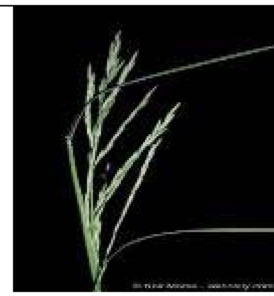
Pitseed goosefoot Chenopodium berlandieri Forb/herb S6 https://www.calflora.org	 
Thistle *(specificity depends on the specific type)* Cirsium species Forb/Herb M9 https://plants.usda.gov	
Swamp pricklegrass Crypsis schoenoides Graminoid M9 https://plants.usda.gov	
Fiveangled dodder Cuscuta campestris Forb/herb,Vine S11,S6,C4 https://plants.usda.gov	
Bermudagrass (+ variants) Cynodon dactylon Graminoid S11,S6,M9,S2 https://plants.usda.gov	 
Variable flatsedge Cyperus difformis Graminoid C1, S11 https://plants.usda.gov	 

Tall flatsedge (+ variants) Cyperus eragrostis Graminoid R7,S6,M9,S2 https://plants.usda.gov	 
Yellow nutsedge Cyperus esculentus Graminoid W1 https://plants.usda.gov	 
Fragrant flatsedge Cyperus odoratus Graminoid W1,R7,S6,M9,C4 https://www.calflora.org	 
Sacred thorn-apple Datura wrightii Forb/herb, Subshrub R7,S6,E1 https://plants.usda.gov	
Saltgrass Distichlis spicata Graminoid W1 https://plants.usda.gov	 
Jungle rice Echinochloa colona Graminoid C1,S11,S6,M9,E1,C4,S2 https://www.calflora.org	 

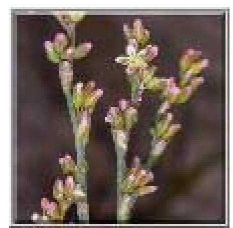
Upright burhead Echinodorus berteroi (submerged) Forb/herb W1 https://plants.usda.gov	 
False daisy Eclipta prostrate Forb/herb W1,R7,C1,S11,S6,M9,E1,C4,S2 https://www.calflora.org	  
Common spikerush Eleocharis palustris (or less likely E. macrostachya) Graminoid C2 https://plants.usda.gov	 
Parish's spike rush Eleocharis parishii Graminoid R7,C2,C1 https://plants.usda.gov	
Spikerush *(specificity depends on the specific type)* Eleocharis sp. Graminoid S2 https://plants.usda.gov	
Canada horseweed Erigeron Canadensis Forb/herb W1,R7,C2,C1,S11,S6,M9,E1,C4,S2 https://www.calflora.org	 

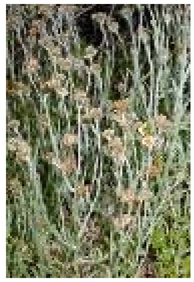
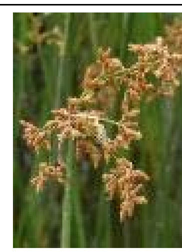
Stork's Bill *(specificity depends on the specific type)* Erodium sp. Forb/herb E1 https://plants.usda.gov	
Great Valley gumweed Grindelia camporum Forb/herb, Subshrub W1, C4 https://plants.usda.gov	
Sunflower Helianthus annuus Forb/herb W1,R7,C2,C1,S11,M9,E1,C4,S2 https://plants.usda.gov	
Salt heliotrope (+ variants) Heliotropium curassavicum Forb/herb, Subshrub W1,R7,M9,E1 https://plants.usda.gov	 
Shortpod mustard (+ variants) Hirschfeldia incana Forb/herb R7,C2,C1,S11,S6,E1 https://plants.usda.gov	 
Alkali goldenbush Isocoma acradenia Subshrub S6,E1 https://plants.usda.gov	 

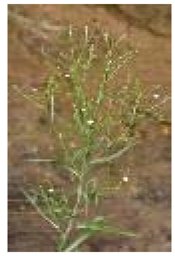
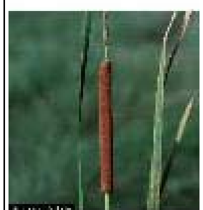
Quillwort *(specificity depends on the specific type)* Isoetes sp. Graminoid C1 https://plants.usda.gov	 
*same as above *(specificity depends on the specific type)* Isoetes sp. (dead, floating on surface) S11,S6	
*same as above *(specificity depends on the specific type)* Isoetes sp. (possibly bolanderi, but no spores to ID) C2	
Rush *(specificity depends on the specific type)* Juncus sp. Graminoid M9 https://plants.usda.gov	
Prickly lettuce Lactuca serriola Forb/herb W1,R7,S6,M9,C4 https://plants.usda.gov	 
Coulter's horseweed Laennecia coulteria Forb/herb W1,R7,M9,E1 https://www.calflora.org	 
Lemna microphylla C2	

Least duckweed Lemna minuta C1,S11,M9,E1,C4 Forb/herb https://www.calflora.org	
*same as above Lemna minuta (or less likely L. minor) (floating) W1	
Mexican sprangletop Leptochloa fusca ssp. Uninervia C1,S11,M9,C4,S2 Graminoid https://www.calflora.org	 
Floating primrose-willow Ludwigia peploides Forb/herb W1,R7,C2,C1,S11,S6,M9,E1,C4,S2 https://plants.usda.gov	
Creeping jenny Lysimachia nummularia? (no flowers, growing rooted underwater) Forb/herb C2 https://plants.usda.gov	
California loosestrife Lythrum californicum Forb/herb R7,C2,M9,C4 https://plants.usda.gov	 

Common mallow or Cheeseweed mallow Malva neglecta or M. parviflora (indistinguishable without flowers) Forb/herb S6 https://plants.usda.gov	 
Mallow *(specificity depends on the specific type)* Malva sp. Forb/herb R7,C4,S2 https://plants.usda.gov	
Alkali mallow Malvella leprosa Forb/herb E1 https://www.calflora.org	
Hairy waterclover Marsilea vestita Forb/herb E1, C2 https://plants.usda.gov (only one recorded in Kern county)	
Green carpetweed Mollugo verticillata Forb/herb E1 https://www.calflora.org	 

Dotted smartweed Persicaria punctata Forb/herb R7,C2,C1,S11,S6,M9,C4,S2 https://www.calflora.org	
Turkey tangle fogfruit Phyla nodiflora Forb/herb C1,S6,M9,E1,C4,S2 https://plants.usda.gov	 
Groundcherry Physalis lanceifolia M9	
Silver sheath knotweed Polygonum argyrocoleon Forb/herb S11,S6,M9,C4 https://www.calflora.org	 
Rabbitsfoot grass Polypogon monspeliensis Graminoid R7,C2,S6,M9,C4,S2 https://plants.usda.gov	
Honey mesquite Prosopis glandulosa Shrub Tree S6 https://plants.usda.gov	 

Jersey cudweed Pseudognaphalium luteoalbum Forb/herb R7,C1 https://plants.usda.gov	 
Narrowleaf dock Rumex stenophyllus Forb/herb R7,C2,C1,S11,S6,M9,C4,S2,W1 https://plants.usda.gov	 
Goodding's willow Salix gooddingii Tree R7,C1,S11,E1,S2 https://plants.usda.gov	 
Prickly russian thistle Salsola tragus Forb/herb S6,E1,C4,S11 https://plants.usda.gov	 
California bulrush Schoenoplectus californicus Graminoid C2 https://plants.usda.gov	 

American black nightshade Solanum americanum Forb/herb, Subshrub W1,C1,M9,S2 https://plants.usda.gov	 
Eastern annual saltmarsh aster Symphyotrichum subulatum Forb/herb C1,M9 https://plants.usda.gov	 
Narrowleaf or broadleaf cattail Typha domingensis or T. latifolia (didn't see flowers) Forb/herb W1 https://plants.usda.gov	 
Cattail *(specificity depends on the specific type)* Typha sp. Forb/herb R7,C2,C1,M9,S2 https://plants.usda.gov	
Horned pondweed or Widgeon grass Unidentified submerged plant: possibly Zannichellia palustris or Ruppia maritime Both Forb/herb C2 https://plants.usda.gov	  Horned Pondweed Widgeongrass

Big bract verbena Verbena bracteata Forb/herb R7 https://plants.usda.gov	 
Rough cockleburr Xanthium strumarium Forb/herb W1,R7,S11,M9,E1,S2 https://plants.usda.gov	 

PHYSICAL/CHEMICALPOND VARIABLES

Water temperature, turbidity, dissolved oxygen (as mg/L & % saturation), pH, Secchi depth

Note: S2: Low water August & September; S6: Low water September

Physical and chemical variables of water quality can be symptomatic of the value of the system as habitat for aquatic organisms as well as facultative-aquatics such as waterbirds and amphibians. Biota can also affect these properties as well as respond to them. For example, aquatic plants and algae generate oxygen in well-illuminated and nutrient-rich systems. However, their respiration and subsequent decomposition consume oxygen, that can negatively affect heterotrophic organisms (such as fish) that depend on the relatively low concentrations of oxygen in water compared to air. Primary producer effects on oxygen also apply to carbon dioxide (CO_2), and thus the dissolved inorganic carbon (DIC) dynamics in small aquatic systems. Consequently, water pH can be dictated by the concentrations of CO_2 in the water. When plants and algae are especially productive, oxygen levels are high, and CO_2 levels are low (plants take up CO_2 as part of their metabolism). When CO_2 levels are low, hydrogen atoms are bound to carbonate to form bicarbonate and carbonic acid. A low concentration of hydrogen atoms in solution is 'basic' and reflected as high pH. In summary then, very high levels of dissolved oxygen and high pH are indicative of very high levels of primary production, which typically forms the base of aquatic food webs. Dissolved oxygen and pH are easily and accurately measured with basic field meters, especially compared direct measures of production and CO_2.

$$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow HCO_3^- + H^+ \leftrightarrow CO_3^{2-} + 2H^+$$

Water temperatures in ponds of the KWB are likely to be strongly influenced by external factors, primarily air temperature (conduction), solar radiation (radiative), and wind (convection). The very shallow (and thus low volume) ponds have a very low heat capacity, meaning that they will readily change temperatures. The pond water is relatively clear, allowing for heating through the water column by infrared light. The KWB landscape is fairly open and flat, allowing for high winds that can mix the water (and it's heat) through the shallow depths.

Summary

The main variation in these data was across months (seasonal) effects, with little differences among low and high waterbird ponds. This is not surprising, since the ponds are hydrologically connected and likely with high turnover times due to water flow-through and evaporation. What is a bit unexpected is the lack of 'precision' in the measured variables among ponds sampled in the same day. However, given the dynamic and often biologically mediated flux in these variables, intra-day differences even within ponds would not be unexpected. Overall, the ponds display levels of these variables that indicate healthy functioning ecosystems.

Methods

At each pond, a representative location >5m from shore was established and marked to ensure repeatability over subsequent sampling events. All metered variables and water samples were taken from the mid-depth at each location.

Water temperature and dissolved oxygen (mg/L & % saturation) were measured using a YSI 556 field multimeter. Water temperatures were also monitored at 1hr intervals using Hobo Tidbit temperature loggers secured near the surface and bottom of each monitored pond. Unfortunately, both shallow and deep loggers were recovered from four of the ten ponds.


Secchi disk

Turbidity and pH were determined using basic field meters from a collected water sample. Turbidity is a measure of light scattering by water, whether by dissolved or particulate matter. Secchi depth is also a conventional measure of water clarity which uses a secchi disk (image). The secchi depth is determined when the lines between black and while quadrants are no longer discernable (due to lack of water clarity). This measure approximates ~5% of remaining surface light. The secchi depth exceeded water column depth (i.e. high light penetration to pond bottom) in 77% of all applications across ponds and months. Noteable exceptions where secchi depth < pond depth included S6 (3 of 5), W1 (3 of 5), and M9 (2 of 4). We recorded that pond S6 had some drawdown and refilling during the montoring period, which could have created suspension of pond sediments which would block light penetration.

Results

Figure 12. Meter-recorded instantaneous **water temperature** measurements among months (Aug-Dec) and pond types ('Low' and 'High' waterbirds). Temperatures cooled rapidly over the sampling period and there was little difference among pond types.

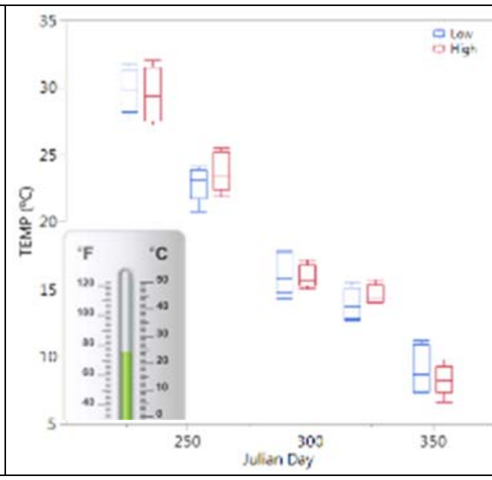


Figure 13. **Water temperature** from continuous monitoring; ponds C4,S2,S6,S11. Lines are smoothed averages from hourly measurements. The very close fit between deep and shallow sensors strongly suggest the mixing of the water column and the even distribution of heat. An

implication of this is that there is no 'cold water refuge' for aquatic organisms that might not be able to tolerate the high late summer temperatures even in the deeper pond portions.

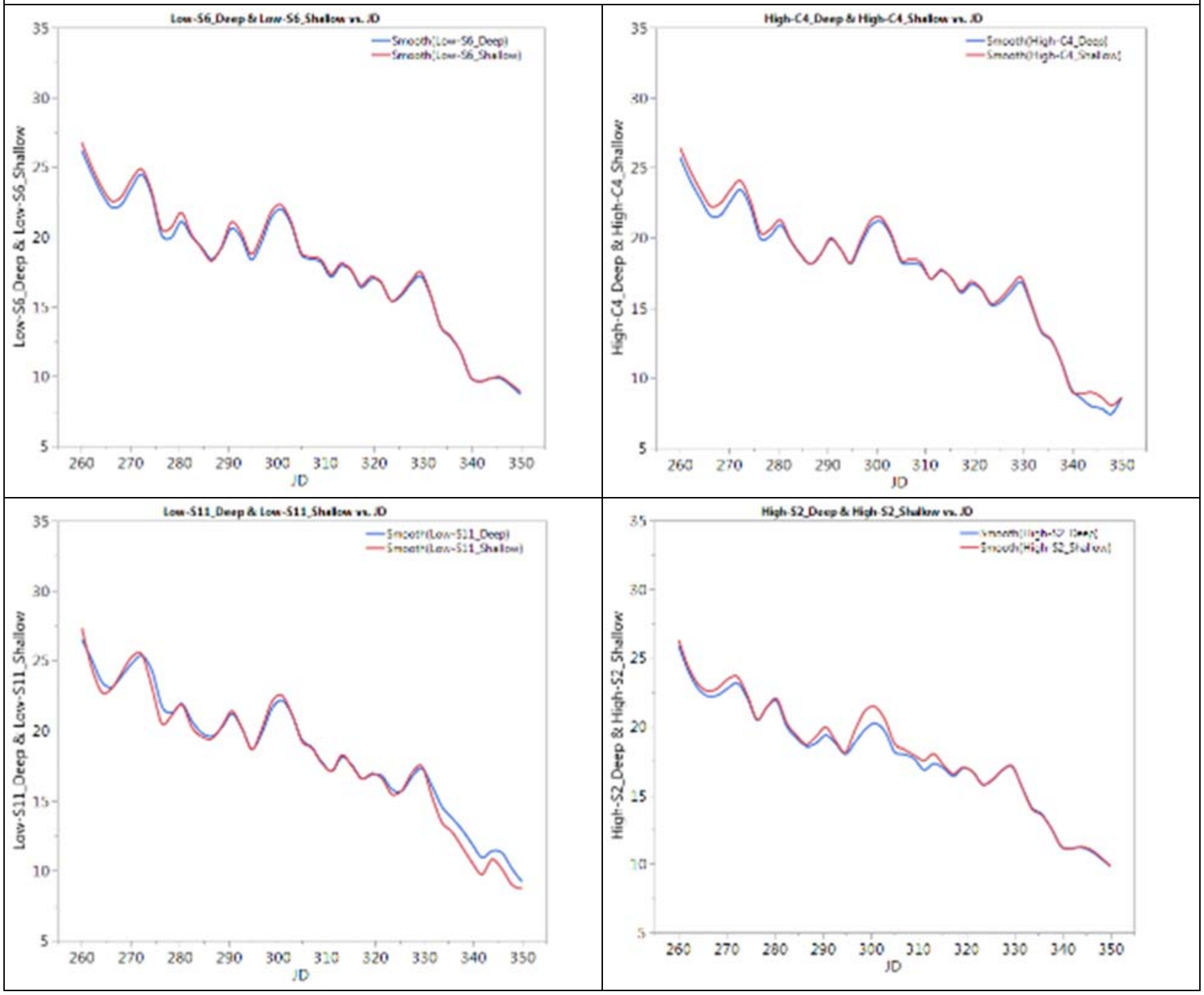


Figure 14. **Air temperatures** (daily average) for comparison with water temperatures.

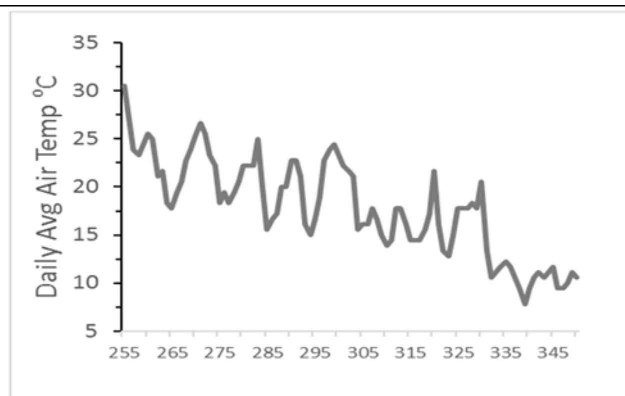
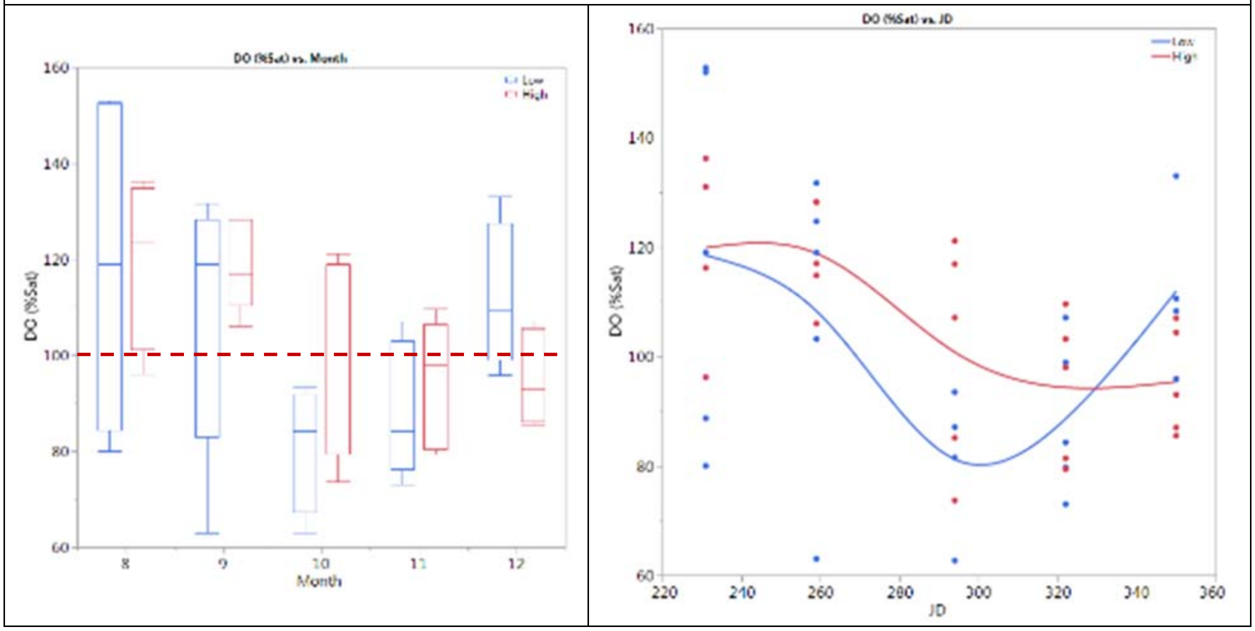
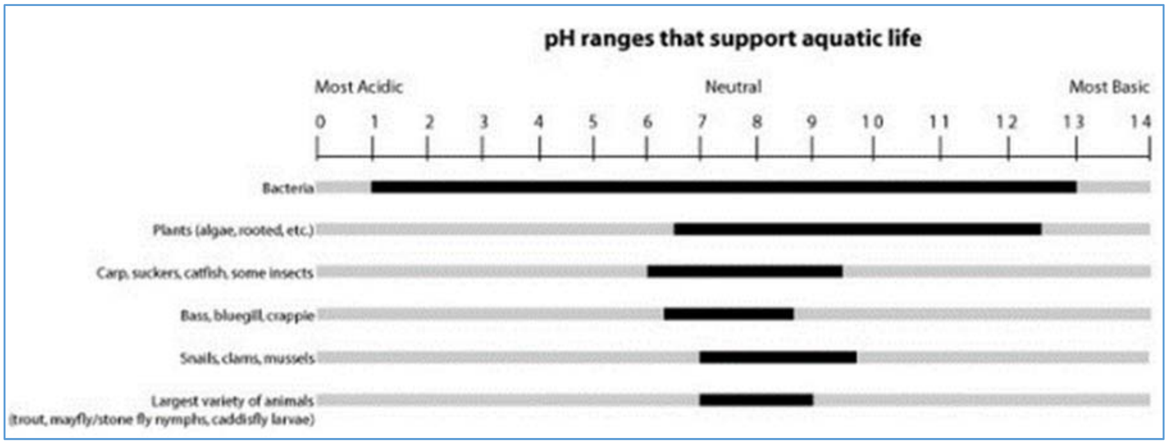


Figure 15. **Dissolved oxygen (as % saturation)** levels across months and pond types. Left panel: Box and whisker plot of DO %Sat showing variation within and among months and pont types. Right panel: Smooted plot of raw data highlighting seasonal patterns and differences between pond types.



Dissolved oxygen levels were mostly above saturation levels, indicative of very productive systems. Monthly sampling events were during sunny days, with midday sampling when primary production would be expected to be high and generating oxygen. However, both figures show a more pronounced decline in oxygen saturation levels into October and November in 'Low' bird ponds. This is not much of a concern, because only four measurements are less than 75% saturation and all are greater than 60%.

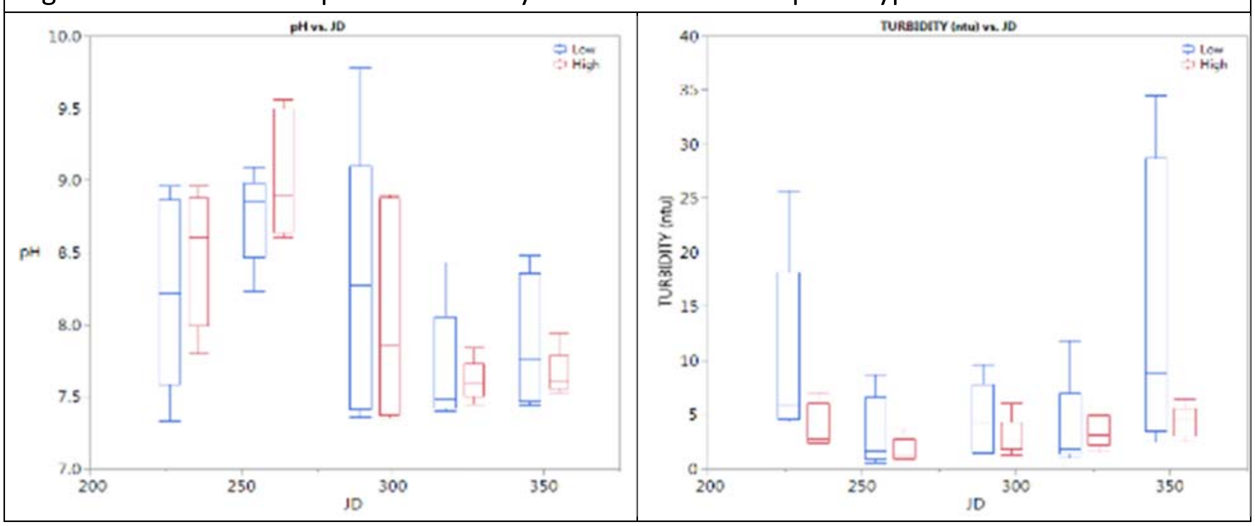


http://www.miseagrant.umich.edu

Average pH levels across months and pond types ranged from ~7.5-8.8, which is quite normal for relatively productive freshwater systems (see chart above). Although there are no clear differences among pond types, the variation in data points (span of the bars) among months and pond types, with the lowest pH values recorded later in the season, perhaps due to less primary production in the system and enhanced CO_2 levels.

Turbidity levels were low, indicating relatively clear water conditions that could foster production of benthic (bottom) primary producers including attached algae and aquatic plants.

Figure 16. Variation in pH and turbidity across months and pond types.



ALGAE

Algae in freshwaters are important resources for consumers and typically form the energy base for river, pond, and lake ecosystems. The abundance of algae (via it's production) is both a *response* and *symptom* to water quality. For example, algae often respond to high nutrient (typically nitrogen and/or phosphorous) concentrations through excessive blooms, especially if water turnover rate is low.

Different types of major algal Divisions such as blue-greens (Cyanobacteria), greens (Chlorophyta), and diatoms (Bacillariophyceae) respond differently to different nutrient inputs. While nitrogen and phosphorous (N & P) are typically limiting nutrients to algal growth, blue-green algae can 'fix' atmospheric N and are thus at an advantage when N is limiting. Blue-green algae can be problematic in aquatic ecosystems. First, they can produce genus-specific toxins (cyanotoxins) in the water that are capable of severe health impacts and even death in waterfowl and mammals. Cyanobacterial blooms have even been associated with avian botulism (Wurzbaugh 2011). Second, many or most blue-green algae taxa are relatively unpalatable to consumers in aquatic food webs. Green algae and diatoms do not produce toxins, and are relatively palatable and nutritious for consumers.

Algal production (regardless of group) in excess of consumption and export can lead to other problems in aquatic ecosystems, especially under low water turnover conditions. While algae are primary producers and produce oxygen with abundant light (e.g. measured supersaturation of oxygen in most ponds), they respire and consume oxygen at night.

Algae Collection Procedures

1. Label container with location, date, depth, and your initials
2. Sampling depths will be 25% of total depth from surface and 25% from bottom
3. Rinse Van Dorn Sampler (lower into water and rinse 2x at desired collection depth)
4. Lower sampler from the surface and release messenger triggering the seal of the bottle
5. Remove end cap or open drain valve to pour water into sample bottle (bottle should not be filled more than 1/2 full)
6. Place about 7-8 drops of lugol solution and place labeled container into cooler

Algae Identification

Rosen, B.H., and A. St. Amand. Field and laboratory guide to freshwater cyanobacteria harmful algal blooms for Native American and Alaska Native Communities: U.S. Geological Survey Open-File Report 2015–1164, 44 p., http://dx.doi.org/10.3133/ofr20151164.

Table 5. Major groups of algae found in water column samples taken from relatively shallow and deep portions of pond water columns during each sampling event. "BG"=Blue-Green (Cyanobacteria) algae. Blank represents sample not taken or processed.

'Low' Bird Ponds				**'High' Bird Ponds**			
Site	**Mon**	**Surface**	**Bottom**	**Site**	**Mon**	**Surface**	**Bottom**
C1	Aug	Diatoms	Diatoms	C2	Aug	Greens	Diatoms
C1	Sept	Diatoms					Greens
C1	Oct	Greens	Diatoms	C2	Sept		
			BG (*Anabaena*)	C2	Oct	Diatoms	
C1	Nov	Diatoms	Diatoms			Greens	
		Greens	Greens	C2	Nov	Diatoms	Diatoms
		BG (Nostoc)	BG (*Nostoc*)			Greens	Greens
C4	Aug	Diatoms	Diatoms	R7	Aug	Greens	Diatoms
		Greens	Greens				
C4	Sept			R7	Sept	Diatoms	
C4	Oct	Diatoms	Diatoms			Greens	
		Greens		R7	Oct	Diatoms	Diatoms
						Greens	
C4	Nov	Diatoms	Diatoms			BG	
		Greens	Greens	R7	Nov	Diatoms	Greens
E1	Aug	Diatoms	Greens	S6	Aug	Diatoms	Diatoms
		BG (traces)				Greens	Greens
E1	Sept			*S6*	Sept		
E1	Oct	Diatoms	Diatoms	*S6*	Oct	Diatoms	Diatoms
E1	Nov	Diatoms	Diatoms				Greens
		Greens	Greens				BG (*Spirulina*)
				S6	Nov	Diatoms	Diatoms
M9	Aug	Diatoms	Diatoms			Greens	Greens
M9	Sept					BG	BG
M9	Oct	Diatoms	Diatoms				
		Greens	Greens	S11	Aug	Diatoms	Diatoms
M9	Nov	Diatoms	Greens				BG (Traces)
		Greens	BG	S11	Sept		
				S11	Oct	Diatoms	Diatoms
S2	Aug					Greens	BG

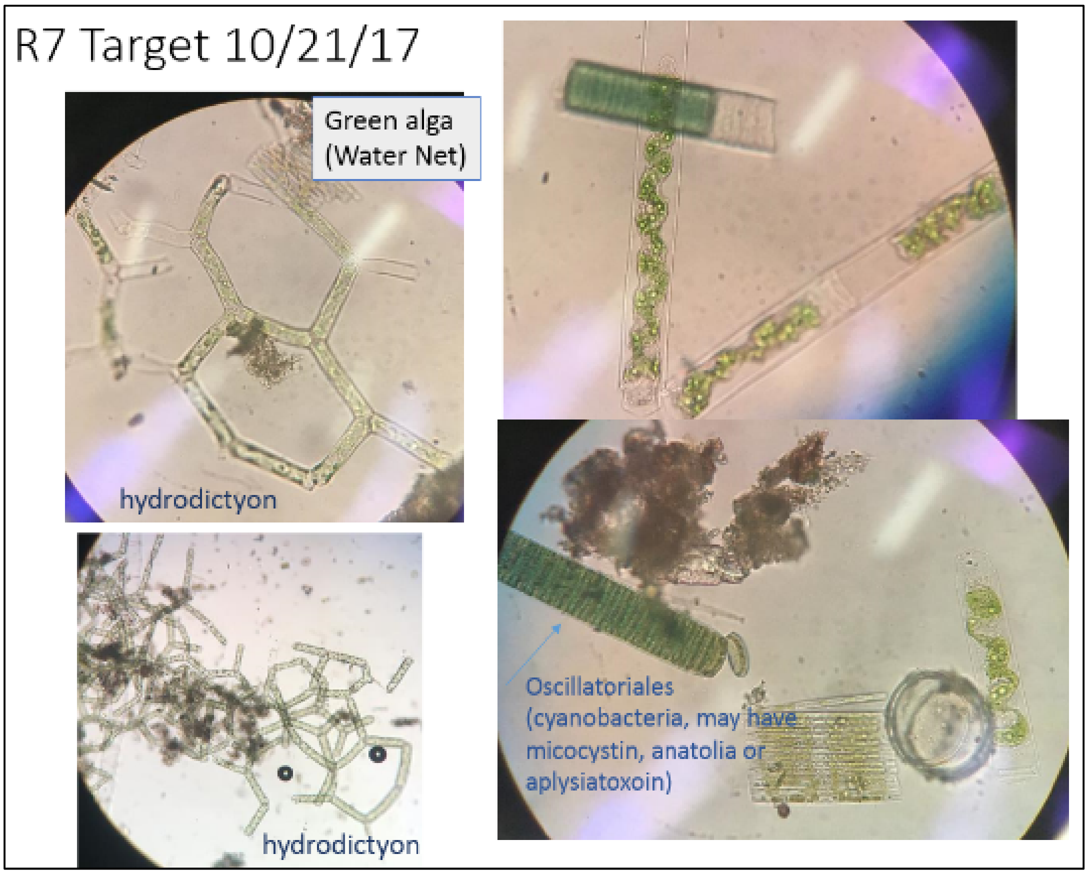
S2	Sept			S11	Nov	Diatoms	Diatoms
S2	Oct	Diatoms	Diatoms			Greens	Greens
		Greens					
		BG		W1	Aug	Diatoms	Diatoms
						Greens	Greens
S2	Nov	Diatoms	Diatoms		Sept		
S2		Greens	Greens		Oct	Greens	Greens
							BG
					Nov	Diatoms	Diatoms
						Greens	Greens

Table 6. Frequency of occurrence of primary algal groups

	Blue-Greens	Greens	Diatoms
'Low' Bird			
Surface	2	13	13
Bottom	5	10	12
'High' Bird			
Surface	3	10	12
Bottom	3	8	11

Figure 17. October images of what is most likely floating Blue-Green algae

Example microscope image of algal sample with Blue-Green algae.



INVERTEBRATES

Invertebrates in freshwater ponds and wetlands are typically comprised of species of crustaceans, insects, and other taxa such annelids (segmented worms) and molluscs. These organisms can be indicators of pond productivity, and function as important food sources for fish, waterbirds (aquatic stages), and birds in general (insects with aquatic life history stages). Wetland insect assemblages are typically dominated numerically by chironomid midges, whose densities vary with wetland water depth (Batzer et al. 1997, Moss et al. 2009). All of the non-insect taxa reside permanently in water, whereas insects tend to rely on aquatic habitats for immature life stages only. For example, dragonflies and mosquitoes are quite noticeable during their very short time as flying adults (days-weeks), but ~80% of their life cycle as eggs, larvae, nymphs, and pupae are obligate aquatic. Invertebrate composition and abundance can serve as indicators of aquatic habitat health and condition.

A high abundance of invertebrates can indicate very productive habitats. However, even in very productive ponds, low invertebrate abundances may be due to heavy levels of predation by fish or birds. For example, the KWBA introduced 140,000 mosquito fish to the ponds during 2017.

Categories of sampled pond invertebrates:

- Zooplankton (water column)
  - -Open water
    - -Video
      - *Taking water sample:* *https://youtu.be/zOGBqY6HEkI*
      - *Zooplankton Sample:* *https://youtu.be/wejN26NSLI4*
  - -Fish exclusion
- Benthic (bottom-dwelling) invertebrates
  - -Monthly monitoring
  - -Emergence traps

Methods & Results

Zooplankton (water column invertebrates)

Zooplankton are typically microcrustaceans that are free-living in the water column of ponds, lakes, and oceans. Most taxa consume organic matter such as algae, but some are predators. They are able to regulate the abundance of algae (phytoplankton) in water columns if their densities and size-structures are not limited by predators such as fish. Fish can greatly affect zooplankton assemblages by reducing the relative proportion of large-bodied taxa and overall abundances.

We used a Van Dorn bottle to collect 6L composite samples near surface & bottom if total pond depth >0.4m. Sample water was sieved through a 80um plankton net to concentrate the collected sample material, which was drained into pre-labelled jars and preserved with 80% ethanol. Rose Bengal was used to stain the zooplankton when returned to lab in order to facilitate counting and identification.

Zooplankton from August (and subsequent months) sampling were characterized by low abundances of small individuals, suggesting potential predation effects on zooplankton size structure by fish. This observation led to an experiment to test this effect by using fish exclosures, which were deployed in September. We sampled zooplankton inside and outside fish exclosure cages on subsequent sampling events.

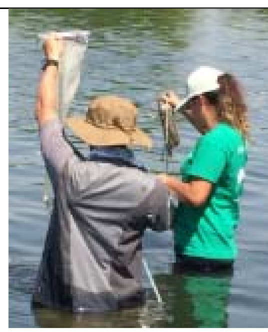
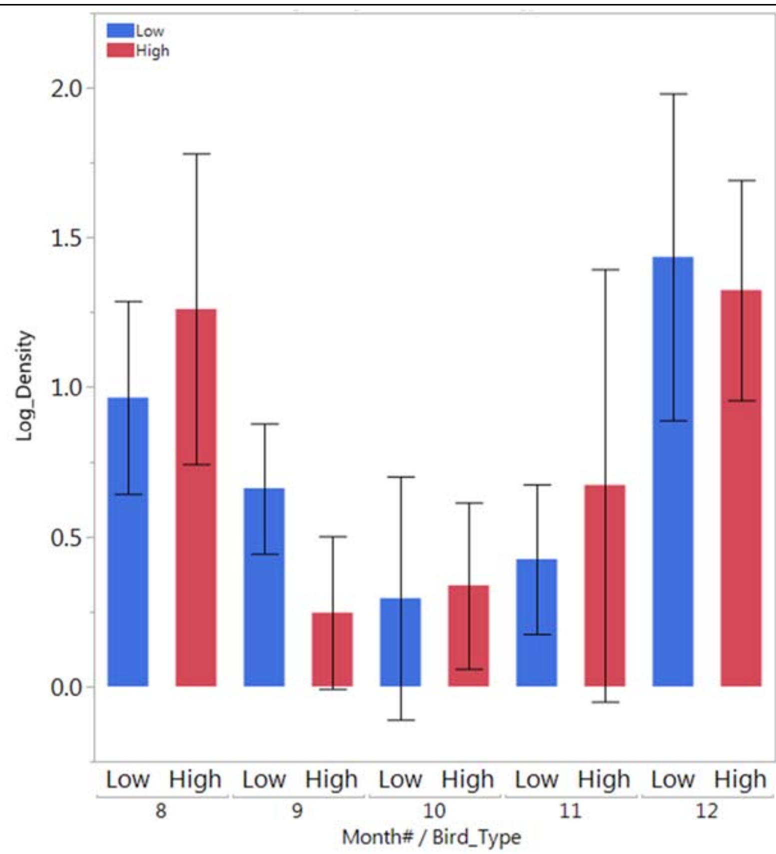
<table>
<tr><td>Zooplankton sample collection (Van Dorn) (click for video)</td><td colspan="2">Sample water from the Van Dorn bottle were sieved through a plankton net</td><td>Collected material (click for video)</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
</table>

Figure 18. Zooplankton density (#/L) across months and waterbird pond status. Note that the scale is based on log_{10}, meaning that 1.0 on the scale=10/L.

October densities were significantly lower than the overall average, while August and December densities were significantly higher. There was no significant differences in densities in Low (avg=9.7/L) vs. High (avg=18.4/L) waterbird ponds.



Fish Exclusion Nets

The fish exclusion nets are a method to sample zooplankton density while excluding any affects fish predation. These samples can be used to assess any differences in invertebrate assemblages between the samples inside the nets and samples outside the nets.

The exclusion nets were deployed during the September trip and sampled during the November 18th sample event. Two nets were placed in each pond. The locations were noted based on reference points (i.e. weirs, drains, trees, etc.). Unfortunately, many of the traps were not found during the November sampling trip. We could not find either net in ponds R7 and C2. We were able to find one net in ponds M9, W1, C1, S11, C4, S6, and S2. The only pond we were able to find both nets was E1.

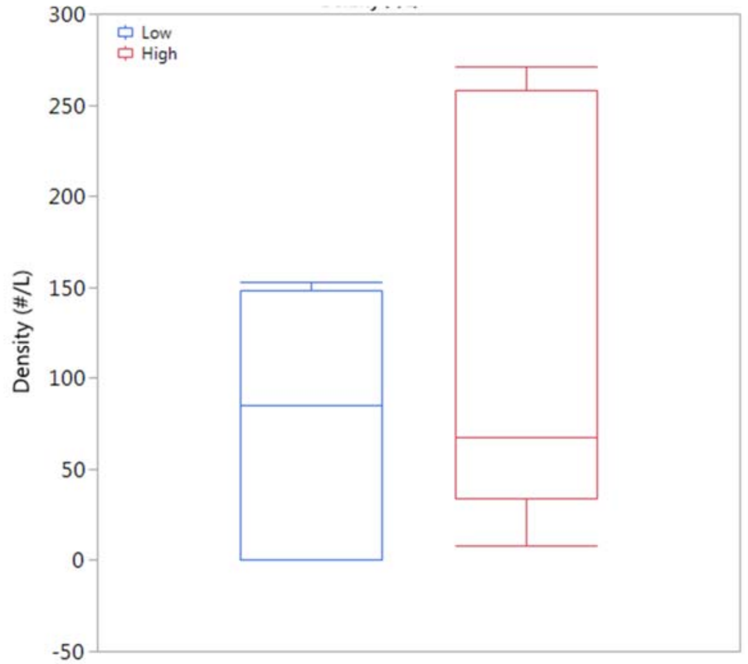
The nets were sampled using a core sampler made from a two-foot section of PVC pipe and a rubber stopper at one end. Parafilm was placed at the open end to allow for pressure to hold water more effectively. A small cut was made in the netting to allow the sampler to be inserted. The stopper would then be removed allowing the sample to enter the tube. When filled, the core sampler holds a volume of 118 mL. This sample volume was kept consistent by filling the core sampler completely each time an exclusion net was sampled. Doing this we could ensure to have an accurate volume to estimate zooplankton density. The collected samples were placed into a labelled Nalgene jar and preserved with ethanol. The cut in the netting was then secured shut with small zip ties.

Images of fish exclusion nets (cages) and their deployment.	
	

Figure 19. Zooplankton densities in fish exclusion cages. Densities were highly variable and not significantly different between Low and High waterbird ponds.

Zooplankton densities were much higher in exclusion cages compared to open water, suggesting a strong fish predation effect.

Median Zoop Density (#/L)		
	Low	High
Exclusion cages	85	68
Open water	3.9	3.3



Benthic (bottom-dwelling) Invertebrates: Collection Methods

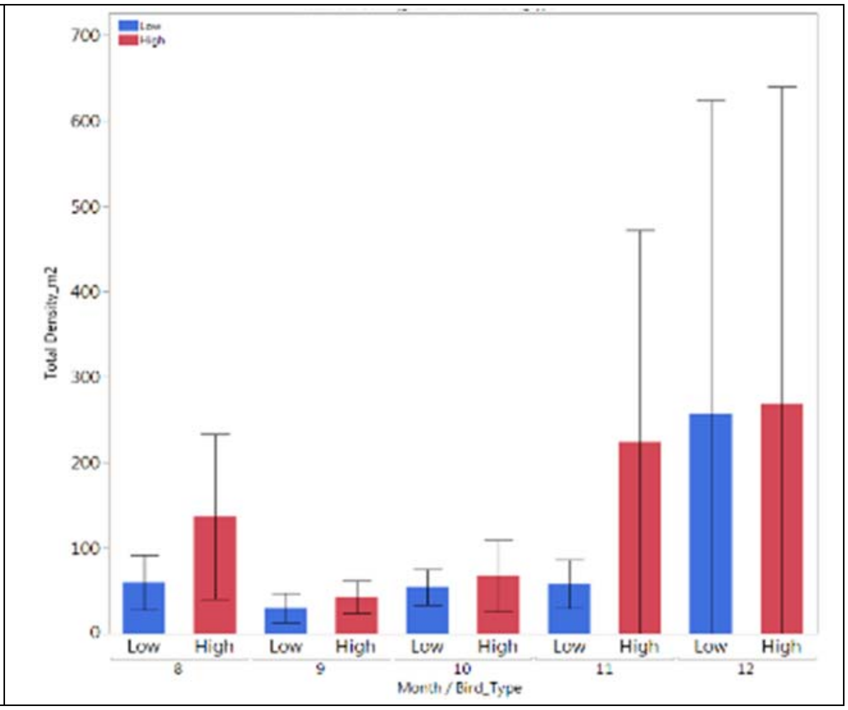
1. Walk to previously determined location cautiously, attempting to minimize water disturbance.
2. At location, dip the D-frame net into water with opening facing you. When the net is on the substrate, swiftly drag the net towards you for approximately one meter while lightly scraping the substrate. At the end of one meter, swiftly pull the net straight up.
3. Hold net with opening pointed up while delivering the sample material to the person with the pre-labelled collection jar.
4. Using a wash bottle (filled with water filtered through a plankton net), wash down the inside of the net, flushing everything to a bottom corner. Grabbing the corner with all of the sample material push the corner inside out over the sample jar. Use the wash bottle to rinse any of the sample clinging to the net into the bottle.
5. Properly close, label and store the sample jar in a cooler. Add preservative (ethanol) to the samples as soon as they are brought into the lab.

Collecting benthic sample	Transporting sample	Material to sample jar
		

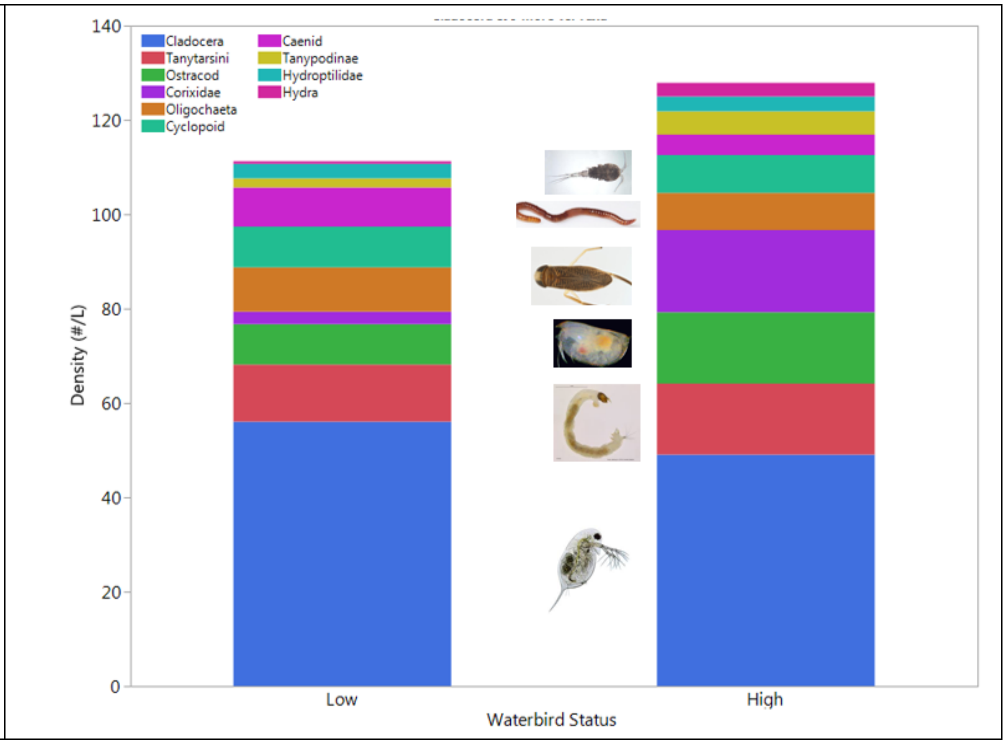
Figure 20. Benthic invertebrate densities (#/m²) among months and Low vs. High waterbird ponds.

Overall densities were significantly lower in September compared to other months, and in Low waterbird status ponds compared to High. (Analyses based on $\log_{10}$ transformed raw data)



Taxonomic Composition: Invertebrates collected from pond sediments were mainly comprised of small-bodied non-insect taxa (70% by number). This is interesting for non-permanent ponds, because unlike insects, which can recolonize 'new' habitats via ovopositing females flying to sites, non-insect taxa must establish in new habitats via resting eggs (many crustaceans), transport by waterfowl, or arriving in source water.

Figure 21. Average density of benthic invertebrates by taxa. Images are of the six most abundant taxa (Cladocera, Tanytarsini, Ostracoda, Corixidae, Oligochaeta, Cyclopoda)



Emergence Traps

Emergence trap collection and deployment.

Emergence traps are used to measure the emergent insect production of various water bodies. The emergent insect abundances can be used to quantify water bird food production in each pond. The traps are designed to float on the surface of the pond and capture any insect that has developed past the aquatic life stage and into the emergent or adult stage.

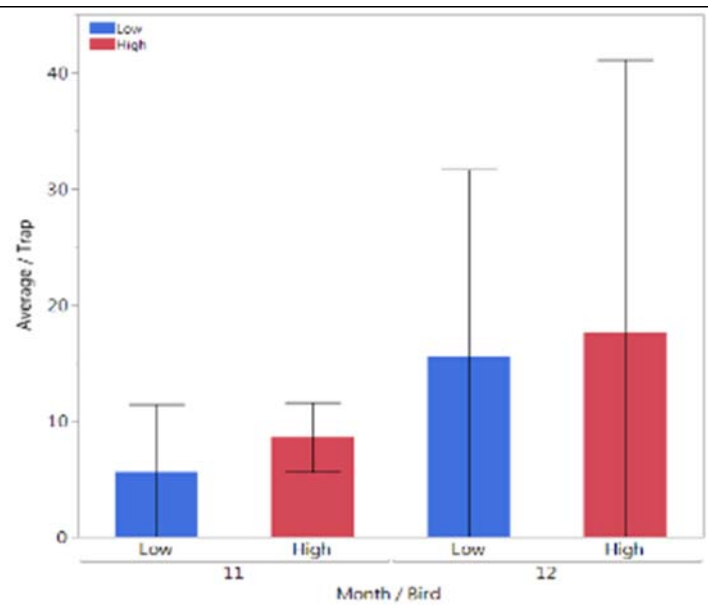
For the month of November, various changes were made in the design of the emergence traps to account for flaws causing them to sink after the October deployment. The deployment trip was conducted on November 11th and a group-sampling trip was conducted on November 18th. Originally, insulation tubes were used for floatation around the base of the traps. These did not prove to be buoyant enough so pool noodles were used during the month of November.

For the initial design, two rope segments were measured based on the depth of the pond at the time of deployment. The ropes were then secured to bricks that served as the anchors. The two anchors on each side was an attempt to prevent the traps from tipping from wind, birds, etc. These could have been another cause of the traps sinking. So, for the November trip, one rope segment was used. Each segment was measured with plenty of excess rope (> 6 ft.) to try and account for the anchor potentially pulling the traps downward.

The updated design proved to be much more successful. With the exception of one missing trap on M9, all of them were able to collect some emergent insects. The Nalgene jars from the traps were each labeled with the pond site number and location. The same method was applied for the month of December and Nalgene jar replacements were replaced during the last trip in November.

Figure 22. Number of emerging insects captured/trap (over ~1 month period).

Averages were quite low overall (commensurate with low benthic invertebrate densities), and not significantly different between sample months or waterbird pond status.



REFERENCES:

Batzer, D.P., F. de Szalay,and V.H. Resh. 1997. Opportunistic response of a benthic midge (Diptera:Chironomidae) to management of California seasonal wetlands. Environmental Entomology 26:215-222.

Connelly, D. P., and D. L. Chesemore. 1980. Food habits of pintails, Anas acuta, wintering on seasonally flooded wetlands in the northern San Joaquin Valley, California. California Fish and Game 66:233-237.

Dahl, T.E. 1990. Wetlands losses in the United States 1780's to 1980's. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. Jamestown, ND: Northern Prairie Wildlife Research Center Online. http://www.npwrc.usgs.gov/resource/wetlands/wetloss/index.htm (Version 16JUL97).

de Szalay, F.A., N.H. Euliss, Jr., and D.P. Batzer. 1999. Seasonal and Semipermanent Wetlands of California. Ch. 34 In: Invertebrates in Freshwater Wetlands of North America: Ecology and Management. D.P. Batzer, R.B. Rader, and S.A. Wissinger, eds. John Wiley & Sons, Inc.

Fleskes, J. P., R. L. Jarvis, and D. S. Gilmer. 2003. Selection of flooded agricultural fields and other landscapes by female northern pintails wintering in Tulare Basin, California. Wildlife Society Bulletin 31:793–803.

Hodgens, L.S., S.C. Blumenshine, and J.C. Bednarz. 2004. Trout predation by great blue herons in a tailwater fishery: a bioenergetics model application. North American Journal of Fisheries Management 24:63-75.

Isola, C. R., M. A. Colwell, O. W. Taft, and R. J. Safran. 2000. Interspecific differences in habitat use of shorebirds and waterfowl foraging in managed wetlands of California’s San Joaquin Valley. Waterbirds 23:196–203.

Legendre, P., and L.F. Legendre. 1998. Numerical Ecology. Elsevier Science.

Moss, R.C., S.C. Blumenshine, J.P. Fleskes, and J. Yee. 2009. Emergent Insect Production in Post-Harvest Agricultural Fields Flooded for Waterbird Habitat Mitigation. Wetlands 29:875-883.

Pollock, M. M., Naiman, R. J., & Hanley, T. A. 1998. Plant species richness in riparian wetlands—a test of biodiversity theory. Ecology 79:94-105.

Safran, R. J., C. R. Isola, O. E. Williams, and M. A. Colwell. 1997. Benthic invertebrates at foraging locations of ten waterbird species in managed wetlands of the northern San Joaquin Valley, California. Wetlands 17:407–15.

Taft, O.W. and S.M. Haig. 2005. The value of agricultural wetlands as invertebrate resources for wintering shorebirds. Agriculture, Ecosystems and Environment 110:249-256.

Wurtsbaugh, W.A. 2011. Relationships between eutrophication, cyanobacteria blooms and avian botulism mortalities in the Great Salt Lake. Watershed Sciences Faculty Publications. Paper 880. https://digitalcommons.usu.edu/wats_facpub/880

Acknowledgements:

We would like to thank Jon Parker for his leadership on this study throughout all phases, as well as Bill Phillimore and the KWBA Board. KWBA support staff Sam Handel and Manda Wood were very generous and helpful. Ken Jones of CSUF College of Science & Mathematics coordinated vehicle use. Student leaders and technicians are included on the title page.