Kern Water Bank Authority

Habitat Conservation Plan/

Natural Community Conservation Plan

2018 Compliance Report and 2019 Management Plan

May, 2019


White-tailed Kite (*Elanus leucurus*)

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Executive Summary

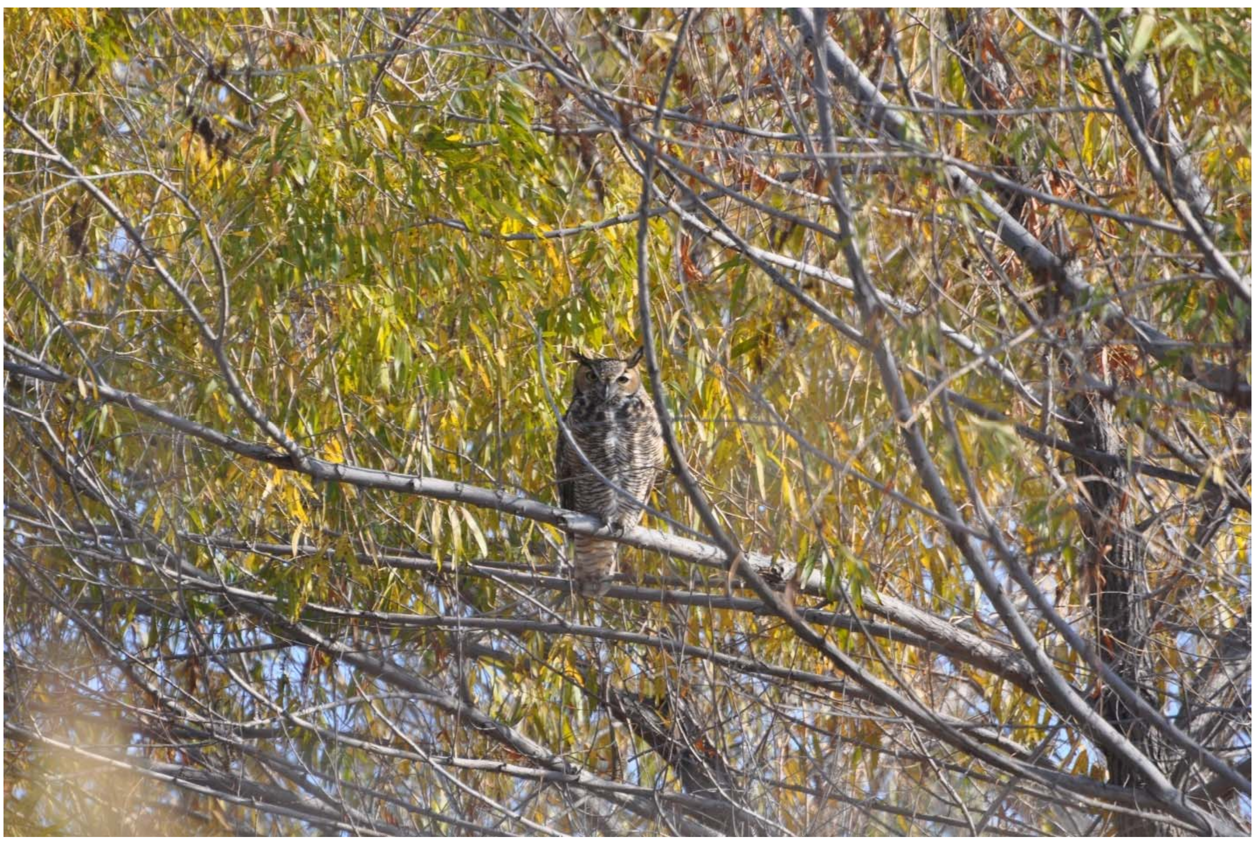
The Kern Water Bank (KWB) occupies approximately 20,000 acres in the southern San Joaquin Valley. It is operated under a Habitat Conservation Plan/Natural Community Conservation Plan (HCP/NCCP) which prescribes reporting and planning requirements, adaptive management methodologies, and avoidance and mitigation measures.

The KWB is well located to provide significant benefits to wildlife in the southern San Joaquin Valley. The water banking activities of the Kern Water Bank have re-established a thriving intermittent wetland habitat along the Pacific Flyway that is ideal for water birds, and the areas outside of the recharge basins provide excellent upland habitat for raptors, other migratory birds, terrestrial wildlife, and rare and endangered plants. Ornithological studies completed during the fall and winter of 2011, throughout 2017, and this Spring indicate 79 different species of water birds were present with populations reaching 35,000 individuals. The studies conclude that: "Overall, in terms of bird abundance, species diversity, acreage, location and habitat diversity, [the KWB] is one of the most important freshwater wetlands in California, especially when compared to other privately managed wetlands." A recent study of the ecology of the recharge basins indicates they provide a productive, healthy environment for aquatic wildlife.

Upland habitat has also been re-established on lands once farmed using the adaptive management methods prescribed in the HCP/NCCP. These lands support many special-status species, including Tipton kangaroo rats, burrowing owls, tricolored blackbirds, and San Joaquin woolly threads. The careful implementation of adaptive management techniques has significantly improved upland habitat value – follow-up ornithological studies indicate that even when basins are dry, the KWB is an important area of upland habitat in terms of bird abundance, species diversity, and habitat diversity. Overall, the KWB has become a very important wildlife resource of regional significance.

This report documents water banking activities in 2018, provides a management plan for 2019, summarizes Conservation Bank transactions, and describes other HCP/NCCP compliance measures.


Great Horned Owl (*Bubo virginianus*)



1.0 Introduction

The Kern Water Bank (KWB) occupies approximately 20,000 acres in the southern San Joaquin Valley of California (Figure 1). The Water Bank is operated by the Kern Water Bank Authority (KWBA) under a Habitat Conservation Plan/Natural Community Conservation Plan (HCP/NCCP) executed on October 2, 1997. The HCP/NCCP provides for the overall management of Water Bank lands with the stated purpose of "accomplish[ing] both water conservation and environmental objectives. The primary water conservation objective is the storage of water in the aquifer during times of surplus for recovery during times of shortage. The primary environmental objective is to set aside large areas of the KWB for threatened, endangered, and sensitive species and to implement a program to protect and enhance the habitat." The keystone of the HCP/NCCP is balanced achievement of both goals, and issuance of "incidental take permits" by USFWS and "management authorizations" by CDFW applied to specific activities and use of the KWB.

Since the implementation of the HCP/NCCP, KWBA has complied with its' preservation, construction and operational, monitoring, adaptive management, and reporting requirements. The Implementation Agreement (IA) requires the submittal of an Annual Report of the previous year's activities and a Management Plan describing the coming year's activities. Specifically, the Annual Report is to provide the following information:[1]

1) Summary of all activities that have taken place on the Kern Water Bank in the previous year, including construction, operation and maintenance of water recharge and water extraction facilities;
2) Summary of all Take that has occurred within the previous year, including Take of Covered Species and Covered Habitat;
3) Summary of all mitigation measures implemented in the previous year;
4) Results of completed studies;
5) Status of ongoing activities;
6) Results from the implementation of monitoring programs;

[1] Implementation Agreement, Section 3.3.4.

7) Results from the implementation of avoidance and minimization measures;
8) Report regarding the status of the Viability Fund;
9) Copy of KWBA's annual financial report; and
10) Certification by KWBA officer that the information in the report is "true, accurate and complete."

The Management Plan is to describe the operational activities contemplated for the KWB during the next year, including construction, maintenance and repair of the infrastructure, and a description of the adaptive management activities to be carried out.[2]

In addition to the reporting requirement in the IA, the Conservation Bank Agreement (CBA) requires the submittal of an annual report detailing Conservation Bank transactions.

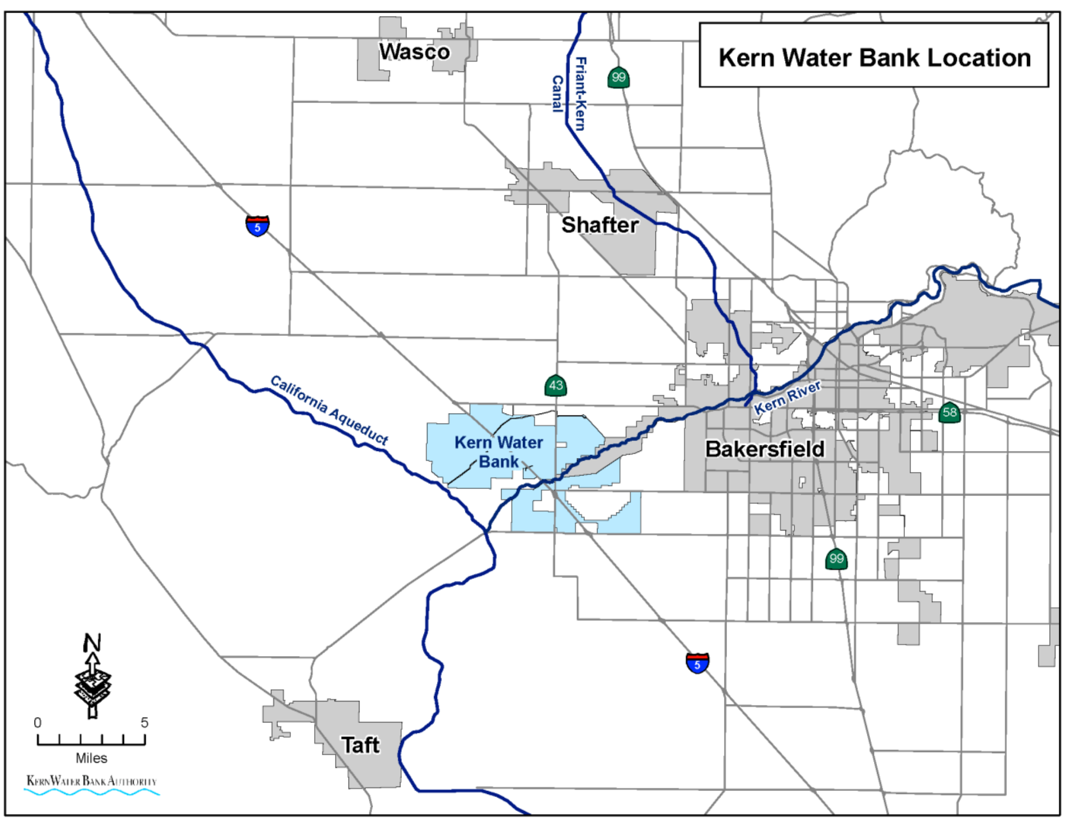


Figure 1. Kern Water Bank location.

[2] Implementation Agreement, Section 3.3.5.

This report is intended to meet the reporting requirements of the IA and CBA. It consists of eight sections:

- Section 1 is this introduction, which reviews the objectives of the HCP/NCCP and describes the basis for the report;
- Section 2 includes a summary of activities completed in the 2018 reporting year (May 1, 2018 – April 30, 2019) and the status of ongoing activities;
- Section 3 provides a summary of take, a summary of mitigation measures implemented during the reporting year, and the results of avoidance and minimization measures;
- Section 4 discusses adaptive management and the results of monitoring programs and completed studies;
- Section 5 is the Conservation Bank Report for the calendar year 2018;
- Section 6 is the Management Plan;
- Section 7 discusses the Viability Fund and the annual financial report for the calendar year 2018; and
- Section 8 is the certification regarding the accuracy of the report.


American White Pelicans Feeding (*Pelecanus erythrorhynchos*)

Greater Roadrunner (*Geococcyx californianus*)

Common Raven (*Corvus corax*)

2.0 Summary of 2018 Activities

Activities in 2018 were primarily focused on recharge operations in January and February and limited recovery operations from March through September. Construction activities included finalizing the equipping of two replacement wells (T30S/R25E-4L02 and T30S/R25E-15B02) and connecting them to existing pipelines, rehabilitating four wells, and replacing 21 failed recharge basin control structures. Routine maintenance activities included clearing brush from fence lines and facilities. These activities are discussed below.

2.1 Water Banking Operations and Maintenance Activities

Recharge operations continued in January and February 2018 as a result of the very wet conditions in 2017. During that time approximately 13,000 AF of water was stored. However, precipitation levels in the 2018 season were low and the State Water Project allocation was only 35%. As a result, limited recovery operations began in March and continued through September. During that time, approximately 38,000 acre-feet of stored water was recovered. No recovery or recharge operations for the Kern Water Bank participants occurred for the remainder of the year. The KWB canal was used to deliver water to the West Kern project from late October through early December.

Maintenance activities focused on supporting recovery operations and preparing for potential recharge operations in 2019. Given the potential for recharge operations in 2019, canals and ditches continued to be cleared of vegetation and sediment. These activities were conducted on existing facilities and none resulted in new habitat disturbance.

2.2 Construction Activities

Construction activities in 2018 included:

- Equipping two replacement wells, which were drilled and cased in 2017, and connecting these wells to existing pipelines;
- Rehabilitating four wells;
- Replacing 21 recharge-basin control structures; and
- Graveling existing roads.

The pipeline connections resulted in 0.25 acres of temporary disturbance, which is already reverting to habitat. The balance of these activities was all conducted on existing facilities on previously disturbed lands. A summary of all project disturbance is shown on Table 1. The 9 acres of temporary disturbance discussed in the 2017 report have reverted to habitat.

2.3 Security

Security patrols are conducted daily on KWB lands. The purpose of the patrols is to protect the property from trespassers, poachers, and thieves. Minor security issues included illegal dumping and trespassing. At KWBA's request, Kern County closed Munzer Road located in the southwest quarter of Section 12 eliminating trash dumping in this area.

Table 1. Habitat Disturbance Summary in Acres.

Recharge Basins

	HCP/NCCP Estimated Disturbance	Actual Disturbance as of 12/31/18
Recharge Basins[1]	5,900	5,658

Permanently Disturbed Areas

	HCP/NCCP Estimated Disturbance	Actual Disturbance as of 12/31/18
Recovery Facilities	66	39
Conveyance Facilities	397	195
Kern River Reverse Flow	18	0
Roads	0	23
Total	481	257

Temporary Disturbed Areas

	HCP/NCCP Estimated Disturbance	Current Disturbance as of 12/31/18
Canal Construction	73	0
Pipelines	218	0.25
Total	291	0.25

[1] Does not include emergency basins in the farming area.

2.4 Third Party Activities

Third party activities that occurred on the property in 2018 included:

- Ongoing oil recovery activities Grayson Service, Inc., Crimson Resource Management Corporation, Target Drilling, and California Resources Corporation; and
- Minor pole-line maintenance activities conducted by PG&E.

KWBA is not aware of any take associated with these activities.

Ring-necked Pheasant (*Phasianus colchicus*)

3.0 Take, Mitigation Measures, and Avoidance and Minimization

The connections of two wells to existing pipelines resulted in 0.25 acres of temporary habitat disturbance in the Compatible Habitat Sector. No take of covered species occurred because of these activities. The amount of total project disturbance is listed in Table 1. The temporary disturbance areas are expected to revert to habitat in the near future.

Mitigation measures for the minimization of impacts are prescribed in the IA[3]. They include: the use of a biological monitor, specific construction practices, practices for ongoing activities, notification requirements regarding listed animals, and special requirements for actions which might threaten fully protected species. All of the requirements are provided in Appendix A for reference.

The specific measures implemented in 2018 (and more fully described in Appendix A) for the activities described in Section 2.0 included:

- Use of a biological monitor prior to construction and maintenance activities that would disturb habitat;
- Oversight of construction and maintenance activities by KWBA personnel;
- Delineation of disturbance areas prior and during construction;
- Construction site review to ensure that no animals including kit foxes are trapped in pipes, culverts, or other like structures;
- Employee orientation in which endangered species concerns were explained;
- Equipment storage in non-habitat areas;
- Limiting traffic to existing roads and speeds of no more than 25 mph;
- Proper disposal of food-related trash and scraps;
- Prohibiting dogs (except for hunting) from the property; and
- Use of herbicides only in accordance with the Vegetation Management Plan.

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[3] Implementation Agreement, Exhibit H, Minimization of Impacts Requirements.

4.0 Adaptive Management, Monitoring Programs and Studies

The HCP/NCCP's Vegetation Management Plan (VMP) describes vegetation management and restoration practices for the long-term adaptive habitat management and enhancement of Kern Water Bank lands. The priorities of the adaptive management program are protection of sensitive habitat areas and control of exotic pest plants; the primary tools of the program are livestock grazing, mowing, and burning.

Section IV.B.1. of the HCP/NCCP requires rare plant surveys and monitoring of San Joaquin kit fox and Tipton kangaroo rat populations. The plant surveys are to be conducted at least every other year; the population monitoring is to be conducted annually. KWBA has also developed additional surveys and monitoring not required or described in the HCP/NCCP which includes an ongoing ornithological study and the development of an observation monitoring grid. These topics are discussed in more detail below.

4.1 Adaptive Management and Vegetation Monitoring

The primary tools available under the VMP, livestock grazing, mowing, and prescribed burning, are used to varying degrees in response to ever-changing conditions on KWB lands. Herbicide use for exotic pest plant control is also provided for in the VMP. South Valley Biology (SVB) oversees much of the adaptive management measures undertaken throughout the year on the KWB and also documents conditions at the Observation Monitoring Sites (see report in Appendix B).

4.1.1 Livestock Grazing

The primary goal of the grazing program is to minimize tumbleweeds and manage excessive growth. Tumbleweeds are an exotic pest which crowd out native species and create significant maintenance problems after windstorms. Cattle will graze on young palatable plants and in some cases trample older plants helping to minimize this problem.

Excessive growth of other plants can exacerbate mosquito problems and diminish habitat value for some species. Mosquitos prefer to breed in vegetation choked portions of basins rather than in open water. Heavy vegetation can also make it difficult to reach areas for abatement purposes. Grazing helps to minimize vegetation in basin bottoms before recharge events and along basin margins during recharge events, thereby diminishing areas favorable to mosquito breeding and providing access for abatement.

Heavy vegetation can also diminish habitat value for many species. Long-term studies of carefully managed grazing programs have indicated reducing herbaceous cover to about 500 lbs per acre Residual Dry Matter (RDM) is beneficial to many native vertebrate species. This RDM value has been an informal goal of the grazing program on the KWB.

Precipitation in the winter of 2017-2018 approached average conditions, and over 17,700 acres were grazed at some time. Cattle numbers by area and month are shown with the graphs on Figure 2. The 2018 grazing program is discussed in detail in Appendix B.

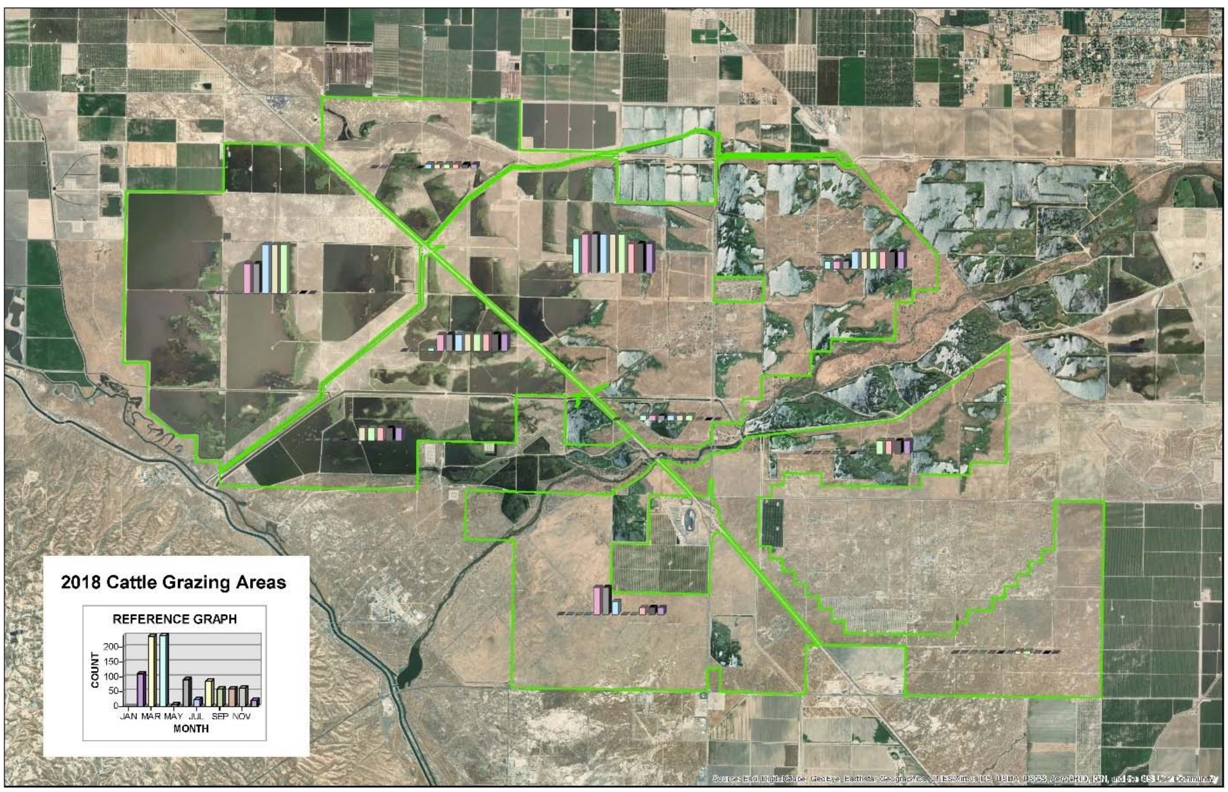

Figure 2. Areas grazed by cattle in 2018.

4.1.2 Mowing

Mowing was conducted primarily along existing roads and canals to manage plant encroachment and in areas covered by tumbleweed drifts or in basin bottoms choked with stands of dead cattails (Figure 3). The drifts of dead tumbleweeds prevent the germination of desirable native plants and can create significant maintenance issues when they blow into canals. The dead cattails can provide breeding sites for mosquitoes when basins are filled. Canal mowing was only used sparingly so that plant cover remained in place during nesting seasons and so that cover was available for animals using the canals as a water source. Approximately 280 acres, exclusive of areas along roads, were mowed in 2018.

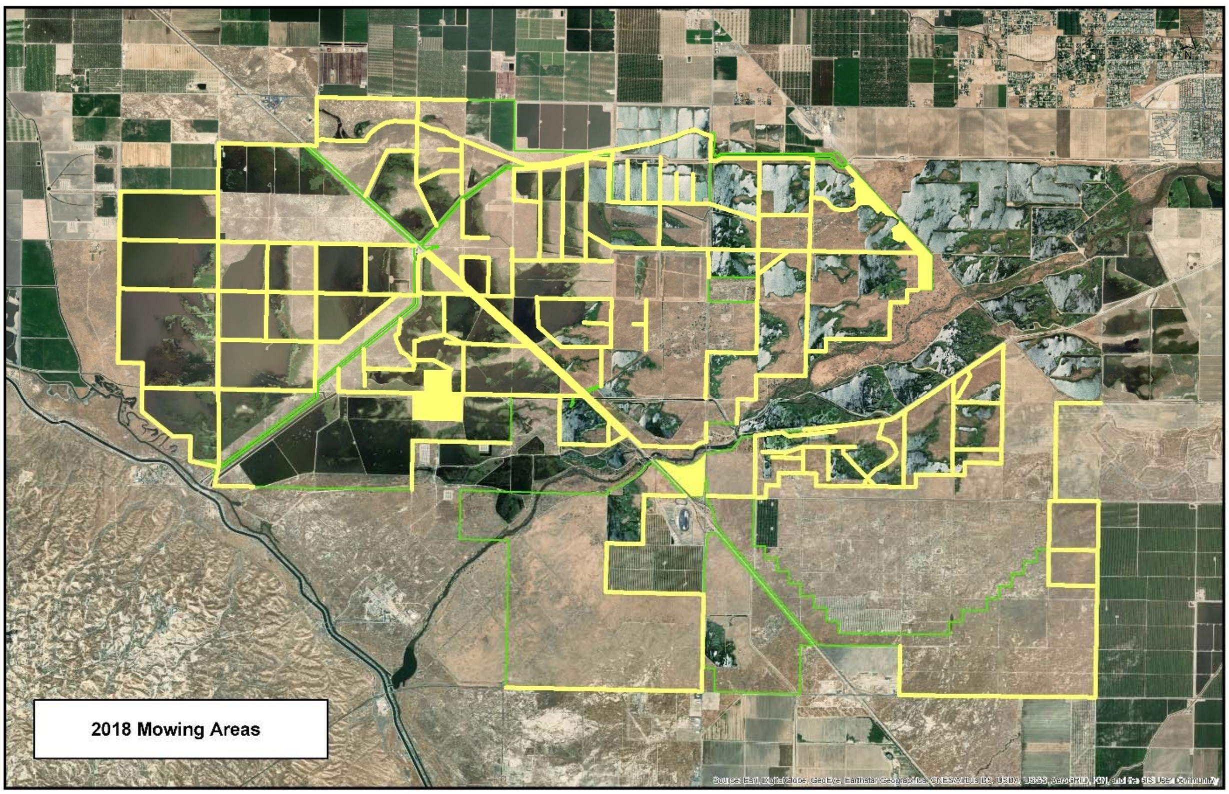

Figure 3. Areas mowed in 2018.

4.1.3 Burning

Burning (under a permit from the San Joaquin Valley Unified Air Pollution Control District) was conducted to eliminate drifts of dead tumbleweeds in the areas shown in Figure 4. As described above, the dead tumbleweeds crowd out desirable native plants and create significant maintenance issues. They can also create fire hazards when they pile up along fences near public highways. Approximately 200 acres were burned in 2018.

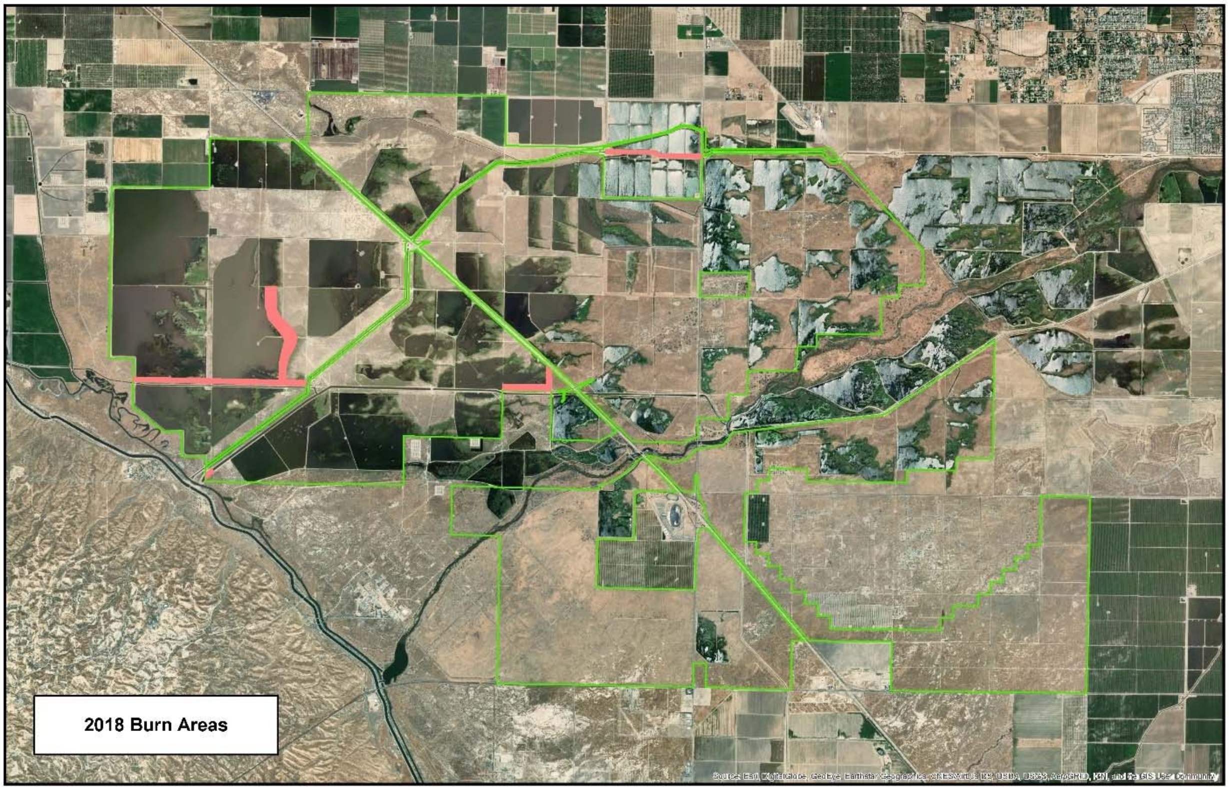

Figure 4. Areas burned in 2018.

4.1.4 Herbicide Use

Herbicides (Diuron and Round-Up) were used to control weeds at well sites, along roads and fences, and at water control structures (Figure 5).

4.1.5 Observation Monitoring Site Program

In 1999, KWBA conceived of and developed an observation monitoring program. This is a voluntary program not required by the HCP/NCCP. Eight sites, referred to as Observation Monitoring Sites (OMS) and representing different aspects of KWB habitat (e.g., canal, ditch, basin, uplands, conservation bank), were selected for surveys and the development of photographic records. Quarterly, staff and/or consultants have observed each site and collected data on weather conditions, general vegetation conditions, and any other pertinent information. Also, photographs were taken looking north, east, south, and west, to be compared with prior and future images to identify changes. KWBA will continue the quarterly OMS program, building a photographic record and informational database, which will help provide insight for adaptive management of different sectors of the KWB. The OMS report is provided in Appendix B.

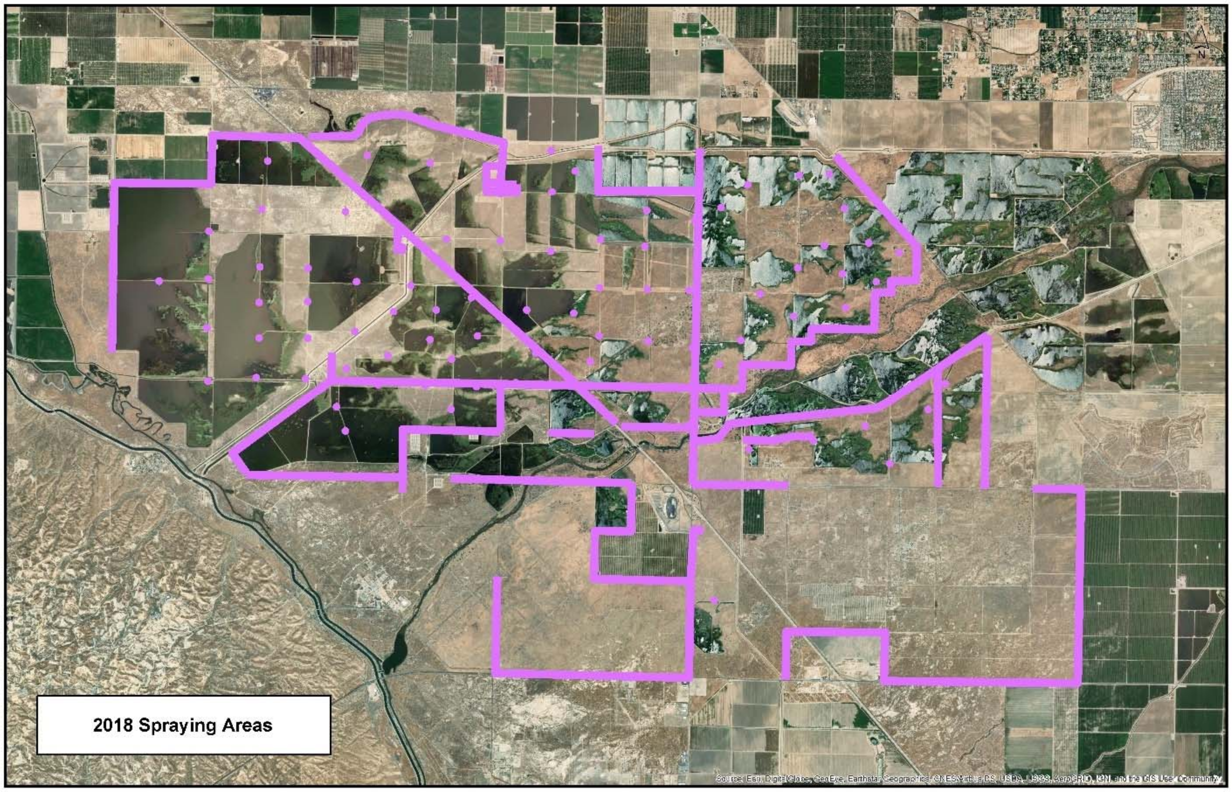

Figure 5. Areas sprayed in 2018.

4.2 Ornithological Studies

The Kern Water Bank Authority has commissioned ornithological surveys since 2011 to help document the benefits KWB lands provide to the region. This is another voluntary program not required by the HCP/NCCP. Surveys conducted during the wet winter and spring of 2011-2012 2016-2017, and 2018-2019 have documented substantial benefits to water birds provided by KWB recharge programs. These surveys also document significant benefits to upland birds and raptors in both wet and dry years. All told, these surveys have identified 206 species of birds on KWB lands.

4.2.1 Water Bird Surveys

Prior to the development of Kern County's water infrastructure, much of the area was intermittently flooded by the Kern River and other minor streams. This flooding supported extensive wetlands, marshes, and Kern and Buena Vista Lakes, all along the Pacific Flyway. Numerous canals and Isabella Dam were constructed during the 20th century to capture and regulate waters for beneficial uses. However, this redirection also resulted in a reduction in wetland and marsh habitats by as much as 90%.[4] The development of the Kern Water Bank (and other banking projects in Kern County) has re-established thousands of acres of intermittent wetlands in the region and provide much-needed habitat for migrating water birds.

Sterling Wildlife Biology has been contracted to complete bird surveys since October 2011 (see report in Appendix C). During that period, there have been three significant recharge events: the winter and spring of 2011/2012, January 2017 through February 2018, and January 2019 and continuing through at least early summer 2019. Overall water bird numbers ranged from 20,000 to 35,000 for the 2011/2012 event, from 2,600 at the beginning of 2017 to nearly 34,000 in December 2017, and nearly 12,000 water birds in the spring of 2019. Seventy-nine water bird species have been identified during these surveys, 10 of which are special-status species.

After the 2011/2012 survey, Sterling concluded that: "Overall, in terms of bird abundance, species diversity, acreage, location and habitat diversity, [the KWB] is one of the most important freshwater wetlands in California, especially when compared to other privately managed wetlands." For the 2017/2018 survey, he concluded that: "The watering of many recharge ponds from January 2017 to January 2018 had created exceptional conditions for most water birds. Forster's terns, Clark's and western grebes and several duck species had re-established breeding populations. A large white-faced ibis breeding colony of several hundred pairs also formed in M1 for spring 2017. Although peak population levels for some groups did not reach those of 2011-2012, there was still a sizeable population for all groups of water birds including some that exceeded the 2011-12 population peaks. As fish populations grew into late 2017, fish-eating birds, including herons, egrets, terns, gulls, grebes, double-crested cormorant and American white pelican numbers increased dramatically to take advantage of their fish prey. Ducks and American coots also boosted their populations in response to the increased aquatic vegetation and invertebrate prey. As ponds were drying in late winter and spring 2018, much mudflat was exposed creating ideal conditions for shorebird habitat. Shorebird numbers peaked at close to 8,000 by early spring." Sterling's full report is located in Appendix D.

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[4] Hundley, Norris, Jr., The Great Thirst, Californians and Water, A History, University of California Press, Berkley, CA.

4.2.2 Upland and Raptor Surveys

Further ornithological studies were initiated in August 2012 to document bird use of the project area absent recharge activities during the winter, spring migration and the start of the breeding seasons. Upland bird surveys were conducted on 9 fixed transects, whereas raptor surveys were conducted by driving most water bank roads. A detailed report through May 2019 is provided in Appendix D. The results of the surveys can be summarized as follows:

- One hundred and twelve species of birds were identified during the upland surveys;
- Upland species richness did not vary significantly through time, but populations did;
- A comprehensive survey for raptors and loggerhead shrikes (Lanius ludovicianus) on the entire project area indicated the presence of high numbers of raptors including red-tailed hawks (Buteo jamaicensis) and loggerhead shrikes;
- Raptor and loggerhead shrike numbers declined significantly during drought conditions and increase dramatically during wet years;
- The surveys documented 16 species of raptors including: American kestrels, bald eagles, Cooper's hawks, ferruginous hawks, golden eagles, merlins, northern harriers, osprey, peregrine falcons, prairie falcons, red-shouldered hawks, red-tailed hawks, sharp-shinned hawks, Swainson's hawks, turkey vultures, and white-tailed kites;
- Twenty-five special-status bird species have been identified during the raptor and upland bird surveys since the project began; and
- Rare birds identified during the surveys included a black-throated sparrow, a clay-colored sparrow, eight Brewer's sparrows which were wintering, sage thrashers, a chesnut-collared longspur, an eastern phoebe, Cassin's kingbirds, a purple martin, Lucy's and Virginia's warblers, a glossy sided ibis, a glaucous gull, and a neotropic cormorant.

Sterling states that: "The Kern Water Bank has exceptional habitats for birds and many rare birds will likely be found and documented in the future dependent upon survey efforts… The bird use of property managed by the Kern Water Bank Authority is clearly very high in accordance to the large acreages of upland habitats. Overall, in terms of bird abundance, species diversity, acreage, location and habitat diversity, it is an important area of upland habitat, especially when compared to surrounding agricultural lands."

4.3 Sensitive Species Monitoring

As discussed above, the HCP/NCCP requires rare plant surveys and the monitoring of San Joaquin kit fox and Tipton kangaroo rat populations. South Valley Biology Consulting LLC (SVB) was contracted to conduct these activities in 2018 (see report in Appendix E). Some key points from their report are presented below.

SVB utilized four methods to complete sensitive species monitoring:

- Nighttime spotlighting surveys to determine San Joaquin kit fox populations;
- Infrared motion camera stations to further determine San Joaquin kit fox populations;
- Small mammal trapping to determine Tipton kangaroo rat populations; and
- Site surveys for special-status plant species.

Three San Joaquin kit fox were identified during the spotlighting surveys. Other mammals that were identified during the surveys included: coyotes, bobcats, desert cottontails, black-tailed jackrabbits, and kangaroo rats. Raptors included barn owls and burrowing owls. Species identified with the infrared cameras included San Joaquin kit fox (at times as many as three individuals in one frame), black-tailed jackrabbit, desert cottontail, and striped skunk.
As discussed in more detail in the report in Appendix E, the cessation of drought conditions in 2018 appear to have increased the populations of predator species.

Small mammal trapping was conducted on two grids. One grid is located north of the Kern River in Sensitive Habitat (the "Strand" grid) and the other is located south of the Kern River in the Conservation Bank Area (the "Southeast" grid). Forty-three Tipton kangaroo rats were captured at the Southeast grid, documenting a healthy and robust population of the species. No Tipton kangaroo rats were captured at the Strand grid. Other animals captured included Heermann's kangaroo rats, San Joaquin pocket mice and deer mice.

Special-status plants identified on the KWB in 2018 included San Joaquin woolly threads (federally endangered), Kern mallow, and recurved larkspur. Hoover's woolly star was not observed. Precipitation in 2018 was low, impacting all populations of special-status plants.

The SVB report provides a detailed discussion of factors that may have contributed to the changes seen in the populations of both wildlife and plants (Appendix E).

4.4 Aquatic Ecology Monitoring & Assessment

The Kern Water Bank Authority commissioned a study of the ecology of the filled recharge basins in 2017. This is another voluntary program not required by the HCP/NCCP. The characteristics of the basins that were investigated included the physical and chemical parameters of the water, the types of algae and invertebrates present, and the types of terrestrial plants present along the basin margins.

Some of the results of the study are:

- The water in the basins maintained adequate temperature ranges for algae, invertebrates, and fish. Daytime oxygen concentrations were very high, suggesting a very productive aquatic system. The pH range was suitable for a wide variety of aquatic organisms;
- The water was generally clear. Concentrations of palatable green algae and diatoms were common, blue-green algae was less common; and
- Zooplankton exhibited small body sizes and generally low abundance which is likely due to predation by fish and/or birds.

The full report is present in Appendix F.

4.5 Miscellaneous Studies

Local members of the Audubon Society conducted a bird survey on January 27, 2018. Eighty-five were identified (Appendix G). Final reports for the CDFW Terrestrial Species Stressor Monitoring project also became available at the end of 2018. These reports are in (Appendix H).

American Avocet (*Recurvirostra americana*)

5.0 Conservation Bank Report

The Kern Water Bank Authority Conservation Bank was established concurrently with the HCP/NCCP by the Conservation Bank Agreement (CBA). The CBA provides for 3,267 Conservation Credits (Credits) representing one-acre each. These Credits are provided by the KWBA as mitigation for impacts to Covered Species in the Permit Area as authorized by USFWS and CDFW. The Agreement requires that KWBA file an Annual Report to the CDFW Agencies each year documenting:

- The number of Credits available, sold, used, eliminated, and suspended, both cumulatively and in the preceding year;
- The name and address of each party purchasing Credits and the number of Credits that were sold, optioned, or transferred in the preceding year;
- A map showing the portion of the KWB Conservation Bank for which KWBA has delivered a Conservation Easement to the Department, and the portion of the KWB Conservation Bank unencumbered by a Conservation Easement; and
- Copies of the annual reports submitted by the Included Parties.

No conservation credit transactions occurred in 2018. Through December 2018, 1,349 of the 3,267 credits have been sold. Figure 6 shows the portions of the Conservation Bank encumbered by Conservation Easements.

Gadwall Family (*Anas strepera*)

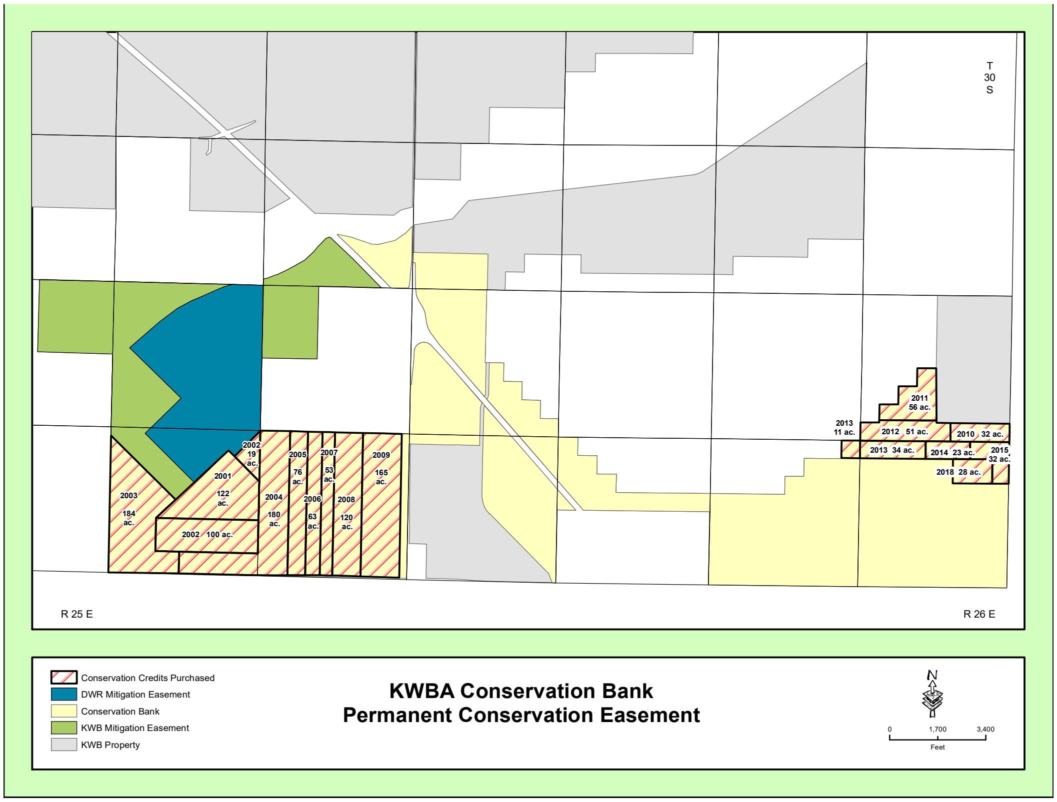


Figure 6. Conservation Bank Easements.

White-faced Ibis (*Plegadis chihi*)

6.0 Management Plan

The Management Plan is to describe the operational activities contemplated for the Kern Water Bank during the next year, including construction, maintenance and repair of the infrastructure, and a description of the adaptive management activities to be carried out.[5]

6.1 Water Bank Operations and Construction

Precipitation levels in the 2018/2019 season have been significant enough to provide for recharge operations. These operations began January 28, 2019, and an estimated 142,000 acre-feet have been recharged though April 30. It is expected that recharge operations will continue through May and June. These recharge operations entail routine berm maintenance, canal maintenance, and pump repairs as needed. These activities are conducted on existing facilities, and no new habitat disturbance occurred or is contemplated.

In addition to the activities associated with recharge operations, the KWBA is contemplating several projects in the near future. They may include:

- Recharge basin construction and associated lift pumps;
- Construction of pumping facilities on the Kern Water Bank Canal; and
- Replacement of recharge basin control structures and road crossings.

In all cases, the appropriate Minimization of Impacts Requirements described in detail in Appendix A will be carried out.

6.2 Vegetation Management

KWBA expects to continue to graze portions of the KWB lands again in 2019 in response to average precipitation in the winter of 2018-2019 (Figure 8). Mowing, burning (when permissible), and herbicide applications will also be used where appropriate.

[5] Implementation Agreement, Section 3.3.5.

6.3 Hunting Programs

Very limited bird-hunting programs may be undertaken on KWB land. The hunts will be limited to KWBA board members and staff and their guests.

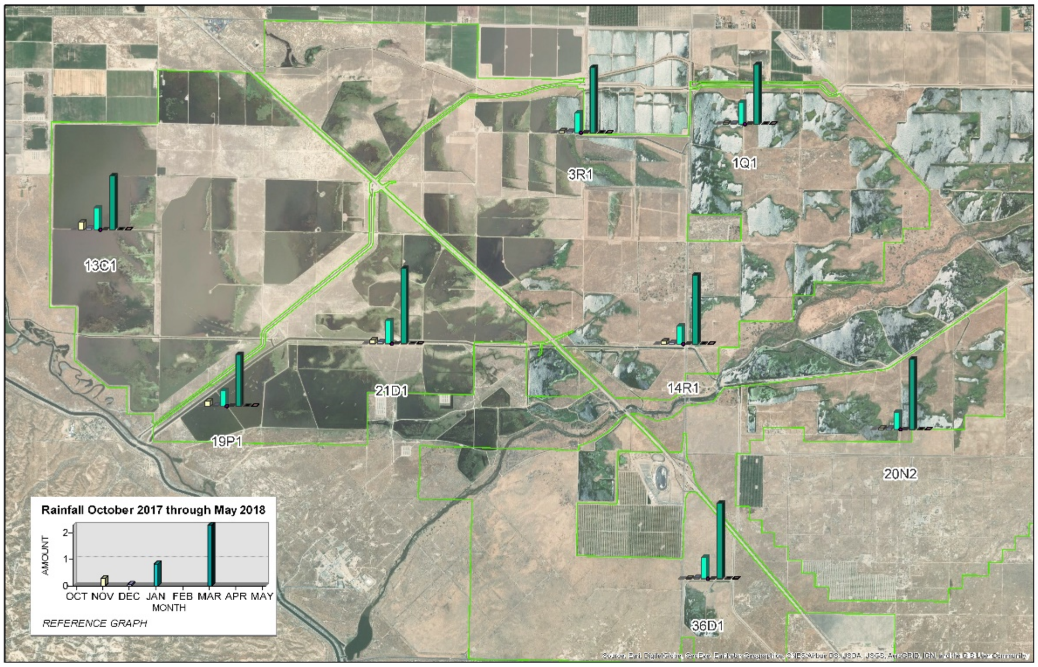


Figure 7. Rainfall for the 2017-2018 winter season.

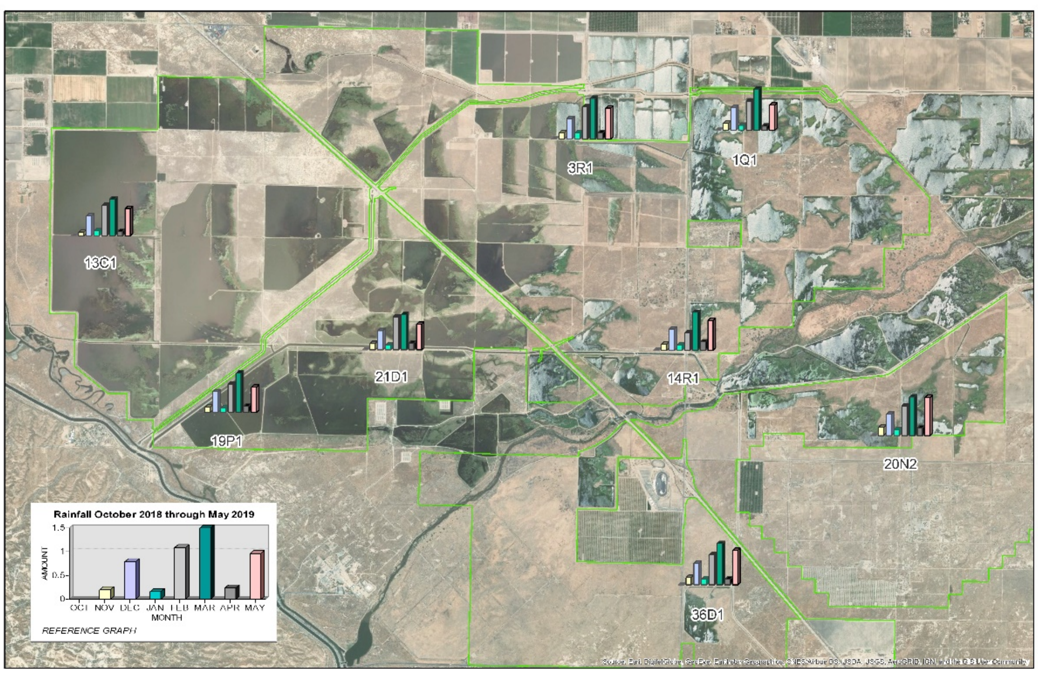


Figure 8. Rainfall for the 2018-2019 winter season

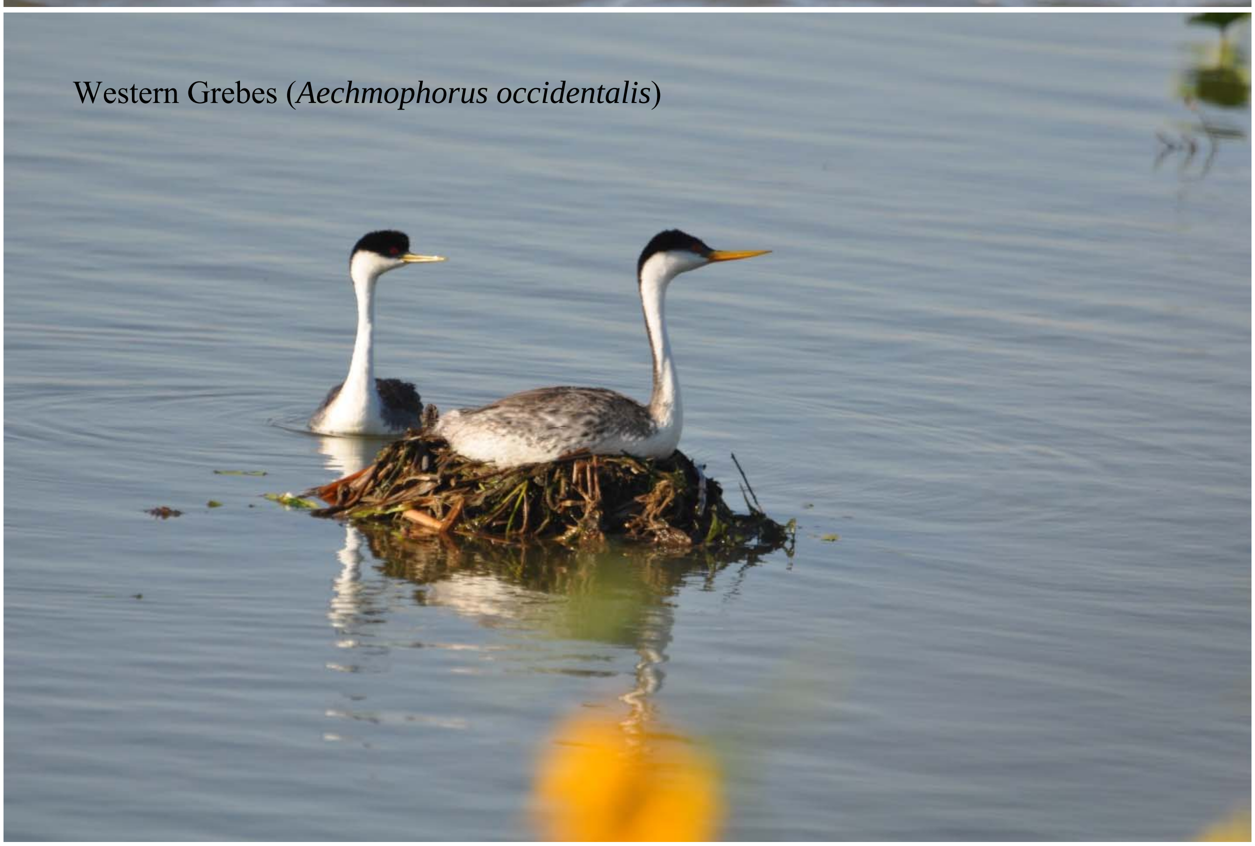
7.0 Viability Fund Status and Financial Report

The IA establishes the Kern Water Bank Species Viability fund in the amount of $50,000. The County of Kern Auditor-Controller's Office reported that, as of December 31, 2018, the balance in the Viability Fund was $55,142.49. This sum represents the principal balance of $50,000 plus $5,142.49 in accrued interest.

A copy of the "Kern Water Bank Authority Financial Statements - December 31, 2018 and 2017" is included in Appendix I of this report. The independent accounting firms of Barbich Hooper, King, Dill & Hoffman and Brown Armstrong Accountancy Corporation prepared the financial statements and auditor's report, respectively. Total assets on December 31, 2018 were $72,938,472, current liabilities were $5,900,262, and long-term liabilities (debt) were $10,872,472.

American Coot (*Fulica americana*)


Clark’s Grebes (*Aechmophorus clarkii*)


Western Grebes (*Aechmophorus occidentalis*)

8.0 Certification

Under penalty of law, I certify that, to the best of my knowledge, after appropriate inquiries of all relevant persons involved in the preparation of this report, the information submitted is true, accurate and complete.

Kern Water Bank Authority

By:

William D. Phillimore,
Chairman, Board of Directors

Date: July 29, 2019

Nesting Gadwalls (*Anas strepera*)


Cattle Egret (*Bubulcus ibis*)

9.0 Contact Information and Distribution List

The contact person for the KWBA is:

Jonathan Parker
Kern Water Bank Authority
1620 Mill Rock Way, Suite 500
Bakersfield, CA 93311
661-398-4900

Table 2. Report Distribution List

Binder	Download	Name	Address
1	1	Patricia Cole San Joaquin Branch Chief	USFWS 2800 Cottage Way #W2605 Sacramento CA 95825
0	1	Julie Vance Regional Manager	CDFW 1234 East Shaw Avenue Fresno, CA 93710
1	1	Craig Bailey	CDFW 1234 East Shaw Avenue Fresno, CA 93710
0	1	Dave Hacker	CDFW 3196 S. Higuera St. Ste. A San Luis Obispo, CA 93401
0	1	Justin Sloan	USFWS 1130 E. Shaw Ave, Suite 206 Fresno, CA 93710
0	1	Steve Torigiani	Young Wooldridge 1800 - 30th Street, 4th Floor Bakersfield, CA 93301
0	1	Robert Thornton	Nossaman, Guthner, Knox, Elliott Lakeshore Towers #1800 18101 Van Karman Avenue Irvine, CA 92623-9772
0	1	Steve Jackson	Dudley Ridge Water District
0	1	David Beard	KCWA Improvement District 4
0	1	Wilmar Boschman	Semitropic Water Storage District
0	1	Dennis Atkinson	Tejon-Castac Water District
0	1	William Phillimore	Westside Mutual Water Co.
0	1	Kimberly Brown	Westside Mutual Water Co.
0	1	Rob Yraceburu	Westside Mutual Water Co.
0	1	William Taube	Wheeler-Ridge Maricopa Water Storage District
1	1	Jim Jones	South Valley Biology 6510 Montagna Drive Bakersfield, CA 93306

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Appendix A

Exhibit H to Implementation Agreement - Minimization of Impacts Requirements

American Bittern (*Botaurus lentiginosus*)

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Exhibit H to Implementation Agreement

Minimization of Impacts Requirements

1. Biological Monitor

A qualified biologist shall monitor all ground-disturbing activities prior and during construction in the Sensitive Habit Sector and will oversee measures undertaken to reduce Incidental Take of Covered Species.

2. Construction Practices

a. KWBA Oversight

During construction a representative of the company with the authority to assure compliance with these Required Management obligations, and adequately trained to understand the obligations imposed hereby and to notice the presence of Covered Species shall be present on the construction site at all times that construction work is ongoing.

b. Delineation of Disturbance Areas Prior and during construction

KWBA shall clearly delineate disturbance area boundaries by stakes, flagging, or by reference to terrain features, as directed by the Department and the Service, to minimize degradation or loss of adjacent wildlife habitats during operation.

c. Signage

Prior and during construction, KWBA shall post signs and/or place fencing around construction sites to restrict access of vehicles and equipment unrelated to site operations.

d. Resource Agency Notification

At least 20 working days prior to initiating ground disturbance for project facilities in designated salvage/relocation areas, KWBA shall notify the Fresno Field Office of the Department and the Sacramento Field Office of the Service of their intention to begin construction activities at a specific location and on a specific date. The Agencies will have 10 working days to notify the KWBA of their intention to salvage or relocate Covered Species in the construction area. If KWBA is notified, they will wait an additional five days to allow the salvage/relocation to take place.

e. Salvage and Relocation

KWBA will allow time and access to the Service and/or the Department, or their designees, to relocate Covered Species, at the Resource Agencies' expense, from construction areas prior to disturbance of areas that have been identified by the Resource Agencies as having known populations of the Covered Species they wish to salvage or relocate.

f. Construction Site Review

All construction pipes, culverts, or similar structures with a diameter of three inches or greater that are stored at a construction site on the Kern Water Bank for one or more overnight periods shall be thoroughly inspected for trapped kit foxes and other animals before the subject pipe is subsequently buried, capped, or otherwise used or moved in any way. Pipes laid in trenches overnight shall be capped. If during construction a kit fox or other animal is discovered inside a pipe, that section of pipe will not be moved or, if necessary, will be moved only once to remove it from the path of construction activity until the animal has escaped.

g. Employee Orientation

An employee orientation program for construction crews, and others who will work on-site during construction, shall be conducted and shall consist of a brief consultation in which persons knowledgeable in endangered species biology and legislative protection explain endangered species concerns. The education program shall include a discussion of the biology of the Covered Species, the habitat needs of these species, their status under FESA and CESA, and measures being taken for the protection of these species and their habitats as a part of the project. The orientation program will be conducted on a as needed basis prior to any new employees commencing work on the Kern Water Bank. Every two years or at the beginning of construction for the Supply/Recovery canal a refresher course will be conducted for employees previously trained. A fact sheet conveying this information shall also be prepared for distribution to all employees. Upon completion of the orientation, employees shall sign a form stating that they attended the program and understand all protection measures. These forms shall be filed at KWBA's offices and shall be accessible by the Department and the Service.

h. Standards for Construction of Concrete Canals

Concrete lined canals will have a side slope of 1.5 to 1 or less and the sides will have a concrete finish which will assist in the escape of animals. If canals are determined by the Department or the Service to be substantial impediments to kit fox movement, plank or pipe crossings will be provided across concrete canals in areas identified by the Resource Agencies as having high kit fox activity.

i. Standards for Construction of Earthen Canals

Earthen canals will have a side slope of 1.5 to 1 or less. With the exception of the supply/recovery canal, interconnected earthen canals may be as wide as 40 feet. If canals are determined by the Department or the Service to be substantial impediments to kit fox movement, plank or pipe crossings will be provided across the canals in areas identified by the Resource Agencies as having high kit fox activity.

3. On-Going Practices

a. Equipment Storage

All equipment storage and parking during site development and operation shall be confined to the construction site or to previously disturbed off-site areas that are not habitat for covered species.

b. Traffic Control

KWBA's project representative shall establish and issue traffic restraints and signs to minimize temporary disturbances. All construction related vehicle traffic shall be restricted to established roads, construction areas, storage areas, and staging and parking areas. Project related vehicles shall observe a 25 MPH speed limit in all project areas except on county roads and state and federal highways.

c. Food Control

All food-related trash items such as wrappers, cans, bottles, and food scraps generated both during construction and during subsequent facility operation shall be disposed of in closed containers and shall be regularly removed from the site. Food items may attract kit foxes onto a project site, consequently exposing such animals to increased risk of injury or mortality.

d. Dog Control

To prevent harassment or mortality of kit foxes or destruction of kit fox dens or predation on this species, no domestic dogs or cats, other than hunting dogs, shall be permitted on-site.

e. Pesticide Use

Use of rodenticides and herbicides on the site shall be permitted only in accordance with the Vegetation Management Plan approved by the Department and the Service or if such use is otherwise approved by the Department and the Service on a case-by-case basis. This is necessary to prevent primary or secondary poisoning of Covered Species utilizing adjacent habitats, and the depletion of prey upon which kit foxes depend.

4. Project Representatives

KWBA shall designate a specific individual as a contact representative between KWBA, the Service, and the Department to oversee compliance with protection measures detailed in this Exhibit. KWBA shall provide written notification of the contact representative to the Department and the Service within 30 days of issuance of the Section 1O(a) Permit and Section 2081/2835 Management Authorization. Written notification shall also be provided by KWBA to the Department and the Service in the event that the designee is changed.

5. Notification Regarding Dead, Injured or Entrapped Listed Animals

Any employee who kills or injures a San Joaquin kit fox, blunt-nosed leopard lizard, Tipton kangaroo rat, San Joaquin antelope squirrel, or other Covered Species listed as a threatened or endangered animal under FE SA or CESA, or who finds any such animal either dead, injured, or entrapped shall report the incident immediately to KWBA's representative who shall, in turn, report the incident or finding to the Service and the Department. In the event that such observations are of entrapped animals, escape ramps or structures shall be installed immediately to allow the animal(s) to escape unimpeded. In the event that such observations are of injured or dead animals, KWBA shall immediately notify the Service and the Department by telephone or other expedient means. KWBA shall then provide formal notification to the Service, and the Department, in writing, within three working days of the finding of any such animal(s). Written notification shall include the date, time, location, and circumstances of the incident. The Service contact for this information shall be the Chief, Endangered Species Division, Sacramento Field Office. The Department contact shall be the Environmental Services Supervisor at the San Joaquin Valley-Southern Sierra Region Headquarters. The Service or the Department will be notified if any other animal which is otherwise a Covered Species is found dead or injured.

6. Construction of Supply/Recovery Canal

Within sixty days prior to the construction of the supply/recovery canal within the zone marked within the Map of the Kern Water Bank, KWBA shall conduct a limited survey within the area of the Kern Water Bank which will be affected by that construction, with the sole goal of identifying potential San Joaquin kit fox dens and/or burrows occupied by burrowing owls. KWBA shall contact the Service and the Department pursuant to the salvage procedures set forth above if any kit fox dens are found.

7. Fully-Protected Species

KWBA, the Service and the Department recognize that certain species found on the Kern Water Bank, including the blunt-nosed leopard lizard, have certain special statutory protections ("Fully-Protected Species") pursuant to sections 3511, 4700,5050 and 5515 of the California Fish and Game Code (the "Fully Protected Species Statutes"). The Department agrees that compliance by KWBA with the following procedures shall constitute compliance with the Fully Protected Species Statutes: (A) KWBA will review with the Resource Agencies all actions which risk causing the Take of a Fully-Protected Species prior to engaging in any such action. (B) KWBA will review the project site, adjacent area and existing survey information to determine the likelihood of the presence of Fully-Protected Species. (C) If the review indicates the presence of Fully-Protected Species in the project site or adjacent area, KWBA will engage in project-specific measures to assure that no Take of such Fully-Protected Species occurs. Measures include monitoring, avoidance, hand excavation and relocation, trapping, enclosures, inspection of trenches, project timing, and modification of project site disturbance areas. Any relocation, trapping or other activity which would be considered a "take" of the species under CESA shall be done either by the Service or at the direction of the Service by individuals who possess their own incidental take permits for scientific purposes from the Service.

Appendix B

Vegetation Monitoring Program Observation Monitoring Sites and Livestock Grazing Summary for the Kern Water Bank

Great Blue Heron (*Ardea herodias*)

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2018 Vegetation Monitoring Program Observation Monitoring Sites and Livestock Grazing Summary for the Kern Water Bank

SUBMITTED TO:

KERN WATER BANK AUTHORITY

PREPARED BY:

svb
south valley biology consulting llc

July 18, 2019

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2018 VEGETATION MONITORING PROGRAM OBSERVATION MONITORING SITES AND LIVESTOCK GRAZING SUMMARY for the KERN WATER BANK

Submitted to:

Kern Water Bank Authority
1620 Mill Rock Way, Suite 500
Bakersfield, CA 93311

Prepared by:

South Valley Biology Consulting LLC
6510 Montagna Drive
Bakersfield, CA 93306

July 18, 2019

Vegetation Monitoring Program Observation Monitoring Sites and Livestock Grazing Summary

INTRODUCTION

The Kern Water Bank (KWB) vegetation monitoring program consists of eight permanently established vegetation Observation Monitoring Sites (OMS), each one located in a representative habitat on the KWB (e.g., canal, ditch, pond, uplands, old farm lands, and conservation lands). The locations of monitoring sites have been unchanged since their establishment in the late 1990's. Their locations are shown in Figure 1. The primary purpose of monitoring these sites is to provide a qualitative evaluation and documentation of the dynamic nature of the vegetation on the KWB. Data collected, and observations made at the monitoring sites are used to help guide vegetation management decisions, particularly in regards to livestock grazing strategies in an attempt to help improve and maintain habitat quality, control invasive plants, and to facilitate the application of successful adaptive management strategies for the KWB.

METHODS

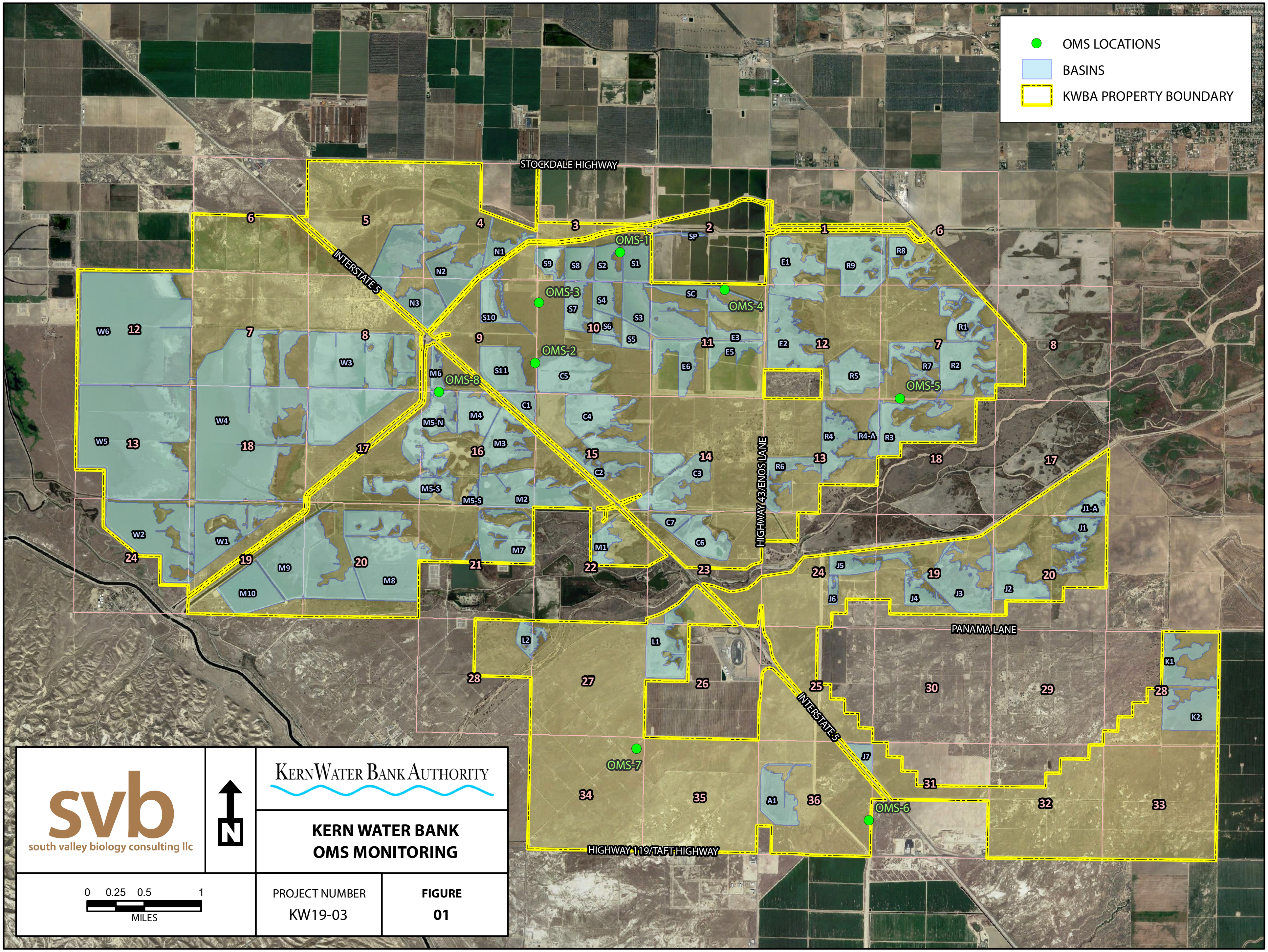
All eight of the vegetation monitoring sites are visited each quarter by one or two biologists. The biologists collect data such as the observed plant and animal species, basic weather conditions, general vegetation conditions, and other pertinent information. Lastly, photographs from all four cardinal directions (North, East, West, and South) are taken to provide a visual representation of the conditions encountered at each site. The only modification made to the photographic methodology is when recharge is occurring and an OMS site is inundated, making it unfeasible to access the site. In these cases, a single photograph is taken showing the OMS location post. This approach has resulted in many years of successive photographic data that help to illustrate the dynamic nature of the KWB. The data collected from each observation monitoring site is provided as Attachment 1.

RESULTS AND DISCUSSION

Rainfall during the 2018 rain year (October 1, 2017 – September 30, 2018) for the KWB and surrounding vicinity was approximately 3.95 inches, which represents a sharp decrease (-46%) from the 2017 rain year that brought 7.37 inches. The long-term average rainfall for the Bakersfield area is approximately 6.12 inches annually, making the 2018 rain year just under 65% of normal. This was a significant difference and it led to a low primary production. However, the KWB underwent a massive recharge cycle during nearly all of 2017 and into early 2018. This recharge cycle provided an abundance of water that helped to supplement the low natural precipitation over much of the KWB recharge area. Photographs 1 through 7 help to illustrate the conditions experienced in 2018 and the changes over the season helped by adaptive management techniques such as cattle grazing and mowing to improve habitat conditions for wildlife at KWB.

Figures 2 - 9 provide graphic representations of the number of cattle, expressed as Animal Units (AU, defined as one adult cow and her calf) that were present during each month in areas that were grazed in 2018. Cattle grazing was used in all areas of the KWB in 2018 to help remove the dense growth of vegetation in the pond basins and other areas resulting from the recharge cycle of 2017. Because cattle have been shown to sometimes cause excessive damage to the pond and canal berms when these structures are inundated, grazing was not used in the Main, West, Strand, North, and River Areas in 2017. It was these areas that experienced the most growth from the abundant water in 2017. Once these areas had dried in early 2018, cattle were turned out to help thin the herbaceous growth. Cattle turnout commenced in early April of 2018 in the River, Main, and Strand Areas (Figures 3 – 5), as these areas had experienced the highest level of growth. Cattle were turned out later in the season into the James, West, North, South, and Southeast Areas (Figures 2, 6, 7, 8, and 9). Cattle grazing continued in all areas throughout the rest of 2018, holding AU numbers steady in the James, Strand, North, and Southeast Areas (Figures 2, 5, 7, and 9), while drawing down AU in the River, Main, West, and South Areas (Figures 3, 4, 6, and 8).

In conclusion, the 2017 – 2018 rain year was well below the long-term average, but the abundant water from the 2017 recharge cycle was the key to vegetation growth and management in 2018. Many areas in the compatible habitat sectors (the areas between recharge ponds) experienced growth that provided essential cover and nesting habitat for birds, while other areas that function as movement corridors for predators were grazed to facilitate their movements around the pond basins. The wildlife habitats at KWB were once again in excellent condition at the end of the season and looking even better now in 2019 with another significant recharge cycle in full swing.


OMS LOCATIONS
BASINS
KWBA PROPERTY BOUNDARY
STOCKDALE HIGHWAY
INTERSTATE 5
HIGHWAY 43/ENOS LANE
PANAMA LANE
HIGHWAY 119/TAFT HIGHWAY
OMS-1
OMS-2
OMS-3
OMS-4
OMS-5
OMS-6
OMS-7
OMS-8
svb
south valley biology consulting llc
N
0 0.25 0.5 1
MILES
KERN WATER BANK AUTHORITY
KERN WATER BANK
OMS MONITORING
PROJECT NUMBER
KW19-03
FIGURE
01

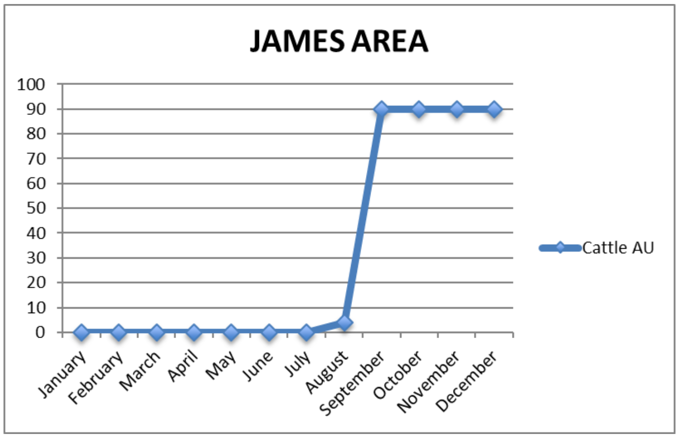


Figure 2. Cattle AU for the James Area during 2018.

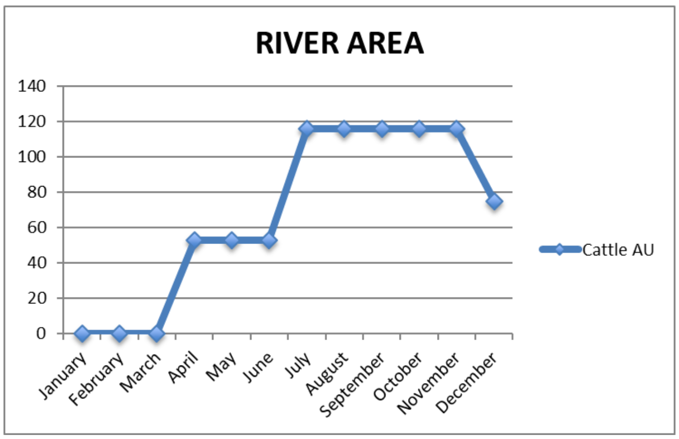


Figure 3. Cattle AU for the River Area during 2018.

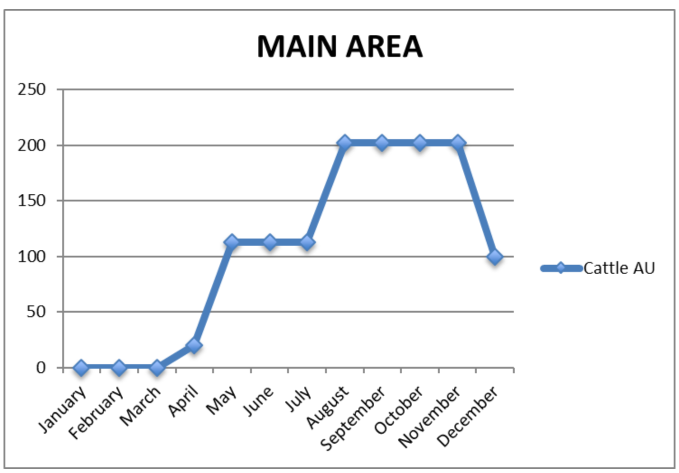


Figure 4. Cattle AU for the Main Area during 2018.

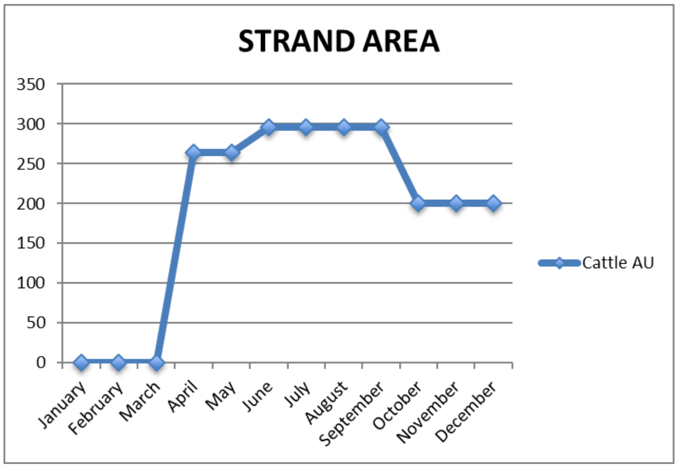


Figure 5. Cattle AU for the Strand Area during 2018.

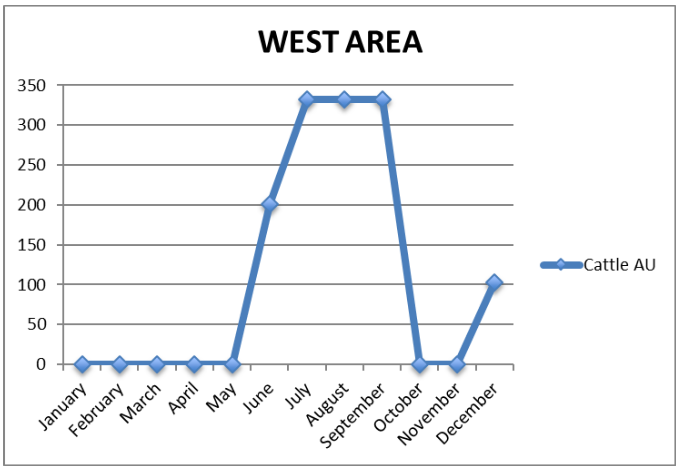


Figure 6. Cattle AU for the West Area during 2018.

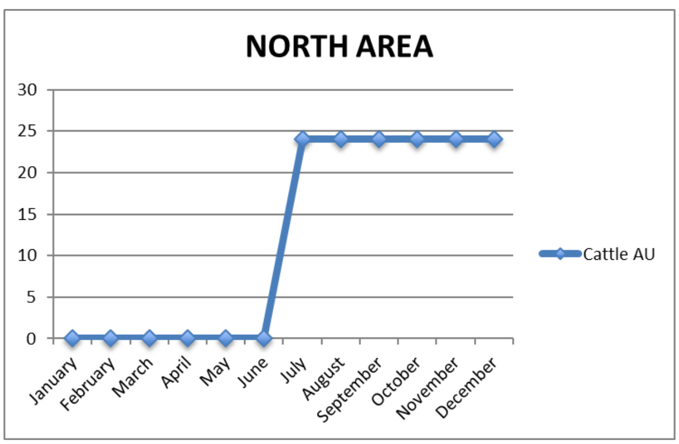


Figure 7. Cattle AU for the North Area during 2018.

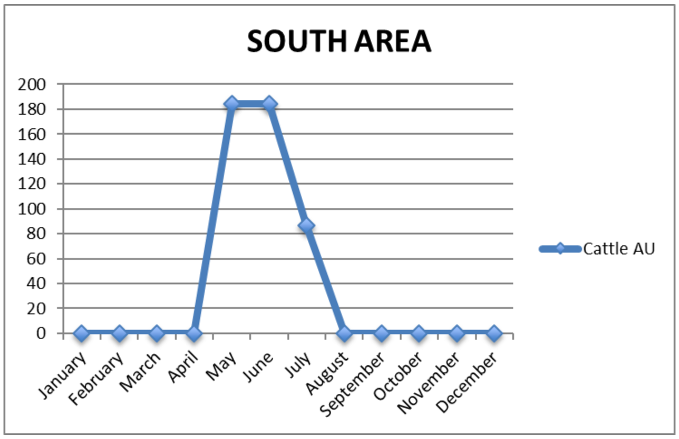


Figure 8. Cattle AU for the South Area during 2018.

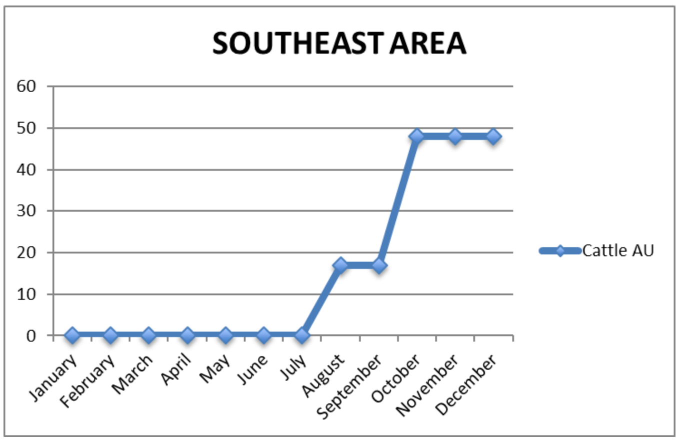


Figure 9. Cattle AU for the Southeast Area during 2018.

Photograph 1.

Vegetation conditions at OMS 1 in the S2 Pond on June 8, 2018 showing the abundant remaining vegetation from the recharge cycle of 2017. Cattle were used to help thin the area.

Photograph 2.

OMS 4 (site post is visible in the water) as it appeared on March 9, 2018 showing receding water in the canal. This area dried a few weeks later and cattle were turned out in early April.

Photograph 3.

OMS 4 in canal as it appeared on August 2, 2018 showing dense growth of vegetation. Cattle had begun grazing the site, but had not yet had much of an impact.

Photograph 4.

Same area as shown in Photograph 3 as it appeared on December 11, 2018. Cattle were effective at thinning the vegetation here and only a light mowing was needed at the end of 2018.

Photograph 5.

OMS 5 in the River Area compatible habitat sector on March 9, 2018 showing very little primary production and standing dry vegetation (thatch) still present from 2017.

Photograph 6.

Same area as in Photograph 5 as it appeared on August 2, 2018 showing full growth of primary production in 2018 and standing dry vegetation (thatch) from 2017.

Photograph 7.

Same area as shown in Photographs 5 and 6 as it appeared on December 11, 2018. Cattle had removed the thatch from 2017 by this time and the area was rapidly growing new primary production from a terrific rainfall start to the 2019 rain year.

Photograph 8.

Same area as shown in Photographs 5 - 7 as it appeared on March 13, 2019 showing the continued rapid growth vegetation from the exceptional 2019 rain year that continued into May 2019.

ATTACHMENT 1

Kern Water Bank 2018 Observation Monitoring Site Program Observations

KERN WATER BANK 2018 VEGETATION MONITORING PROGRAM SITE OBSERVATIONS

LOCATION INFORMATION

LOCATION: OMS-1
SECTION: 3
TOWNSHIP/RANGE: 30S/25E
COORDINATES (CA5-NAD83): 6181490, 2313744
NUMBER OF ACRES: 40
VEGETATION TYPE: EMERGENT WETLAND SPECIES PRESENT
SITE TYPE: POND BASIN/POND LITTORAL ZONES

SURVEY INFORMATION AND PHOTOGRAPHS

1ST QUARTER

SURVEY DATE: 03/09/2018
TIME: 09:50 AM
MONITOR(S): J. JONES
RAINFALL TO DATE: 3.73 IN
WIND DIRECTION: W
WIND VELOCITY: 2.5 MPH
TEMPERATURE: 69.0 F
HUMIDITY: 50.0%

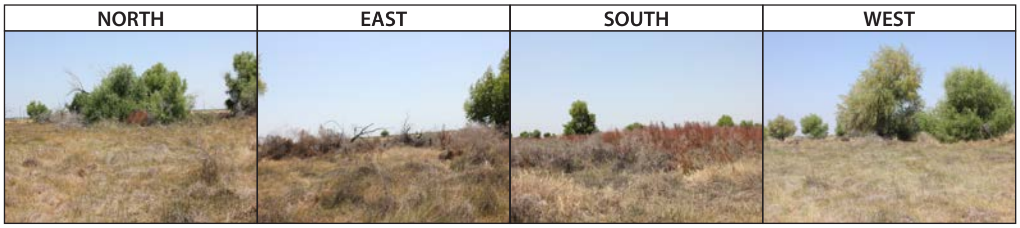
NORTH | EAST | SOUTH | WEST

NOTES: VERY DENSE. DRYING STAND OF ELEOCHARIS.
WILDLIFE PRESENT: MOURNING DOVE, TRICOLORED BLACKBIRD, WHITE-CROWNED SPARROW.
PLANTS PRESENT: ALISMA PLANTAGO-AQUATICA, CONYZA CANADENSIS, CONYZA COULTERI, ELEOCHARIS MACROSTACHYA, HELIANTHUS ANNUUS, JUNCUS BALTICUS, POLYGONUM LAPATHIFOLIUM, POLYPOGON MONSPELIENSIS, RUMEX CRISPUS, SALIX GOODDINGII.

2ND QUARTER

SURVEY DATE: 06/08/2018
TIME: 11:28 AM
MONITOR(S): J. JONES
RAINFALL TO DATE: 3.95 IN
WIND DIRECTION: N
WIND VELOCITY: 3.0 MPH
TEMPERATURE: 86.9 F
HUMIDITY: 25.4%

NORTH | EAST | SOUTH | WEST

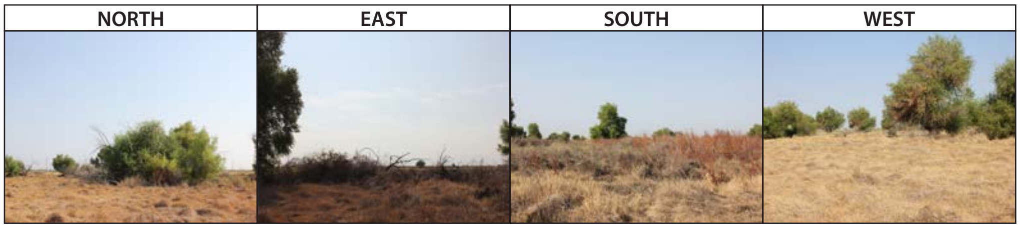


NOTES: DENSE ELEOCHARIS STANDS.
WILDLIFE PRESENT: CALIFORNIA GROUND SQUIRREL.
PLANTS PRESENT: ALISMA PLANTAGO-AQUATICA, ELEOCHARIS MACROSTACHYA, JUNCUS BALTICUS, LACTUCA SERRIOLA, POLYGONUM LAPATHIFOLIUM, POLYPOGON MONSPELIENSIS, SALIX GOODDINGII, TYPHA LATIFOLIA.

3RD QUARTER

SURVEY DATE: 08/02/2018
TIME: 08:35 AM
MONITOR(S): J. JONES
RAINFALL TO DATE: 3.95 IN
WIND DIRECTION: -
WIND VELOCITY: 0.0 MPH
TEMPERATURE: 89.8 F
HUMIDITY: 32.0%

NORTH | EAST | SOUTH | WEST

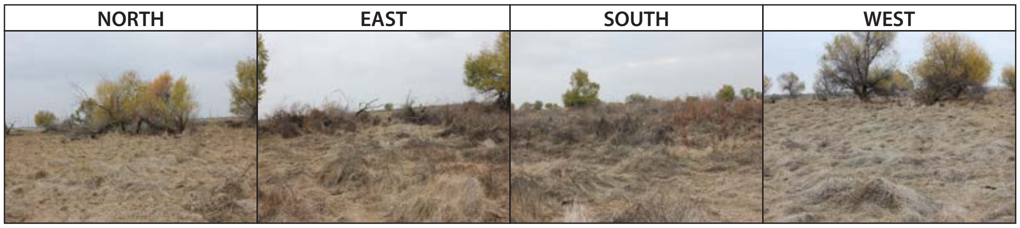


NOTES: CATTLE PRESENT AND ACTIVELY GRAZING.
WILDLIFE PRESENT: CALIFORNIA GROUND SQUIRREL, CALIFORNIA QUAIL, MOURNING DOVE, RAVEN.
PLANTS PRESENT: ALISMA PLANTAGO-AQUATICA, ELEOCHARIS MACROSTACHA, HELIANTHUS ANNUUS, LYTHRUM CALIFORNICUM, POLYPOGON MONSPELIENSIS, RUMEX CRISPUS, SALIX GOODDINGII, TYPHA LATIFOLIA.

4TH QUARTER

SURVEY DATE: 12/11/2018
TIME: 12:50 PM
MONITOR(S): J. JONES
RAINFALL TO DATE: 1.30 IN
WIND DIRECTION: -
WIND VELOCITY: 0.0 MPH
TEMPERATURE: 56.5 F
HUMIDITY: 59.8%

NORTH | EAST | SOUTH | WEST



NOTES:
WILDLIFE PRESENT: CALIFORNIA GROUND SQUIRREL, RAVEN.
PLANTS PRESENT: BROMUS SSP. RUBENS, CONYZA CANADENSIS, ELEOCHARIS MACROSTACHYA, SALIX GOODDINGII, THYPA LATIFOLIA, XANTHIUM STRUMARIUM.

KERN WATER BANK 2018 VEGETATION MONITORING PROGRAM SITE OBSERVATIONS

LOCATION INFORMATION

LOCATION: OMS-2
SECTION: 9
TOWNSHIP/RANGE: 30S/25E
COORDINATES (CA5-NAD83): 6177540, 2308574
NUMBER OF ACRES: >1
VEGETATION TYPE: EMERGENT WETLAND SPECIES PRESENT/MOSTLY DOMINATED BY ANNUAL GRASSES AND WEEDS
SITE TYPE: DITCH BANK/DITCH BOTTOM

SURVEY INFORMATION AND PHOTOGRAPHS

1ST QUARTER

SURVEY DATE: 03/09/2018
TIME: 10:20 AM
MONITOR(S): J. JONES
RAINFALL TO DATE: 3.73 IN
WIND DIRECTION: SW
WIND VELOCITY: 1.5 MPH
TEMPERATURE: 72.1 F
HUMIDITY: 40.1%

NORTH

EAST

SOUTH

WEST


NOTES:
WILDLIFE PRESENT: GREAT EGRET, RED-TAILED HAWK.
PLANTS PRESENT: BROMUS SSP. RUBENS, HELIANTHUS ANNUUS, HIRSCHFELDIA INCANA, JUNCUS BALTICUS, LEYMUS TRITICODES, MELILOTUS INDICA, RUMEX CRISPUS, SALIX GOODDINGII, SISYMBRIUM IRIO.

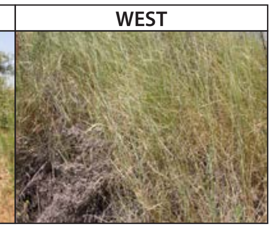
2ND QUARTER

SURVEY DATE: 06/08/2018
TIME: 10:58 AM
MONITOR(S): J. JONES
RAINFALL TO DATE: 3.95 IN
WIND DIRECTION: NW
WIND VELOCITY: 2.5 MPH
TEMPERATURE: 80.1 F
HUMIDITY: 28.9%

NORTH

EAST

SOUTH

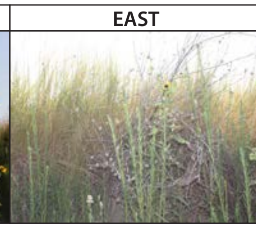
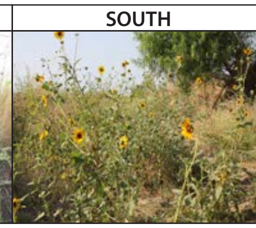
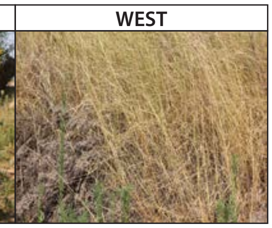
WEST


NOTES: GRAZING NEEDED. CATTLE PRESENT.
WILDLIFE PRESENT: SWAINSON'S HAWK.
PLANTS PRESENT: ATRIPLEX SERENANA, BASSIA HYSSOPIFOLIA, CHENOPODIUM ALBUM, CONYZA CANADENSIS, HELIANTHUS ANNUUS, HIRSCHFELDIA INCANA, JUNCUS BALTICUS, LEYMUS TRITICOIDES, POLYPOGON MONSPELIENSIS, RUMEX CRISPUS, SALIX GOODDINGII.

3RD QUARTER

SURVEY DATE: 08/02/2018
TIME: 08:58 AM
MONITOR(S): J. JONES
RAINFALL TO DATE: 3.95 IN
WIND DIRECTION: -
WIND VELOCITY: 0.0 MPH
TEMPERATURE: 90.5 F
HUMIDITY: 24.6%

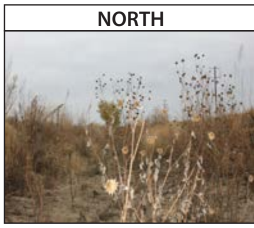
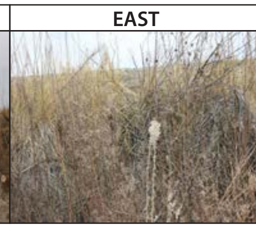
NORTH

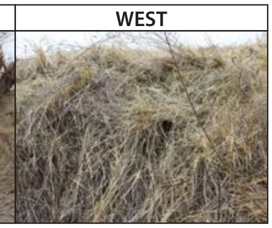
EAST

SOUTH

WEST


NOTES: CATTLE PRESENT AND ACTIVELY GRAZING.
WILDLIFE PRESENT: LOGGERHEAD SHRIKE, MOURNING DOVE.
PLANTS PRESENT: ATRIPLEX SERENANA, CONYZA CANADENSIS, CONYZA COULTERI, HELIANTHUS ANNUUS, HELIOTROPIUM CURASSAVICUM, HIRSCHFELDIA INCANA, JUNCUS BALTICUS, LEYMUS TRITICOIDES, LYTHRUM HYSSOPIFOLIUM, MIMULUS GUTTATUS, POLYPOGON MONSPELIENSIS, RUMEX CRISPUS, SALIX GOODDINGII, SALSOLA TRAGUS.

4TH QUARTER

SURVEY DATE: 12/11/2018
TIME: 01:17 PM
MONITOR(S): J. JONES
RAINFALL TO DATE: 1.30 IN
WIND DIRECTION: -
WIND VELOCITY: 0.0 MPH
TEMPERATURE: 54.4 F
HUMIDITY: 48.4%

NORTH

EAST

SOUTH

WEST


NOTES:
WILDLIFE PRESENT: RAVEN, RED-TAILED HAWK.
PLANTS PRESENT: BASSIA HYSSOPIFOLIA, CONYZA CANADENSIS, HELIANTHUS ANNUUS, HIRSCHFELDIA INCANA, LEYMUS TRITICOIDES, RUMEX CRISPUS, SALIX GOODDINGII.

KERN WATER BANK AUTHORITY

svb
south valley biology consulting llc

KERN WATER BANK 2018 VEGETATION MONITORING PROGRAM SITE OBSERVATIONS

LOCATION INFORMATION

LOCATION: OMS-3
SECTION: 10
TOWNSHIP/RANGE: 30S/25E
COORDINATES (CA5-NAD83): 6177656, 2311449
NUMBER OF ACRES: 80
VEGETATION TYPE: MOSTLY DOMINATED BY ANNUAL GRASSES AND WEEDS/DOMINATED BY RUSSIAN THISTLE AND/OR PRICKLY LETTUCE
SITE TYPE: UPLAND-OLD FARM FIELD

SURVEY INFORMATION AND PHOTOGRAPHS

1ST QUARTER

SURVEY DATE: 03/09/2018
TIME: 10:05 AM
MONITOR(S): J. JONES
RAINFALL TO DATE: 3.73 IN
WIND DIRECTION: -
WIND VELOCITY: 0.0 MPH
TEMPERATURE: 71.2 F
HUMIDITY: 41.1%

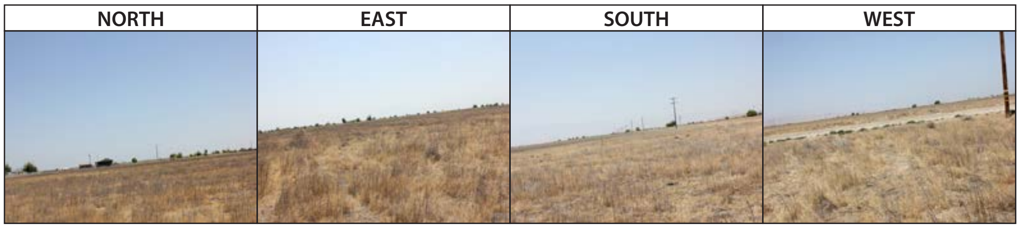
NORTH	EAST	SOUTH	WEST

NOTES: SITE IS A DENSE STAND OF LAST YEAR'S LONDON ROCKET AND FIDDLENECK. MODERATE NEW HEBACEOUS GROWTH AT THIS TIME. NO CATTLE NEEDED AT THIS TIME.
WILDLIFE PRESENT: KANGAROO RAT (BURROWS), WHITE-CROWNED SPARROW.
PLANTS PRESENT: AMSINCKIA MENZIESII, ERODIUM CICUTARIUM, LASTHENIA CALIFORNICA, SISYMBRIUM IRIO.

2ND QUARTER

SURVEY DATE: 06/08/2018
TIME: 11:10 AM
MONITOR(S): J. JONES
RAINFALL TO DATE: 3.95 IN
WIND DIRECTION: N
WIND VELOCITY: 1.8 MPH
TEMPERATURE: 83.5 F
HUMIDITY: 25.9%

NORTH	EAST	SOUTH	WEST

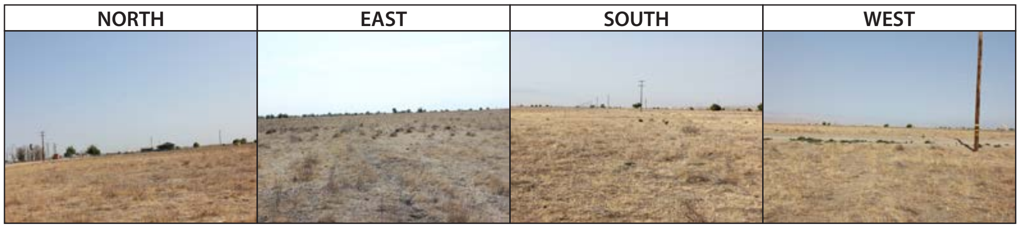


NOTES: NO RUSSIAN THISTLE.
WILDLIFE PRESENT: KANGAROO RAT (BURROWS), LOGGERHEAD SHRIKE, RED-WINGED BLACKBIRD, SWAINSON'S HAWK.
PLANTS PRESENT: AMSINCKIA MENZIESII, HORDEUM MURINUM, SCHISMUS ARABICUS, SISYMBRIUM IRIO.

3RD QUARTER

SURVEY DATE: 08/02/2018
TIME: 09:35 AM
MONITOR(S): J. JONES
RAINFALL TO DATE: 3.95 IN
WIND DIRECTION: N
WIND VELOCITY: 1.2 MPH
TEMPERATURE: 91.3 F
HUMIDITY: 22.0%

NORTH	EAST	SOUTH	WEST

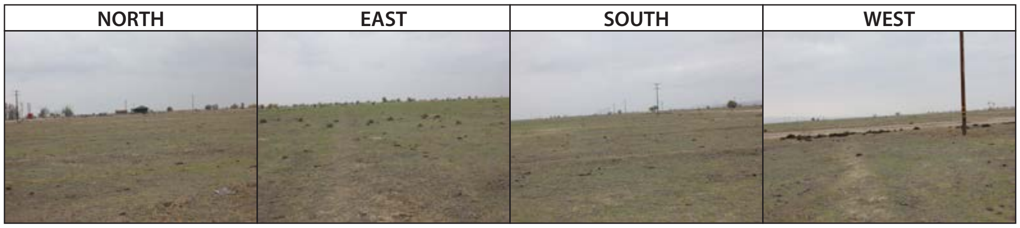


NOTES: NO RUSSIAN THISTLE IN THE AREA. ACTIVE KANGAROO RAT BURROWS PRESENT. AREA ONLY NEED A FEW MORE WEEKS GRAZING AT CURRENT LEVEL.
WILDLIFE PRESENT: GREAT EGRET, RED-TAILED HAWK.
PLANTS PRESENT: AMSINCKIA MENZIESII, BROMUS SSP. RUBENS, HORDEUM MURINUM SSP. LEPORINUM, SCHISMUS ARABICUS, SISYMBRIUM IRIO.

4TH QUARTER

SURVEY DATE: 12/11/2018
TIME: 01:04 PM
MONITOR(S): J. JONES
RAINFALL TO DATE: 1.30 IN
WIND DIRECTION: -
WIND VELOCITY: 0.0 MPH
TEMPERATURE: 54.5 F
HUMIDITY: 57.7%

NORTH	EAST	SOUTH	WEST



NOTES: SCATTERED KANGAROO RAT BURROWS.
WILDLIFE PRESENT: LOGGERHEAD SHRIKE, RAVEN, RED-TAILED HAWK.
PLANTS PRESENT: AMSINCKIA MENZIESII, BROMUS SSP. RUBENS, ERODIUM CICUTARIUM, SCHISMUS ARABICUS, SISYMBRIUM IRIO.

KERN WATER BANK 2018 VEGETATION MONITORING PROGRAM SITE OBSERVATIONS

LOCATION INFORMATION

LOCATION: OMS-4
SECTION: 11
TOWNSHIP/RANGE: 30S/25E
COORDINATES (CA5-NAD83): 6186254, 2311943
NUMBER OF ACRES: 10
VEGETATION TYPE: MOSTLY DOMINATED BY ANNUAL GRASSES AND WEEDS/NON-NATIVE PLANTS
SITE TYPE: DITCH BANK/DITCH BOTTOM

SURVEY INFORMATION AND PHOTOGRAPHS

1ST QUARTER

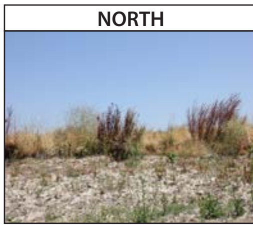
SURVEY DATE: 03/09/2018
TIME: 09:30 AM
MONITOR(S): J. JONES
RAINFALL TO DATE: 3.73 IN
WIND DIRECTION: W
WIND VELOCITY: 2.0 MPH
TEMPERATURE: 68.5 F
HUMIDITY: 47.0%

NORTH	EAST	SOUTH	WEST
			

NOTES: FLOODED.
WILDLIFE PRESENT: BLACK PHOEBE, GREAT EGRET, RED-WINGED BLACKBIRD.
PLANTS PRESENT: HIRSCHFELDIA INCANA, HORDEUM MURINUM SSP. LEPORINUM, MALVA PARVIFLORA, MELILOTUS INDICA, POLYPOGON MONSPELIENSIS, RUMEX CRISPUS, SISYMBRIUM IRIO.

2ND QUARTER

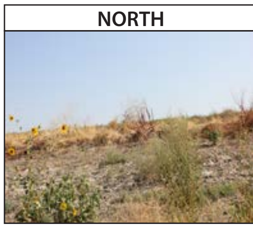
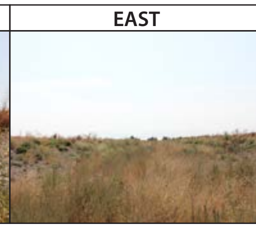
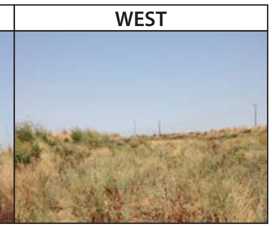
SURVEY DATE: 06/08/2018
TIME: 11:43 PM
MONITOR(S): J. JONES
RAINFALL TO DATE: 3.95 IN
WIND DIRECTION: N
WIND VELOCITY: 2.4 MPH
TEMPERATURE: 86.1 F
HUMIDITY: 28.0%

NORTH	EAST	SOUTH	WEST
			

NOTES:
WILDLIFE PRESENT: RAVEN.
PLANTS PRESENT: ATRIPLEX ARGENTEA, CHENOPODUM ALBUM, CYPERUS SP, GNAPHALIUM PALUSTRE, HELIANTHUS ANNUUS, HELIOTROPIUM CURASSAVICUM, HIRSCHFELDIA INCANA, LACTUCA SERRIOLA, MELILOTUS INDICA, NICOTIANA ATTENUATA, POLYGONUM LAPATHIFOLIUM, POLYPOGON MONSPELIENSIS, RUMEX CRISPUS, SALSOLA TRAGUS.

3RD QUARTER

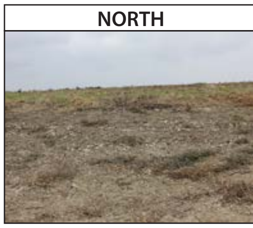
SURVEY DATE: 08/02/2018
TIME: 09:48 AM
MONITOR(S): J. JONES
RAINFALL TO DATE: 3.95 IN
WIND DIRECTION: N
WIND VELOCITY: 1.5 MPH
TEMPERATURE: 90.5 F
HUMIDITY: 20.6%

NORTH	EAST	SOUTH	WEST
			

NOTES: GRAZING OCCURRING AND IS STILL MUCH NEEDED.
WILDLIFE PRESENT: COTTONTAIL, EUROPEAN STARLING, MOURNING DOVE.
PLANTS PRESENT: ATRIPLEX SERENANA, BASSIA HYSSOPIFOLIA, CHENOPODIUM ALBUM, CONYZA COLTERI, HELIANTHUS ANNUUS, HELIOTROPIUM CURASSAVICUM, HIRSCHFELDIA INCANA, JUNCUS BALTICUS, LYTHRUM CALIFORNICUM, NICOTIANA ATTENUATA, RUMEX CRISPUS, SALSOLA TRAGUS, XANTHIUM STRUMARIUM.

4TH QUARTER

SURVEY DATE: 12/11/2018
TIME: 12:40 PM
MONITOR(S): J. JONES
RAINFALL TO DATE: 1.30 IN
WIND DIRECTION: -
WIND VELOCITY: 0.0 MPH
TEMPERATURE: 57.4 F
HUMIDITY: 60.0%

NORTH	EAST	SOUTH	WEST
			

NOTES: AREA WAS MOWED. CURRENTLY BEING GRAZED. AREAS OUTSIDE BANKS SHOW ABUNDANT GERMINATION.
WILDLIFE PRESENT: WHITE-CROWNED SPARROWS.
PLANTS PRESENT: AMBROSIA ACANTHICARPA, AMSINCKIA MENZIESII, ATRIPLEX SEMIBACCTA, ERODIUM CICUTARIUM, HELIOTROPIUM CURASSAVICUM, HIRSCHFELDIA INCANA, MALVA PARVIFLORA, RUMEX CRISPUS, SISYMBRIUM IRIO.

KERN WATER BANK 2018 VEGETATION MONITORING PROGRAM SITE OBSERVATIONS

LOCATION INFORMATION

LOCATION: OMS-5
SECTION: 7
TOWNSHIP/RANGE: 30S/26E
COORDINATES (CA5-NAD83): 6194387, 2306947
NUMBER OF ACRES: 50
VEGETATION TYPE: MOSTLY DOMINATED BY ANNUAL GRASSES AND WEEDS/NON-NATIVE PLANTS/RUDERAL VEGETATION
SITE TYPE: UPLAND-OLD FARM FIELDS

SURVEY INFORMATION AND PHOTOGRAPHS

1ST QUARTER

SURVEY DATE: 03/09/2018
TIME: 08:24 AM
MONITOR(S): J. JONES
RAINFALL TO DATE: 3.73 IN
WIND DIRECTION: -
WIND VELOCITY: 0.0 MPH
TEMPERATURE: 64.7 F
HUMIDITY: 60.4%

NORTH | EAST | SOUTH | WEST

NOTES: AREA HAS MODERATELY DENSE STAND OF LAST YEAR'S FIDDLENECK. VERY GOOD NEW GROWTH OF ANNUALS PRESENT.
WILDLIFE PRESENT: KANGAROO RAT (BURROWS), NORTHERN HARRIER, WHITE-CROWNED SPARROW.
PLANTS PRESENT: AMSINCKIA MENZIESII, ERODIUM CICUTARIUM, HIRSCHFELDIA INCANA, PECTOCARYA PENICILLATA, PROSOPIS GLANDULOSA VAR. TORREYANNA, SISYMBRIUM IRIO.

2ND QUARTER

SURVEY DATE: 06/08/2018
TIME: 12:10 PM
MONITOR(S): J. JONES
RAINFALL TO DATE: 3.95 IN
WIND DIRECTION: N
WIND VELOCITY: 2.4 MPH
TEMPERATURE: 85.1 F
HUMIDITY: 22.6%

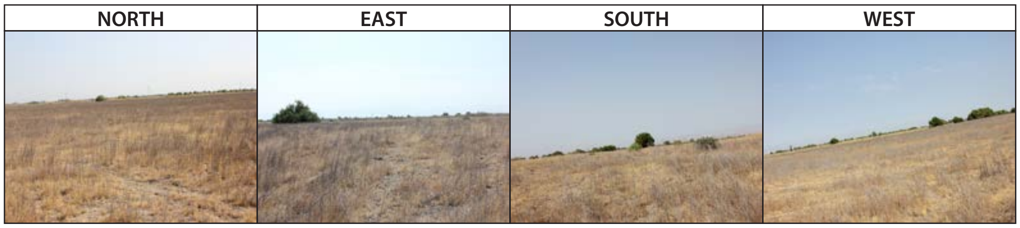
NORTH | EAST | SOUTH | WEST

NOTES: NO RUSSIAN THISTLE. MANY ACTIVE KANGAROO RAT BURROWS. LIGHT GRAZING WOULD BE BENEFICIAL.
WILDLIFE PRESENT: SWAINSON'S HAWK.
PLANTS PRESENT: AMSINCKIA MENZIESII, BROMUS SSP. RUBENS, DATURA WRIGHTII, HORDEUM MURINUM SSP. LEPORINUM, PROSOPIS GLANDULOSA VAR. TORREYANA, SCHISMUS ARABICUS, SISYMBRIUM IRIO.

3RD QUARTER

SURVEY DATE: 08/02/2018
TIME: 10:04 AM
MONITOR(S): J. JONES
RAINFALL TO DATE: 3.95 IN
WIND DIRECTION: NW
WIND VELOCITY: 2.2 MPH
TEMPERATURE: 91.8 F
HUMIDITY: 20.2%

NORTH | EAST | SOUTH | WEST

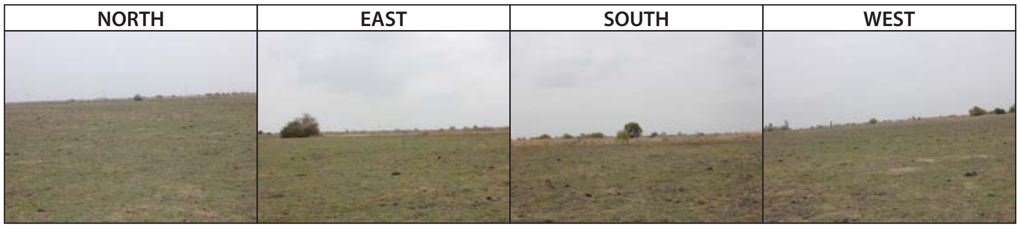


NOTES: GRAZING STILL NEEDED. NUMEROUS ACTIVE KANGAROO RAT BURROWS.
WILDLIFE PRESENT: CALIFORNIA QUAIL, MOURING DOVE, ROADRUNNER.
PLANTS PRESENT: AMSINCKIA MENZIESII, BROMUS SSP. RUBENS, DATURA WRIGHTII, HIRSCHFELDIA INCANA, PROSOPIS GLANDULOSA VAR. TORREYANA, SCHISMUS ARABICUS.

4TH QUARTER

SURVEY DATE: 12/11/2018
TIME: 12:20 PM
MONITOR(S): J. JONES
RAINFALL TO DATE: 1.30 IN
WIND DIRECTION: NW
WIND VELOCITY: 3.5 MPH
TEMPERATURE: 59.2 F
HUMIDITY: 50.2%

NORTH | EAST | SOUTH | WEST



NOTES: ABUNDANT EARLY GERMINATION. MODERATE ACTIVE KANGAROO RAT BURROWS.
WILDLIFE PRESENT: HOUSE FINCH, RAVEN, WHITE-CROWNED SPARROW.
PLANTS PRESENT: AMSINCKIA MENZIESII, ERODIUM CICUTARIUM, PROSOPIS GLANDULOSA VAR. TORREYANA, SCHISMUS ARABICUS, SISYMMBRIUM IRIO.

KERN WATER BANK 2018 VEGETATION MONITORING PROGRAM SITE OBSERVATIONS

LOCATION INFORMATION

LOCATION: OMS-6
SECTION: 36
TOWNSHIP/RANGE: 30S/25E
COORDINATES (CA5-NAD83): 6192992, 2287399
NUMBER OF ACRES: 160
VEGETATION TYPE: MIXED ANNUAL GRASSLAND WITH SCATTERED SHRUBS/SCATTERED SHRUBS-BARE SOIL
SITE TYPE: UPLAND-SENSITIVE HABITAT

SURVEY INFORMATION AND PHOTOGRAPHS

1ST QUARTER

SURVEY DATE: 03/09/2018
TIME: 11:38 AM
MONITOR(S): J. JONES
RAINFALL TO DATE: 3.73 IN
WIND DIRECTION: -
WIND VELOCITY: 0.0 MPH
TEMPERATURE: 78.9 F
HUMIDITY: 35.6%

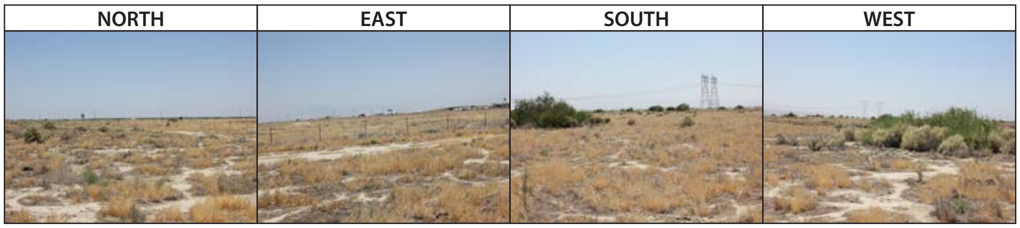
NORTH	EAST	SOUTH	WEST

NOTES: VERY LITTLE GERMINATING AT THIS TIME. MODERATE NUMBER OF ACTIVE-LOOKING KANGAROO RAT BURROWS, SITE MOSTLY A MODERATE STAND OF LAST YEAR'S RED BROME.
WILDLIFE PRESENT: JACKRABBIT, MOURNING DOVE.
PLANTS PRESENT: ATRIPLEX POLYCARPA, BROMUS SSP. RUBENS, ERODIUM CICUTARIUM, PROSOPIS GLANDULOSA VAR. TORREYANA.

2ND QUARTER

SURVEY DATE: 06/08/2018
TIME: 01:35 PM
MONITOR(S): J. JONES
RAINFALL TO DATE: 3.95 IN
WIND DIRECTION: N
WIND VELOCITY: 3.5 MPH
TEMPERATURE: 87.2 F
HUMIDITY: 22.1%

NORTH	EAST	SOUTH	WEST

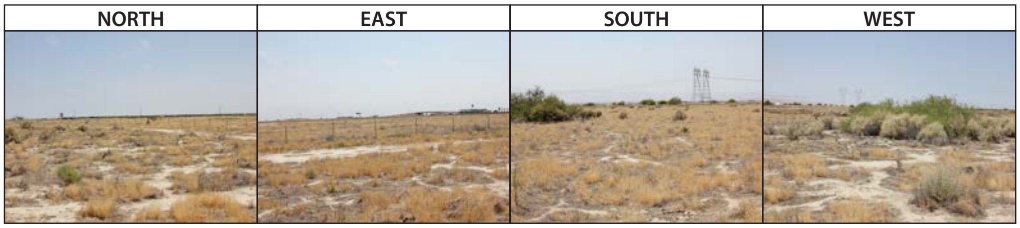


NOTES: VERY FEW KANGAROO RAT BURROWS.
WILDLIFE PRESENT: SAGE SPARROW, WESTERN KINGBIRD.
PLANTS PRESENT: AMSINCKIA MENZIESII, ATRIPLEX ARGENTEA, ATRIPLEX POLYCARPA, BROMUS SSP. RUBENS, HORDEUM MURINUM SSP. LEPORONUM, PROSOPIS GLANDULOSA VAR. TORREYANA, SCHISMUS ARABICUS, SISYMBRIUM IRIO.

3RD QUARTER

SURVEY DATE: 08/02/2018
TIME: 12:05 PM
MONITOR(S): J. JONES
RAINFALL TO DATE: 4.47 IN
WIND DIRECTION: N
WIND VELOCITY: 1.5 MPH
TEMPERATURE: 93.8 F
HUMIDITY: 12.7%

NORTH	EAST	SOUTH	WEST

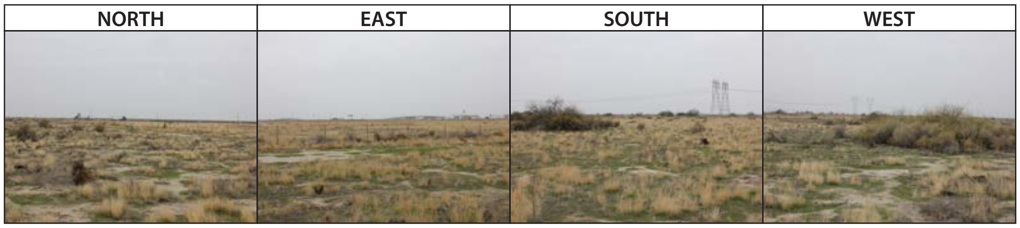


NOTES: SCATTERED ACTIVE KANGAROO RAT BURROWS.
WILDLIFE PRESENT: JACKRABBIT, LOGGERHEAD SHRIKE.
PLANTS PRESENT: AMSINCKIA MENZIESII, ATRIPLEX POLYCARPA, ATRIPLEX SERENANA, BROMUS SSP. RUBENS, PROSOPIS GLANDULOSA VAR. TORREYANA, SCHISMUS ARABICUS.

4TH QUARTER

SURVEY DATE: 12/11/2018
TIME: 11:40 AM
MONITOR(S): J. JONES
RAINFALL TO DATE: 1.30 IN
WIND DIRECTION: NW
WIND VELOCITY: 1.5 MPH
TEMPERATURE: 59.8 F
HUMIDITY: 53.6%

NORTH	EAST	SOUTH	WEST



NOTES: SCATTERED ACTIVE KANGAROO RAT BURROWS. EARLY GERMINATION PRESENT.
WILDLIFE PRESENT: KILLDEAR, WHITE-CROWNED SPARROW.
PLANTS PRESENT: AMSINCKIA MENZIESII, ATRIPLEX POLYCARPA, ATRIPLEX SERENANA, BROMUS SSP. RUBENS, ERODIUM CICUTARIUM, PROSOPIS GLANDULOSA VAR. TORREYANA, SCHISMUS ARABICUS, SISYMBRIUM IRIO.

KERN WATER BANK 2018 VEGETATION MONITORING PROGRAM SITE OBSERVATIONS

LOCATION INFORMATION

LOCATION: OMS-7
SECTION: 34
TOWNSHIP/RANGE: 30S/25E
COORDINATES (CA5-NAD83):612246, 2290740
NUMBER OF ACRES: 160
VEGETATION TYPE: MOSTLY DOMINATED BY ANNUAL GRASSES AND WEEDS
SITE TYPE: UPLAND-SENSITIVE HABITAT/UPLAND-OLD FARM FIELDS

SURVEY INFORMATION AND PHOTOGRAPHS

1ST QUARTER

SURVEY DATE: 03/09/2018
TIME: 11:10 AM
MONITOR(S): J. JONES
RAINFALL TO DATE: 3.73 IN
WIND DIRECTION: W
WIND VELOCITY: 3.2 MPH
TEMPERATURE: 76.8 F
HUMIDITY: 38.5%

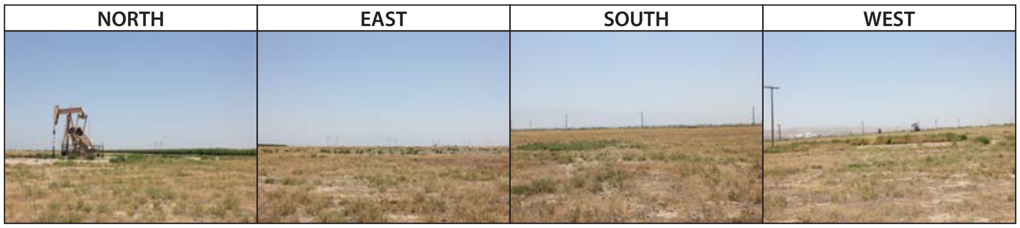
NORTH | EAST | SOUTH | WEST

NOTES: VERY LITTLE GERMINATING AT THIS TIME. GROUND IS NEARLY DEVOID OF GROWTH. NUMEROUS ACTIVE-LOOKING KANGAROO RAT BURROWS AND FRESH SCATS.
WILDLIFE PRESENT:
PLANTS PRESENT: ERODIUM CICUTARIUM, SCHISMUS ARABICUS.

2ND QUARTER

SURVEY DATE: 06/08/2018
TIME: 12:45 PM
MONITOR(S): J. JONES
RAINFALL TO DATE: 3.95 IN
WIND DIRECTION: N
WIND VELOCITY: 2.5 MPH
TEMPERATURE: 85.2 F
HUMIDITY: 24.3%

NORTH | EAST | SOUTH | WEST

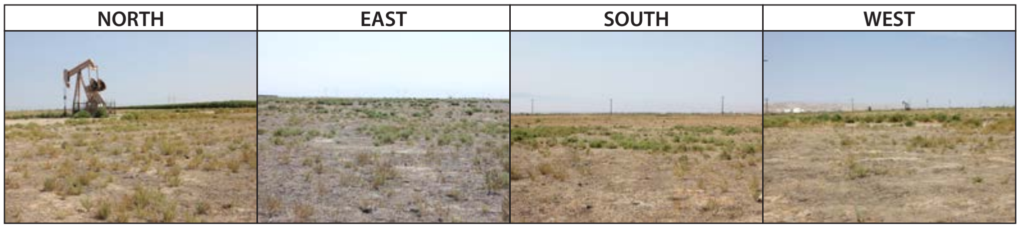


NOTES: RUSSIAN THISTLE IS BEGINNING TO DOMINATE THE AREA. CATTLE CURRENTLY GRAZING. ONLY OCCASIONAL ACTIVE KANGAROO RAT BURROWS.
WILDLIFE PRESENT: RAVEN, SIDE-BLOTCHED LIZARD, WESTERN KINGBIRD.
PLANTS PRESENT: BROMUS SSP. RUBENS, DATURA WRIGHTII, SALSOLA TRAGUS, SCHISMUS ARABICUS, SISYMBRIUM IRIO.

3RD QUARTER

SURVEY DATE: 08/02/2018
TIME: 10:29 AM
MONITOR(S): J. JONES
RAINFALL TO DATE: 3.95 IN
WIND DIRECTION: NW
WIND VELOCITY: 2.5 MPH
TEMPERATURE: 92.2 F
HUMIDITY: 15.3%

NORTH | EAST | SOUTH | WEST

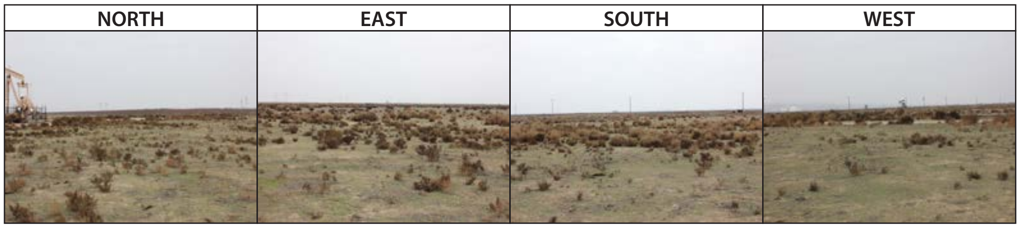


NOTES: ABUNDANT RUSSIAN THISTLE AT THIS SITE. CATTLE ARE GRAZING BUT DO NOT APPEAR TO BE EATING THE RUSSIAN THISTLE. A FEW KANGAROO RAT BURROWS.
WILDLIFE PRESENT: RAVEN.
PLANTS PRESENT: AMSINCKIA MENZIESII, DATURA WRIGHTII, SALSOLA TRAGUS, SCHISMUS ARABICUS, SISYMBRIUM IRIO.

4TH QUARTER

SURVEY DATE: 12/11/2018
TIME: 10:50 AM
MONITOR(S): J. JONES
RAINFALL TO DATE: 1.30 IN
WIND DIRECTION: NW
WIND VELOCITY: 2.5 MPH
TEMPERATURE: 56.2 F
HUMIDITY: 57.4%

NORTH | EAST | SOUTH | WEST



NOTES: MANY ACTIVE KANGAROO RAT BURROWS. ABUNDANT EARLY GERMINATION.
WILDLIFE PRESENT: AMERICAN KESTREL, LOGGERHEAD SHRIKE, RAVEN, RED-TAILED HAWK.
PLANTS PRESENT: AMSINCKIA MENZIESII, ERODIUM CICUTARIUM, SALSOLA TRAGUS, SISYMBRIUM IRIO.

KERN WATER BANK 2018 VEGETATION MONITORING PROGRAM SITE OBSERVATIONS

LOCATION INFORMATION

LOCATION: OMS-8
SECTION: 16
TOWNSHIP/RANGE: 30S/25E
COORDINATES (CA5-NAD83): 6173009, 2307209
NUMBER OF ACRES: 40
VEGETATION TYPE: MOSTLY DOMINATED BY ANNUAL GRASSES AND WEEDS/NON-NATIVE PLANTS
SITE TYPE: POND BASIN

SURVEY INFORMATION AND PHOTOGRAPHS

1ST QUARTER

SURVEY DATE: 03/09/2018
TIME: 10:30 AM
MONITOR(S): J. JONES
RAINFALL TO DATE: 3.73 IN
WIND DIRECTION: W
WIND VELOCITY: 1.6 MPH
TEMPERATURE: 77.2 F
HUMIDITY: 42.2%

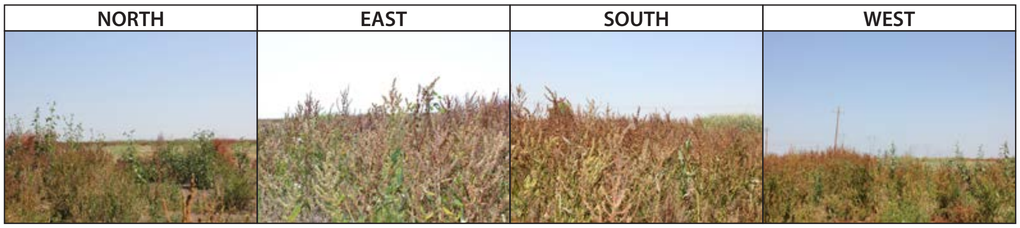
NORTH	EAST	SOUTH	WEST

NOTES:
WILDLIFE PRESENT: TURKEY VULTURE.
PLANTS PRESENT: ALISMA PLANTAGO-AQUATICA, ELEOCHARIS MACROSTACHYA, HELIANTHUS ANNUUS, HIRSCHFELDIA INCANA, RUMEX CRISPUS, SALIX GOODDINGII, TYPHA LATIFOLIA, XANTHIUM STRUMARIUM.

2ND QUARTER

SURVEY DATE: 06/08/2018
TIME: 10:30 AM
MONITOR(S): J. JONES
RAINFALL TO DATE: 3.95 IN
WIND DIRECTION: NW
WIND VELOCITY: 2.0 MPH
TEMPERATURE: 81.2 F
HUMIDITY: 26.1%

NORTH	EAST	SOUTH	WEST

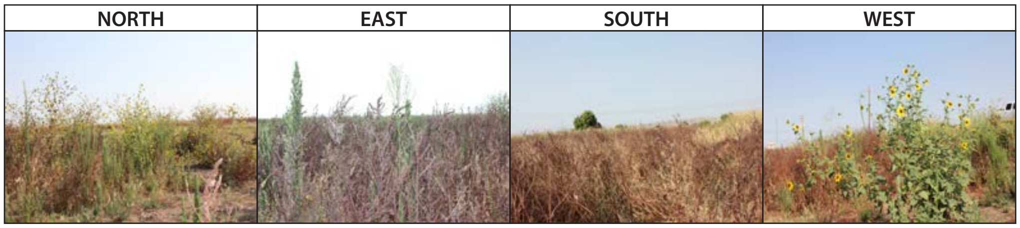


NOTES: GRAZING NEEDED. VERY DENSE VEGETATION.
WILDLIFE PRESENT: RAVEN, RED-WINGED BLACKBIRD.
PLANTS PRESENT: ACROPTILON REPENS, GNAPHALIUM PALUSTRE, HELIANTHUS ANNUUS, JUNCUS BALTICUS, LYTHRUM CALIFORNICUM, PHYLA NODIFLORA, POLYGNUM LAPATHIFOLIUM, POLYPOGON MONSPELIENSIS, RORRIPA ISLANDICA, RUMEX CRISPUS, RUMEX SP., SAGITORIA SP., SALIX GOODDINGII, SALSOLA TRAGUS, TYPHA LATIFOLIA.

3RD QUARTER

SURVEY DATE: 08/02/2018
TIME: 09:17 AM
MONITOR(S): J. JONES
RAINFALL TO DATE: 3.95 IN
WIND DIRECTION: NW
WIND VELOCITY: 1.1 MPH
TEMPERATURE: 91.1 F
HUMIDITY: 26.2%

NORTH	EAST	SOUTH	WEST

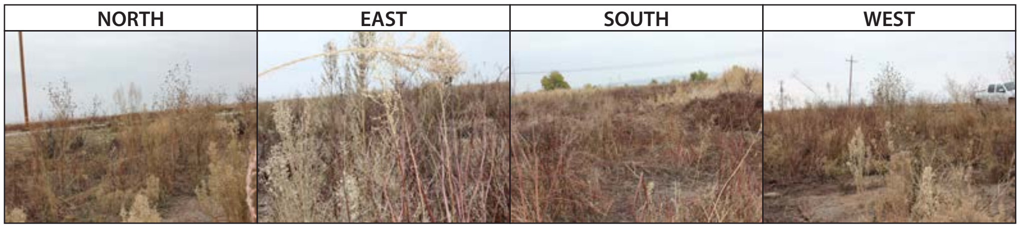


NOTES: VERY TALL DENSE VEGETATION. CATTLE GRAZING IS OCCURRING.
WILDLIFE PRESENT: MOURNING DOVE.
PLANTS PRESENT: ATRIPLEX ARGENTEA, CONYZA BONARIENSIS, CONYZA CANADENSIS, CONYZA COULTERI, HELIANTHUS ANNUUS, LYTHRUM CALIFORNICUM, LYTHRUM HYSSOPIFOLIUM, PHYLA NODIFLORA, POLYGONUM ARENASTRUM, POLYGONUM LAPATHIFOLIUM, RUMEX CRISPUS, SALIX GOODDINGII, TYPHA LATIFOLIA.

4TH QUARTER

SURVEY DATE: 12/11/2018
TIME: 01:47 PM
MONITOR(S): J. JONES
RAINFALL TO DATE: 1.30 IN
WIND DIRECTION: -
WIND VELOCITY: 0.0 MPH
TEMPERATURE: 60.2 F
HUMIDITY: 47.8%

NORTH	EAST	SOUTH	WEST



NOTES:
WILDLIFE PRESENT: CALIFORNIA HORNED LARK, LOGGERHEAD SHRIKE, RED-TAILED HAWK, WHITE-CROWNED SPARROW.
PLANTS PRESENT: ATRIPLEX SERENANA, CONYZA CANADENSIS, CONYZA COULTERI, CYNODON DACTYLON, GNAPHALIUM PALUSTRE, HELIANTHUS ANNUUS, PHYLA NODIFLORA, POLYGONUM LAPATHIFOLIUM, RUMEX CRISPUS, SALIX GOODDINGII, THYPA LATIFOLIA.

Appendix C

Kern Water Bank Bird Survey Report: October – mid-April 2012

Great Egret (*Ardea alba*)

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Sterling Wildlife Biology

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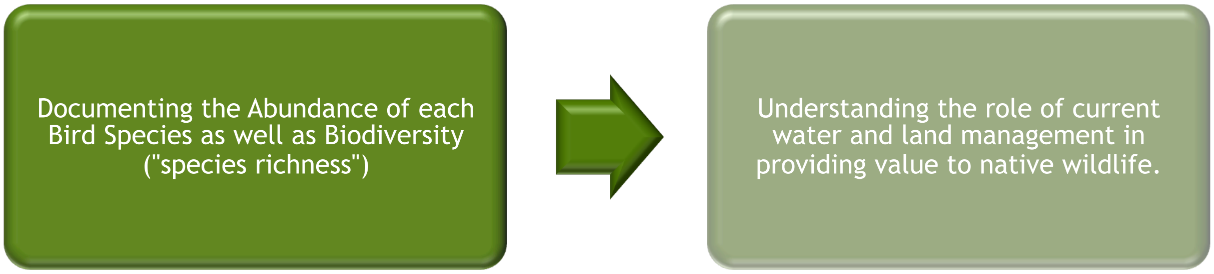
Kern Water Bank

Bird Survey Report: October – mid-April 2012

27 April 2012

Introduction

The property managed by the Kern Water Bank Authority supports a wealth of native wildlife, especially an abundance of water birds and raptors attracted to the recharge ponds and/or the upland habitats. In order to document and quantify this natural resource value, John Sterling of Sterling Wildlife Biology conducted bird surveys from mid October 2011 to mid April 2012. These surveys were intended to capture a snapshot of the bird use of the project area during the winter and early spring season. The resulting data serve to document the regional and statewide importance of these wetlands to waterbirds during this period. The data may also be used to inform management practices with regard to productive bird habitat.



Methods

For the waterbird surveys, John Sterling visited watered ponds over ten survey periods. The dates of the surveys were 18-19 October, 25-26 October, 15-16 November, 30 November – 1 December, 13-14 December, 23-25 January, 10-11 February, 28-29 February, 10-11 March, and 8-9 April. Each pond was labeled in the datasheet according to the name on the map provided by the Kern Water Bank Authority. One pond was not marked on the map and was labeled CX for this study. For each pond, Mr. Sterling counted all individuals for species with fewer than one hundred individuals. For species with larger numbers of individuals, he made estimates by counting in increments of ten or one hundred. All watered ponds were visited in all ten surveys with the exception of Pond W3. All data were entered into Microsoft Excel spreadsheets (See attached Appendix A excel file).

Mr. Sterling conducted upland bird surveys by walking transects and recording all birds heard or seen within 100 meters of the transect line (Figure 1). He tabulated the numbers of each species. Each transect was surveyed twice, once in October (one transect in December) and again in February. Transects were 0.25 - 0.5 miles long. For five sets of raptor surveys (14 December, 9 January, 24 January, 29 February and 1 April), Mr. Sterling drove most roads to cover the entire project area and kept running tallies of numbers of individuals of all raptor species and Loggerhead Shrike detected in wetland and upland habitats.

Results

Waterbirds

A total of sixty-six native waterbird species were detected during these surveys. Overall numbers were consistently high during the first eight survey periods (mid-October through February) with 19,823 – 34945 individuals estimated (Figure 2). After mid December, ponds started drying out. However, numbers climbed and remained high through February despite the drop in the number of watered ponds (Figures 2 and 3). The study area was able to absorb these increases as watered ponds held higher concentrations of birds. The peak was on 24-25 January when large numbers of ducks were present (Figure 5), most likely pushed south by winter storms in the north. There was a sharp decline in waterbird numbers by mid March and April as there were few watered ponds remaining—most of which had greatly reduced water levels and surface area.

The sixty-six species of waterbirds are grouped according to foraging ecology and evolutionary relationships. Grebes (Figure 4), gulls (Figure 5), dabbling and diving ducks (Figure 6), egrets/herons (Figure 7), and shorebirds (sandpipers and plovers) (Figure 8) were classified into separate categories. American Coot (*Fulica americana*), White-faced Ibis, Double-crested Cormorant (*Phalacrocorax auritas*), and White Pelican (*Pelicanus erythrorhyncos*) were treated individually in the summary data (Figures 9-11). There were two over-arching seasonal patterns in abundance amongst the groups of waterbirds. Grebes, herons and egrets, coots, and pelicans and cormorants numbers peaked during the late fall and early winter surveys, while ducks, gulls, shorebirds and White-faced Ibis (*Plegadis chihi*) numbers peaked in late winter and early spring surveys (Figures 3-10). Overall numbers of species per pond (species richness) as an index of biodiversity increased from mid October to 14 December, then slowly decreased (Table 1). The ponds that were most important for high numbers of species and populations throughout the winter were W2, W4, W5, W6, M1, M8, and M10. But many other ponds were important, especially earlier in the season when water was most prevalent east of Hwy 5 (for details see Appendix excel file). The average number of birds per pond varied across the survey periods but didn't change dramatically until decreases started in late February

(Table 2). The variation in ponds was dramatic with several ponds consistently having over 2,000 birds and others fewer than 100. Because of the varied topography of many of the ponds and the lack of direct measurements of water depths, it was not possible to determine average depths or the range of depths for the ponds during the surveys. Likewise, because many of the ponds were drying during the late winter and spring, the acreages of these ponds were not measured. However, the largest ponds consistently had the largest number of species and concentrations of birds.

Marsh species such as Sora (*Porzana carolina*), Virginia Rail (*Rallus limicola*), Black-crowned Night-Heron (*Nycticorax nycticorax*), and Marsh Wren (*Cistothorus palustris*) were found in nearly every pond with substantial amount of cattails, sedges and other emergent wetland vegetation. Curiously, no American Bitterns (*Botaurus lentiginosus*) or Least Bitterns (*Ixobrychus exilis*) were found despite plenty of suitable habitat, but these species are cryptic and usually in low density so are difficult to detect when not vocalizing.

Upland Birds

Additional bird surveys that sampled the diverse upland habitats had 9 - 21 species with 9 – 245 individual birds in October (Table 3). By far the most abundant species was White-crowned Sparrow (*Zonotrichia leucophyrs*), but large numbers of the typically uncommon Lincoln's Sparrow (*Melophiza lincolnii*) were found on two transects. All birds found during these surveys were typical wintering species with the exception of Yellow Warbler (*Setophaga petechia*), which was a late migrant.

The second set of surveys conducted in February had fewer species and individuals than in October with the exception of Transect G, which was surveyed in December, not October. These results may indicate an overall reduction in the populations of upland bird species on the study area. Among the factors that could play a role are reduced food (seed, insects), birds were temporarily stopping on the study area while enroute to wintering locations further south, and the loss of individuals through predation. Predators such as long-tailed weasel (*Mustela freneta*), bobcat (*Lynx rufus*), coyote (*Canis latrans*), striped skunk (*Mephitis mephitis*), many raptors including owls, and Loggerhead Shrikes were observed on the study area during the surveys and undoubtedly prey upon many upland birds during the winter.

Raptors and Shrikes

The comprehensive survey for raptors and Loggerhead Shrikes (*Lanius ludovicianus*) on the entire project area resulted in high numbers of Red-tailed Hawks (*Buteo jamaicensis*) and Loggerhead Shrikes, but also documented thirteen species of raptors using either the wetland or upland habitats during the surveys (Figure 12-16). Ferruginous Hawks (*Buteo regalis*), American Kestrels (*Falco sparverius*), Prairie Falcons (*Falco mexicanus*) and Loggerhead Shrikes preferred upland to wetland habitats, but Red-tailed Hawks and Northern Harriers (*Circus cyaneus*) were found nearly equally in both sets of habitats during the first survey (Figure 11). During subsequent surveys, Red-tailed Hawks were found primarily in upland habitats. The sample sizes are too small to draw definitive conclusions based upon the data, but Osprey (*Pandion haliaetus*), and Peregrine Falcon (*Falco peregrinus*) preference for wetlands and Prairie Falcon preference for uplands can be inferred based upon their primary diet—fish for Osprey, ducks and shorebirds for Peregrine Falcons, and rodents and upland birds for Prairie Falcons. Red-shouldered Hawk (*Buteo lineatus*) and White-tailed Kites (*Elanus leucurus*) were present in very small numbers and primarily associated with wetlands and/or rank fallow fields. Both Cooper's (*Accipiter cooperi*) and Sharp-shinned (*Accipiter striatus*) hawks, which prey upon small birds, were also found in small numbers in both upland and wetlands, but primarily where there were flocks of sparrows.

Overall numbers of raptors dipped sharply on 9 January, then rebounded on 24 January and declined to low levels found on 1 April. Likewise, Loggerhead Shrikes followed the same trend to drop to ~30% of the peak number by 1 April. The 17 remaining shrikes on 1 April were likely resident breeders. The decline from December was likely due to an influx of winter visitors that departed by April to their breeding grounds outside of the study area. The extent of immigration to the Central Valley is unknown, but it is likely that some shrikes breeding eastern Washington, Oregon and the Great Basin winter in the Central Valley.

Rare Birds

A few rare birds were discovered during the surveys. A female Barrow's Goldeneye was on M10 on 25 January, which established only the third documented record for Kern County. Two female Greater Scaup on 14 December on E2 were the only ones reported in Kern County during 2011. Several Eurasian Wigeon were also seen including a female and three males. Other than Canada Goose, geese are rare in the Tulare Basin, so multiple records of Snow, Ross's, Cackling and Greater White-fronted geese were notable. A Glaucous Gull was on M1 on 29 February, which established the fourth or fifth record for the Tulare Basin. Other rare gulls included several Glaucous-winged, Thayer's and Mew gulls. Although not rare, an adult Golden Eagle put in a visit on 29 February. On 1 April, a Cassin's Kingbird and a male Purple Martin were photographed on the study area. The kingbird is a very rare breeder in Kern County and is only known from the South Fork Kern River Valley and a location near Bakersfield. This bird was probably a very rare wandering migrant. Purple Martins are only known to breed in Kern County in the high mountains of the Tejon Ranch, and there are very few records of migrants in the San Joaquin Valley and Tulare Basin.

The Kern Water Bank has exceptional habitats for birds and many rare birds will likely be found and documented in the future dependent upon survey efforts.

Figure 1. Locations of Upland Bird Survey Transects on the Kern Water Bank

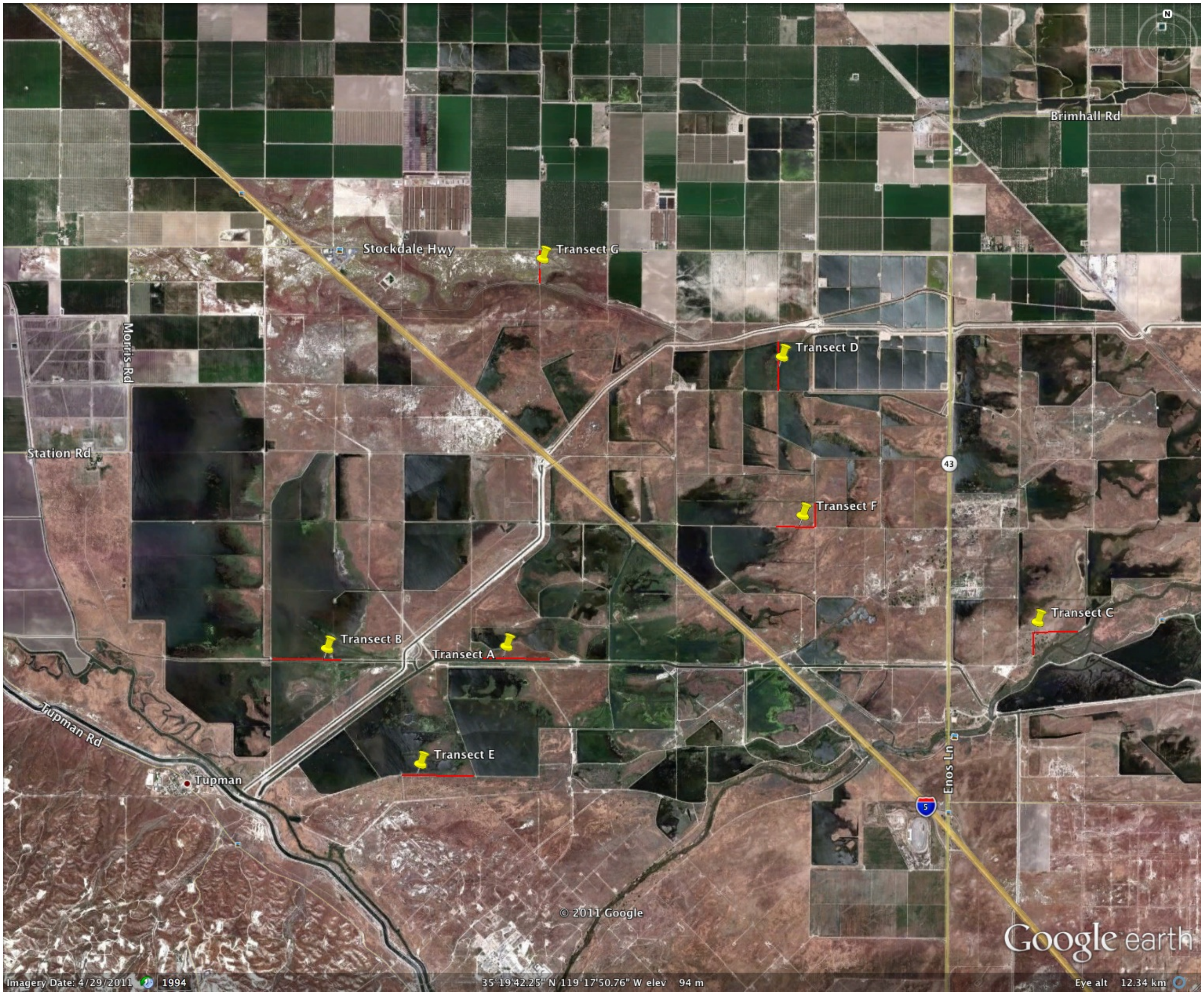
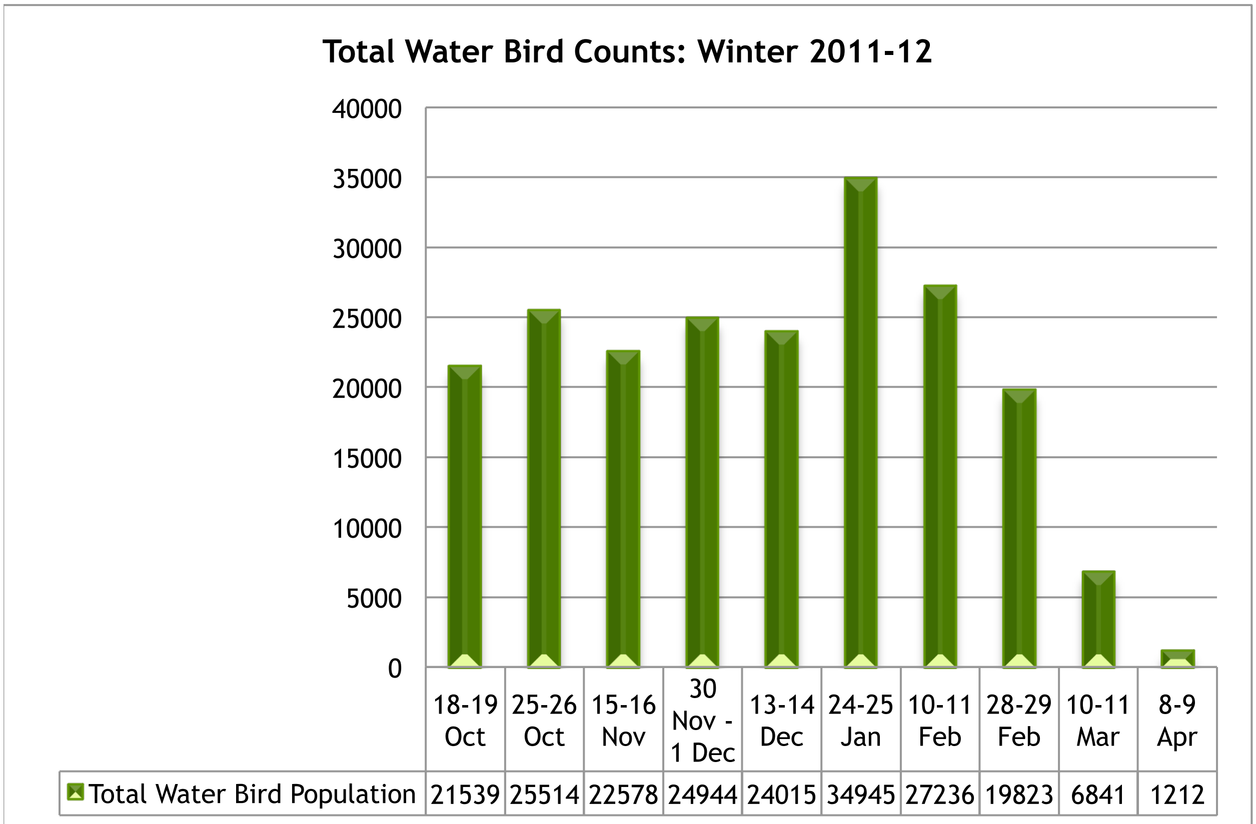
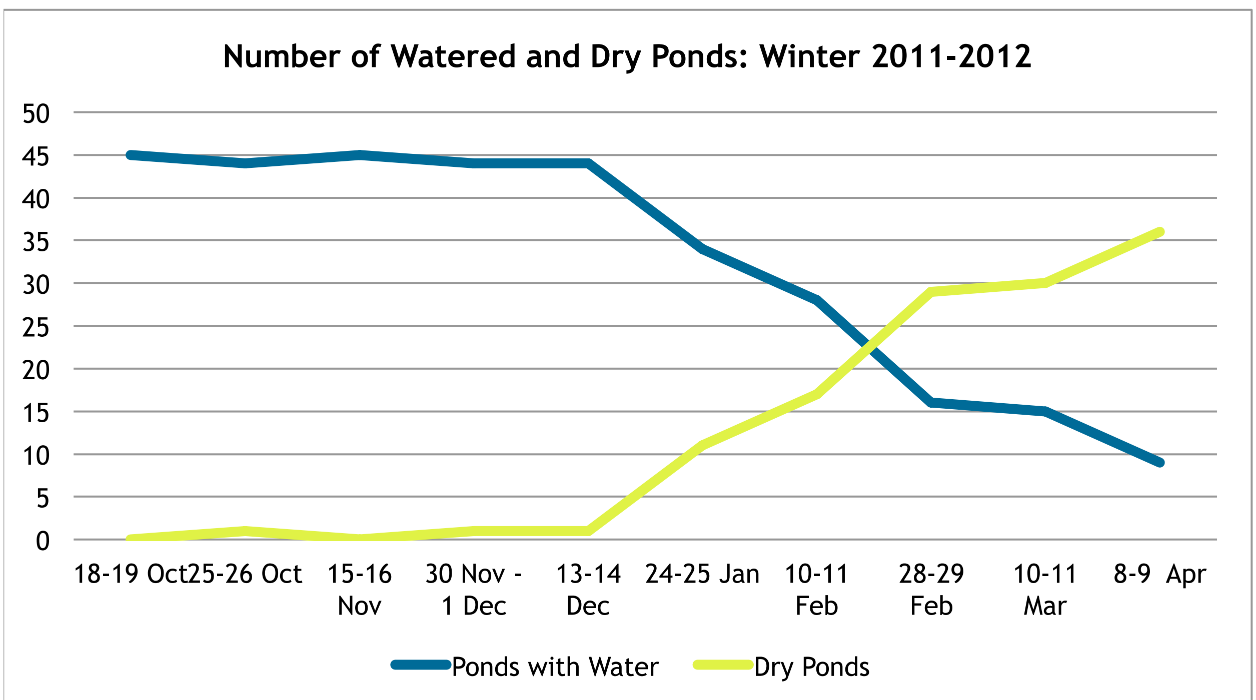


Figure 2. Results of Ten Waterbird Surveys in Winter 2011-2012: total waterbird counts.



	18-19 Oct	25-26 Oct	15-16 Nov	30 Nov - 1 Dec	13-14 Dec	24-25 Jan	10-11 Feb	28-29 Feb	10-11 Mar	8-9 Apr
Total Water Bird Population	21539	25514	22578	24944	24015	34945	27236	19823	6841	1212

Figure 3. Seasonal Variation in Watered Ponds Surveyed for Birds: Winter 2011-2012.



Great and Snowy egrets, White-faced Ibis, American White Pelicans and Double-crested Cormorants

Figure 4. Results of Grebe Counts.

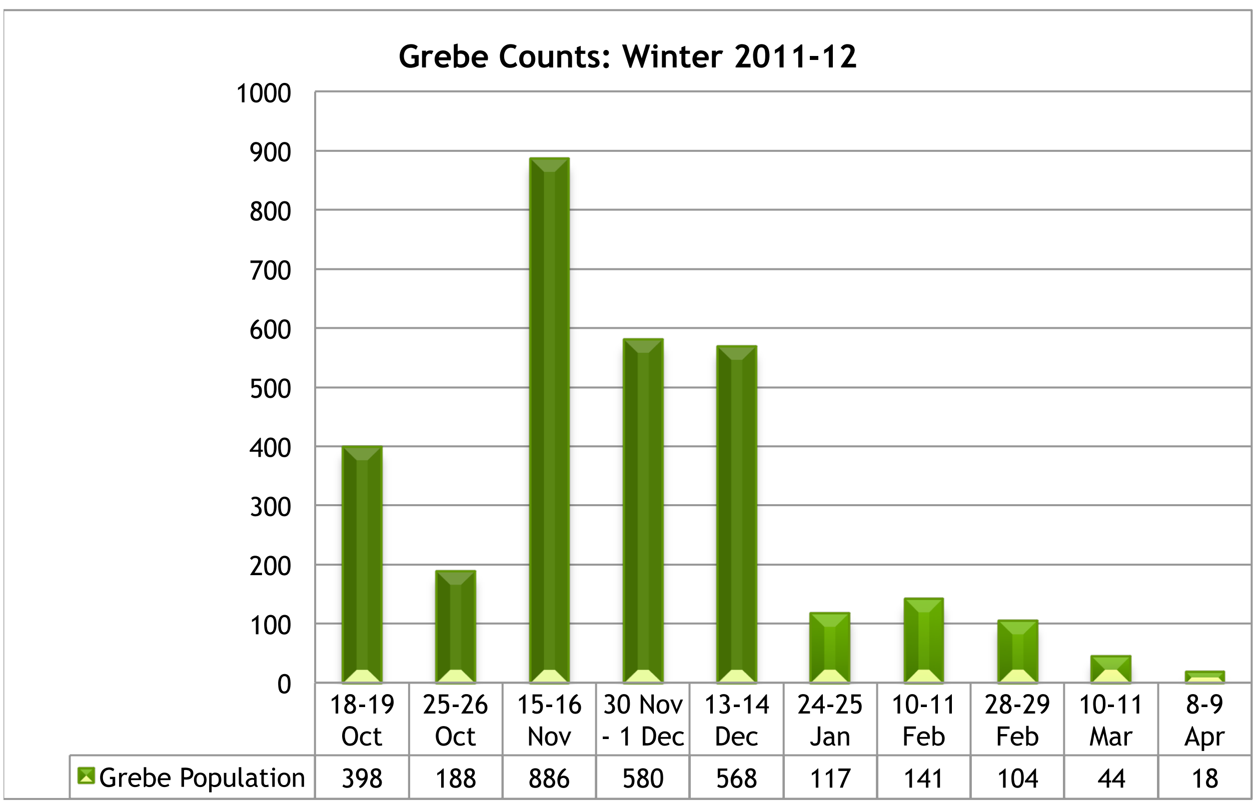
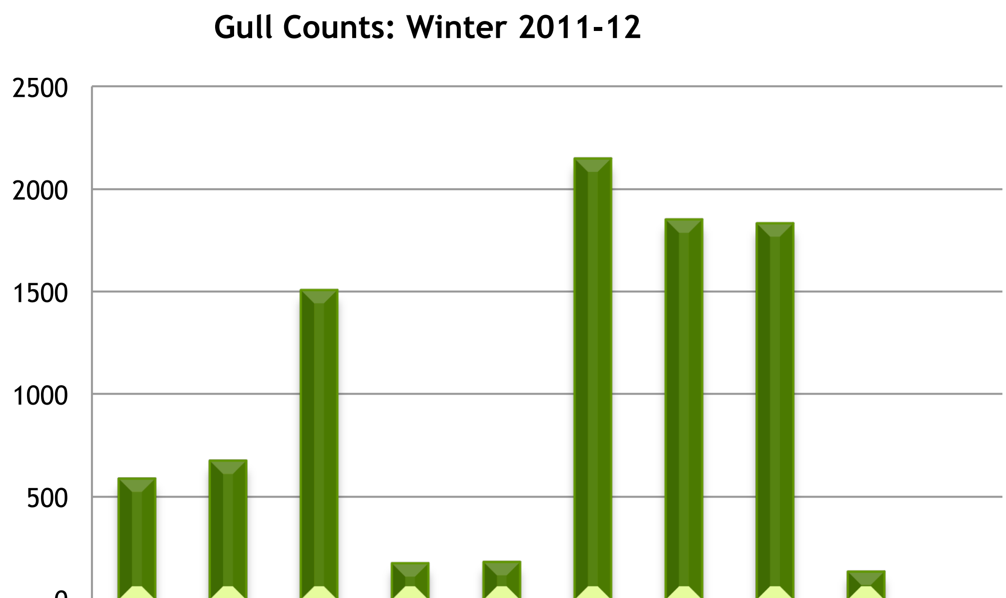
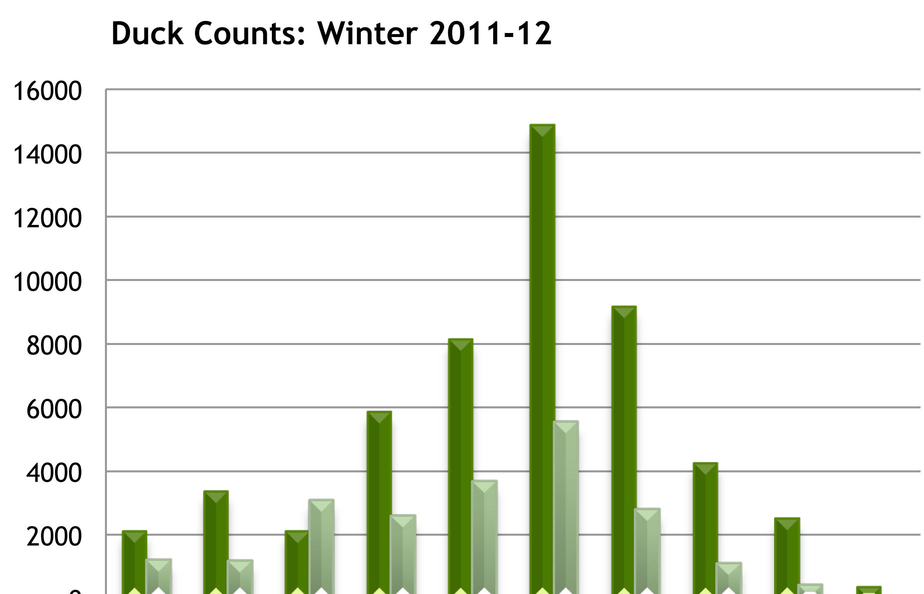


Figure 5. Results of Gull Counts.



	18-19 Oct	25-26 Oct	15-16 Nov	30 Nov - 1 Dec	13-14 Dec	24-25 Jan	10-11 Feb	28-29 Feb	10-11 Mar	8-9 Apr
Gull Population	590	676	1505	178	185	2145	1850	1830	138	0

Figure 6. Results of Duck Counts.



	18-19 Oct	25-26 Oct	15-16 Nov	30 Nov - 1 Dec	13-14 Dec	24-25 Jan	10-11 Feb	28-29 Feb	10-11 Mar	8-9 Apr
Dabbling Duck Population	2135	3372	2123	5863	8136	14855	9171	4257	2525	379
Diving Duck Population	1191	1185	3072	2589	3680	5540	2792	1101	425	25

Figure 7. Results of Egret and Heron Counts.

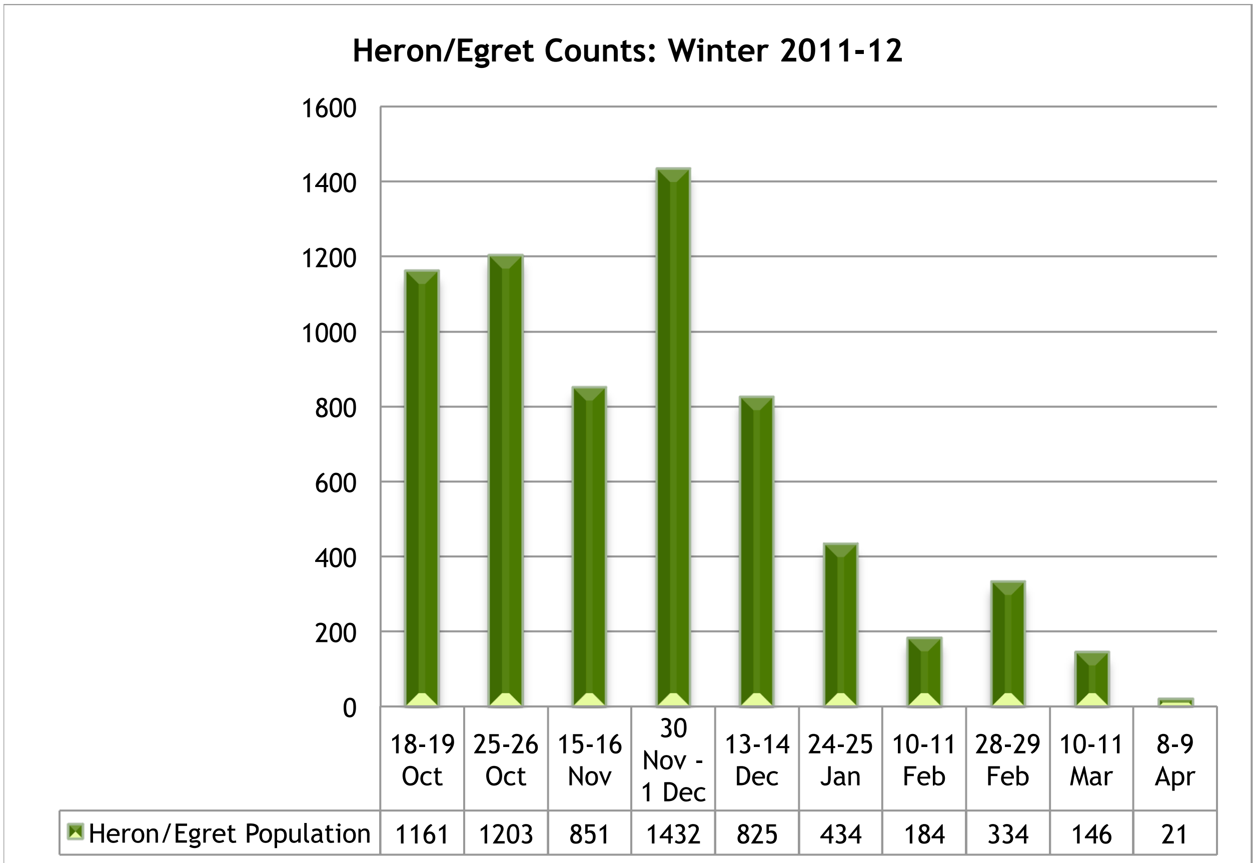


Figure 8. Results of Shorebird Counts.

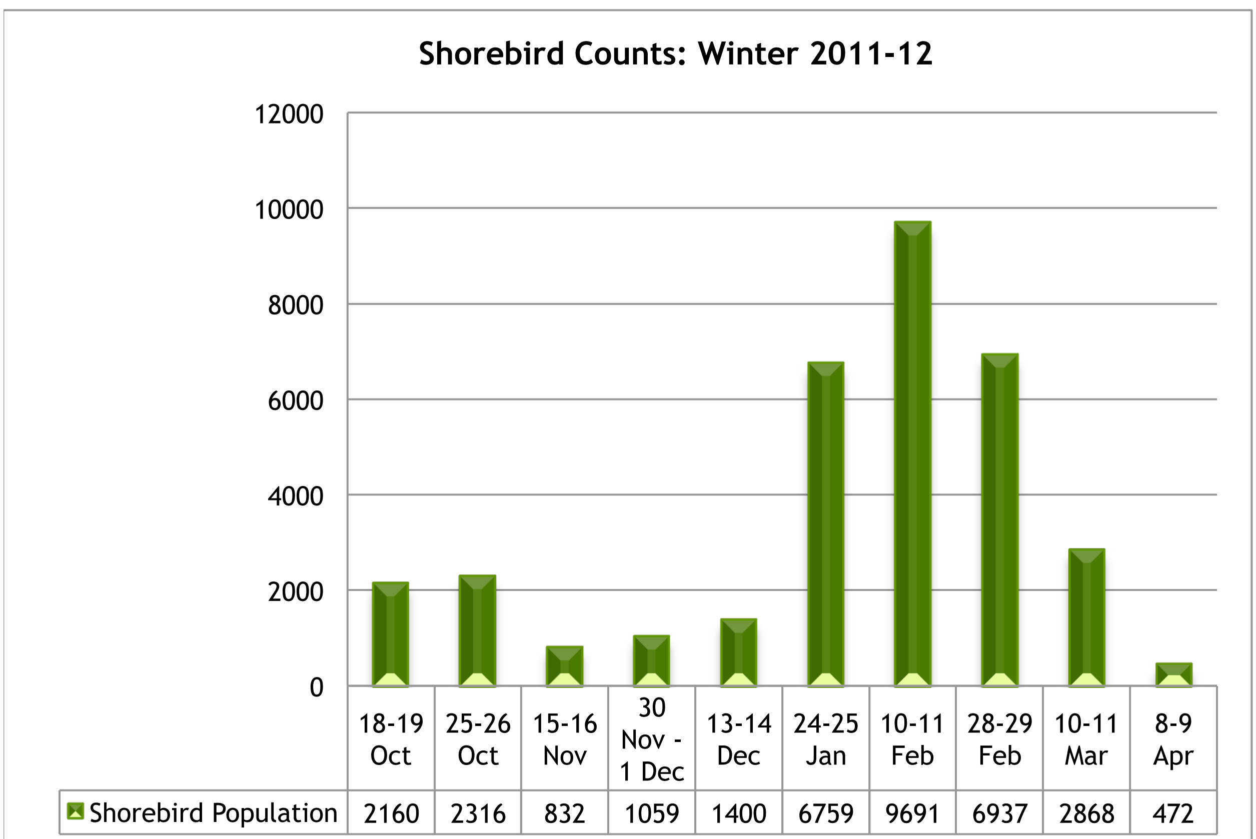
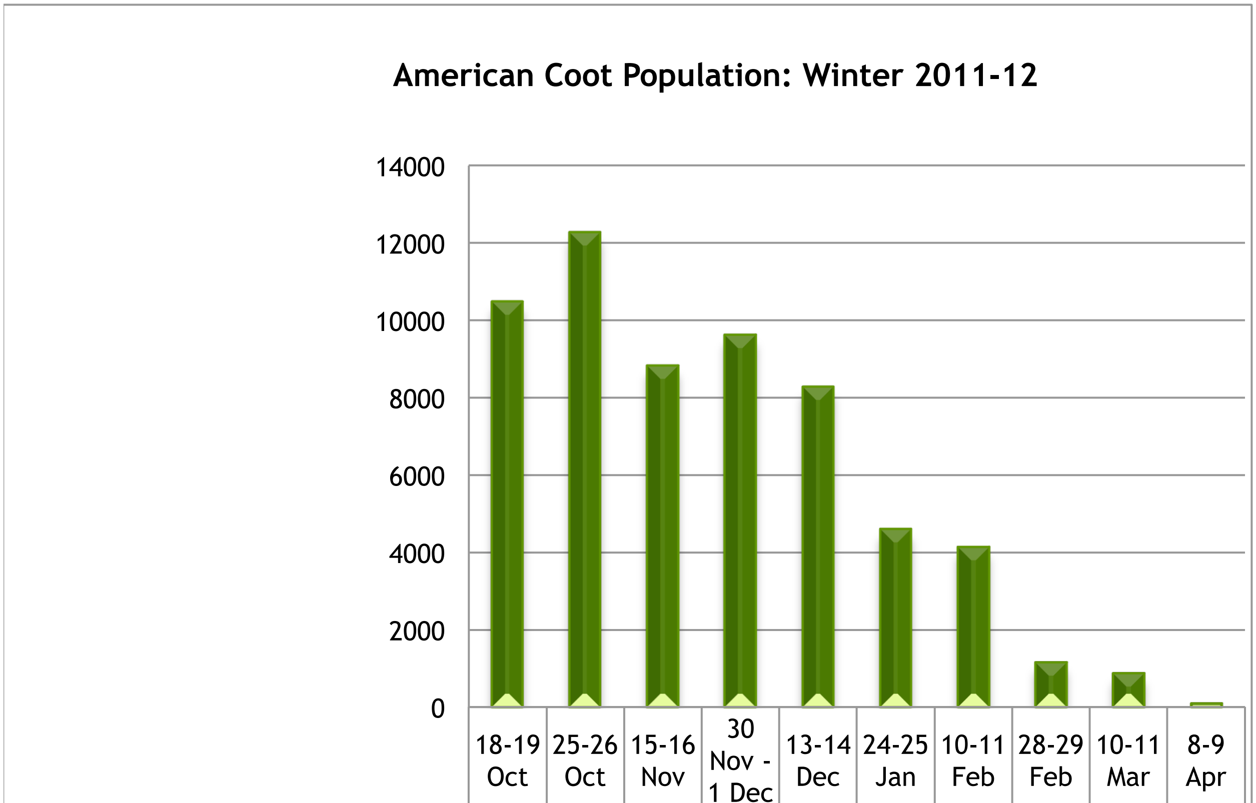
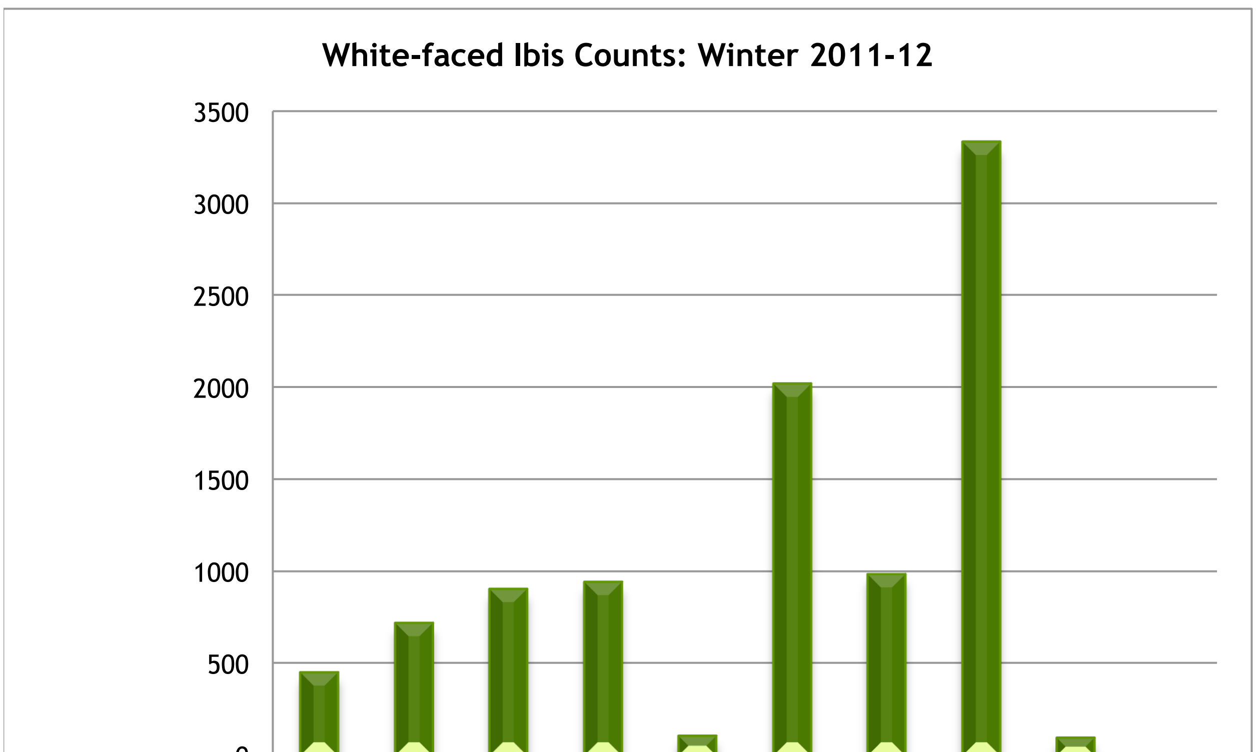


Figure 9. Results of American Coot Counts.



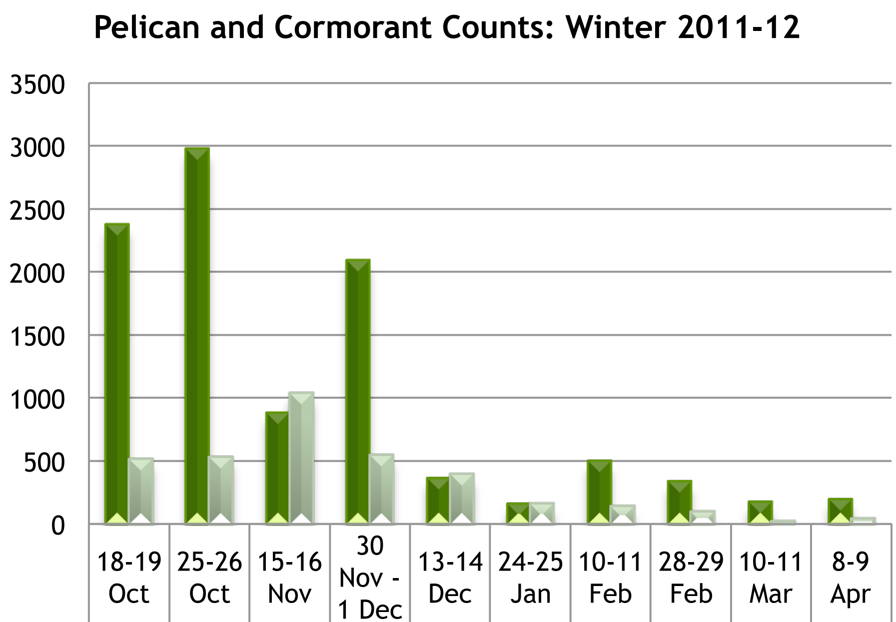
	18-19 Oct	25-26 Oct	15-16 Nov	30 Nov - 1 Dec	13-14 Dec	24-25 Jan	10-11 Feb	28-29 Feb	10-11 Mar	8-9 Apr
American Coot Population	10483	12270	8830	9620	8280	4599	4136	1170	879	101

Figure 10. Results of White-faced Ibis Counts.



	18-19 Oct	25-26 Oct	15-16 Nov	30 Nov - 1 Dec	13-14 Dec	24-25 Jan	10-11 Feb	28-29 Feb	10-11 Mar	8-9 Apr
Ibis Population	451	722	904	943	108	2019	986	3329	97	9

Figure 11. Results of Cormorant and Pelican Counts.



	18-19 Oct	25-26 Oct	15-16 Nov	30 Nov - 1 Dec	13-14 Dec	24-25 Jan	10-11 Feb	28-29 Feb	10-11 Mar	8-9 Apr
American White Pelican Population	2380	2976	886	2095	367	165	504	341	179	202
Double-crested Cormorant Population	515	531	1036	547	392	157	140	97	23	44

Table 1. Number of Species per Pond.

Survey Period	Average Species Richness	Standard Error	Range
18-19 Oct	9.56	5.47	1 - 23
25-26 Oct	10.35	5.67	0 - 21
15-16 Nov	11.95	6.44	1 - 28
30 Nov - 1 Dec	13.36	5.75	0 - 26
13-14 Dec	13.25	7.41	0 - 28
23-25 Jan	10.82	9.20	0 - 31
10-11 Feb	8.22	8.69	0 - 26
28-29 Feb	6.02	9.56	0 - 32
11 Mar	4.24	7.75	0 - 27
9 Apr	2.38	5.34	0 - 22

Table 2. Number of Birds per Pond.

Survey Period	Average Number of Birds	Standard Error	Range
18-19 Oct	552	660	12 - 2539
25-26 Oct	668	997	0 - 4373
15-16 Nov	599	638	3 - 3042
30 Nov - 1 Dec	640	691	0 - 3725
13-14 Dec	536	586	0 - 2274
23-25 Jan	790	1935	0 - 11432
10-11 Feb	637	1249	0 - 7050
28-29 Feb	445	1221	0 - 6121
11 Mar	162	443	0 - 2390
9 Apr	31	74	0 - 334

Table 3. Results of Upland Bird Surveys: October.

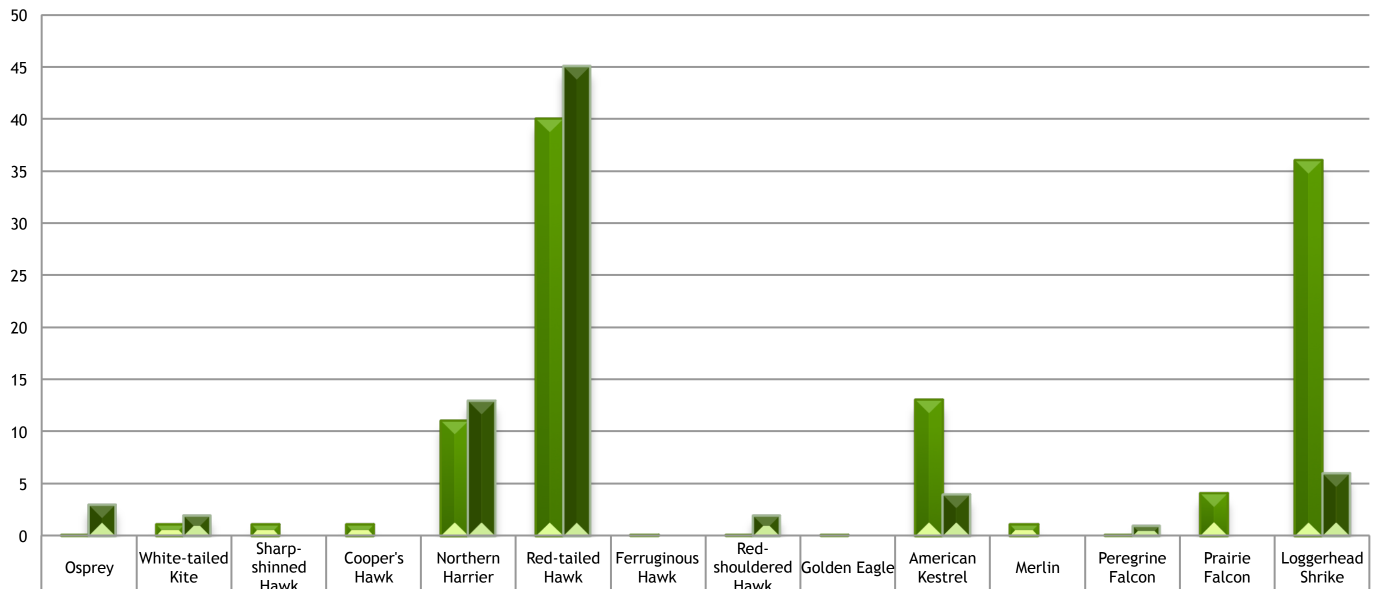
	Transect A	Transect B	Transect C	Transect D	Transect E	Transect F	Transect G
Date	19-Oct	19-Oct	20-Oct	20-Oct	26-Oct	27-Oct	12-Dec
Transect Length (miles)	0.5	0.5	0.5	0.35	0.5	0.5	0.25
Species							
COOPER'S HAWK	2				1		
RED-SHOULDERED HAWK		1	1				
RED-TAILED HAWK		1		2		2	1
AMERICAN KESTREL			1			1	
KILLDEER							1
CALIFORNIA QUAIL			71		43	2	
MOURNING DOVE			2	1		12	1
GREATER ROADRUNNER			1		1		
BARN OWL	3						
NORTHERN FLICKER			1		1		
BLACK PHOEBE	1	1	1	2	4	2	
SAY'S PHOEBE			1				
HORNED LARK			3			40	1
TREE SWALLOW	4			40			
WESTERN SCRUB-JAY			3				
COMMON RAVEN			3				1
BEWICK'S WREN			11		7		
HOUSE WREN	6			1	4		
MARSH WREN				4	1		
AMERICAN ROBIN			1				
NORTHERN MOCKINGBIRD	4	1	6	3	3	1	1
CALIFORNIA THRASHER			1		1		
AMERICAN PIPIT						3	
LOGGERHEAD SHRIKE	2	2	2	2	5	1	1
ORANGE-CROWNED WARBLER			2	6	1		
YELLOW WARBLER		2		1			
AUDUBON'S WARBLER		3	5	3	6		
COMMON YELLOWTHROAT		2		1			
LARK SPARROW					1		
SAVANNAH SPARROW					2	2	
SONG SPARROW	2	7		3	1		
LINCOLN'S SPARROW	47	3		33	4	1	
WHITE-CROWNED SPARROW	130	50	60	60	150	40	
RED-WINGED BLACKBIRD	10			60			
WESTERN MEADOWLARK	3		2	1		8	1
BROWN-HEADED COWBIRD				2			
HOUSE FINCH	18	6		2	1	9	1
AMERICAN GOLDFINCH		20		2	8		
Individuals	**232**	**99**	**183**	**229**	**245**	**124**	**9**
Species	**13**	**13**	**21**	**20**	**20**	**14**	**9**

Table 3. Results of Upland Bird Surveys: February.

	Transect A	Transect B	Transect C	Transect D	Transect E	Transect F	Transect G
Date	29-Feb	29-Feb	9-Feb	9-Feb	29-Feb	9-Feb	9-Feb
Transect Length (miles)	0.5	0.5	0.5	0.35	0.5	0.5	0.25
Species							
GREEN HERON		1					
COOPER'S HAWK			1				
WHITE-TAILED KITE	2						
NORTHERN HARRIER	1			1			
RED-TAILED HAWK			3				1
AMERICAN KESTREL				2			1
KILLDEER							1
CALIFORNIA QUAIL	20		1		40		
RING-NECKED PHEASANT	1						
MOURNING DOVE			4	4	3		
GREATER ROADRUNNER							1
GREAT HORNED OWL	1		3				
NORTHERN FLICKER			1				
BLACK PHOEBE		1	2	2			
HORNED LARK			14				2
TREE SWALLOW				3			
CLIFF SWALLOW					2		
WESTERN SCRUB-JAY							1
COMMON RAVEN			1		2		
BEWICK'S WREN		1	5	1	2		
HOUSE WREN					2		
MARSH WREN	1	1		8			
RUBY-CROWNED KINGLET		1	1	1			
NORTHERN MOCKINGBIRD	1		4				2
CALIFORNIA THRASHER			2		1		
AMERICAN PIPIT				1			
EURASIAN STARLING			4				
LOGGERHEAD SHRIKE	1		2		6		2
ORANGE-CROWNED WARBLER				1	1		
AUDUBON'S WARBLER	1	5	3		3		
SAVANNAH SPARROW		6				12	
SONG SPARROW		2		10			
LINCOLN'S SPARROW	6	4		17	1		
WHITE-CROWNED SPARROW	20	10	50	7	50	8	10
RED-WINGED BLACKBIRD				21			
WESTERN MEADOWLARK	4		2	2	6	6	10
HOUSE FINCH	2		1	2			
individuals	**61**	**32**	**104**	**83**	**119**	**26**	**31**
species	**13**	**10**	**19**	**16**	**13**	**3**	**10**

Figure 12. Results of the Raptor Survey on 14 December 2011.

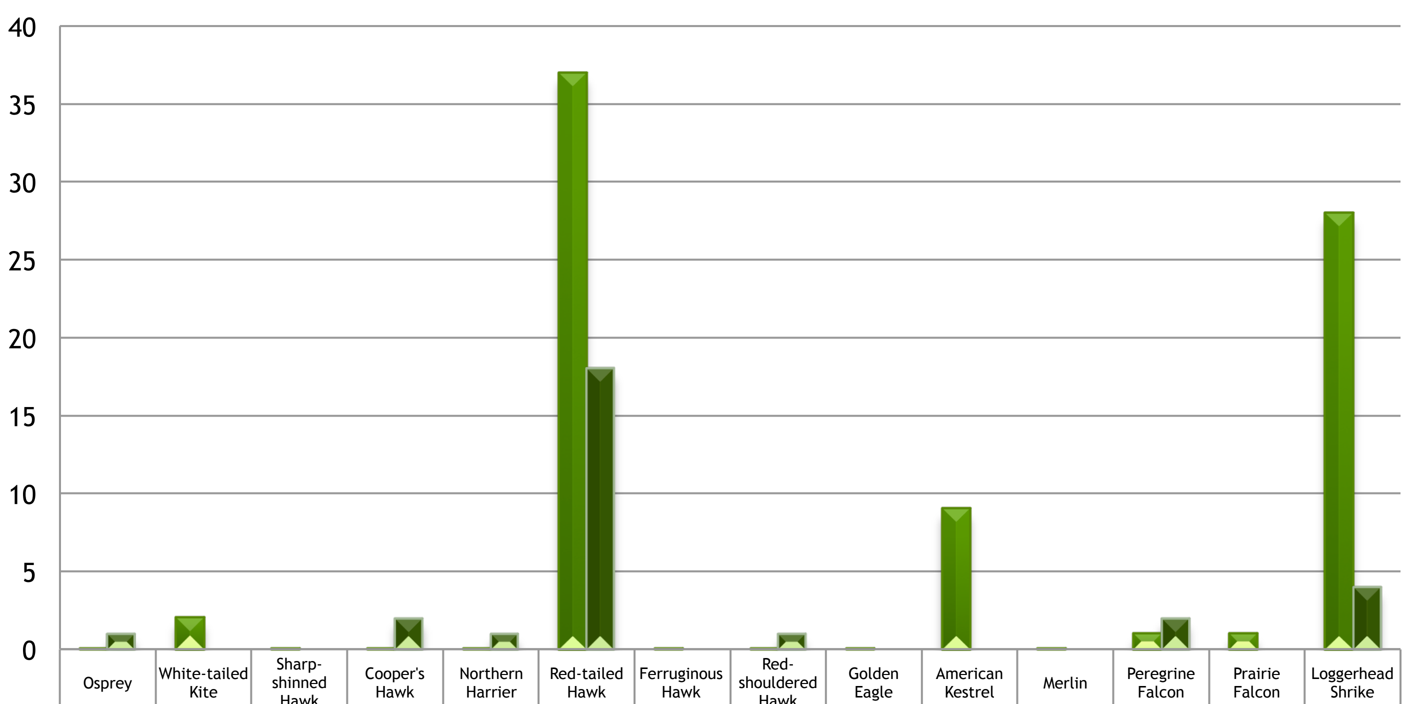
Numbers of Raptors and Shrikes Counted in Upland and Wetland Habitats: 14 December



	Osprey	White-tailed Kite	Sharp-shinned Hawk	Cooper's Hawk	Northern Harrier	Red-tailed Hawk	Ferruginous Hawk	Red-shouldered Hawk	Golden Eagle	American Kestrel	Merlin	Peregrine Falcon	Prairie Falcon	Loggerhead Shrike
Upland Habitats	0	1	1	1	11	40	0	0	0	13	1	0	4	36
Wetland Habitats	3	2	0	0	13	45	0	2	0	4	0	1	0	6

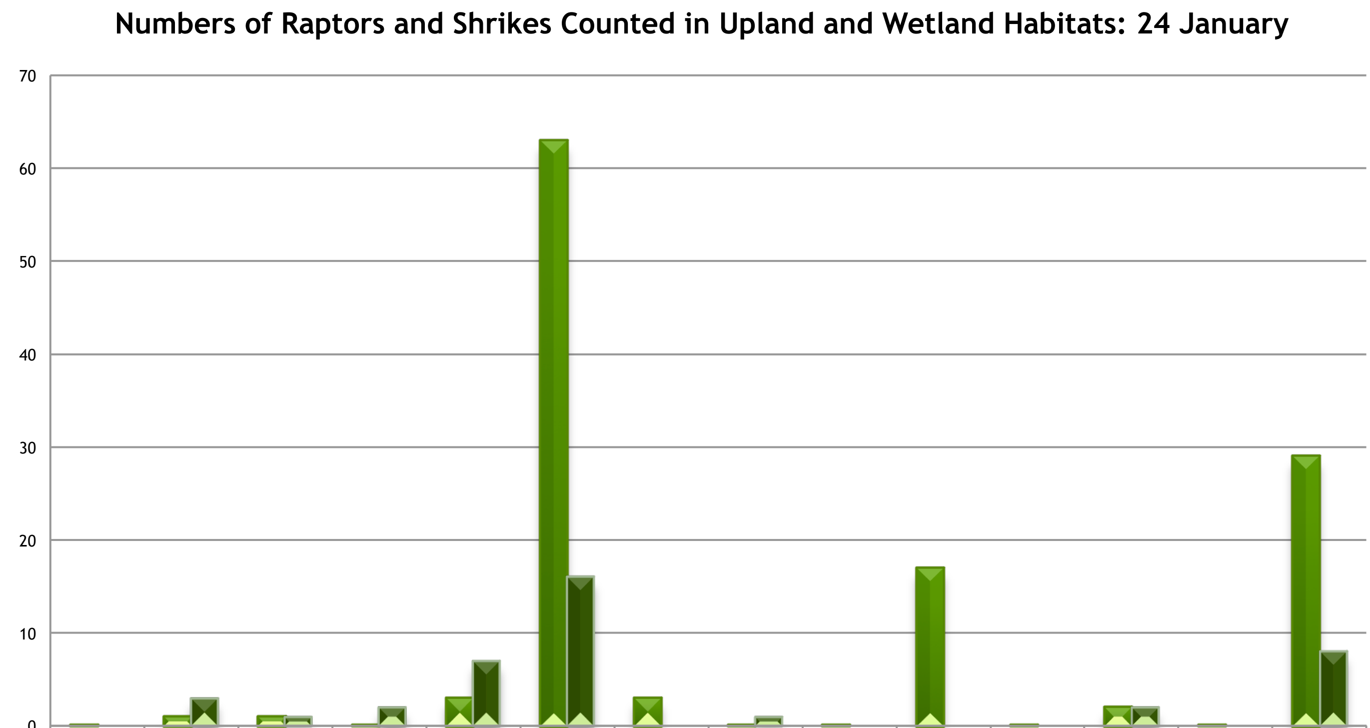
Figure 13. Results of the Raptor Survey on 9 January 2012.

Numbers of Raptors and Shrikes Counted in Upland and Wetland Habitats: 9 January



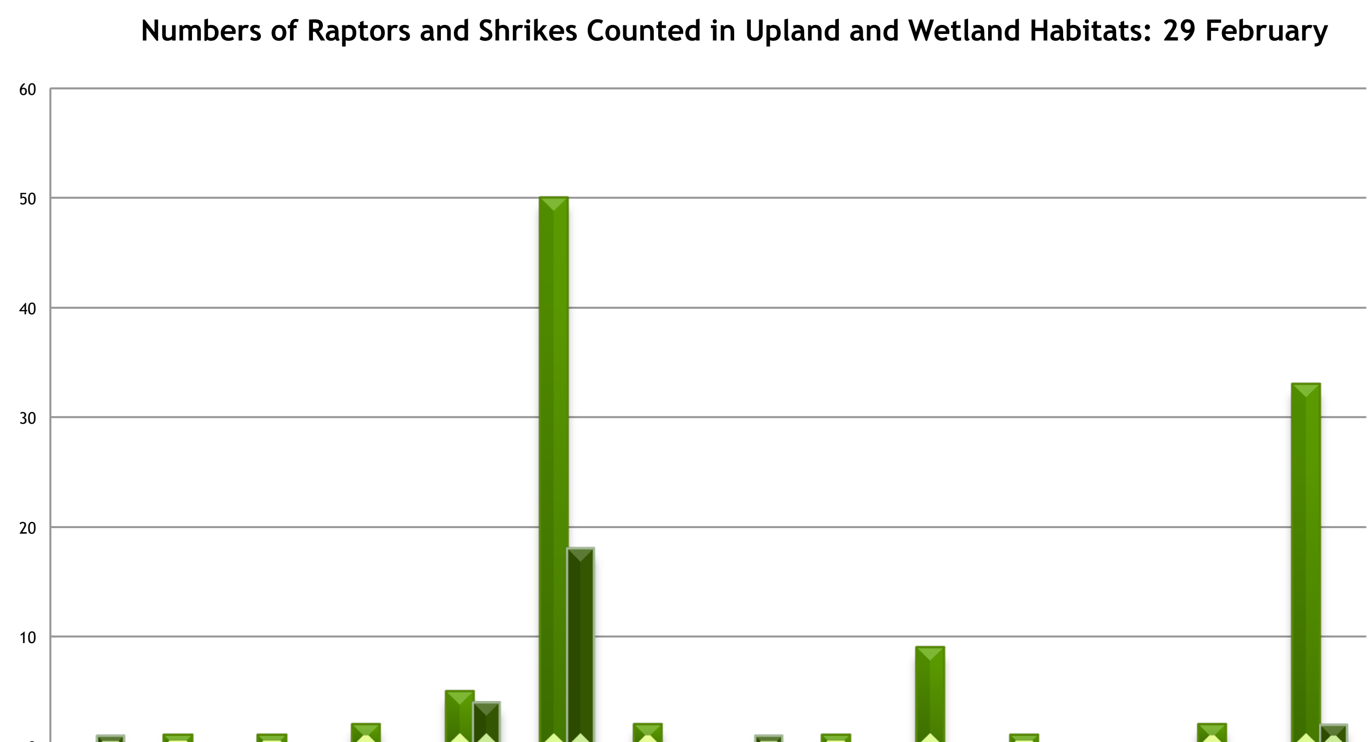
	Osprey	White-tailed Kite	Sharp-shinned Hawk	Cooper's Hawk	Northern Harrier	Red-tailed Hawk	Ferruginous Hawk	Red-shouldered Hawk	Golden Eagle	American Kestrel	Merlin	Peregrine Falcon	Prairie Falcon	Loggerhead Shrike
Upland Habitats	0	2	0	0	0	37	0	0	0	9	0	1	1	28
Wetland Habitats	1	0	0	2	1	18	0	1	0	0	0	2	0	4

Figure 14. Results of the Raptor Survey on 24 January 2012.



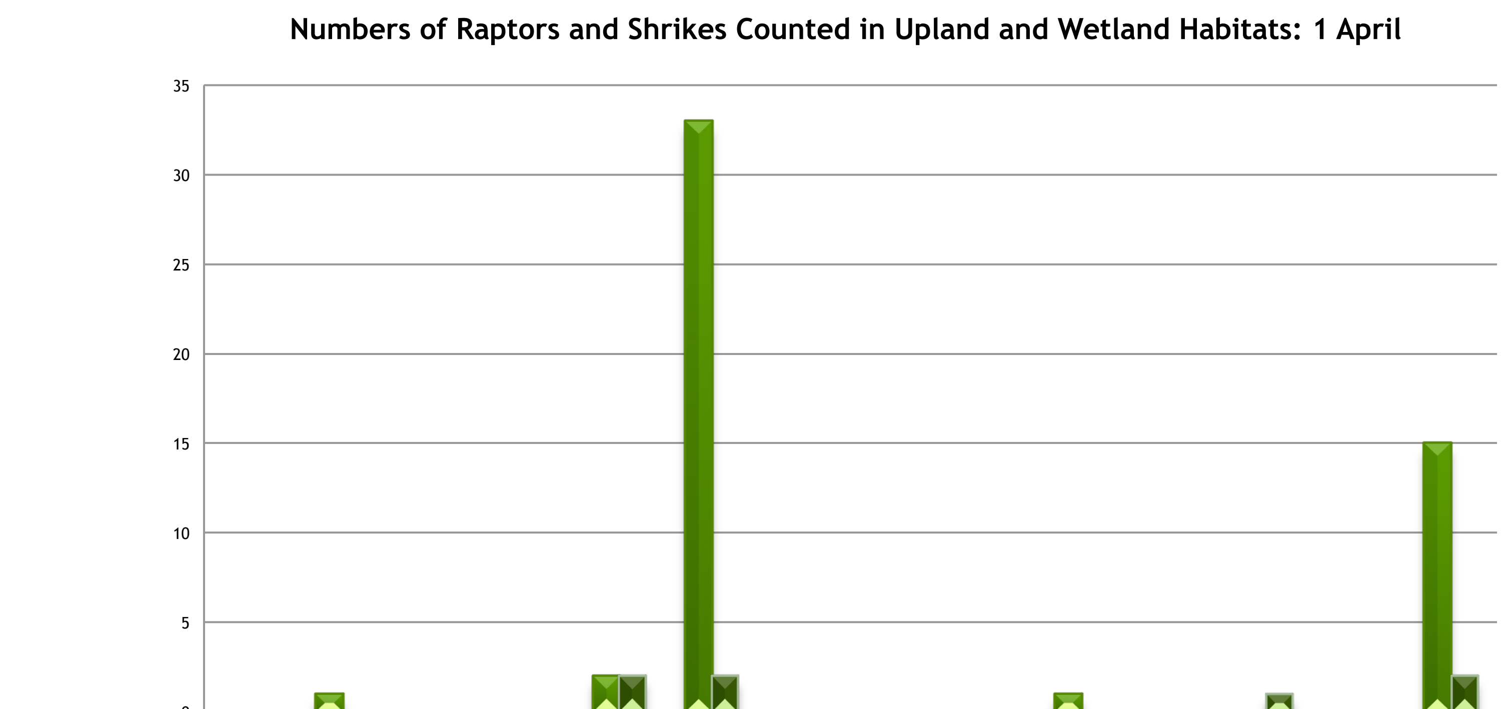
	Osprey	White-tailed Kite	Sharp-shinned Hawk	Cooper's Hawk	Northern Harrier	Red-tailed Hawk	Ferruginous Hawk	Red-shouldered Hawk	Golden Eagle	American Kestrel	Merlin	Peregrine Falcon	Prairie Falcon	Loggerhead Shrike
Upland Habitats	0	1	1	0	3	63	3	0	0	17	0	2	0	29
Wetland Habitats	0	3	1	2	7	16	0	1	0	0	0	2	0	8

Figure 15. Results of the Raptor Survey on 29 February 2012.



	Osprey	White-tailed Kite	Sharp-shinned Hawk	Cooper's Hawk	Northern Harrier	Red-tailed Hawk	Ferruginous Hawk	Red-shouldered Hawk	Golden Eagle	American Kestrel	Merlin	Peregrine Falcon	Prairie Falcon	Loggerhead Shrike
Upland Habitats	0	1	1	2	5	50	2	0	1	9	1	0	2	33
Wetland Habitats	1	0	0	0	4	18	0	1	0	0	0	0	0	2

Figure 16. Results of the Raptor Survey on 1 April 2012.



	Osprey	White-tailed Kite	Sharp-shinned Hawk	Cooper's Hawk	Northern Harrier	Red-tailed Hawk	Ferruginous Hawk	Red-shouldered Hawk	Golden Eagle	American Kestrel	Merlin	Peregrine Falcon	Prairie Falcon	Loggerhead Shrike
Upland Habitats	0	1	0	0	2	33	0	0	0	1	0	0	0	15
Wetland Habitats	0	0	0	0	2	2	0	0	0	0	0	1	0	2

Figure 17. Total Numbers of Raptors Surveyed through the Winter 2011-12.

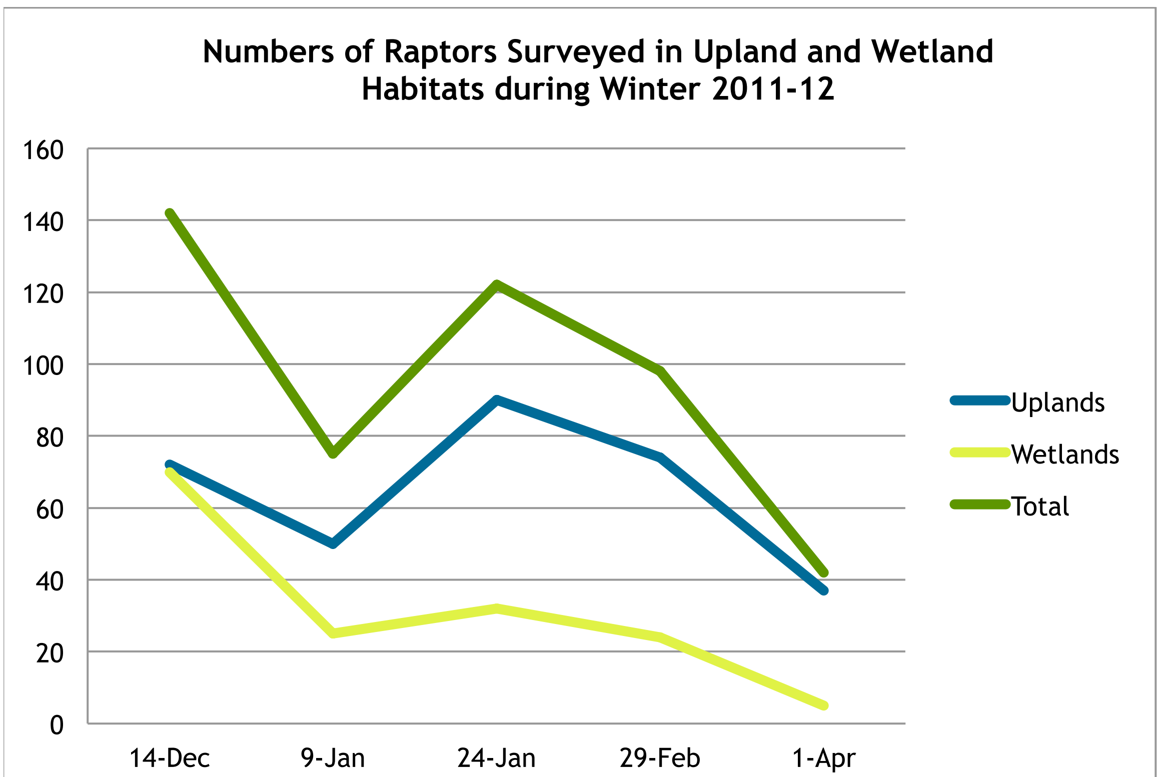
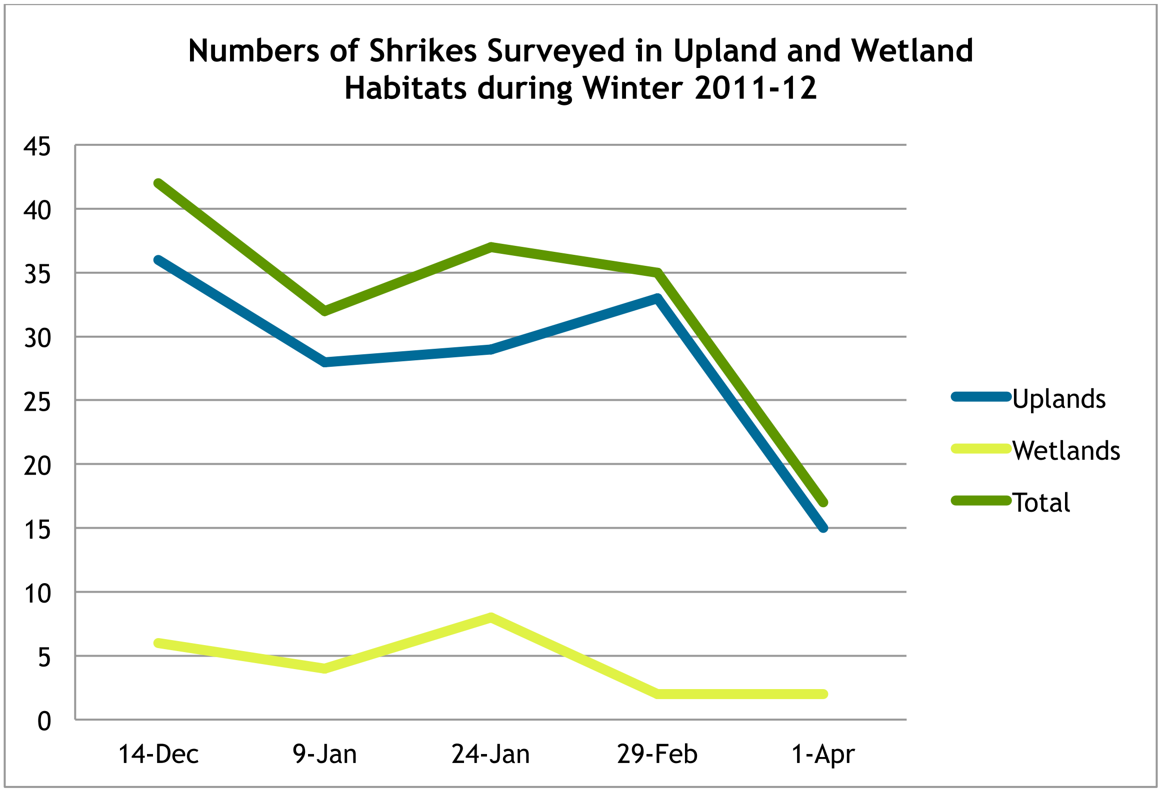


Figure 18. Total Numbers of Shrikes Surveyed through the Winter 2011-12.



Discussion

The bird use of property managed by the Kern Water Bank Authority is clearly very high in accordance to the large acreages of diverse wetland and upland habitats. Overall, in terms of bird abundance, species diversity, acreage, location and habitat diversity, it is one of the most important freshwater wetlands in California, especially when compared to other privately managed wetlands. These surveys documented particularly large populations of waterfowl, herons/egrets (late fall/early winter), raptors and shorebirds (late winter). Additionally, the wetlands of the Kern Water Bank are very important for large numbers of American White Pelicans, Double-crested Cormorants, and White-faced Ibis that visit these wetlands from throughout this region in search of concentrations of prey. Some of the population changes documented during this study may be caused by birds moving to and from other nearby wetlands, including those adjacent to the project area, the Buena Vista Lake, the Kern National Wildlife Refuge, South Wilbur Flood Control Area and other wetlands in the Tulare Basin. There is a lot to be learned about the population dynamics not only of the project area but also of this greater region in the Tulare Basin. An important topic of future study would be the annual variation in species richness, overall abundance and species use throughout the winter. From a management perspective, research exploring the relationship and seasonal dynamics of water, food and bird abundance/diversity may provide meaningful recommendations to further enhance the carrying capacity of the existing habitats. Furthermore, it would be important to monitor spring and fall migrations as well as breeding bird populations, in both wetland and upland habitats in order to more fully understand bird use of this important area. Research on ecology and seasonal movements of Loggerhead Shrikes (a California Species of Special Concern and a federal Species of Conservation Concern) could provide significant and valuable information on this species that has not been studied much in the Central Valley and California. The project area has a large enough population to warrant such a study.

Appendix D

Waterbird, Raptor, and Upland Bird Survey Report for Kern Water Bank


Great Egret (*Ardea alba*)

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Sterling Wildlife Biology

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Kern Water Bank

Waterbird, Raptor and Upland Bird Survey Report: August 2012 – May 2019

23 May 2019

Introduction

The property managed by the Kern Water Bank Authority supports a wealth of native wildlife, especially an abundance of upland birds and raptors attracted to the recharge ponds and/or the upland habitats. In order to document and quantify this natural resource value, John Sterling of Sterling Wildlife Biology conducted bird surveys from late August 2012 to May 2019. These surveys are intended to capture a snapshot of the bird use of the project area during the winter, spring/fall migration and the breeding seasons. The resulting data serve to document the regional importance of habitats on the Kern Water Bank for raptors and upland birds during this period. Most importantly, the data describe the baseline of existing conditions that may be used to inform range management practices with regard to productive bird habitat. This baseline data will be used to measure population trends with range management enhancement and/or unmanaged changes in habitat due to the extension or end of current drought conditions.

Methods

Survey Methods

For the waterbird surveys, John Sterling visited watered ponds. The survey dates for 2011-12 were 18-19 October, 25-26 October, 15-16 November, 30 November – 1 December, 13-14 December, 23-25 January, 10-11 February, 28-29 February, 10-11 March, and 8-9 April; for 2017 were 21-22 January, 3-4 February, 23-24 February, 14-15 March, 23-24 March, 1-2 April, 9-10 April, 21-22 April, 3-4 May, 11-12 May, 1 October, 19 October, 2 December; for 2018 were 17 January, 16 February, 20 March; and for 2019 only one visit (1 April) due to fluctuations of ponds. Each pond was labeled in the datasheet according to the name on the map provided by the Kern Water Bank Authority. One pond was not marked on the map and was labeled CX for this study. For each pond, Mr. Sterling counted all individuals for species with fewer than one hundred individuals. For species with larger numbers of individuals, he made estimates by counting in increments of ten or one hundred. All watered ponds were visited in all surveys. All data were entered into Microsoft Excel spreadsheets (See attached Appendix A excel file).

For the raptor/Loggerhead Shrike and upland bird surveys, John Sterling visited the sites approximately every two weeks for a total of 162 raptor/Loggerhead Shrike and 130-132 upland bird surveys. The dates of the surveys were approximately every two weeks starting on 31 August 2012 to 4 May 2019, with breaks in June and July in some years. Raptor/Loggerhead Shrike surveys were conducted in June and July only in 2015—2018. Upland bird surveys were not conducted during much of the summer period as most nesting had been completed by 31 May and there were few birds remaining on the study area until fall migration began in September. Upland bird surveys were conducted on fixed, one-half mile long transects (Figure 1). Mr. Sterling conducted upland bird surveys by walking transects and recording all birds heard or seen within 200 meters of the transect line. He tabulated the numbers of each species. Transects were 0.5 miles long with the exception of Transect G, which was 0.25 miles long due to the small size of that habitat fragment. For one hundred and sixteen of raptor surveys, Mr. Sterling drove most roads to cover the entire project area and kept running tallies of numbers of individuals of all raptor species and Loggerhead Shrike. All data were compiled onto spreadsheets (See attached Appendix B & C files).

Figure 1. Locations of Upland Bird Survey Transects on the Kern Water Bank

Descriptions of Upland Bird Survey Transects

The following are brief descriptions of the bird habitat along each of the survey transects including photographs showing conditions on 7 June 2013.

Transect A

The transect borders a large canal that is watered and supports a few water birds. As such, it also supports tules and some sunflowers and other ruderal plants along its edge. There are several large willow trees (*Salix sp.*) but the habitat is mostly open, ruderal fields with some tumbleweed cover (*Salsola* sp.). During wet years, the ruderal vegetation is rank and relatively tall (up to 4 ft).

Transect B
This transect borders a canal that was watered until spring 2012. It supports several willow trees along its banks along with mulefat, thistles and other ruderal vegetation. The fields are dry ponds and support ruderal vegetation.

Transect C
This transect is a honey mesquite (*Propospis glandulosa*) woodland with some tree tobacco, annual grasses and some ruderal vegetation.

Transect D
The west side of this transect is a dry pond that is now an open willow woodland with moderate ruderal and annual grassland cover. The east side is a dry pond that is now a ruderal field with low, sparse vegetative cover.

Transect E
This transect has a honey mesquite woodland on the south side, with some annual grasses, but otherwise little vegetative cover apart from the mesquite. On the north side is a dry pond that is a ruderal field.

Transect F
This transect is relatively barren with some grasses, forbs and in some years dominated by tumbleweed.

Transect G
This transect has several honey mesquite shrubs on the east side, but the west side is dominated by saltbush (*Atriplex sp.*).

Transect H
This transect has some Fremont cottonwood saplings, along with an open honey mesquite woodland and tall ruderal vegetation on the west side. The east side is a dry pond and now a ruderal field.

Transect I
This transect has two small willow trees in a field dominated by tumbleweed on the south side, while the north side is an alfalfa field on property adjacent to the project area.

Special-Status Species Criteria

In evaluating the potential presence of special-status species, the following criteria were used to determine which species should be included:

- Bird species listed, or proposed for listing, as threatened or endangered under the ESA (50 CFR 17.11 [listed animals], and various notices in the Federal Register [proposed species]);
- bird species that are candidates for possible future listing as threatened or endangered under the ESA (61 FR 40: 7596-7613, February 28, 1996);
- bird species listed, or proposed for listing, by the State of California as threatened or endangered under CESA (14 CCR 670.5);
- bird species that meet the definitions of rare or endangered under CEQA (CEQA Guidelines, Section 15380);
- bird species of special concern to CDFG (CDFG in preparation [birds, Shuford and Gardali 2008];
- bird species fully protected in California (California Fish and Game Code, Section 3511 [birds]; and
- bird species included in CDFG's list of special animals and monitored by the California Natural Diversity Database (CNDDB).

Results

Two hundred and twelve species of birds have been recorded thus far at the Kern Water Bank during water bird, upland bird and raptor surveys since this project began in mid October 2011 (Appendix A). Many of those are discussed below or in the previous reports (Sterling Wildlife Biology, 27 April 2012, 9 December 2013, 1 June 2015, 23 May 2016, 11 June 2017 and 26 June 2018).

Upland Birds

One hundred and twelve species of birds were detected during the upland bird surveys. Of the nine transects, Transects A and C have the largest number of species with eighty-two and seventy-nine, respectively (Figure 2). Although species richness (number of species) did not vary greatly over time in each transect, numbers of birds counted fluctuated greatly (Figures 3-11). Transects with the most birds contained mesquite and/or willow trees although Transect I with its grassland and alfalfa harbored large numbers of sparrows during the winter. Each year additional species are found in each transect, so it is likely that more species will continue to be documented.

Figure 2. Cumulative Number of Species Found in Each Transect: 2012-2019

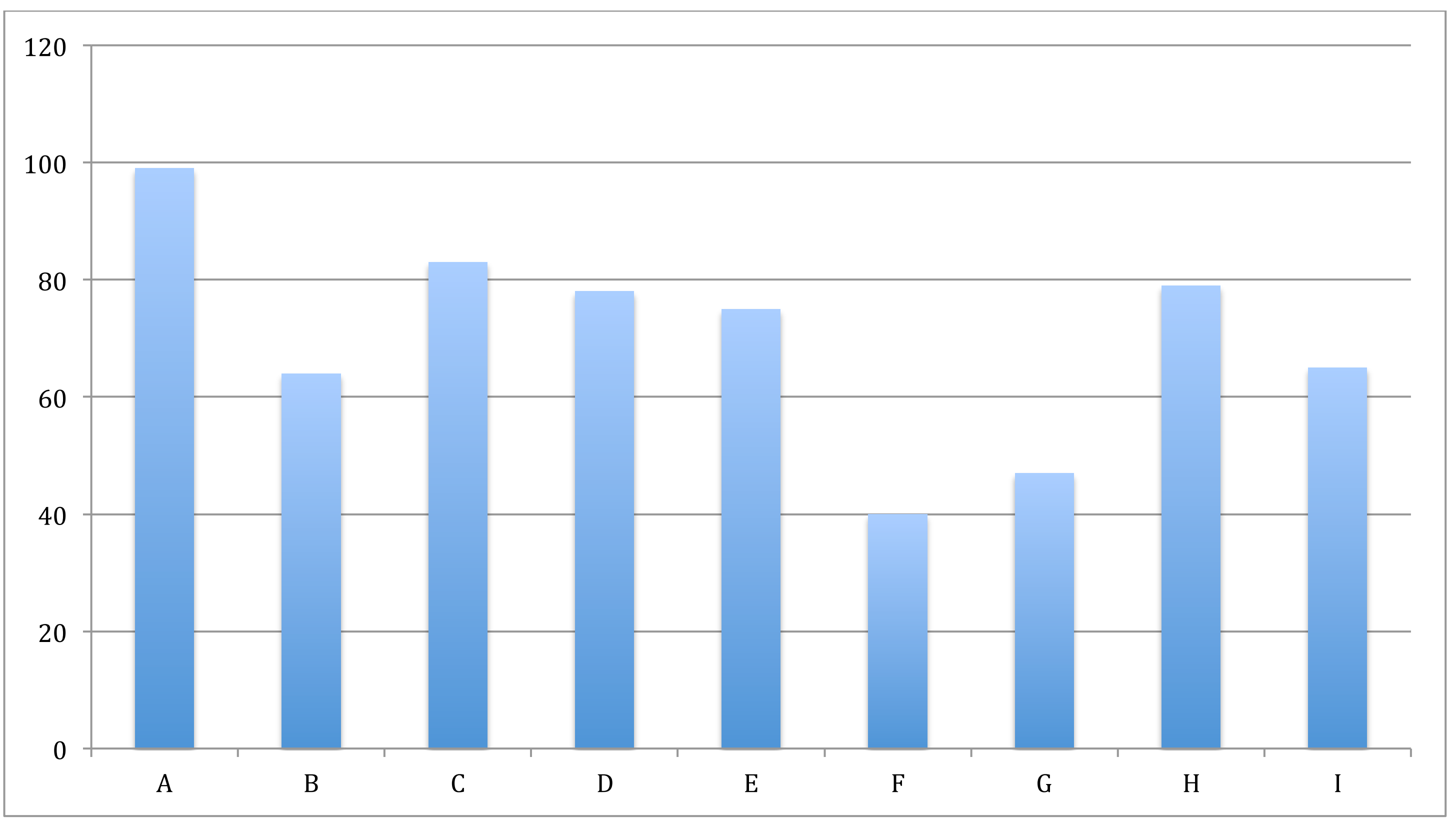


Figure 3. Mean Number of Birds Found During Each Survey in Each Transect: 2012-2019

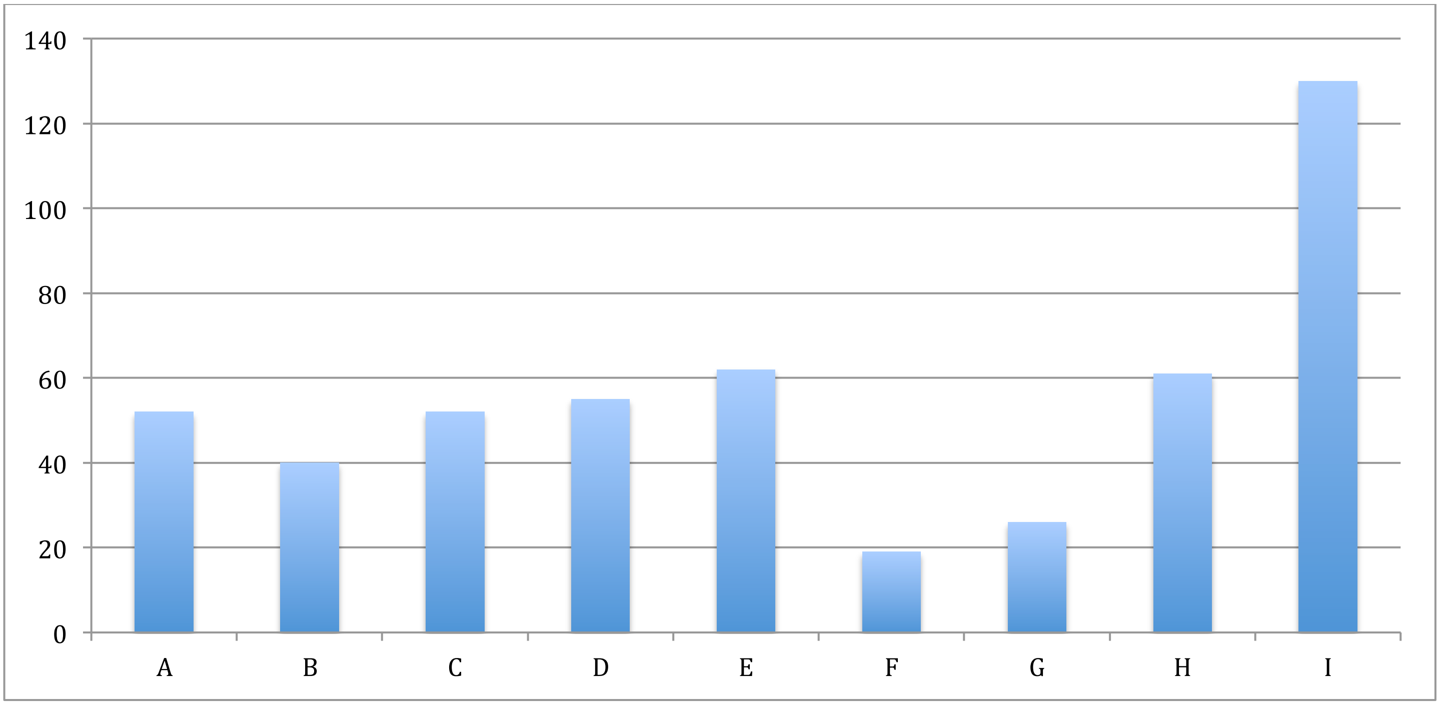


Figure 4. Number of Birds and Bird Species: Transect A.

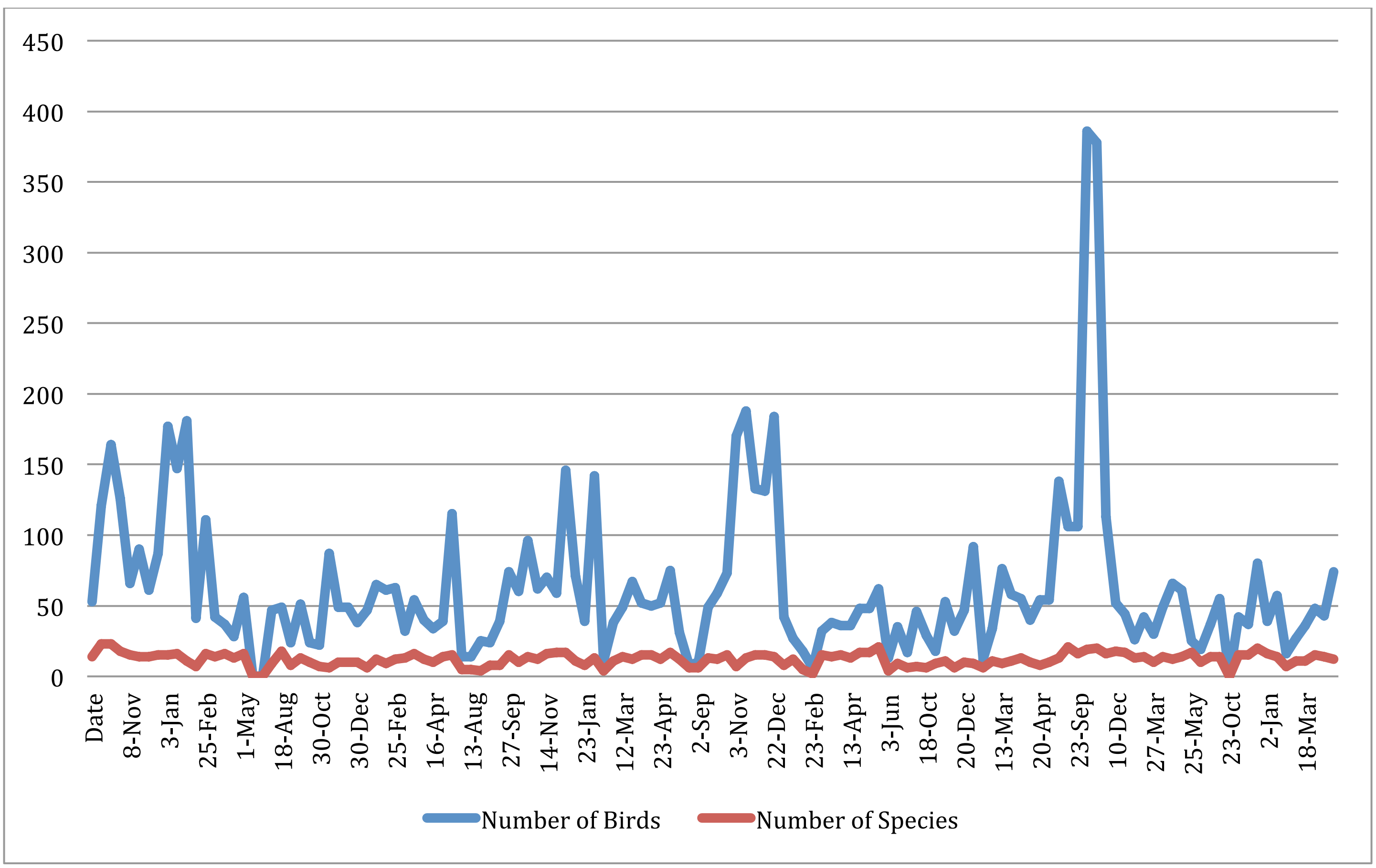


Figure 5. Number of Birds and Bird Species: Transect B.

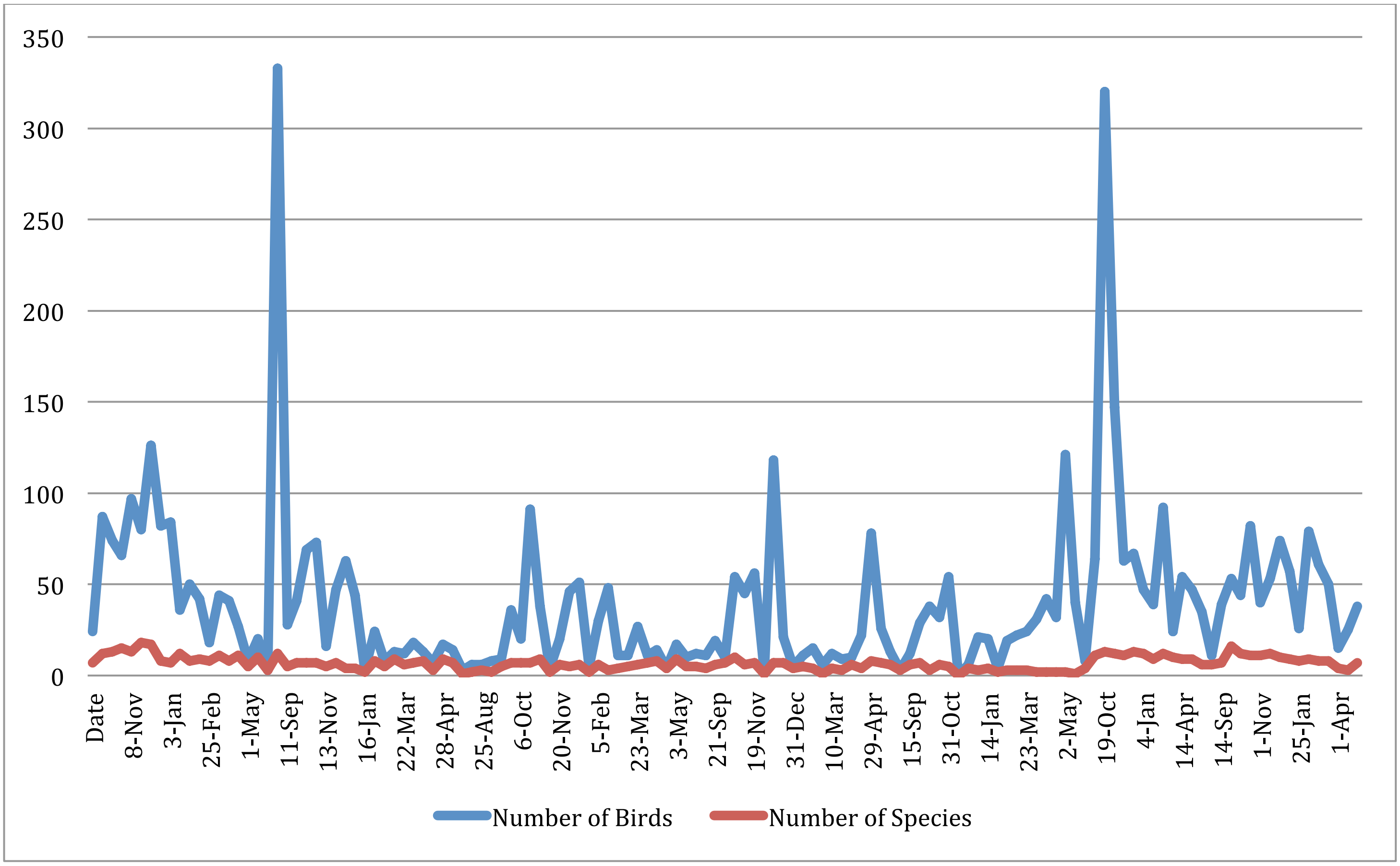


Figure 6. Number of Birds and Bird Species: Transect C.

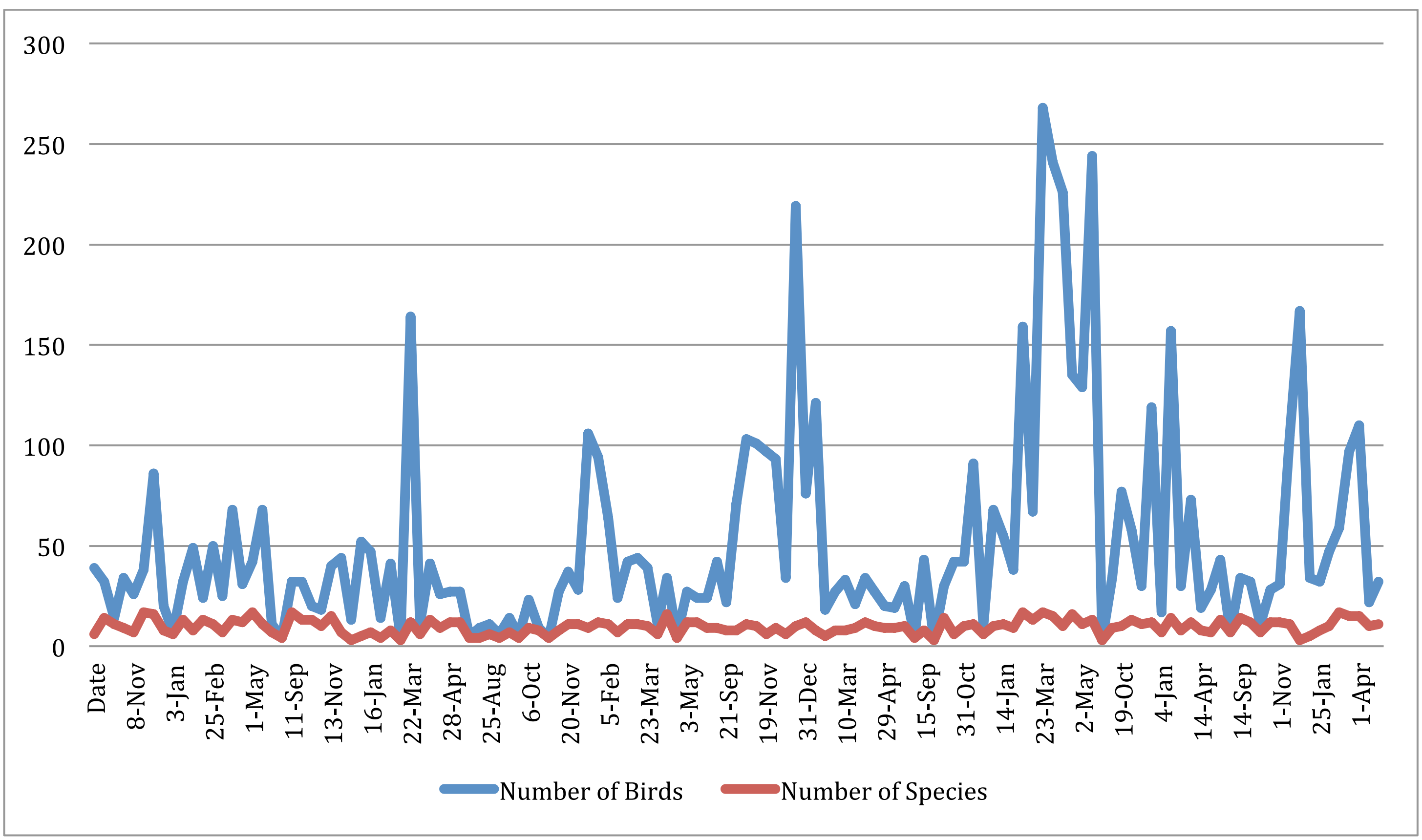


Figure 7. Number of Birds and Bird Species: Transect D.

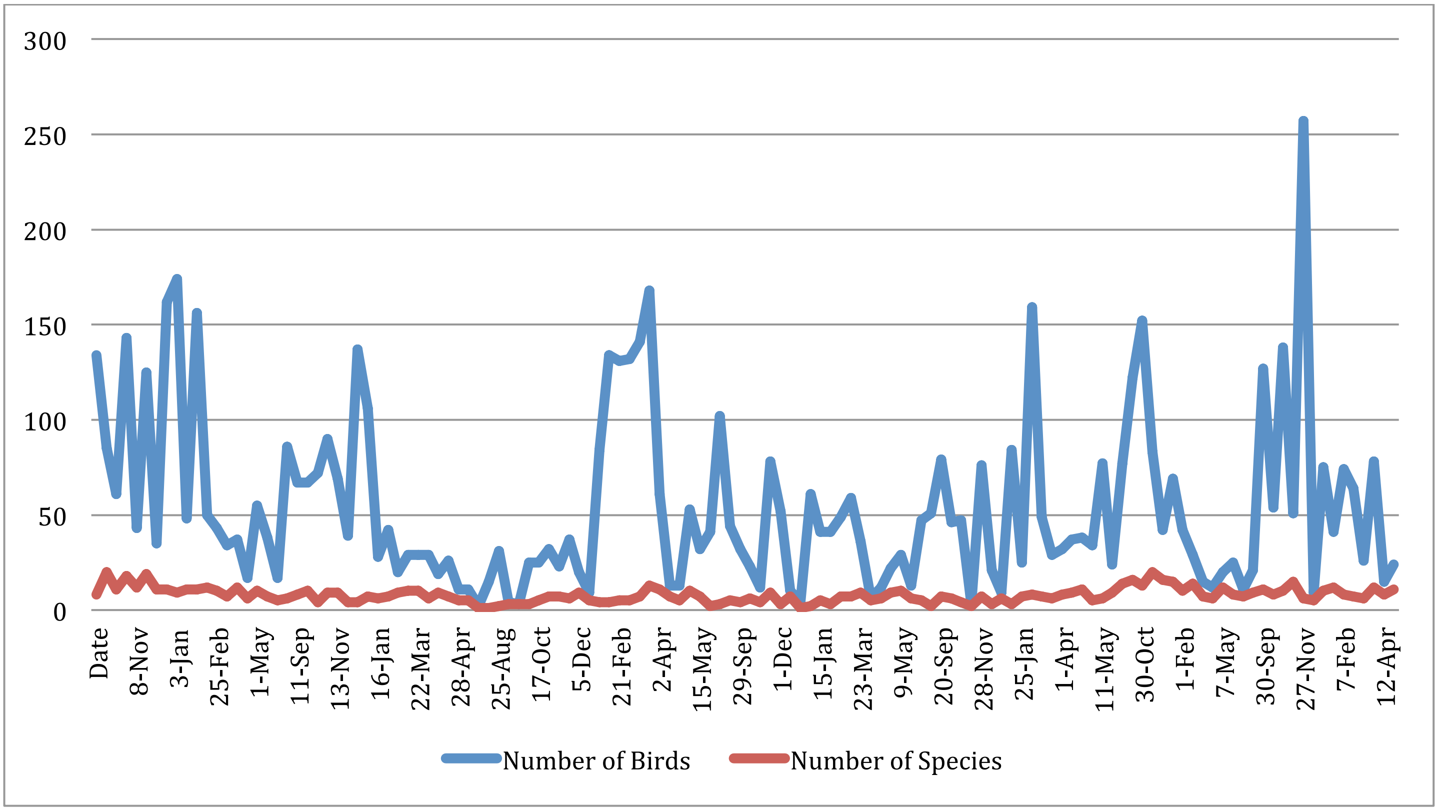


Figure 8. Number of Birds and Bird Species: Transect E.

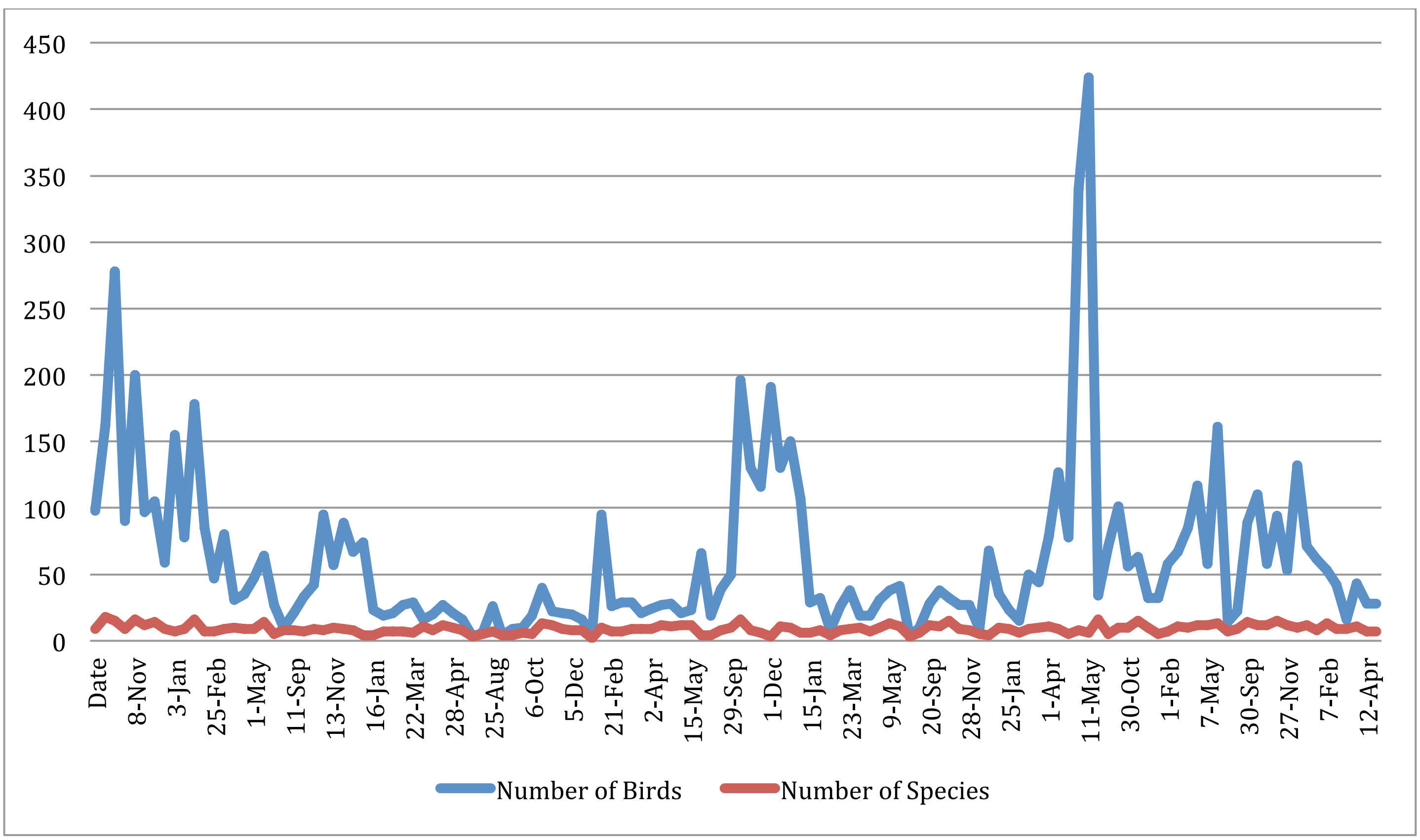


Figure 9. Number of Birds and Bird Species: Transect F.

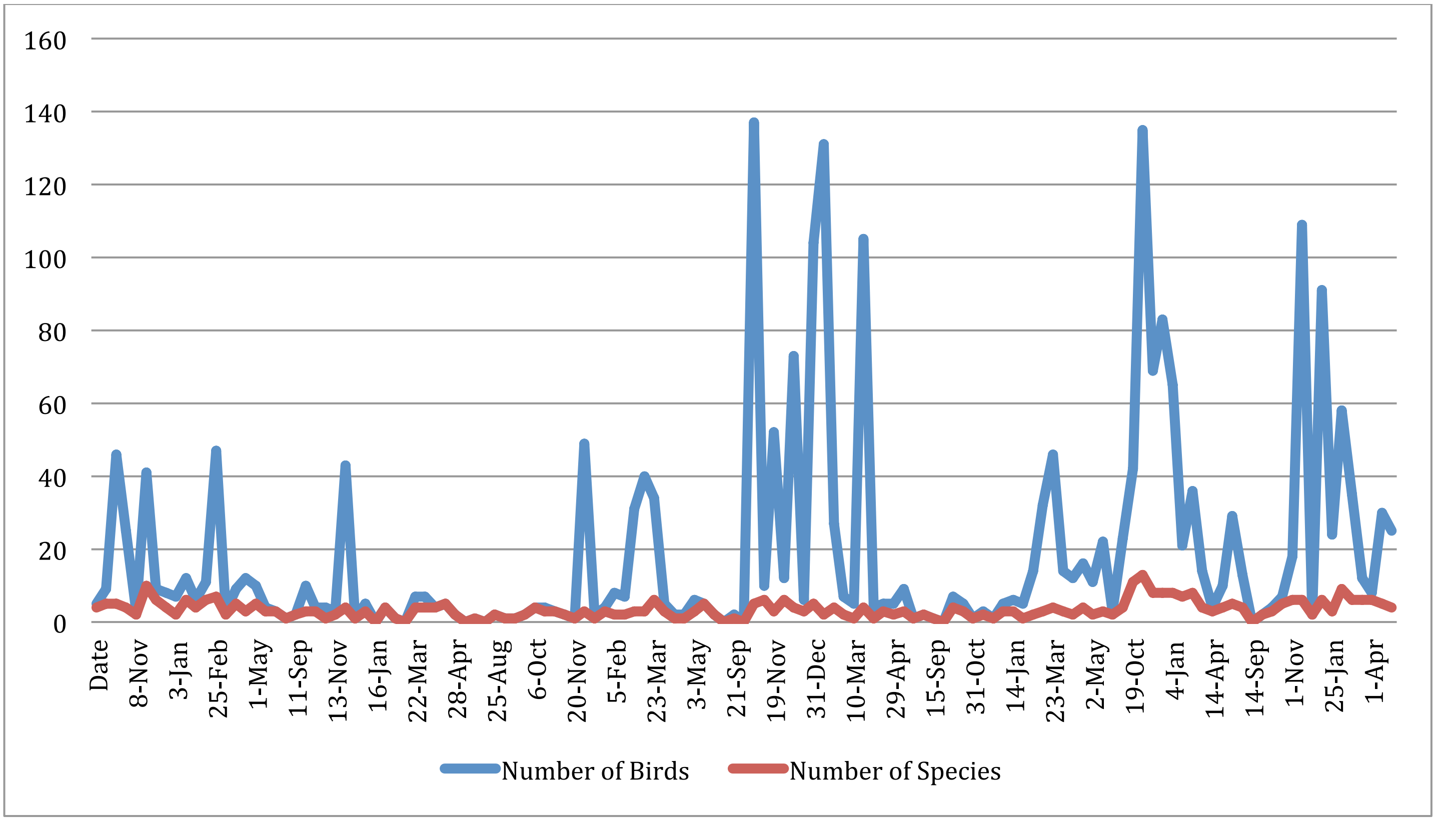


Figure 10. Number of Birds and Bird Species: Transect G.

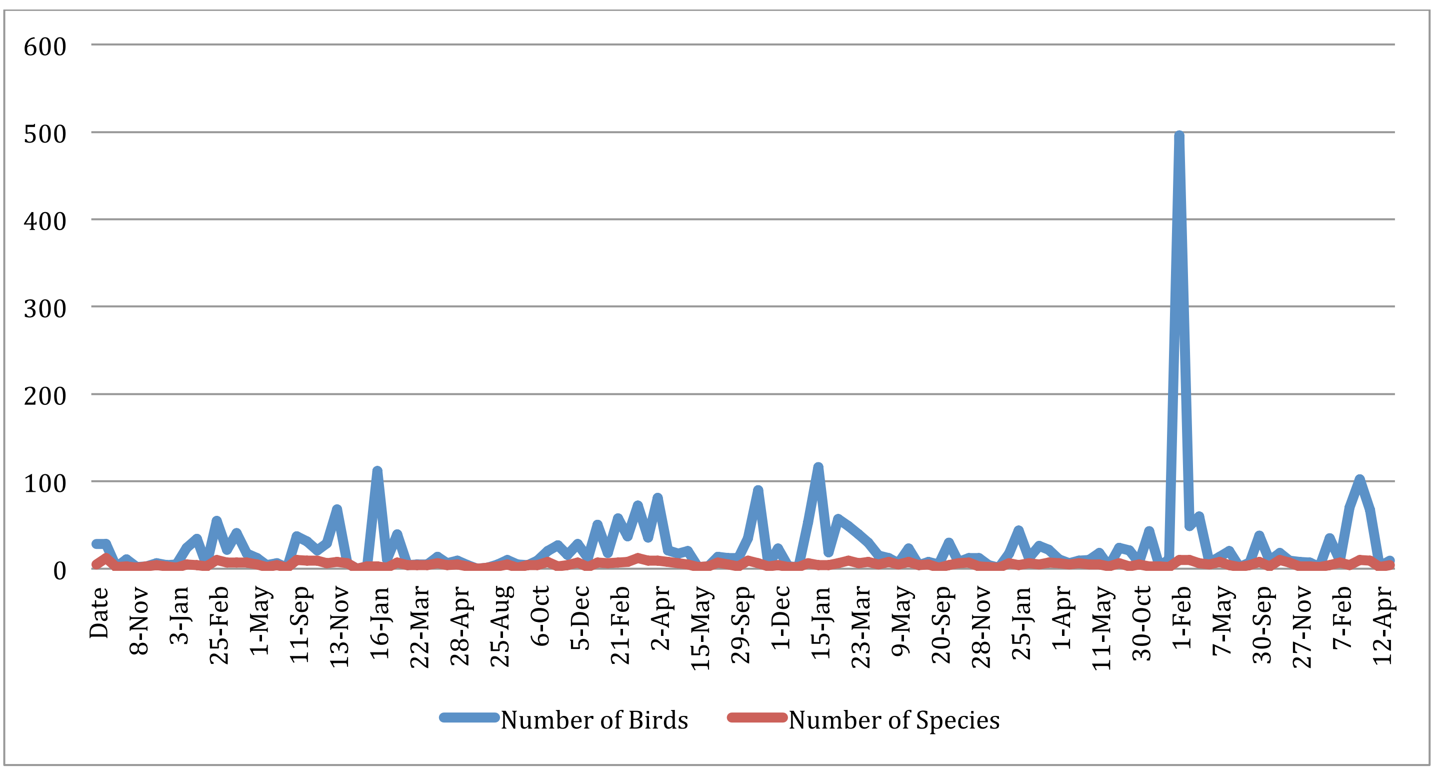


Figure 11. Number of Birds and Bird Species: Transect H.

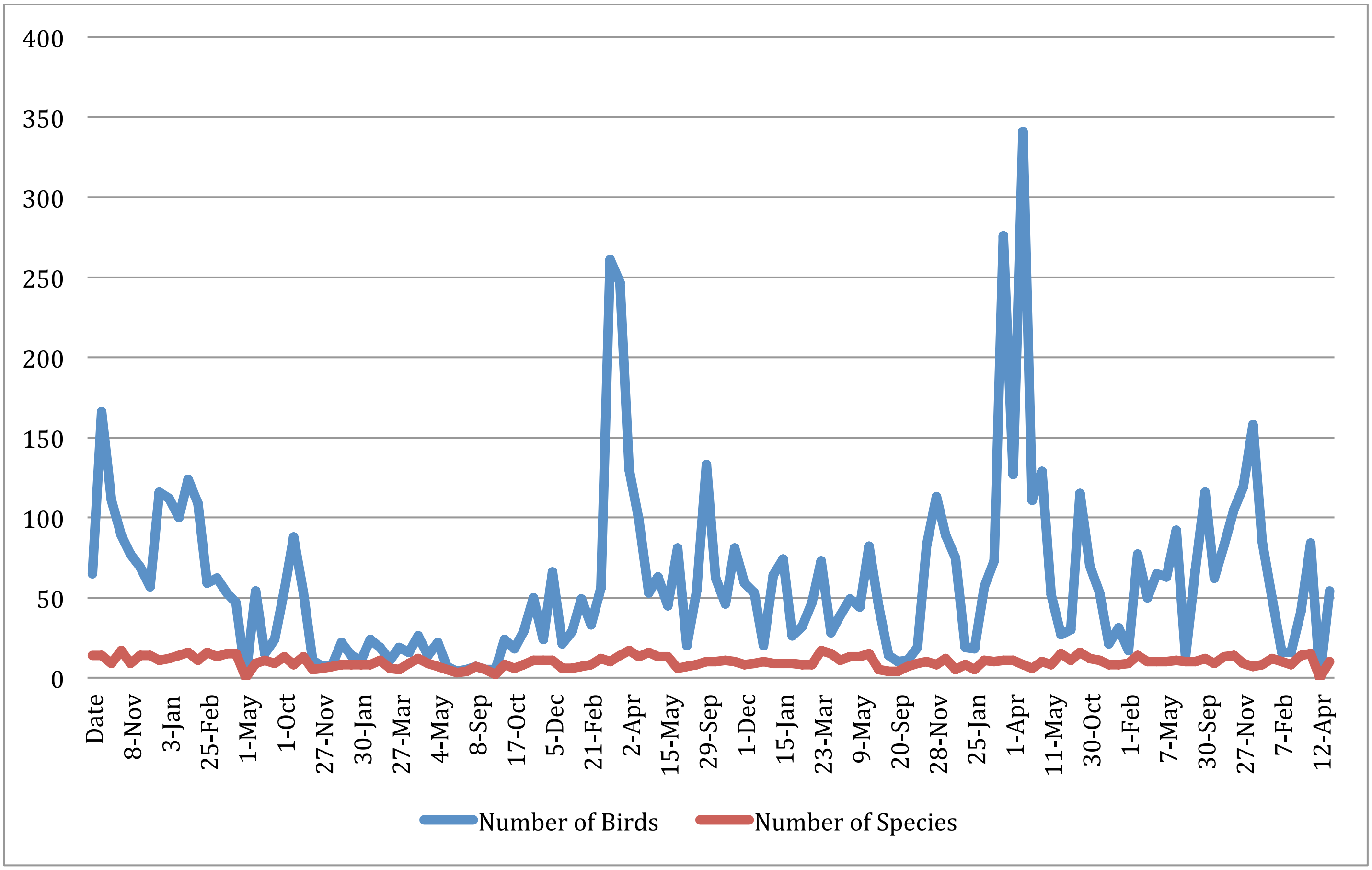
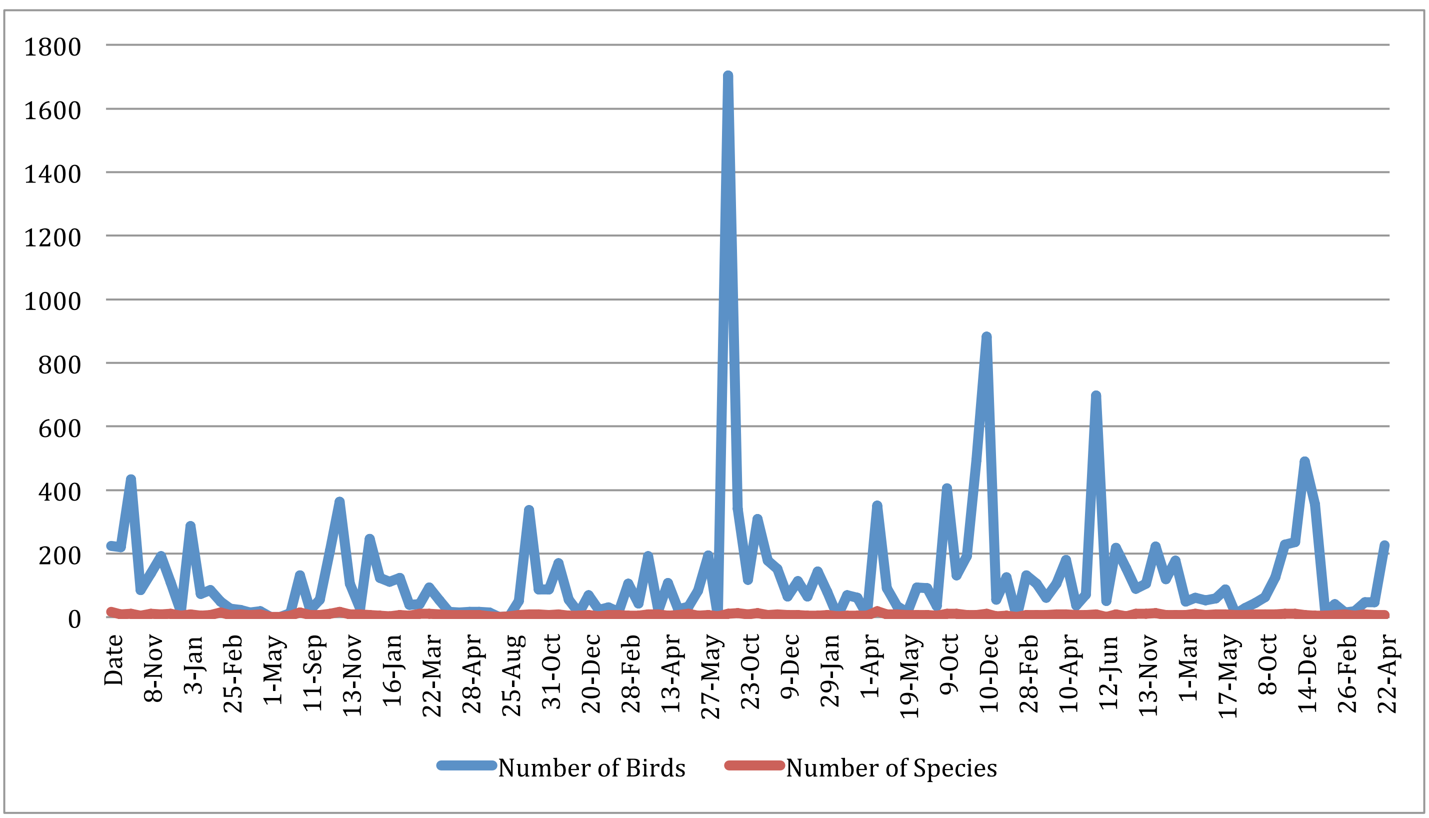


Figure 12. Number of Birds and Bird Species: Transect I.



Raptors and Shrikes

The comprehensive survey for raptors and Loggerhead Shrikes on the entire project area resulted in high numbers of raptors including Red-tailed Hawks and Loggerhead Shrikes (Figures 12-13), but also documented fifteen species of raptors using upland habitats during the surveys (Appendix B). Overall numbers of raptors dipped sharply after the winter of 2012-2013 and then steadily decline to fewer than twenty individuals from February 2014 through May 2015, then consistently over twenty from October 2015 to March 2016, and rising considerably to over sixty for much of the fall and winter of 2017-18. Conversely, Loggerhead Shrikes rebounded during the breeding season in 2015 after a similar decline (Figure 21). The increase from ten to fifty-five during a two-month period in spring 2015 was due to good reproductive success of local breeding population. The primary difference among the habitat conditions between spring of 2014 and 2015 was the lack of grasses and forbs in 2014 that resulted in low prey populations (large insects and lizards) in contrast to the tremendous amount of grasses and forbs in winter and spring of 2015. Although the amount of grasses and forbs were lower in 2016, the higher population maintained through the winter of 2015-2016 led to a higher breeding population that also had good reproductive success. The raptor and shrike populations increased dramatically during the winters of 2017-18 and 2018-19 likely due to increased populations of prey.

Figure 13. Raptor Population: 2012-2019

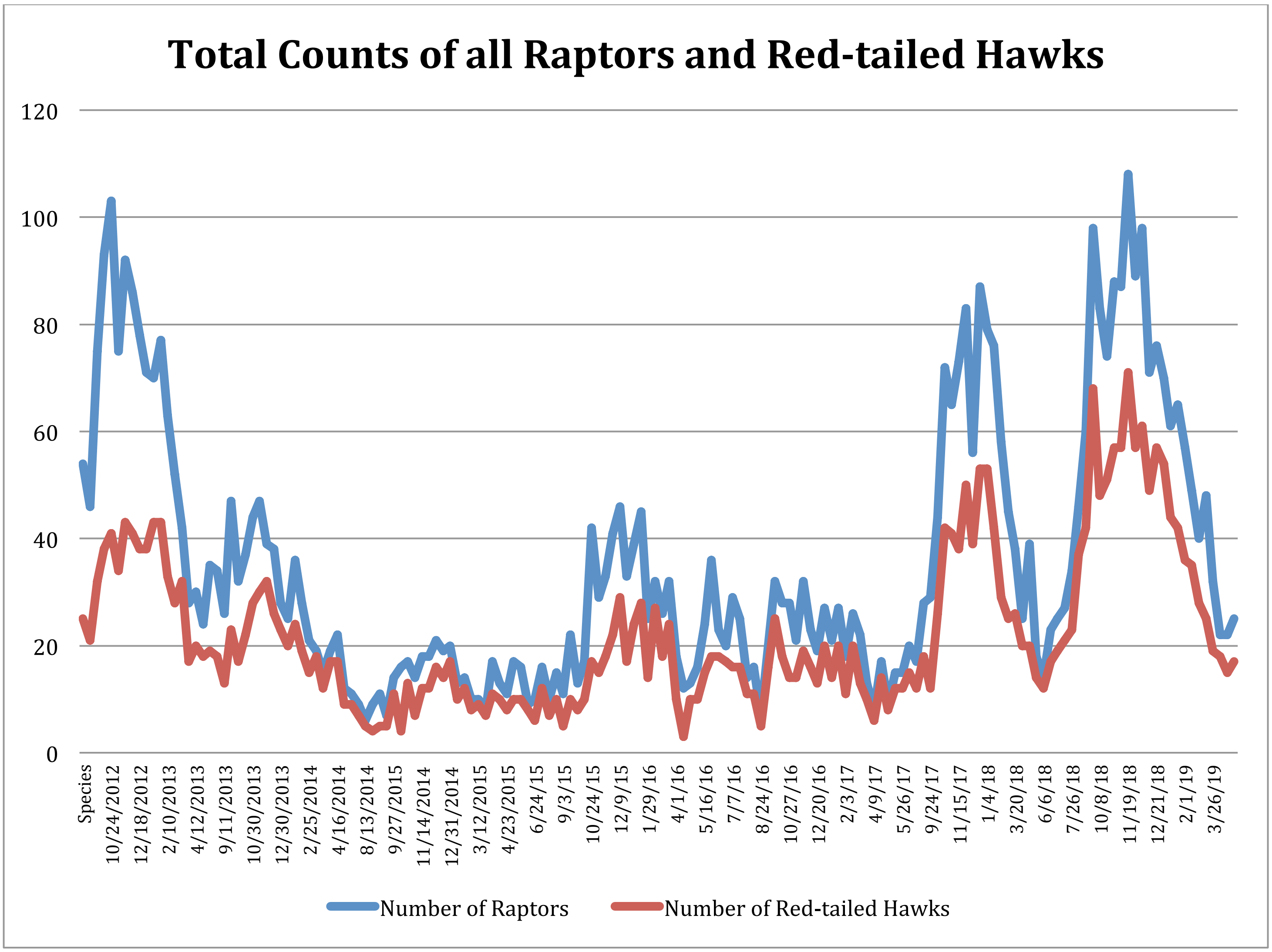
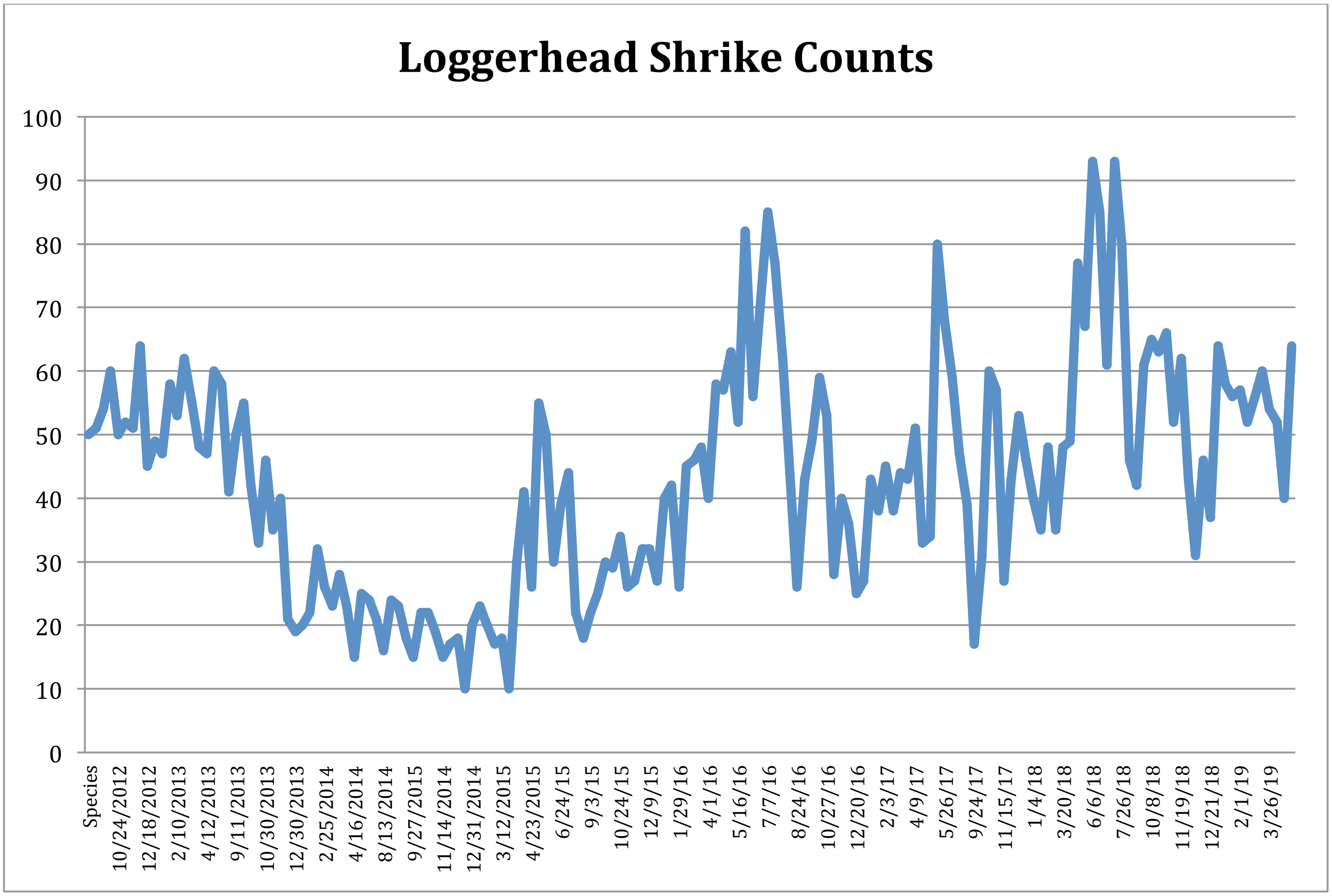


Figure 14. Loggerhead Shrike Population: 2012-2019



Waterbirds

A total of seventy-nine native waterbird species were detected during these surveys in which the number of watered ponds varied (Figures 15 - 17). Overall numbers were consistently high during the first eight survey periods (mid-October through February) with 19,823 – 34945 individuals estimated in 2011-2012. However numbers were much lower overall in early 2017 when ponds were initially watered but then peaked at 33728 in December 2017 as fish and invertebrate prey as well as aquatic vegetation dramatically increased with the re-creation of wetland habitat after five years of drought (Figure 18). The ponds were dry during the fall and early winter of 2018, but water was pumped into ponds intermittently during winter and spring of 2019. A survey on 1 April 2019 yielded 11,903 total waterbirds in 32 watered ponds (13 were dry) (Table 1).

The seventy-nine species of waterbirds are grouped according to foraging ecology and evolutionary relationships. Grebes (Figure 19), gulls and terns (Figure 20), dabbling and diving ducks (Figures 21 and 22), egrets/herons (Figure 23), and shorebirds (sandpipers and plovers) (Figure 24) were classified into separate categories. American Coot (*Fulica americana*), White-faced Ibis (*Plegadis chihi*), Double-crested Cormorant (*Phalacrocorax auritas*), and White Pelican (*Pelicanus erythrorhyncos*) were treated individually in the summary data (Figures 25-28).

The ponds that were most important for high numbers of species and populations throughout the surveys were W2, W4, W5, W6, M1, M8, and M10. But many other ponds were important (for details see Appendix excel file). The variation in ponds was dramatic with several ponds consistently having over 2,000 birds and others fewer than 100. Because of the varied topography of many of the ponds and the lack of direct measurements of water depths, it was not possible to determine average depths or the range of depths for the ponds during the surveys.

Table 1. Number of Waterbirds found in Survey During Peak Water in Winter/Spring of 2018-2019: 1 April 2019.

Total Waterbirds	11,903
Grebes	94
Herons and Egret	83
Dabbling Ducks	3,698
Diving Ducks	619
Shorebirds	206
Gulls and Terns	0
American White Pelicans	11
Double-crested Cormorants	1
White-faced Ibis	129
American Coots	7,022

Figure 15. Number of Watered and Dry Ponds: 2011-2012

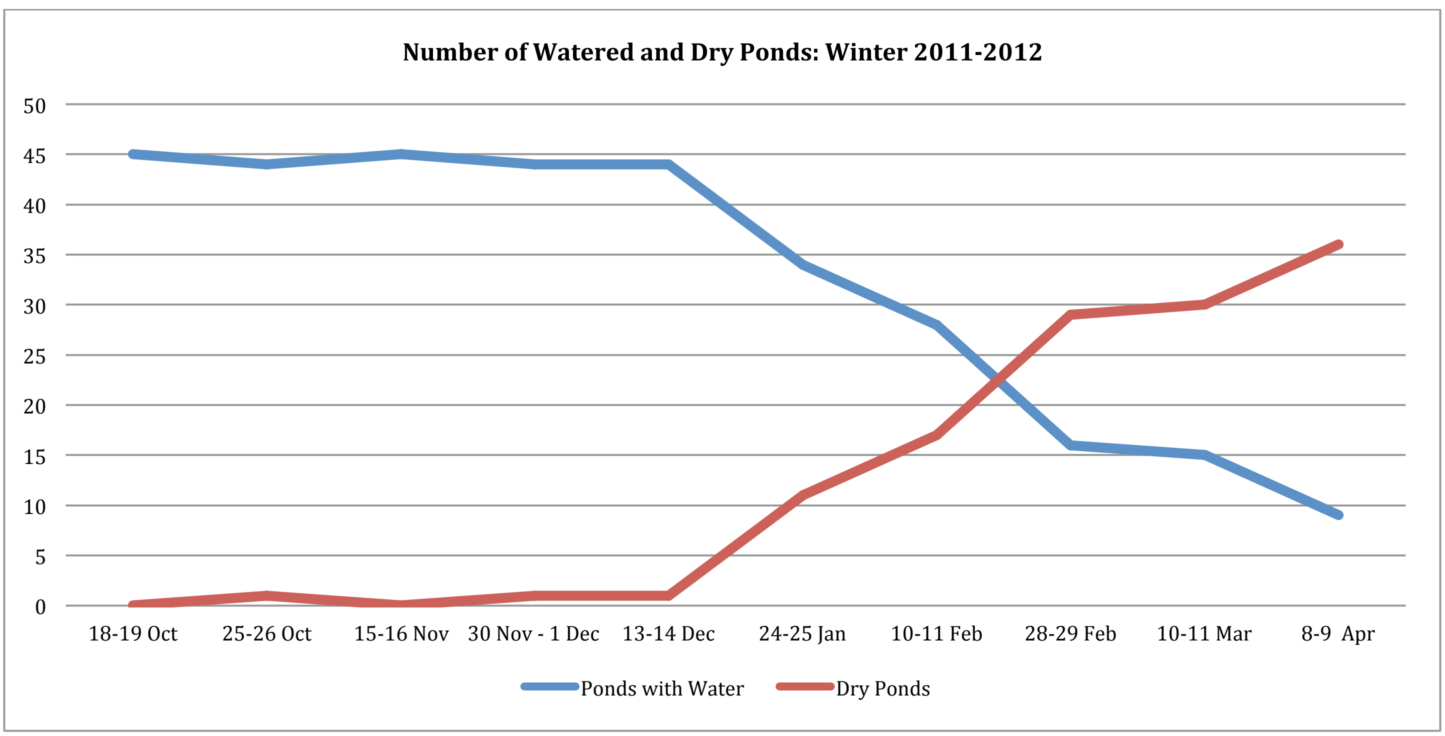


Figure 16. Number of Watered and Dry Ponds: 2017

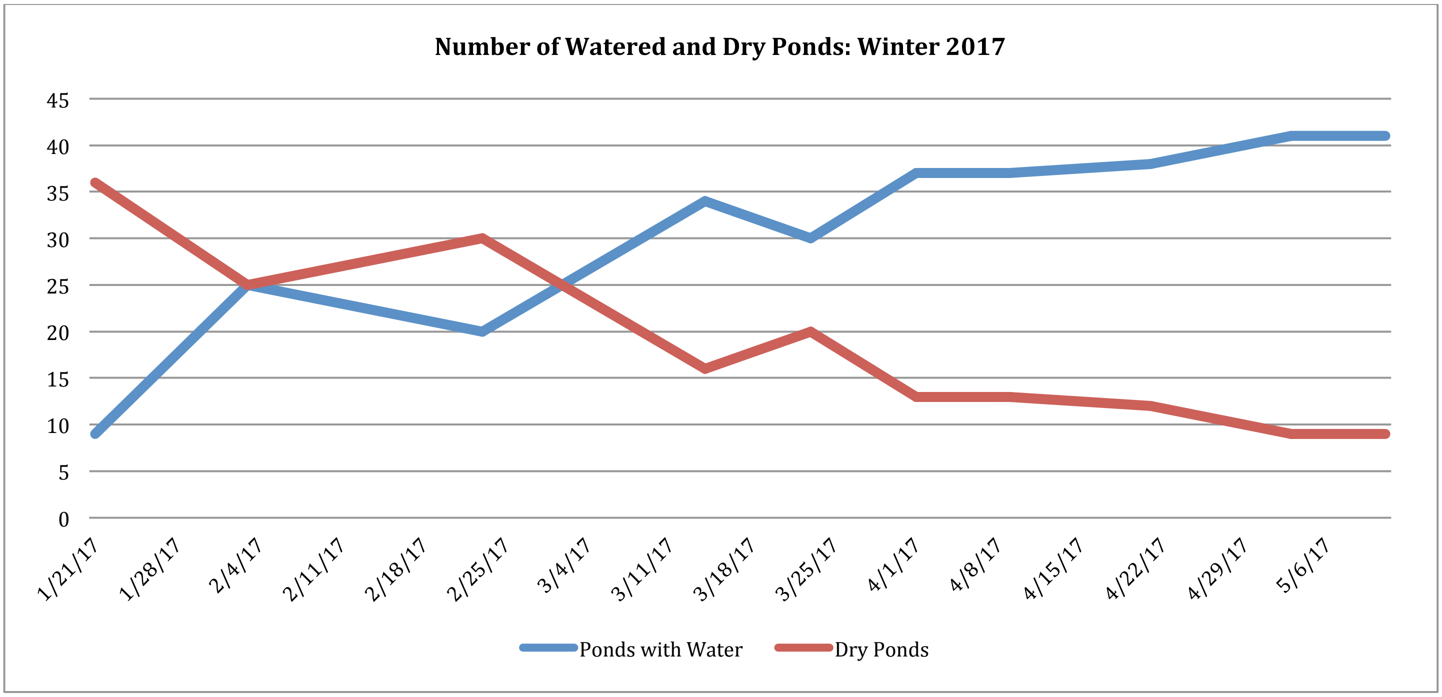


Figure 17. Number of Watered and Dry Ponds: 2018

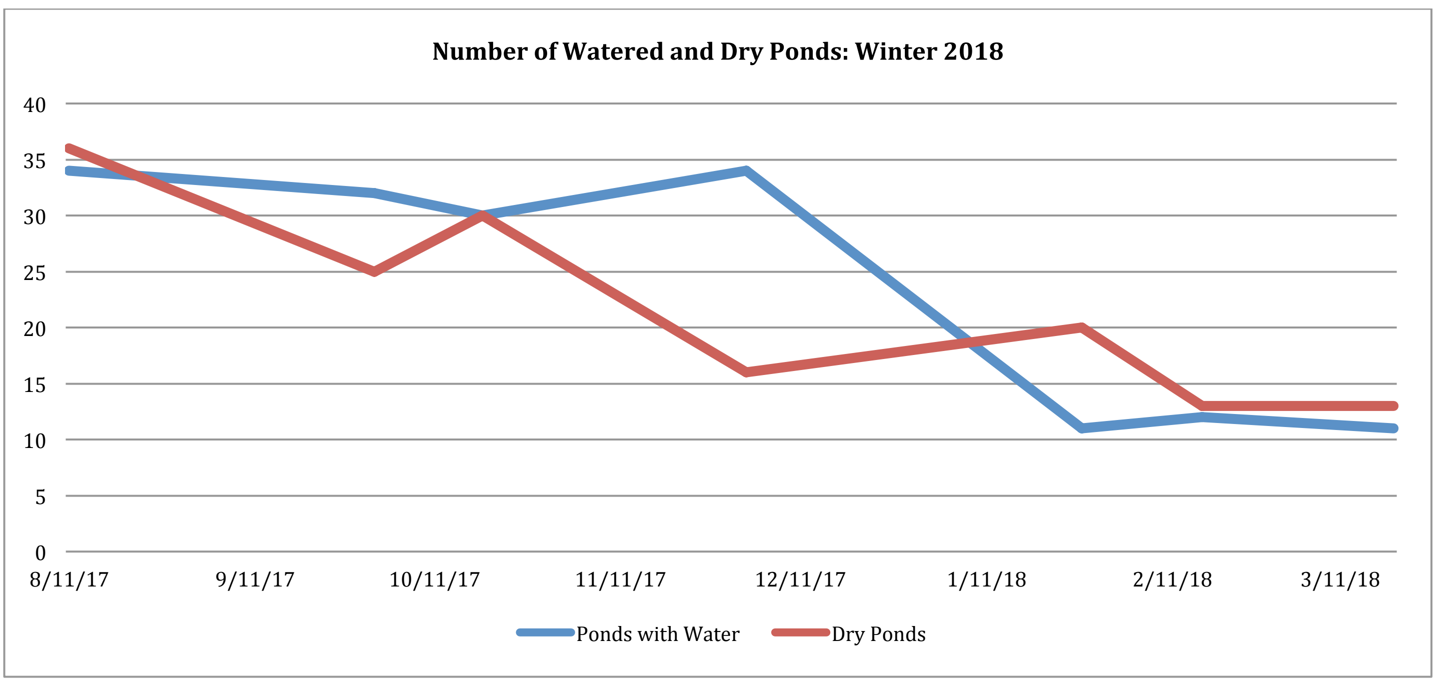


Figure 18. Total Number of Waterbirds Counted

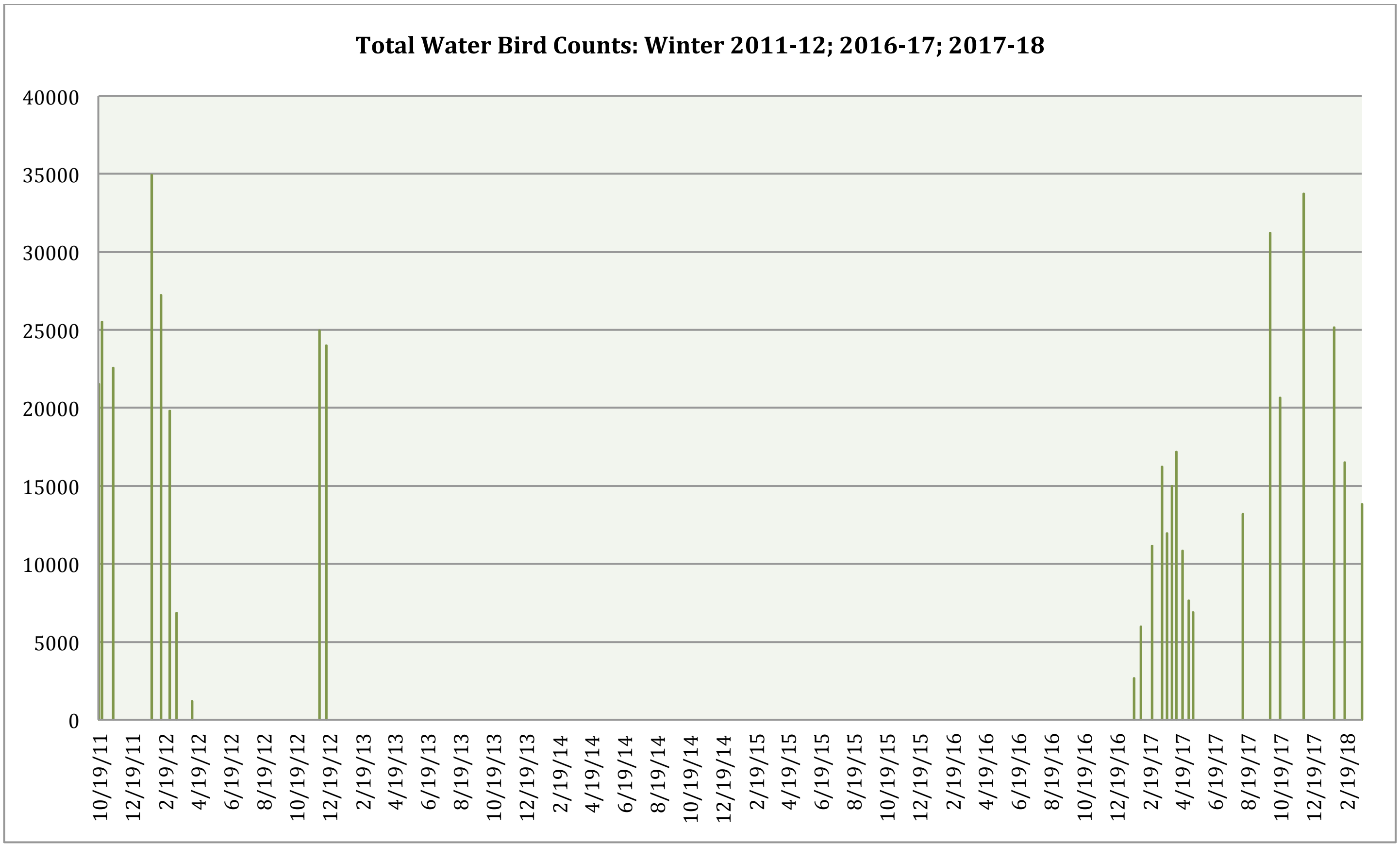


Figure 19. Total Number of Grebes Counted

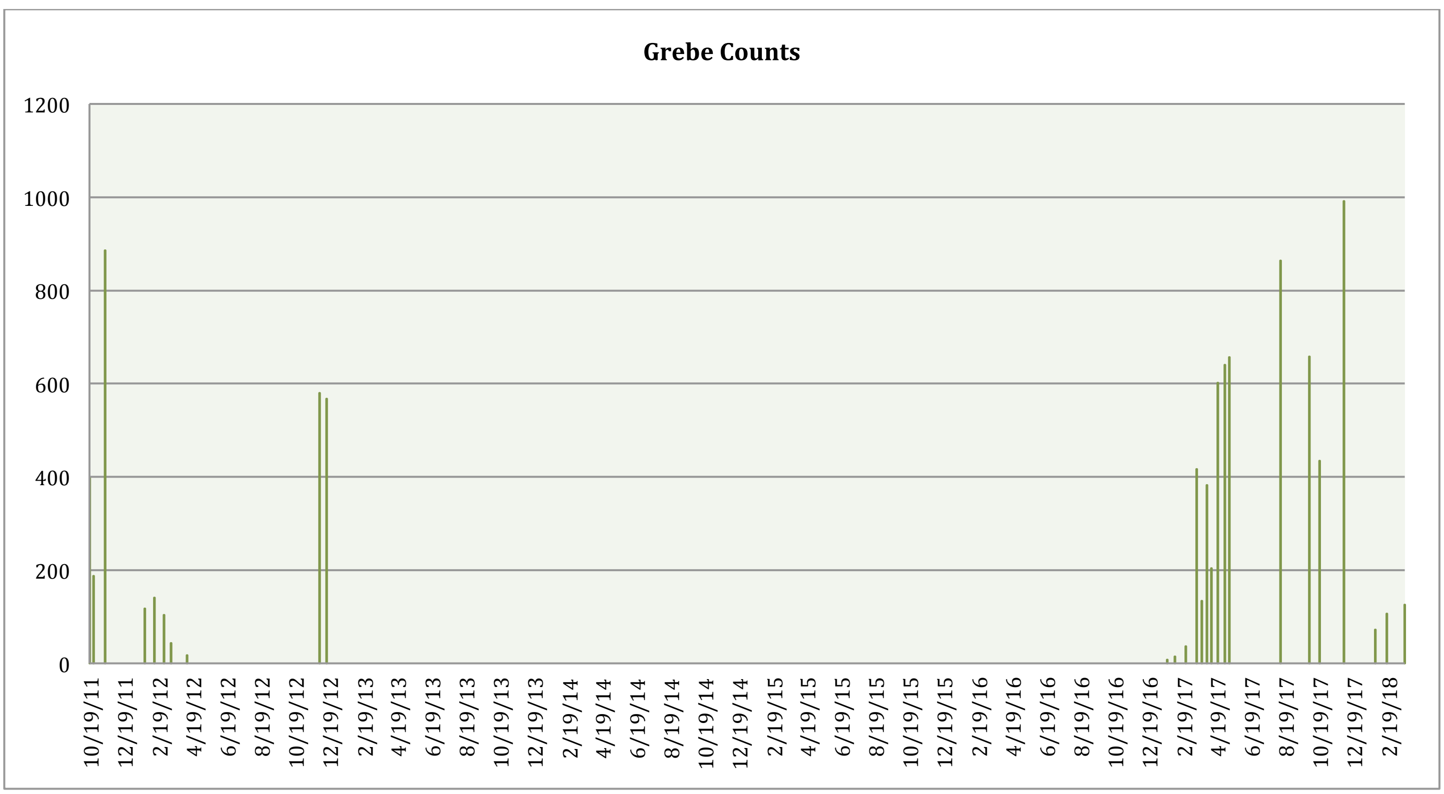


Figure 20. Total Number of Gulls and Terns Counted

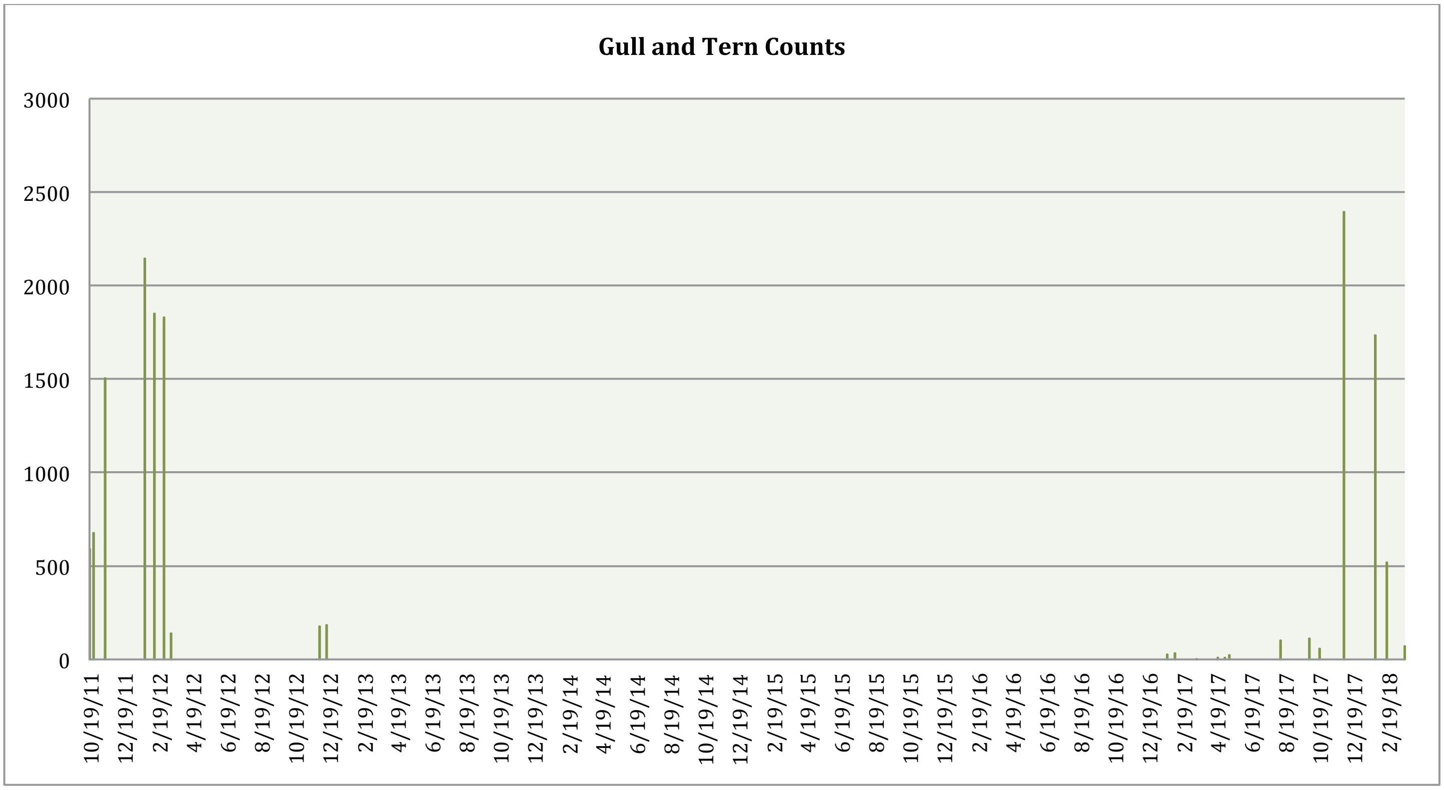


Figure 21. Total Number of Dabbling Ducks Counted

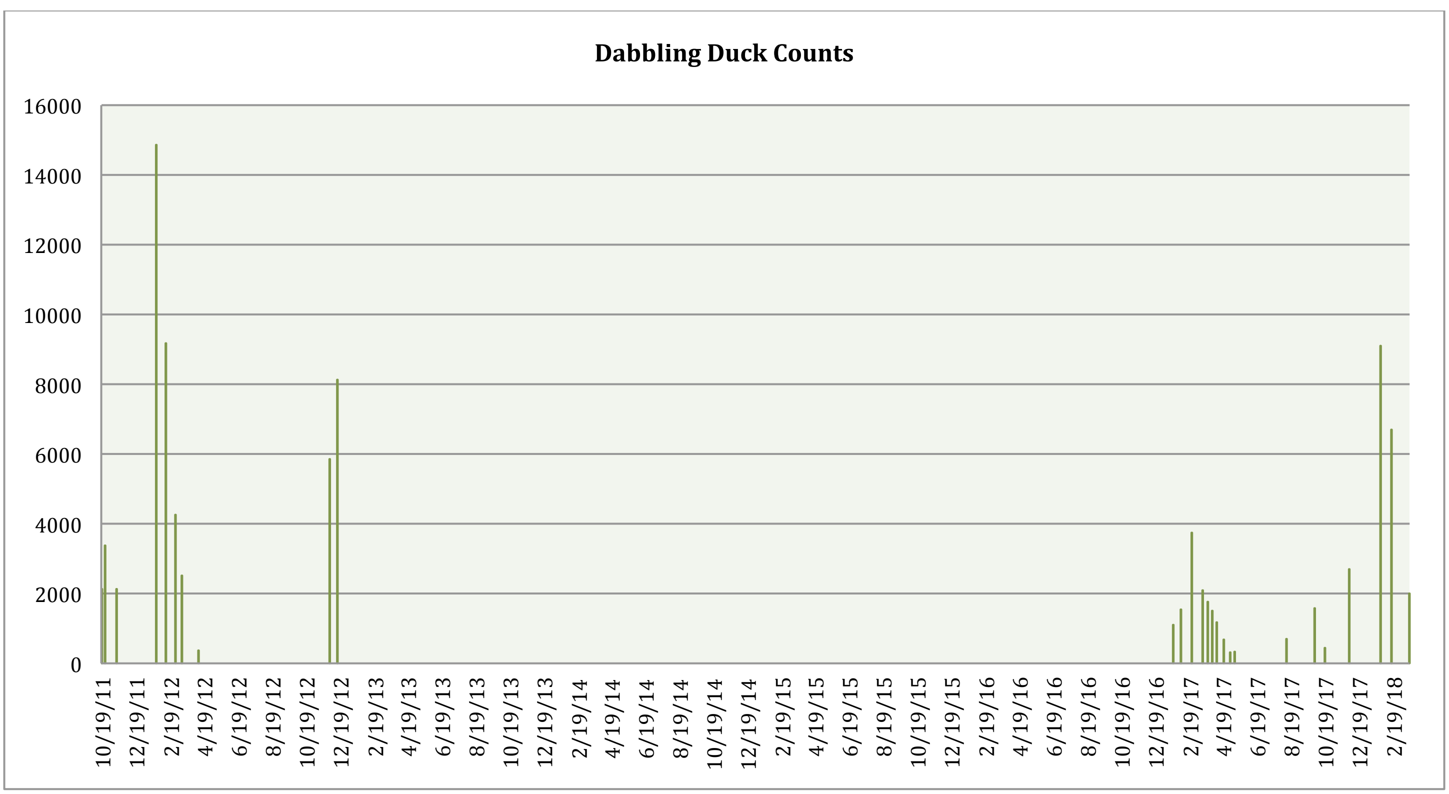


Figure 22. Total Number of Diving Ducks Counted

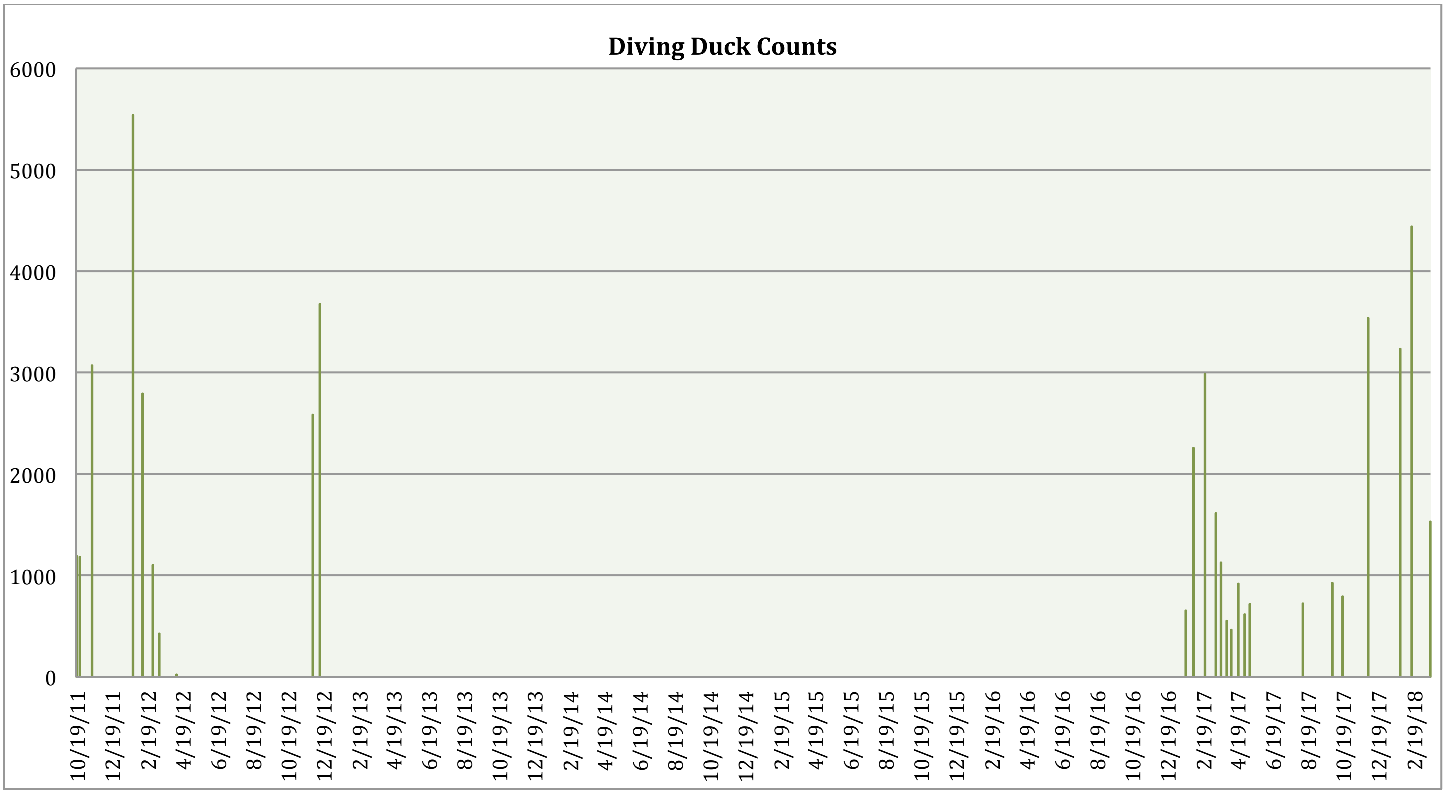


Figure 23. Total Number of Herons and Egrets Counted

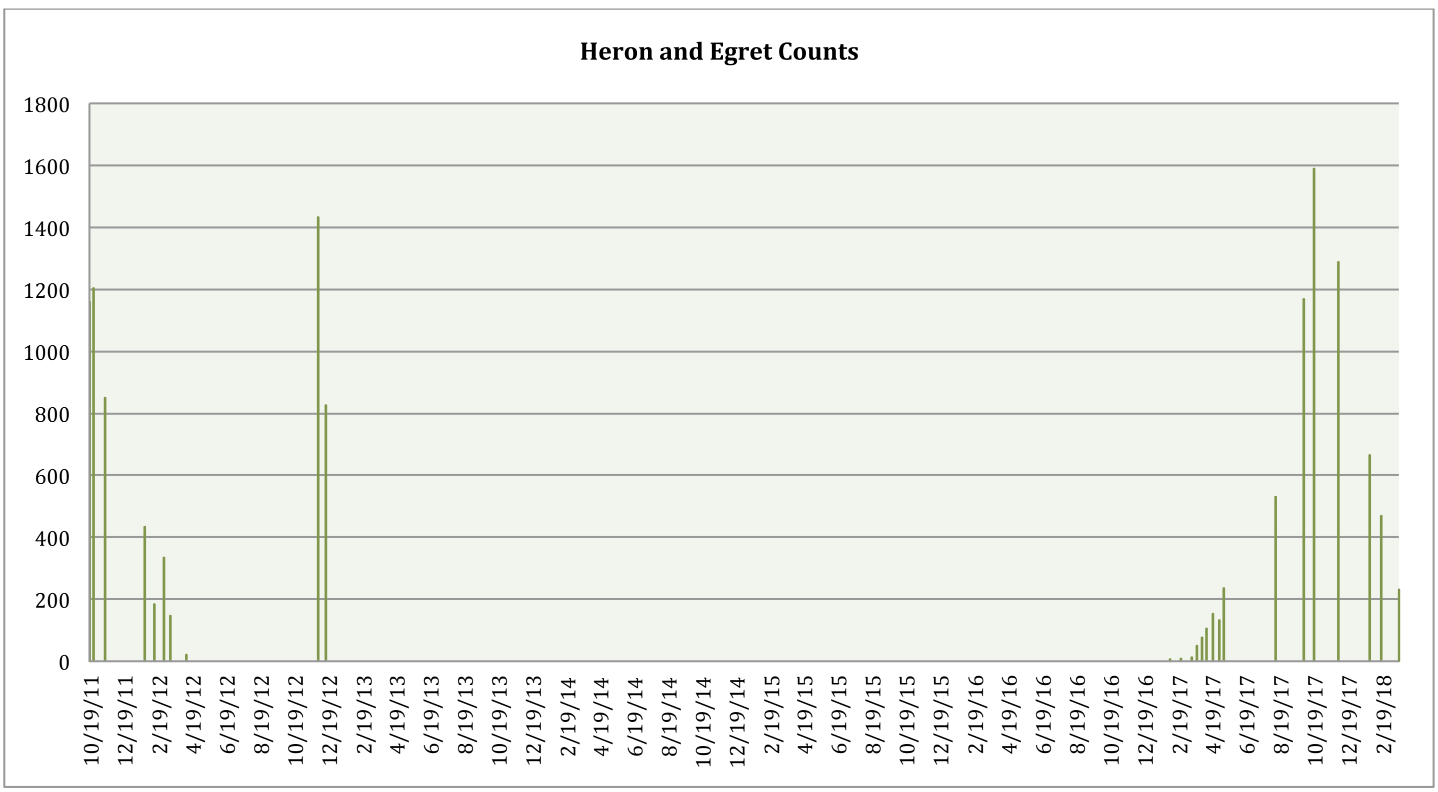


Figure 24. Total Number of Shorebirds Counted

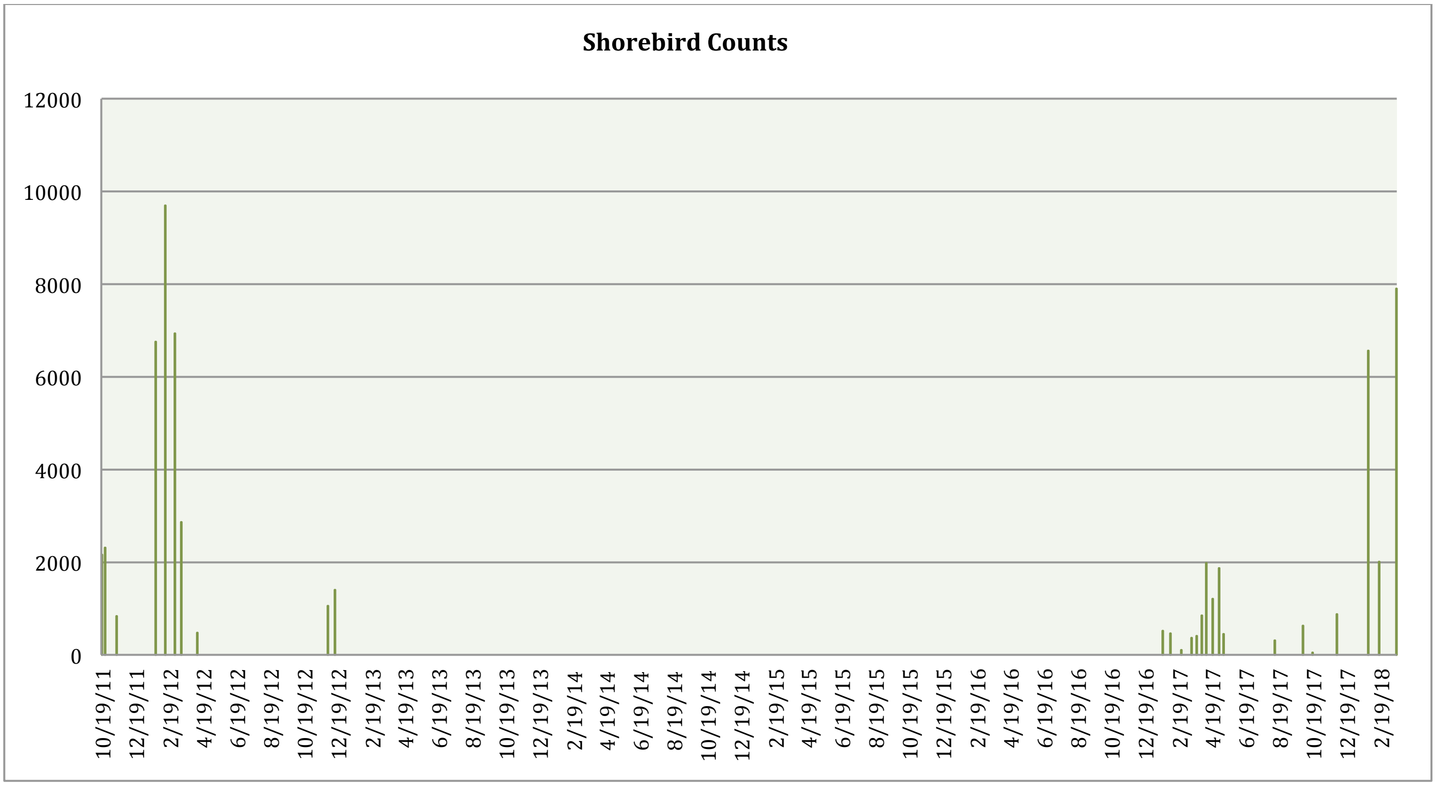


Figure 25. Total Number of American Coots Counted

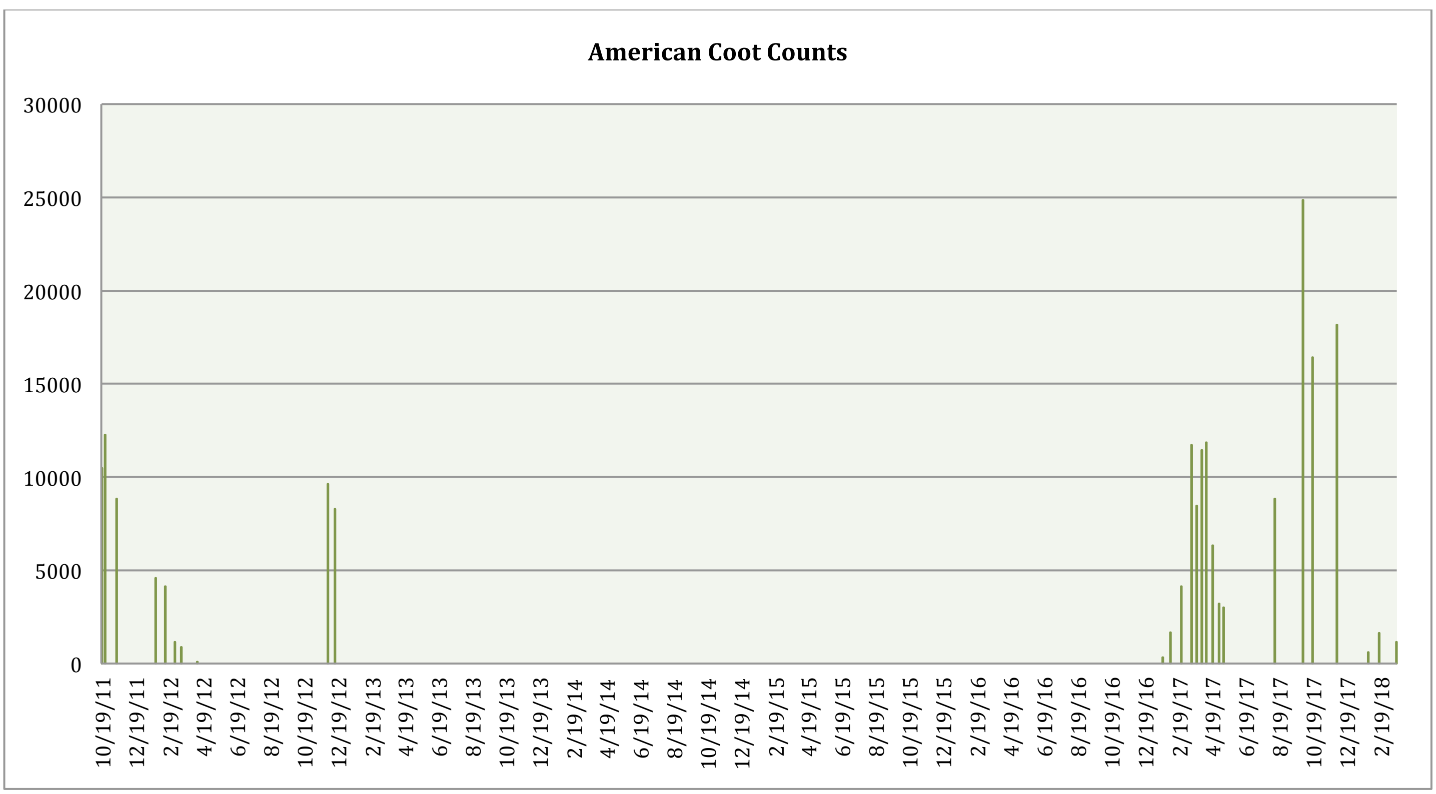


Figure 26. Total Number of Ibis Counted

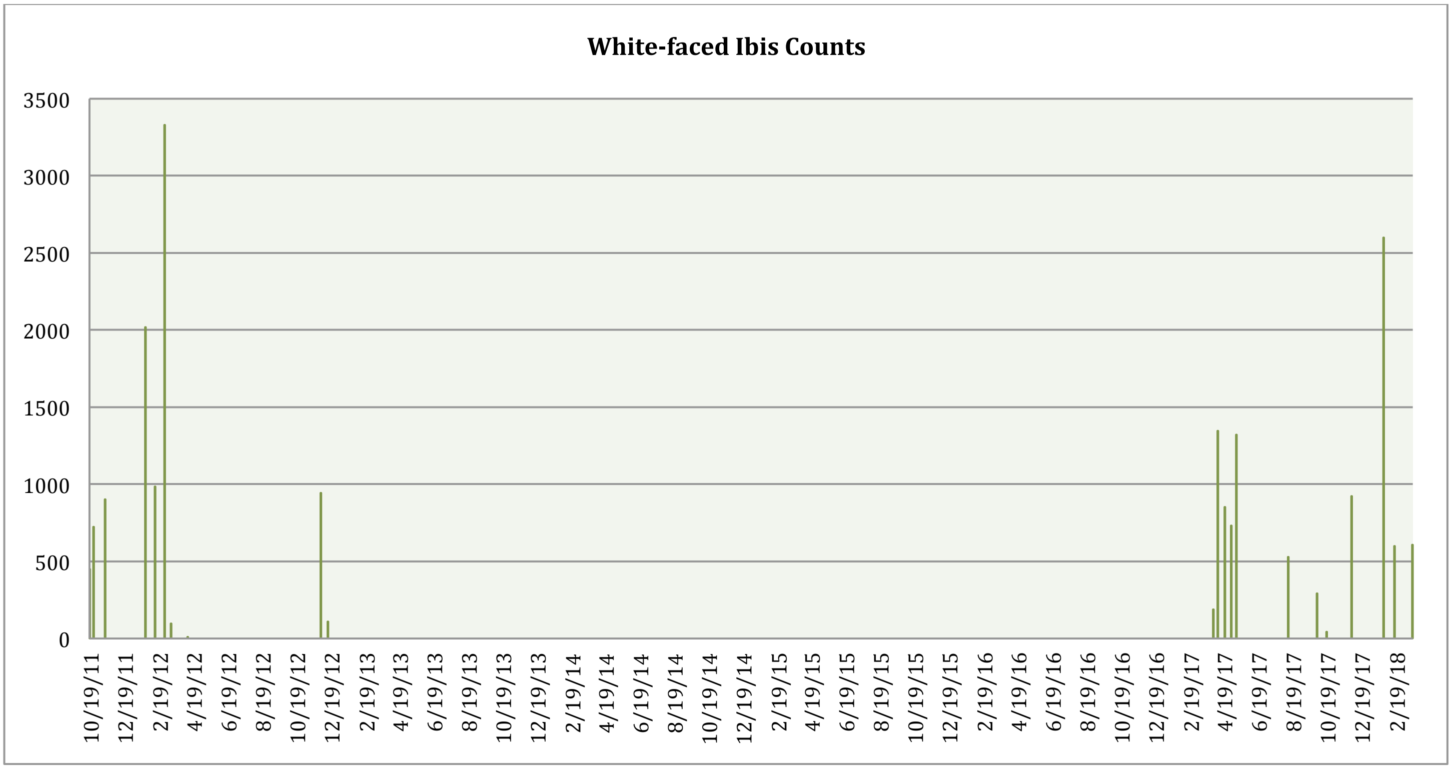


Figure 27. Total Number of Cormorants Counted

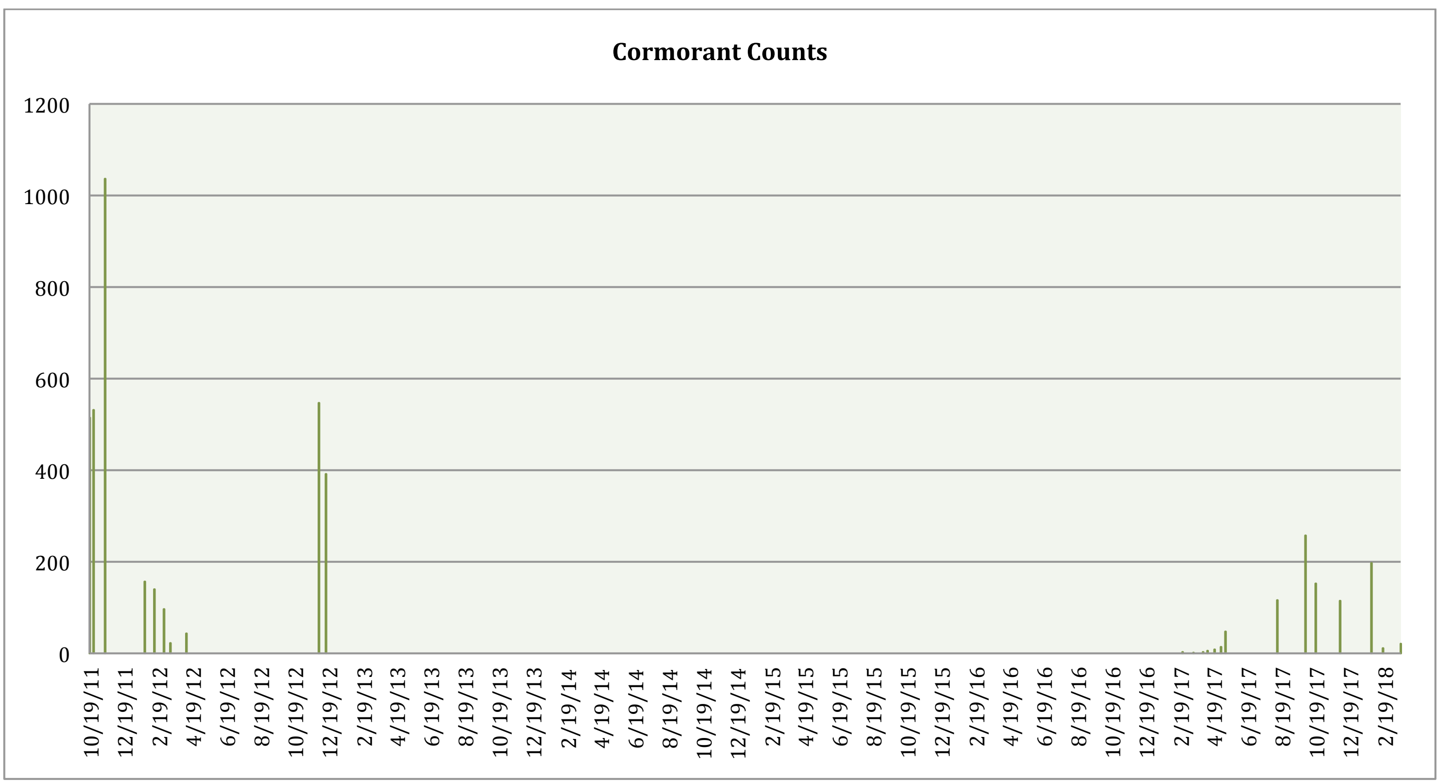
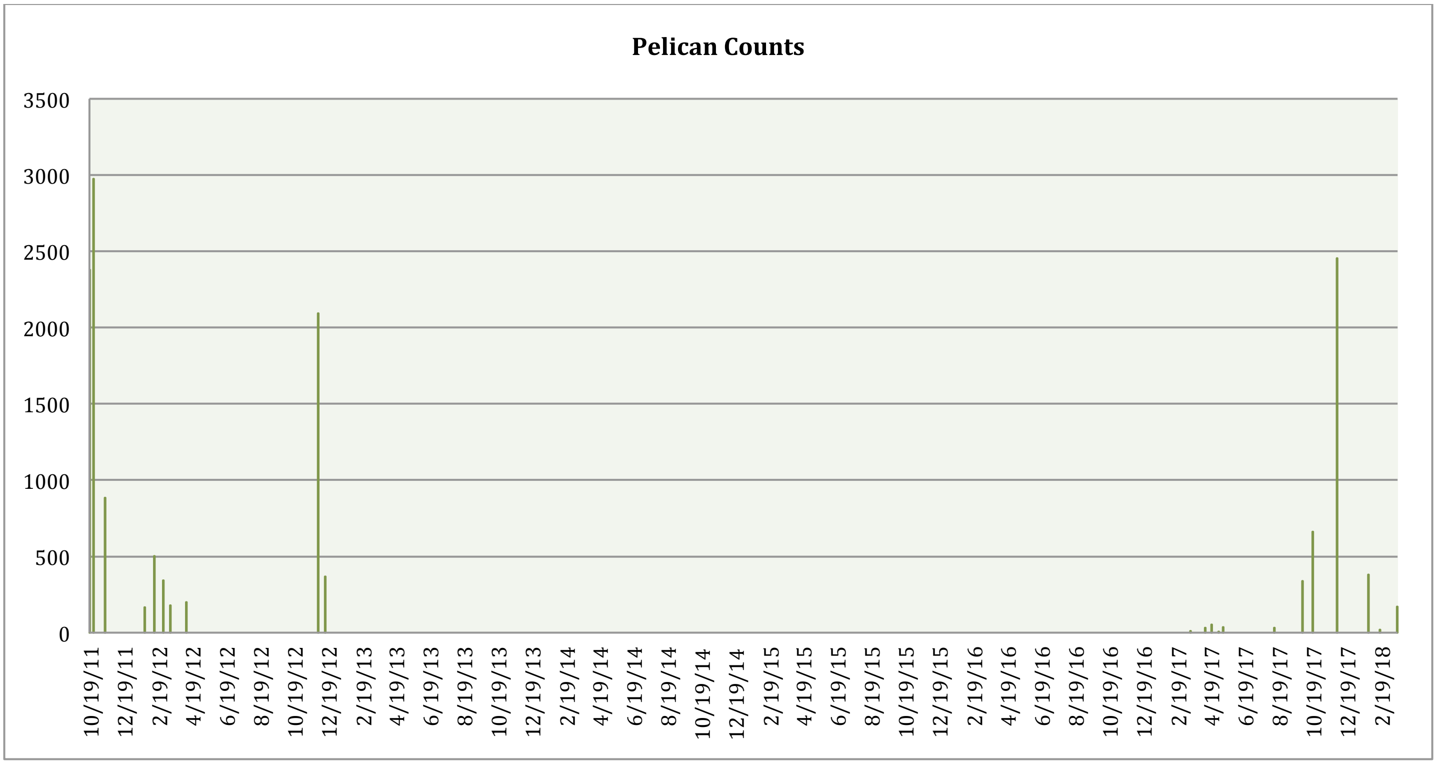


Figure 28. Total Number of Pelicans Counted



Special Status Bird Species

There have been twenty-five special-status bird species found during the raptor and upland bird surveys since the project began in October 2011 (Table 2) with an additional ten species of waterbirds found during waterbird surveys.

Table 1. Species Status Bird Species (Waterbirds, Landbirds and Raptors) found on the Kern Water Bank

Species Name	Conservation/Legal Status	Seasonal Status	Habitat	Record Dates
Canvasback	IUCN Least Concern	Migration, Winter	Marshes and open ponds	Found almost daily in winter and in smaller numbers in spring when habitat is available.
Redhead	CA Species of Special Concern	Migration, Winter, Nesting	Marshes and open ponds	Found almost daily throughout year when habitat is available.
Barrow's Goldeneye	CA Species of Special Concern			One on 25 January 2012
White-faced Ibis	CA Watch List; IUCN Least Concern	Migration, Winter, Nesting	Marshes and open ponds	Found daily throughout year when habitat is available.
American White Pelican	CA Species of Special Concern	Migration, Winter	Marshes and open ponds	Found almost daily throughout year when habitat is available.
Double-crested Cormorant	IUCN Least Concern	Migration, Winter	Marshes and open ponds	Found almost daily throughout year when habitat is available.
Cooper's Hawk	CA Watch List	Migration, Winter, Potential nesting	Nests in trees, hunts in woodlands and open grasslands	Daily during migration with some in winter

White-tailed Kite	State Fully Protected	Migration, Winter, Potential nesting	Nests in trees, hunts in open grasslands	Daily during migration and winter in 2011-2012 with up to 16 individuals, but absent during drought. Only 1-3 in winters of 2017-18 and 2018-19.
Northern Harrier	CA Species of Special Concern	Migration, Winter, Potential nesting	Nests on the ground, hunts in wetlands and open grasslands	Daily during migration and winters in 2011-2012, 2016-17, 2017-18 and 2018-19, but mostly absent in drought winters with a few scattered records of individual migrants. May be nesting in spring 2018 and 2019 as a pair was seen in mid May.
Swainson's Hawk	CA Threated Species	Nesting, Migration, Winter	Nests in trees, hunts in open grasslands	Nesting in summer 2012, scattered winter records in 2011-12; up to five individuals in Mar-May 2013; up to three individuals in Mar-May 2014; and up to four individuals in Apr/May 2015. No nest located on water bank property in 2015. Three active nests on water bank property in 2016 (Figure 14). Approximate locations: 1) 35°20'35.59"N, 119°20'27.20"W; 2) 35°20'43.52"N, 119°15'42.37"W; and 3) 35°19'11.17"N, 119°13'15.58"W. No active nests found in 2017. No active nests found in 2018, but up to fourteen individuals seen in spring 2018 so may be nesting on site. Probable nesting at two locations in 2019.
Ferruginous Hawk	CA Watch List	Winter	Hunts in open grasslands	Daily during winter except in 2017-18 with only one occurrence; rare dark morph individual in March 2016.
Golden Eagle	State Fully Protected and Federal Eagle Protection Act	Winter	Hunts in open grasslands	Five winter records
Bald Eagle	State Fully	Winter, Migration	Hunts in wetlands and	One record of second-

	Protected and Federal Eagle Protection Act		open grasslands	year old bird on 30 October 2018.
Osprey	CA Watch List	Migration, Winter	Hunts in wetlands and canals	Daily during winters of 2011-12, 2016-17 and 2017-2018, only a few sightings of migrants during other periods
Snowy Plover (inland)	CA Species of Special Concern	Migration, potentially in Winter	Open mudflats	Two on 20 March 2018
Mountain Plover	CA Species of Special Concern and Federal Proposed Threatened	Migration, Winter	Roosts and forages in grasslands	Two on 14 October 2013
Long-billed Curlew	CA Watch List and Federal Bird of Conservation Concern	Migration, Winter	Roosts and forages in grasslands and wetlands	Scattered winter and migration records including flocks.
Caspian Tern	CA Watch List; Federal Bird Species of Conservation Concern	Migration, Winter, Potential nesting	Marshes and open ponds	Found almost daily throughout year when habitat is available.
Black Tern	CA Species of Special Concern	Migration	Open ponds	Two on 21 April and 3 May 2017
Burrowing Owl	CA Species of Special Concern	Nesting, Migration, Winter	Nests and hunts in grasslands	Found on most visits through year, and nested each spring
Vaux's Swift	CA Species of Special Concern	Migration	Forages over wetlands and grasslands	Found during a few spring migration visits
Merlin	CA Watch List and Federal Bird of Conservation Concern		Hunts in grasslands and wetlands	Regular during late fall to spring with 32 records.
Peregrine Falcon	Federal Bird of Conservation Concern	Migration, Winter	Hunts in grasslands and wetlands	Regular during fall and winter of 2011-12, scattered records since then, increased sightings in 2017 and 2018. Total of 25 records.
Prairie Falcon	CA Watch List and Federal Bird of Conservation Concern	Migration, Winter	Hunts in grasslands	Found on most visits from Nov through Mar during the drought winters with 52 records.
Nuttall's Woodpecker	Federal Bird of Conservation Concern	Nesting, Migration, Winter	Nests in trees, forages in woodlands	Found during most survey visits on Transect C.
Willow Flycatcher	CA Endangered Species	Migration	Roosts in trees, hunts in open woodlands forages	Regular but sparse during migration
Vermilion Flycatcher	CA Species of Special Concern	Migration, Winter. Potential nesting	Nests in trees, forages in open woodlands and scrublands	Several fall and winter records of at least ten individuals since 2011 including at least six different individuals in 2017
Loggerhead Shrike	CA Species of Special Concern and Federal Bird of Conservation Concern	Nesting, Migration, Winter	Nests in trees, hunts in open woodlands and scrublands	Found during each survey visit with up to 95 recorded on a single visit.

California Horned Lark	CA Watch List	Nesting, Migration, Winter	Nests on ground, forages in barren fields with little grassland cover	Found during each survey visit. Many breeding during 2015-2019.
Purple Martin	CA Species of Special Concern	Migration	Forages over wetlands and grasslands	1 Apr 2012, very rare in Tulare Basin/San Joaquin Valley floor
Lucy's Warbler	CA Species of Special Concern	Migration	Nests in trees, hunts in open woodlands and scrublands	1-4 Oct 2012; second record for the entire Central Valley
Grasshopper Sparrow	CA Species of Special Concern	Migration, Winter, Potential nesting	Nests on ground in grasslands	13 Nov, 10 Dec 2013, 23 Oct 2015
Tricolored Blackbird	CA Species of Special Concern and Federal Bird of Conservation Concern	Nesting, Migration, Winter	Nests in ruderal and marsh vegetation, forages in grasslands, fields and wetlands	Nesting in summer 2012 and 2017, found most days in migration and winter during 2011-2012; nesting off site in 2015 and 2018 but foraging on the water bank property, probable nesting in 2019
Yellow-headed Blackbird	CA Species of Special Concern	Migration, Winter. Potential nesting	Nests in marsh vegetation, forages in grasslands, fields and wetlands	Regular during migration and winter in 2011-12, and spring 2017 and 2019 (may have nested in 2017)
Lawrence's Goldfinch	Federal Bird of Conservation Concern	Migration, Winter, Potential nesting	Nests in trees, forages in open woodlands and scrublands	Two late fall records in 2013, pairs on 23 Apr 2015, 1 Apr and 9 May 2016. Flocks Oct 2015-Jan 2016. Small flocks in April - May 2017 and March - May 2018, and May 2019. Flock of 700 in a single field on 4 Dec 2018, which may be largest flock on record for this species.

Rare Birds

A few birds were discovered during the surveys that are not special-status species, but out of their normal range. These records are very important to our understanding of vagrancy in birds and the data are archived by county editors for "North American Birds" magazine and the online eBird database (administered by Cornell University's Laboratory of Ornithology). During fall migration two Black-throated Sparrows were found on Transects A and C. This desert species is very rare in the Central Valley. A fall migrant Clay-colored Sparrow was in mesquite and cottonwoods between transects A and B on 25 October 2012. This northern and Midwestern species is rare anywhere in California and especially in the Central Valley from which there are fewer than ten documented records. Surprisingly, no fewer than eight Brewer's Sparrows were found wintering in 2012-13 and several have been found each subsequent winter thereby establishing the area as a regular wintering area. Before the project there were almost no documented records of this Great Basin and desert species during winter months in the Central Valley. There have been seven records of migrant Sage Thrashers—a Great Basin species, which is a rare but annual migrant in the Central Valley. During a 2012 fall survey, a Chestnut-collared Longspur was heard calling in flight over Transect I. This is a very rare wintering bird in the San Joaquin Valley and Tulare Basin with fewer than ten records. On a Christmas Bird Count before these surveys began, an Eastern Phoebe was documented for one of very few San Joaquin Valley and Tulare Basin records of this eastern species, which rarely occurs in California. During a spring surveys on 1 April 2012 and 12 March 2015, single Cassin's Kingbirds were found establishing the only Tulare Basin records away from eastern Bakersfield (only one record from nearby Kings County). Also on 1 April 2012, a male Purple Martin was photographed migrating over grasslands for one of few records for the Tulare Basin and San Joaquin Valley. Two rare warblers, a Lucy's (29 September to 4 October 2013) and a Virginia's (21 September 2015) were only the second and third records for the Central Valley, respectively. At least six different Vermilion Flycatchers were present from fall 2017 to early spring 2018. This rare desert species has been increasing in the Central Valley in recent years and has nested in nearby Kings County at least once. Rare inland gulls include Sabine's, Glaucous, and Western found on 1 October 2017, 26 February 2019, and 27 January 2018, respectively. On 12 May 2019, the Central Valley's second Neotropic Cormorant was found and seen again on 15 May. Also the first Kern County record of Glossy Ibis was photographed on 23 April 2019, but could not be relocated as of 15 May 2019.The Kern Water Bank has exceptional habitats for birds and many rare birds will likely be found and documented in the future dependent upon survey efforts. An amazingly large flock of 700 Lawrence's Goldfinches were in one dry field on 4 December 2018, which may be the largest flock on record for this species. High counts in the global database eBird were less than 350.

Discussion

The bird use of property managed by the Kern Water Bank Authority is clearly very high in accordance to the large acreages of upland and wetland habitats. Overall, in terms of bird abundance, species diversity, acreage, location and habitat diversity, it is an important area of upland habitat, especially when compared to surrounding agricultural lands. And it is even more important for its wetland habitat when water is available. These surveys documented particularly large populations raptors and shrikes, sparrows, and many other species typical of native upland habitats on the San Joaquin Valley floor. Of particular interest were the differences in the effect of the drought conditions among the years. There was measureable precipitation in winter of 2014-2015 and in the spring of 2015 with lesser amounts in winter 2015-2016 and spring 2016, and again in winter 2016-2017 which resulted in much growth of grasses and forbs throughout the water bank property. This was in contrast to no new growth during spring 2014 that left the area devoid of grasses and forbs. As a result, Loggerhead Shrike populations rebounded to pre-winter 2013-2014 levels, primarily as a result of good reproductive success of local breeders. These shrikes prey upon large insects and lizards that were common during the springs of 2015, 2016, 2017 and 2018. The highest counts of Loggerhead Shrikes of the survey project were of 93 during two surveys in June and July 2018—the result of a successful breeding season for a large nesting population.

Raptor counts also rebounded to pre-drought year levels in response to relief of severe drought conditions and increase in prey in general. With the likely increase in the vole population in 2017-19 due to much vegetation growth especially near the newly watered ponds, raptors such as White-tailed Kites, Northern Harriers, and American Kestrels responded with increased populations.

The watering of many recharge ponds from January 2017 to January 2018 had created exceptional conditions for most waterbirds. Forster's Terns, Clark's and Western grebes and several duck species had re-established breeding populations. A large White-faced Ibis breeding colony of several hundred pairs also formed in M1 for spring 2017. Although peak population levels for some groups did not reach those of 2011-2012, there was still a sizeable population for all groups of waterbirds including some that exceeded the 2011-12 population peaks. As fish populations grew into late 2017, fish-eating birds, including herons, egrets, terns, gulls, grebes, Double-crested Cormorant and American White Pelican numbers increased dramatically to take advantage of their fish prey. Ducks and American Coots also boosted their populations in response to the increased aquatic vegetation and invertebrate prey. As ponds were drying in late winter and spring 2018, much mudflat was exposed creating ideal conditions for shorebird habitat. Shorebird numbers peaked at close to 8,000 by early spring. Watered ponds in spring of 2019 have created conditions for breeding grebes, herons, egrets, White-faced Ibis, terns, waterfowl and Black-necked Stilts. As of mid-May, many potential breeding species were still present in the ponds.

Appendix A. List of Bird Species Recorded at the Kern Water Bank
Compiled By John Sterling (22 May 2019)
Bold-faced names = species rare in the Tulare Basin

Anseriformes - Screamers, Swans, Geese, and Ducks
Anatidae - Ducks, Geese, and Swans
Greater White-fronted Goose *Anser albifrons*
Snow Goose *Chen caerulescens*
Ross's Goose *Chen rossii*
Cackling Goose *Branta hutchinsii*
Canada Goose *Branta canadensis*
Tundra Swan *Cygnus columbianus*
Wood Duck *Aix sponsa*
Gadwall *Anas strepera*
Eurasian Wigeon *Anas penelope*
American Wigeon *Anas americana*
Mallard *Anas platyrhynchos*
Blue-winged Teal *Anas discors*
Cinnamon Teal *Anas cyanoptera*
Northern Shoveler *Anas clypeata*
Northern Pintail *Anas acuta*
Green-winged Teal *Anas crecca*
Canvasback *Aythya valisineria*
Redhead *Aythya americana*
Ring-necked Duck *Aythya collaris*
Greater Scaup *Aythya marila*
Lesser Scaup *Aythya affinis*
Bufflehead *Bucephala albeola*
Common Goldeneye *Bucephala clangula*
Barrow's Goldeneye *Bucephala islandica*
Hooded Merganser *Lophodytes cucullatus*
Common Merganser *Mergus merganser*
Red-breasted Merganser *Mergus serrator*
Ruddy Duck *Oxyura jamaicensis*

Galliformes - Gallinaceous Birds
Odontophoridae - New World Quail
California Quail *Callipepla californica*

Phasianidae - Partridges, Grouse, Turkeys, and Old World Quail
Ring-necked Pheasant *Phasianus colchicus* - I

Podicipediformes - Grebes
Podicipedidae - Grebes
Pied-billed Grebe *Podilymbus podiceps*
Horned Grebe *Podiceps auritus*
Eared Grebe *Podiceps nigricollis*
Western Grebe *Aechmophorus occidentalis*
Clark's Grebe *Aechmophorus clarkia*

Pelecaniformes - Pelicans, Cormorants, Herons, Ibises, and Allies
Phalacrocoracidae - Cormorants
Double-crested Cormorant *Phalacrocorax auritus*
Neotropic Cormorant *Phalacrocorax brasilianus*

Pelecanidae - Pelicans
American White Pelican *Pelecanus erythrorhynchos*

Ardeidae - Herons, Bitterns, and Allies

Great Blue Heron *Ardea herodias*
Great Egret *Ardea alba*
Snowy Egret *Egretta thula*
Cattle Egret *Bubulcus ibis*
Green Heron *Butorides virescens*
Black-crowned Night-Heron *Nycticorax nycticorax*

Threskiornithidae - Ibises and Spoonbills
White-faced Ibis *Plegadis chihi*
Glossy Ibis *Plegadis falcinellus*

Accipitriformes - Hawks, Kites, Eagles, and Allies
Cathartidae - New World Vultures
Turkey Vulture *Cathartes aura*

Pandionidae - Ospreys
Osprey *Pandion haliaetus*

Accipitridae - Hawks, Kites, Eagles, and Allies
White-tailed Kite *Elanus leucurus*
Bald Eagle *Haliaeetus leucocephalus*
Northern Harrier *Circus cyaneus*
Sharp-shinned Hawk *Accipiter striatus*
Cooper's Hawk *Accipiter cooperii*
Red-shouldered Hawk *Buteo lineatus*
Swainson's Hawk *Buteo swainsoni*
Red-tailed Hawk *Buteo jamaicensis*
Ferruginous Hawk *Buteo regalis*
Golden Eagle *Aquila chrysaetos*

Gruiformes - Rails, Cranes, and Allies
Rallidae - Rails, Gallinules, and Coots
Virginia Rail *Rallus limicola*
Sora *Porzana carolina*
Common Gallinule *Gallinula galeata*
American Coot *Fulica americana*

Charadriiformes - Shorebirds, Gulls, Auks, and Allies
Recurvirostridae - Stilts and Avocets
Black-necked Stilt *Himantopus mexicanus*
American Avocet *Recurvirostra americana*

Charadriidae - Lapwings and Plovers
Black-bellied Plover *Pluvialis squatarola*
Snowy Plover *Charadrius nivosus*
Semipalmated Plover *Charadrius semipalmatus*
Mountain Plover *Charadrius montanus*
Killdeer *Charadrius vociferus*

Scolopacidae - Sandpipers, Phalaropes, and Allies
Spotted Sandpiper *Actitis macularius*
Solitary Sandpiper *Tringa solitaria*
Greater Yellowlegs *Tringa melanoleuca*
Willet *Tringa semipalmata*
Lesser Yellowlegs *Tringa flavipes*
Whimbrel *Numenius phaeopus*
Long-billed Curlew *Numenius americanus*
Marbled Godwit *Limosa fedoa*
Dunlin *Calidris alpina*

Least Sandpiper *Calidris minutilla*
Western Sandpiper *Calidris mauri*
Short-billed Dowitcher *Limnodromus griseus*
Long-billed Dowitcher *Limnodromus scolopaceus*
Wilson's Snipe *Gallinago delicata*
Wilson's Phalarope *Phalaropus tricolor*
Red-necked Phalarope *Phalaropus lobatus*

Laridae - Gulls, Terns, and Skimmers
Bonaparte's Gull *Chroicocephalus Philadelphia*
Franklin's Gull *Leucophaeus pipixcan*
Mew Gull *Larus canus*
Ring-billed Gull *Larus delawarensis*
California Gull *Larus californicus*
Herring Gull *Larus argentatus*
Thayer's Gull *Larus thayeri*
Western Gull *Larus occidentalis*
Glaucous-winged Gull *Larus glaucescens*
Glaucous Gull *Larus hyperboreus*
Sabine's Gull *Xena sabinii*
Caspian Tern *Hydroprogne caspia*
Black Tern *Chlidonias niger*
Common Tern *Sterna hirundo*
Forster's Tern *Sterna forsteri*

Columbiformes - Pigeons, and Doves
Columbidae - Pigeons and Doves
Rock Pigeon *Columba livia* - I
Eurasian Collared-Dove *Streptopelia decaocto* - I
Mourning Dove *Zenaida macroura*

Cuculiformes - Cuckoos and Allies
Cuculidae - Cuckoos, Roadrunners, and Anis
Greater Roadrunner *Geococcyx californianus*

Strigiformes - Owls
Tytonidae - Barn Owls
Barn Owl *Tyto alba*

Strigidae - Typical Owls
Great Horned Owl *Bubo virginianus*
Burrowing Owl *Athene cunicularia*

Caprimulgiformes - Goatsuckers, Oilbirds, and Allies
Caprimulgidae - Goatsuckers
Lesser Nighthawk *Chordeiles acutipennis*

Apodiformes - Swifts, and Hummingbirds
Apodidae - Swifts
Vaux's Swift *Chaetura vauxi*
White-throated Swift *Aeronautes saxatalis*

Trochilidae - Hummingbirds
Black-chinned Hummingbird *Archilochus alexandri*
Anna's Hummingbird *Calypte anna*
Rufous Hummingbird *Selasphorus rufus*

Coraciiformes - Rollers, Motmots, Kingfishers, and Allies
Alcedinidae - Kingfishers

Belted Kingfisher *Megaceryle alcyon*

Piciformes - Puffbirds, Jacamars, Toucans, Woodpeckers, and Allies
Picidae - Woodpeckers and Allies
Nuttall's Woodpecker *Picoides nuttallii*
Downy Woodpecker *Picoides pubescens*
Northern Flicker *Colaptes auratus*

Falconiformes - Caracaras and Falcons
Falconidae - Caracaras and Falcons
American Kestrel *Falco sparverius*
Merlin *Falco columbarius*
Peregrine Falcon *Falco peregrinus*
Prairie Falcon *Falco mexicanus*

Passeriformes - Passerine Birds
Tyrannidae - Tyrant Flycatchers
Olive-sided Flycatcher *Contopus cooperi*
Western Wood-Pewee *Contopus sordidulus*
Willow Flycatcher *Empidonax traillii*
Hammond's Flycatcher *Empidonax hammondii*
Dusky Flycatcher *Empidonax oberholseri*
Gray Flycatcher *Empidonax wrightii*
Pacific-slope Flycatcher *Empidonax difficilis*
Black Phoebe *Sayornis nigricans*
Eastern Phoebe *Sayornis phoebe*
Say's Phoebe *Sayornis saya*
Vermilion Flycatcher *Pyrocephalus rubinus*
Ash-throated Flycatcher *Myiarchus cinerascens*
Cassin's Kingbird *Tyrannus vociferans*
Western Kingbird *Tyrannus verticalis*

Laniidae - Shrikes
Loggerhead Shrike *Lanius ludovicianus*

Vireonidae - Vireos
Cassin's Vireo *Vireo cassinii*
Warbling Vireo *Vireo gilvus*

Corvidae - Crows and Jays
Western Scrub-Jay *Aphelocoma californica*
American Crow *Corvus brachyrhynchos*
Common Raven *Corvus corax*

Alaudidae - Larks
Horned Lark *Eremophila alpestris*

Hirundinidae - Swallows
Purple Martin *Progne subis*
Tree Swallow *Tachycineta bicolor*
Violet-green Swallow *Tachycineta thalassina*
Northern Rough-winged Swallow *Stelgidopteryx serripennis*
Cliff Swallow *Petrochelidon pyrrhonota*
Barn Swallow *Hirundo rustica*

Aegithalidae - Long-tailed Tits and Bushtits
Bushtit *Psaltriparus minimus*

Troglodytidae - Wrens

Rock Wren *Salpinctes obsoletus*
House Wren *Troglodytes aedon*
Marsh Wren *Cistothorus palustris*
Bewick's Wren *Thryomanes bewickii*

Polioptilidae - Gnatcatchers and Gnatwrens
Blue-gray Gnatcatcher *Polioptila caerulea*

Regulidae - Kinglets
Ruby-crowned Kinglet *Regulus calendula*

Turdidae - Thrushes
Western Bluebird *Sialia mexicana*
Mountain Bluebird *Sialia currucoides*
Swainson's Thrush *Catharus ustulatus*
Hermit Thrush *Catharus guttatus*
American Robin *Turdus migratorius*

Mimidae - Mockingbirds and Thrashers
California Thrasher *Toxostoma redivivum*
Sage Thrasher *Oreoscoptes montanus*
Northern Mockingbird *Mimus polyglottos*

Sturnidae - Starlings
European Starling *Sturnus vulgaris* - I

Motacillidae - Wagtails and Pipits
American Pipit *Anthus rubescens*

Bombycillidae - Waxwings
Cedar Waxwing *Bombycilla cedrorum*

Ptiliogonatidae - Silky-flycatchers
Phainopepla *Phainopepla nitens*

Calcariidae - Longspurs and Snow Buntings
Chestnut-collared Longspur *Calcarius ornatus*

Parulidae - Wood-Warblers
Orange-crowned Warbler *Oreothlypis celata*
Lucy's Warbler *Oreothlypis luciae*
Virginia's Warbler *Oreothlypis virginiae*
Nashville Warbler *Oreothlypis ruficapilla*
MacGillivray's Warbler *Geothlypis tolmiei*
Common Yellowthroat *Geothlypis trichas*
Yellow Warbler *Setophaga petechia*
Yellow-rumped Warbler *Setophaga coronata*
Black-throated Gray Warbler *Setophaga nigrescens*
Townsend's Warbler *Setophaga townsendi*
Wilson's Warbler *Cardellina pusilla*

Emberizidae - Emberizids
Spotted Towhee *Pipilo maculatus*
California Towhee *Melozone crissalis*
Chipping Sparrow *Spizella passerina*
Clay-colored Sparrow *Spizella pallida*
Brewer's Sparrow *Spizella breweri*
Vesper Sparrow *Pooecetes gramineus*
Grasshopper Sparrow *Ammodramus savannorum*

Lark Sparrow *Chondestes grammacus*
Black-throated Sparrow *Amphispiza bilineata*
Bell’s Sparrow *Artemisiospiza belli canescens*
Savannah Sparrow *Passerculus sandwichensis*
Fox Sparrow *Passerella iliaca*
Song Sparrow *Melospiza melodia*
Lincoln's Sparrow *Melospiza lincolnii*
White-crowned Sparrow *Zonotrichia leucophrys*
Golden-crowned Sparrow *Zonotrichia atricapilla*
Dark-eyed Junco *Junco hyemalis*

Cardinalidae - Cardinals and Allies
Western Tanager *Piranga ludoviciana*
Black-headed Grosbeak *Pheucticus melanocephalus*
Blue Grosbeak *Passerina caerulea*
Lazuli Bunting *Passerina amoena*

Icteridae - Blackbirds
Red-winged Blackbird *Agelaius phoeniceus*
Tricolored Blackbird *Agelaius tricolor*
Western Meadowlark *Sturnella neglecta*
Yellow-headed Blackbird *Xanthocephalus xanthocephalus*
Brewer's Blackbird *Euphagus cyanocephalus*
Great-tailed Grackle *Quiscalus mexicanus*
Brown-headed Cowbird *Molothrus ater*
Hooded Oriole *Icterus cucullatus*
Bullock's Oriole *Icterus bullockii*

Fringillidae - Fringilline and Cardueline Finches and Allies
House Finch *Haemorhous mexicanus*
Purple Finch *Haemorhous purpureus*
Pine Siskin *Spinus pinus*
Lesser Goldfinch *Spinus psaltria*
Lawrence's Goldfinch *Spinus lawrencei*
American Goldfinch *Spinus tristis*

Passeridae - Old World Sparrows
House Sparrow *Passer domesticus* - I

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Appendix E

Annual Wildlife Monitoring Report for the Kern Water Bank

Mourning Dove (*Zenaida macroura*)

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2018 ANNUAL WILDLIFE MONITORING REPORT for the KERN WATER BANK

Submitted to:

KERN WATER BANK AUTHORITY

Prepared by:

svb
south valley biology consulting llc

July 18, 2019

2018 ANNUAL WILDIFE MONITORING REPORT

for the

KERN WATER BANK

Submitted to:

Kern Water Bank Authority

1620 Mill Rock Way, Suite 500

Bakersfield, CA93311

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July 18, 2019

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Figures

Introduction

This report documents the results of the 2018 annual wildlife monitoring activities conducted at the Kern Water Bank (KWB). On behalf of the Kern Water Bank Authority (KWBA), biologists from South Valley Biology Consulting LLC (SVB) conducted all monitoring activities contained in this report.

As identified on Page IV-6 the KWB Habitat Conservation Plan/Natural Community Conservation Plan (KWBA 1997), hereinafter referred to as HCP/NCCP, the annual and bi-annual monitoring consisted of the following activities:

- San Joaquin kit fox (*Vulpes macrotis mutica*) monitoring

  Nighttime spotlighting surveys to document the presence of San Joaquin kit fox, its predators and competitors, such as coyote (*Canis latrans*), red fox (*Vulpes vulpes*), and bobcat (*Lynx* rufus*),* as well as several other nocturnal animals on the KWB.

  In addition to the prescribed spotlighting surveys, infrared motion camera stations were again used in 2018 to better document kit fox activity on the KWB.

- Tipton kangaroo rat (*Dipodomys nitratoides nitratoides*) monitoring

  Trapping surveys on two established trapping grids to assess known population areas of Tipton kangaroo rats on the KWB.

- San Joaquin woollythreads (*Monolopia congdonii*), Kern mallow (*Eremalche parryi* ssp. *kernensis*) and other rare plant species monitoring.

San Joaquin Kit Fox Monitoring

Introduction

San Joaquin kit fox monitoring at the KWB in 2018 consisted of nighttime spotlighting surveys conducted on established routes located throughout the KWB. These surveys are conducted annually to provide an index of San Joaquin kit fox presence on the property. Data collected from the surveys are useful in supplying insights into the densities of not only kit foxes, but also their predator and competitor species that occur within the KWB property. The main predator/competitor species for the San Joaquin kit fox on the KWB are coyotes (*Canis latrans*), bobcats (*Felis rufus*), and American badgers (*Taxidea taxus*). Although the non-native red fox (*Vulpes vulpes*) is also known to occur in the region, this species has not been reported for many years at the KWB.

Methodology

Prior to conducting the nighttime spotlighting surveys, all the lesser-travelled areas of the established nighttime spotlighting route were driven by the biologists during daylight hours. This is typically done every season in the interest of safety; however, the daylight surveys also allow for identifying areas where the most suitable habitats for San Joaquin kit fox are located and for identifying potential den locations that would be worthwhile to target during the nighttime spotlighting surveys. Although the KWB is a very dynamic place and can vary dramatically from year to year, there has not been any need to significantly alter the established spotlighting route. Figure 1 provides an illustration of the 2018 survey route.

Nighttime spotlighting surveys were conducted for six nights during the evening hours. Surveys commenced at or immediately after dusk and most surveys generally took from 3 to 3.5 hours to complete. Survey dates included November 20th, 21st, 27th, 30th, and December 3rd; and 4th. Because the established survey route is just over 50 miles in length, it was divided into two portions totaling approximately 25 miles each (Figure 1). As in prior years, the East Route consisted of all portions lying east of Enos Lane (Highway 43), and an approximately 6-mile stretch lying west of Interstate 5 and south of the Kern River. The other route, referred to as the West Route, encompassed all remaining portions of the established route that lie west of Enos Lane. Both routes were surveyed three times each over the six nights, yielding approximately 150 miles of nighttime spotlighting surveys conducted during the 2018 survey effort.

Each survey was conducted by two biologists, traveling in a vehicle at approximately 5-10 miles per hour. The biologists each used a 3-million candlepower hand-held spotlight to observe eye-shines and individual animals. A third biologist was responsible for recording the observations onto the data sheet at specified intervals throughout the survey session and to aid in safely navigating the survey route. Double counting of observations was avoided by maintaining a constant communication while surveying and determining pre-defined areas of observation for each biologist. Observations of all identified animals, paying particular attention to kit fox and their predator/competitor and prey species, were recorded onto standardized field data sheets. The data sheets were later compiled into a Microsoft Access® database. All San Joaquin kit fox observations and observations of kit fox predator and competitor species, such as coyote, bobcat, and American badger, were recorded using a hand held Global Positioning System (GPS) and later entered into the database.

Results

Results from the nighttime spotlighting surveys are presented in Figure 2. The locations of San Joaquin kit fox and competitor/predator species observations are presented in Figure 1.

There were three observations of San Joaquin kit fox made during the 2018 nighttime spotlighting surveys. All observations were made on December 3rd.

A total of 20 coyotes were observed during the surveys on 5 of the 6 survey nights. Observations varied from one to 3 individuals at a given location (Figure 1).

No observations of bobcats or American badgers were made during the 2018 nighttime spotlighting surveys.

Other mammalian species observations made during the 2018 nighttime spotlighting surveys included: 167 desert cottontail (*Sylvilagus auduboni*), 89 black-tailed jackrabbit (*Lepus californicus*), and 24 kangaroo rat (*Dipodomys* ssp.).

Several avian species were observed. Birds of prey observations totaled 33 barn owls (*Tyto alba*), 3 great horned owls, 3 burrowing owls (*Athene cunicularia*), 9 northern harriers (*Circus cyaneus*), 6 red-tailed hawks (*Buteo jamaicensis*), and 1 prairie falcon (*Falco mexicanus*). Other avian species included California quail (*Callipepla californica*), cattle egret (*Bubulcus ibis*), great egret (*Ardea* herodius), great blue heron (*Ardea herodias*), killdeer (*Charadrius vociferus*), loggerhead shrike (*Lanius ludovicanus*), and mourning dove (*Zenaida macroura*).

Discussion

It is encouraging that kit foxes were observed during the 2018 nighttime spotlighting surveys. There were no kit foxes seen during the 2017 surveys (SVB 2018). As reported in SVB (2018), the abundant recharge cycle activity that was occurring in 2018 made for more difficulty to identify animals. There was no recharge occurring in late 2018 when the nighttime spotlighting surveys were conducted. At the end of a recharge cycle, vegetation can be quite tall until cattle have had a period of time to graze and trample it down. The tall vegetation can hamper the spotlight surveyors visibility, making it difficult or impossible to see the ground level only a short distance from the vehicle. Although this may have biased the surveys a bit in 2017, it was also very evident that all the available forage produced from the significant precipitation and recharge during 2017 led to higher numbers of prey species which in turn probably explains the large increase in kit fox and coyote observations during the 2018 nighttime spotlighting surveys. The most significant observation during the 2018 nighttime spotlighting surveys was the kit fox observation made in the River Area just east of the R5 Pond. It is not often that kit foxes are observed in the recharge areas of the KWB.

In 2018 SVB biologists placed a total of 8 cameras in several areas spread throughout the KWB. An infrared motion detection camera was placed at each station along with a perforated can of cat food that was securely fastened to the ground with a 12-inch metal stake. All cameras were operated for 12 consecutive days and nights from November 5th through November 17th. Figure 1 shows the locations of the 8 camera stations.

San Joaquin kit fox was photographed on numerous occasions at the camera station located within the conservation bank lands in the Southeast Area, south of the K2 Pond (Figure 1). One and sometimes two individuals were photographed on several nights. at this camera station which included November 5th, 6th, 7th, 8th, 9th, 10th, 11th, 12th, 14th, 15th, 16th, and 17th. Coyotes were plentiful once again in 2018, visiting 6 of the 8 scent stations. The number of individuals photographed ranged from one to three individuals in the same frame. No bobcats or American badges were photographed at any of the camera stations in 2018.

Other wildlife species photographed included black-tailed jackrabbit, desert cottontail, kangaroo rat, striped skunk (*Mephitis mephitis*), common raven (*Corvus corax*), and western meadowlark (*Sturnella neglecta*). Representative photographs of some of the wildlife from the camera station monitoring are provided below.

San Joaquin kit fox at scent station in conservation bank.

Striped skunk at scent station in conservation bank.

Two kit foxes at scent station in conservation bank.

Coyote at scent station in recharge area.

Coyote with partial tail missing.

Jackrabbit at scent station in recharge area.

Tipton Kangaroo Rat Monitoring

Introduction

Tipton kangaroo rat monitoring at the KWB is required annually at two permanently established trapping grids in accordance with the HCP/NCCP. The Strand Grid is located in the northwest ¼ of Section 7, Township 30 South, Range 26 East and the Southeast Area Grid is located in the northwest ¼ of Section 33, Township 30 South, Range 26 East.

Methodology

The Strand Grid and the Southeast Area Grid are both standard 110-meter by 110-meter, 144-station, small mammal trapping grids. Each grid consists of twelve equidistant rows, spaced 10 meters apart. Monitoring efforts at each grid in 2018 consisted of four successive nights of trapping. Trapping was conducted at the Southeast Area Grid on August 28th, 29th, 30th, and 31st; while the Strand Grid was trapped on September 25th, 26th, 27th, and 28th. This technique yielded a total of 1,152 trap nights.

A 15-inch x 4-inch x 4.75-inch Sherman live trap was placed at each trap location. Each trap was baited using a millet-based seed mix. A wadded paper towel was also included in each trap to provide insulation and bedding material for the captured animals. The traps were baited and set in the evening and checked just prior to sunrise the following morning. Two biologists worked independently on separate trap rows and checked 72 traps each morning. This technique was utilized to help reduce the handling time and minimize stress to the captured animals. Each captured animal was identified to species and the individual's weight, age, and sex were also recorded onto a standardized data sheet. After all data were collected and recorded, the animal was temporarily marked ventrally with a non-toxic ink marker and then immediately released at the site of capture. To further minimize subsequent handling times, males were marked with a blue marker and females were marked with red. Additionally, an individual was weighed only once and no re-weighing of recaptured animals was conducted.

Deer mice (*Peromyscus maniculatus*) were not handled in the same manner as all the other species. When a deer mouse was captured, no data on sex, weight, or any other parameter was collected. Therefore, the number of deer mice reported here includes recaptures. This was a safety consideration intended to minimize potential exposure to Hantavirus.

Results

Results from the 2018 Tipton kangaroo rat monitoring are summarized in Figure 3.

No Tipton kangaroo rats were captured at the Strand Grid in 2018. Other animals trapped at the Strand Grid were as follows: 52 Heermann's kangaroo rats (*Dipodomys heermanni*), 1 Tulare grasshopper mouse (*Onychomys torridus tularensis*), and 3 deer mice.

The trapping effort at the Southeast Area Grid yielded a total of 43 Tipton kangaroo rats, 15 Heermann's kangaroo rats, 1 San Joaquin pocket mouse, and 2 deer mice.

Discussion

Adult Tipton kangaroo rat

Juvenile San Joaquin pocket mouse

The Tipton kangaroo rat populations at KWB in 2018 appeared to be healthy and robust, with 43 individuals trapped in 2018 at the Southeast Area Grid. This was only slightly lower than the 46 individuals trapped the previous year in 2017 at the Southeast Area Grid (SVB 2018). Although no Tipton kangaroo rats were trapped at the Strand Grid in 2018, this is not unusual, as there are always only a few to zero trapped at that grid most years. This is likely because a large portion of the Strand Grid has become increasingly dominated by dense stands of mature saltbush shrubs, while the Southeast Area Grid is more or less naturally maintained as high quality Alkali Sink Scrub habitat. The numbers of Heermann's kangaroo rats in 2018 (15) were similar to what were trapped in 2017 (19) at the Southeast Area Grid; however, there was a significant decrease (-62%) in the number of Heermann's kangaroo rats trapped in 2018 (52) from the 157 individuals trapped in 2017. Reasons for this are not clear, but the increasing density in large saltbush shrubs is likely a contributing factor. Although it is widely known that Heermann's kangaroo rats tend to be better at utilizing dense shrubby areas than the Tipton kangaroo rat, there probably comes a point when even the Heermann's kangaroo rat may be negatively affected by this factor.

Sensitive Habitat Botanical Monitoring

Introduction

Six special-status plant species have been reported to occur at the KWB. These are: Hoover's woolly-star (*Eriastrum hooveri*), San Joaquin woollythreads (*Monolopia congdonii*), recurved larkspur (*Delphinium recurvatum*), Kern mallow (*Eremalche kernensis*), Horn's milk-vetch (*Astragalus hornii* var. *hornii*), and slough thistle (*Cirsium crassicaule*). Each year SVB biologists conduct site visits to known populations of the special-status species on the KWB. These site visits continue throughout the late winter and into the early summer and beyond in favorable rainfall years.

The 2017- 2018 rain year (October 1, 2017 - September 30, 2018) was not a favorable year for special-status plants in Kern County. Only 3.95 inches of precipitation was recorded for the Bakersfield area. This is just 65% of the long-term normal of 6.12 inches. As a result, most populations of special-status plants produced fewer plants that were much less vigorous than what was reported for 2017 (SVB 2018).

San Joaquin woollythreads is the earliest to germinate and bloom of all the special-status plants at KWB. Germination is often quite variable, but in most years with adequate precipitation, individual plants begin to germinate in late January or early February. SVB commenced monitoring of known San Joaquin woollythreads populations at KWB on February 7th. As was seen in 2017, several hundred plants were observed at the known populations of this species. However, in 2018 the plants were all very small compared to plants in 2017 (SVB 2018). Regular visits continued throughout most of the flowering period for San Joaquin woollythreads, and on each occasion plants were observed up until April 9th. The plants were still quite small in stature, but many were in full bloom. Many plants had begun flowering by February 13th. By March 6th essentially all plants were in full bloom. 2017 was an exceptionally favorable year for San Joaquin woollythreads at KWB.

San Joaquin woollythreads vegetative stage (Feb. 7, 2018)

San Joaquin woollythreads vegetative stage (Feb. 20, 2018)

San Joaquin woollythreads flowering stage (Mar. 28, 2018)

San Joaquin woollythreads late-flowering/fruiting stage (Apr. 3, 2018)

Site visits to several known populations of Hoover's woolly-star on the KWB in 2018 did not reveal any plants. It is likely that precipitation was not adequate for this species as Hoover's woolly-star seeds are widely known to remain dormant when rainfall is significantly below normal.

Recurved larkspur occurs at the KWB within one sector of the conservation bank lands on both the eastern and western sides of the Alejandro Canal. This is an area that supports alkali sink scrub habitat that is ideal for this species. In 2018, only 5 plants were observed. The plants were first observed on April 3rd. All the plants were small, vegetative, in the "rosette" stage of growth. Two of the plants were already drying out. Two follow-up site visits to this population were unsuccessful at locating any additional plants and it is likely that the plants that were observed on April 3rd had aborted growth for lack of adequate rainfall.

Recurved larkspur vegetative "rosette" stage (Apr. 3, 2018)

Kern mallow was also affected by the low precipitation in 2018, but not as drastically as was observed for the other special-status plants. Vegetative plants were first observed on March 2nd. Plants were small in stature, but there were several hundred individuals observed. Site visits continued into late April with many additional plants observed flowering and fruiting until early May. All plants remained small, with the largest individuals measuring just 10 inches in height. Lastly, one new small population of Kern mallow consisting of about 100 plants was observed in the Southeast Area of the conservation bank in the southeast ¼ of Section 36, Township 30 South, Range 25 East (Figure 1).

Kern mallow in vegetative stage (Mar. 9, 2018)

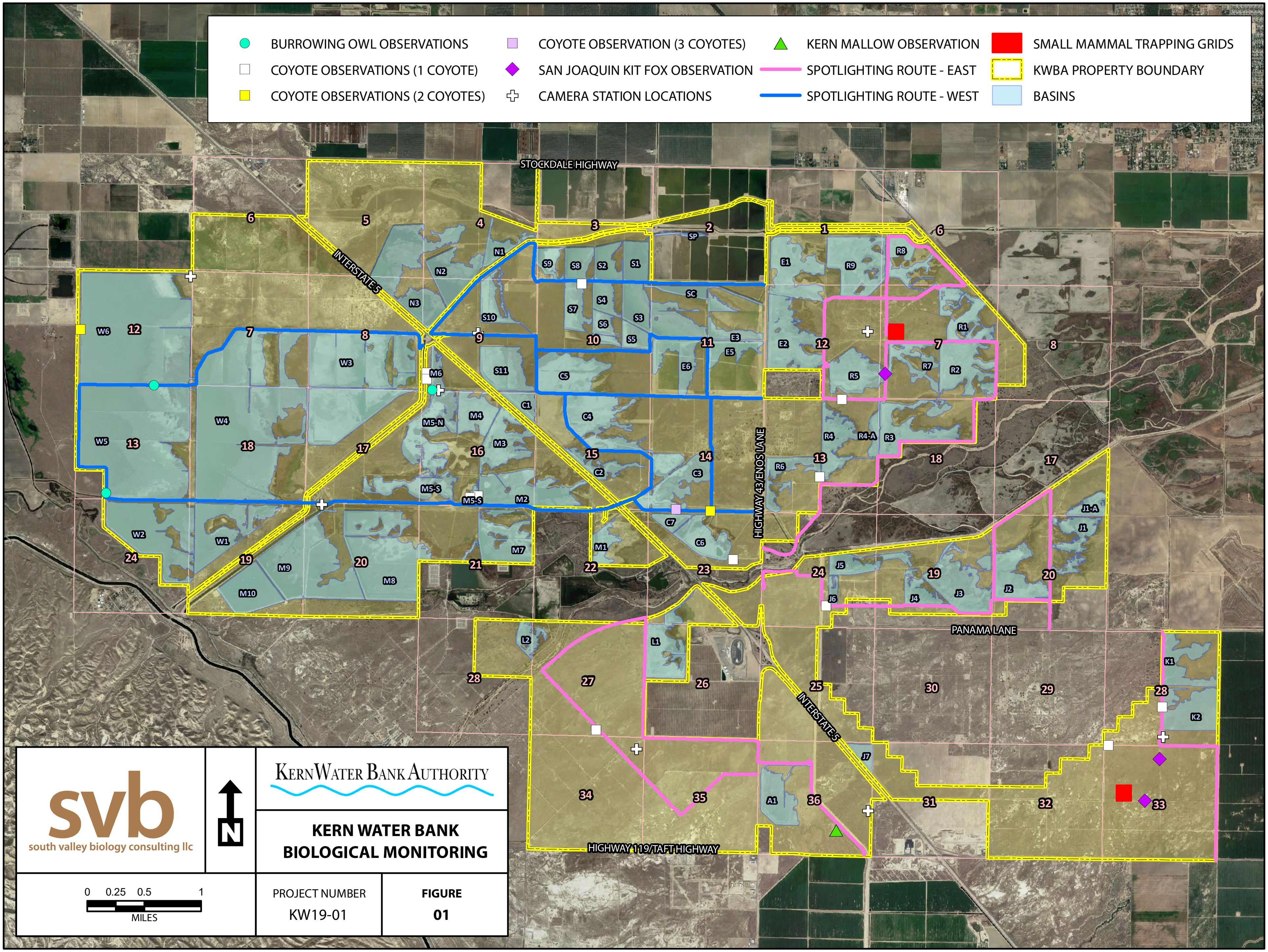
Kern mallow still in vegetative stage (Mar. 28, 2018).

Kern mallow in flowering stage (Apr. 3, 2018).

References

Kern Water Bank Authority. 1997. Habitat conservation plan/natural community conservation plan. Prepared by Kern Water Bank Authority. October 2, 1997.

South Valley Biology Consulting LLC. 2018. 2017 annual wildlife monitoring report for the Kern Water Bank. Prepared by South Valley Biology Consulting LLC for the Kern Water Bank Authority. June 18, 2018.


BURROWING OWL OBSERVATIONS
COYOTE OBSERVATIONS (1 COYOTE)
COYOTE OBSERVATIONS (2 COYOTES)
COYOTE OBSERVATION (3 COYOTES)
SAN JOAQUIN KIT FOX OBSERVATION
CAMERA STATION LOCATIONS
KERN MALLOW OBSERVATION
SPOTLIGHTING ROUTE - EAST
SPOTLIGHTING ROUTE - WEST
SMALL MAMMAL TRAPPING GRIDS
KWBA PROPERTY BOUNDARY
BASINS
STOCKDALE HIGHWAY
INTERSTATE 5
HIGHWAY 43/ENOS LANE
PANAMA LANE
HIGHWAY 119/TAFT HIGHWAY
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south valley biology consulting llc
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MILES
KERN WATER BANK AUTHORITY
KERN WATER BANK
BIOLOGICAL MONITORING
PROJECT NUMBER
KW19-01
FIGURE
01

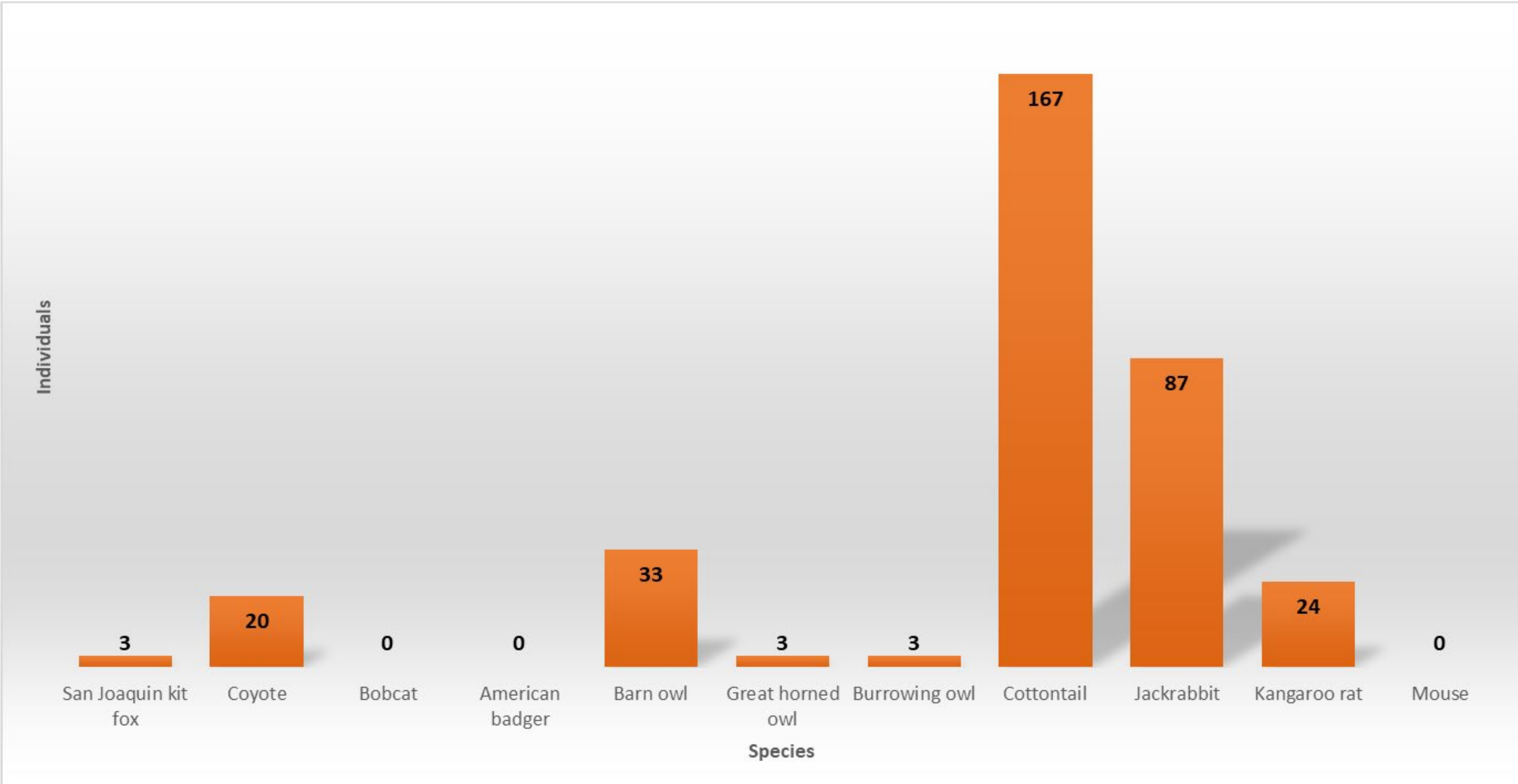

Figure 2. Results of 2018 nighttime spotlighting surveys at the Kern Water Bank.

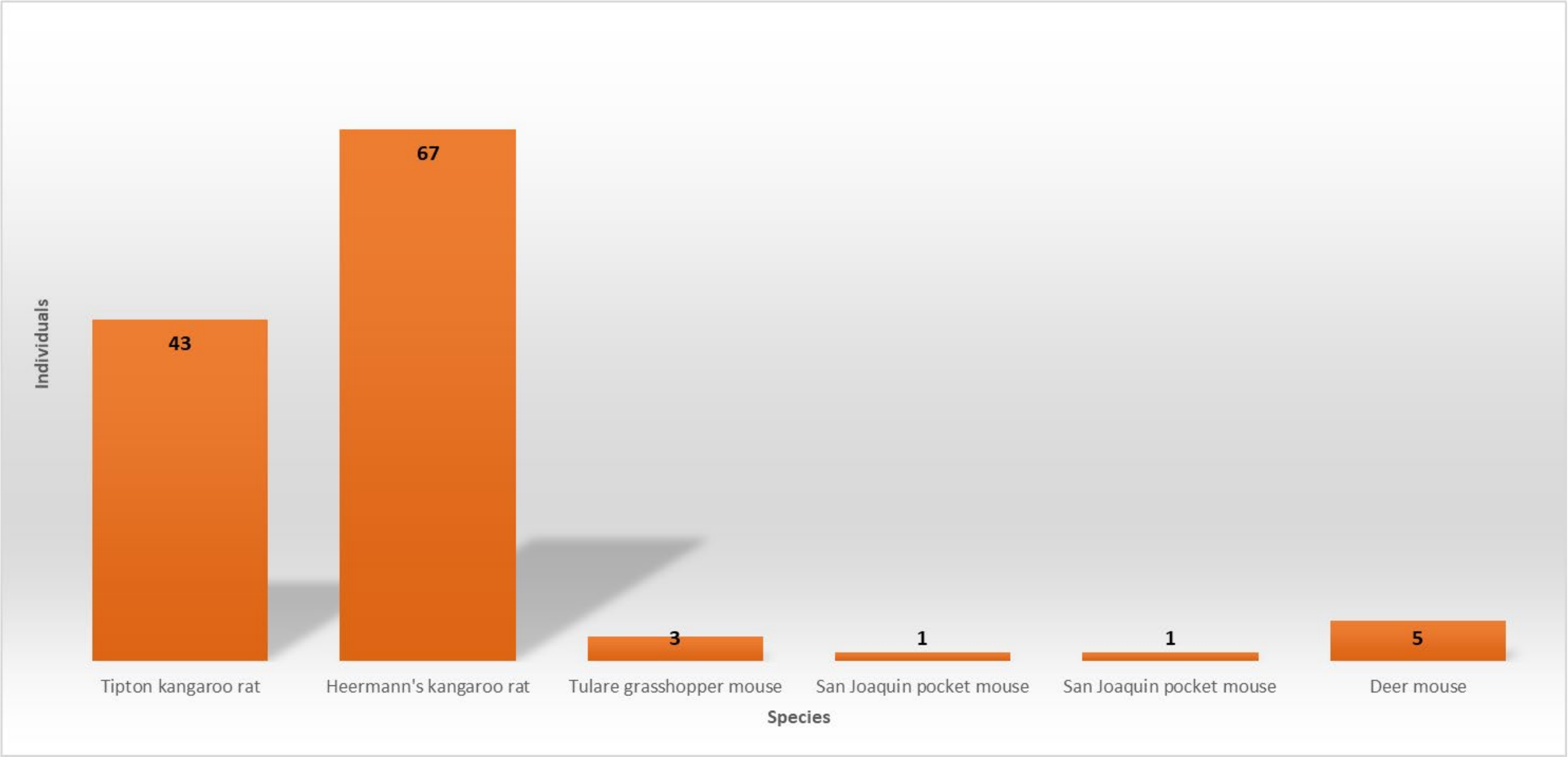

Figure 3. Results of 2018 Tipton kangaroo rat monitoring at the Kern Water Bank.

Appendix F

Kern Water Bank Ponds Aquatic Ecology, Monitoring, and Assessment

Killdeer (*Charadrius vociferous*)

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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

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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.

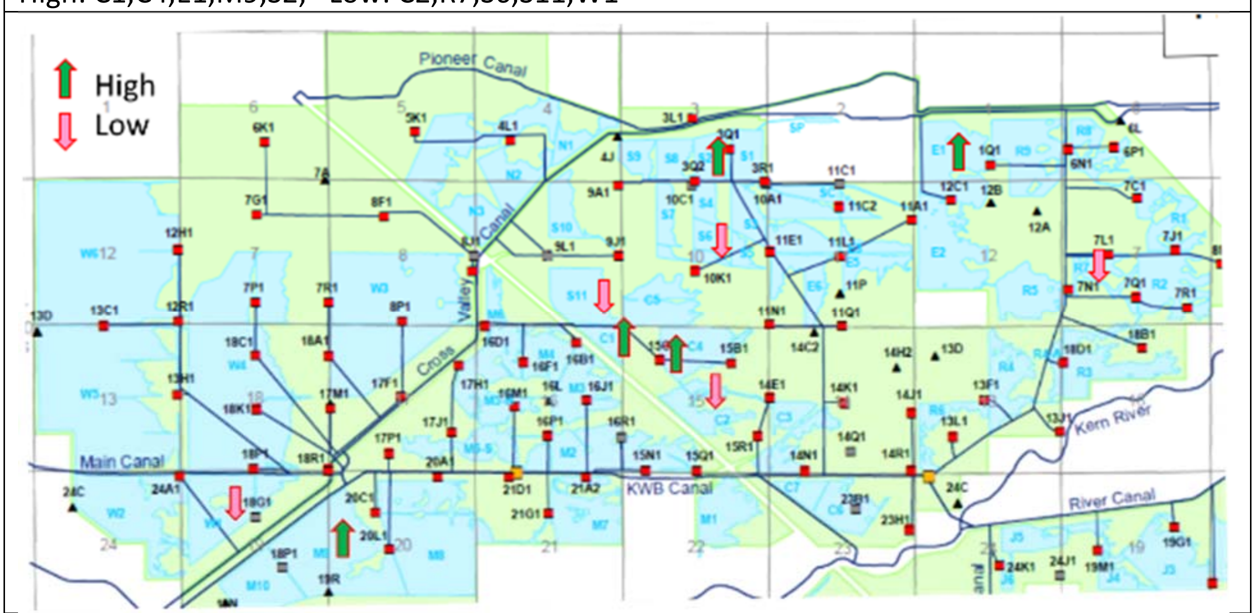
Bird Species	**Average density (#/ha) difference across all ponds: August vs. May 2017 survey**
AMERICAN COOT	1.76
BLACK-CROWNED NIGHT-HERON	0.02
BLACK-NECKED STILT	0.02
CASPIAN TERN	0.02
CATTLE EGRET	0.02
CINNAMON TEAL	0.04
CLARK'S GREBE	0.04
DOUBLE-CRESTED CORMORANT	0.05
GADWALL	0.08
GREAT BLUE HERON	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

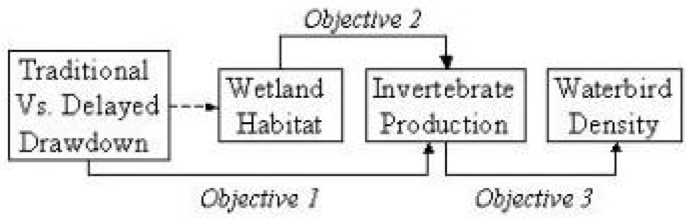
Paired (High,Low) ponds did not significantly differ in area (P=0.24) or elevation (P=0.60)(dependent t-test).

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

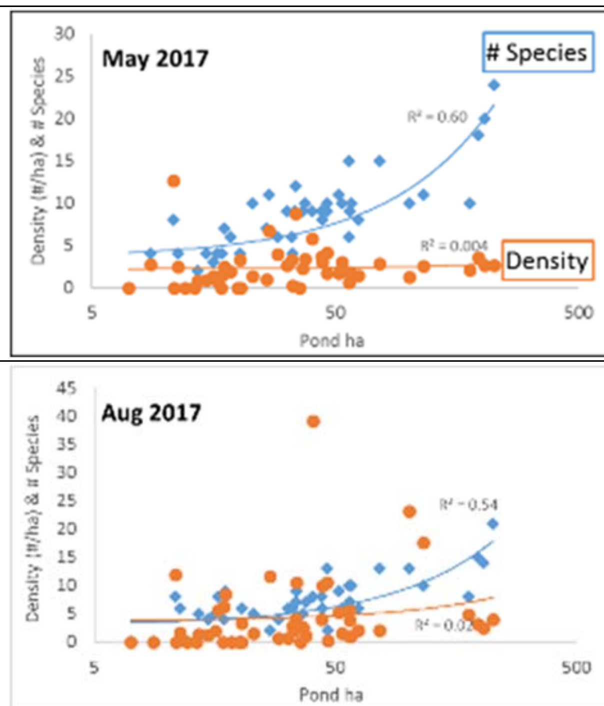
- Impacts of pond inundation cycles on aquatic ecology (disturbance)
- Water residence time impacts on WQ & algae;
- Conditions fostering Blue-Green algal blooms
- Mammal use of ponds & riparian habitat
    - Currently doing such a study along the San Joaquin River restoration area

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.

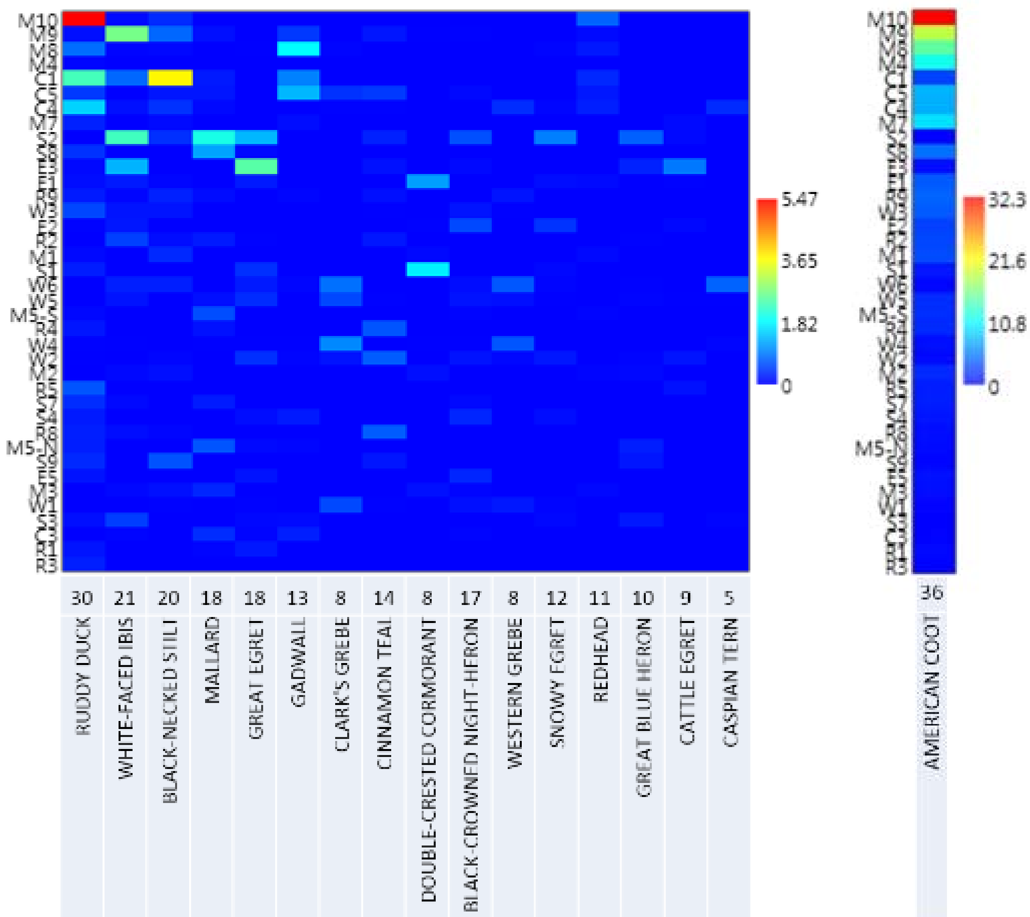
We characterized the August 2017 survey information qualitatively and quantitatively. The overall goal of the data analysis and this study in general is to discern any non-random patterns in bird asseblages and/or pond attributes (abiotic & biotic) during the study period. Any non-random patterns can 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.

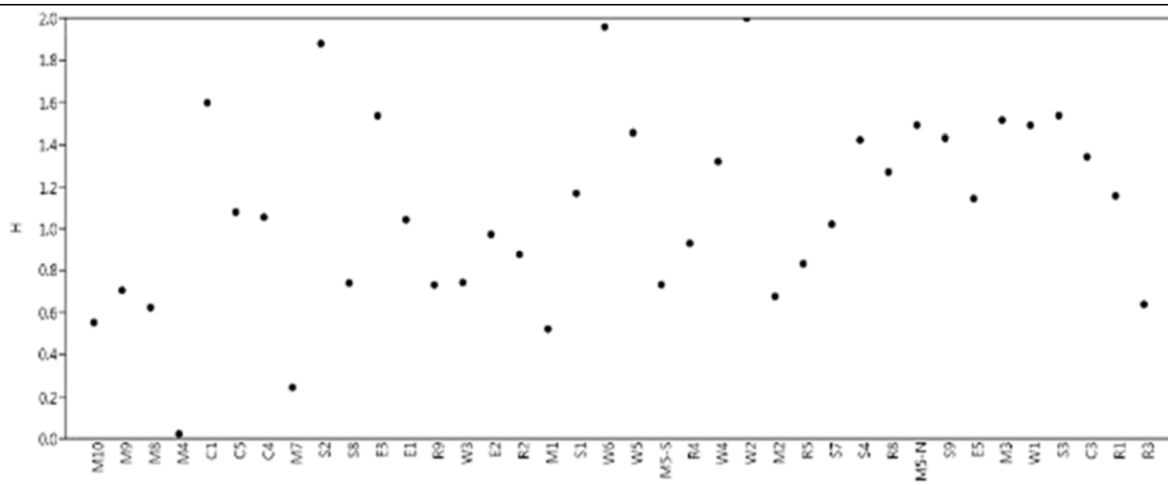
Figure 3. Density by species and pond (based on the waterbird species comprising ~98% of total abundance). The number of ponds occupied (of 50) by species in the August 2017 survey are above the species' labels. Note the relatively high densities and frequency of occurance of American Coot which is plotted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



Diversity

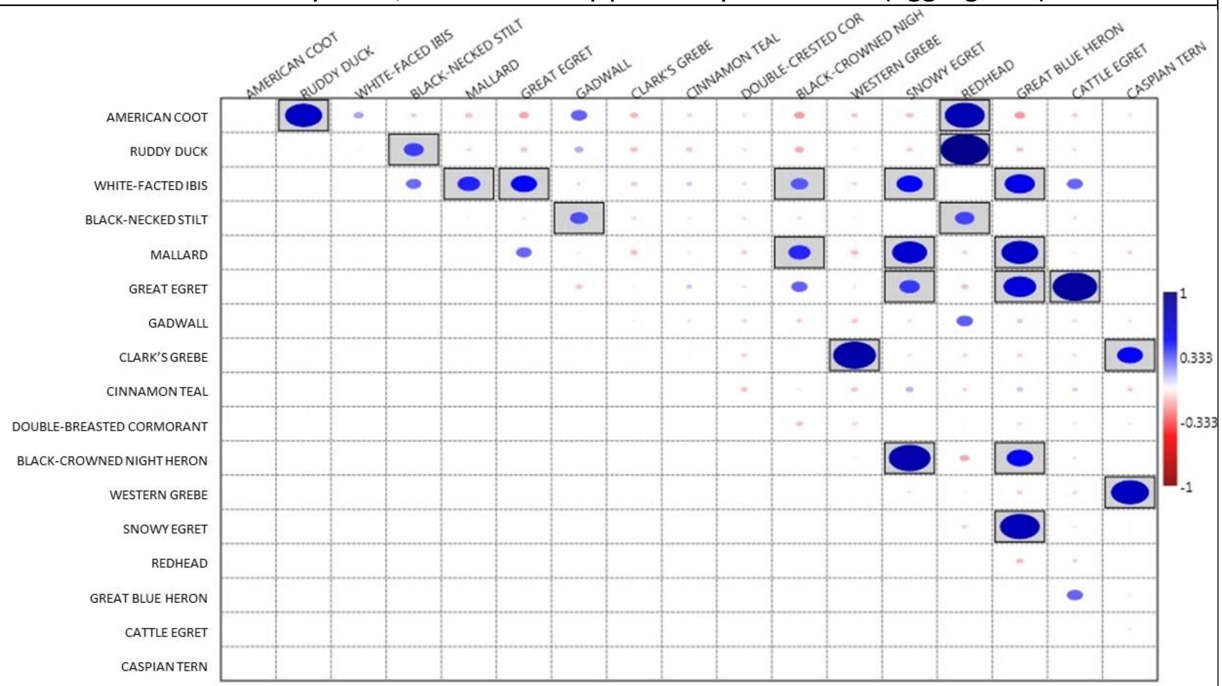
'Diversity' is a function of the number of species and their relative proportions in the assemblage, for example, pond M4 had very high waterbird density, but this was comprised of 220 American Coots and 1 Ruddy Duck. Diversity is highly variable among ponds, even in the same areas (e.g. ponds with same 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.

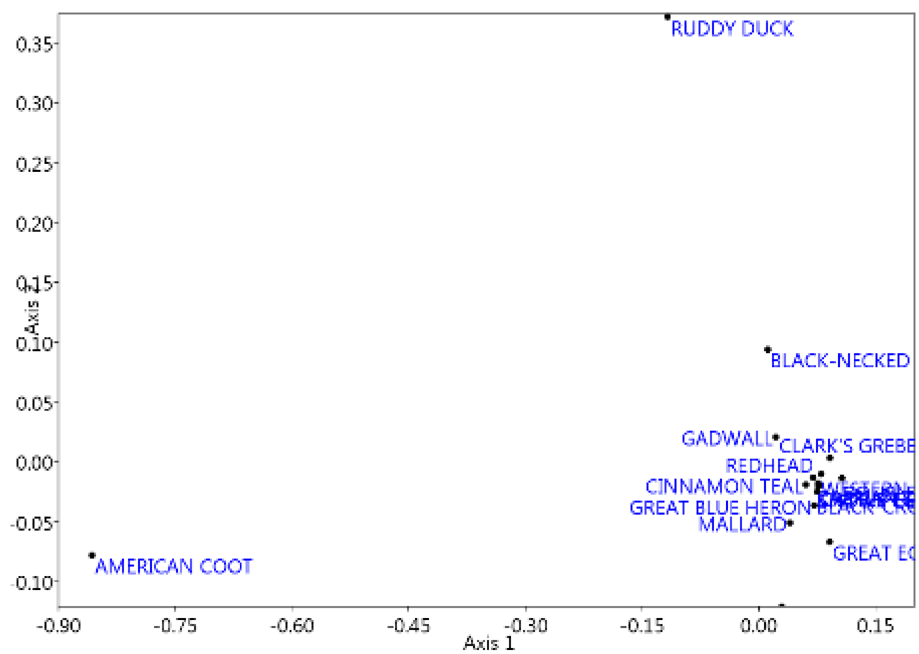


Figure 7. NMDS plot based on waterbird species relationships among ponds. The spread of species in the plot is based on correlations among species, which is based on relative and not absolute abundances. This analysis produces three clear species groupings, which partially suggest distinct body forms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

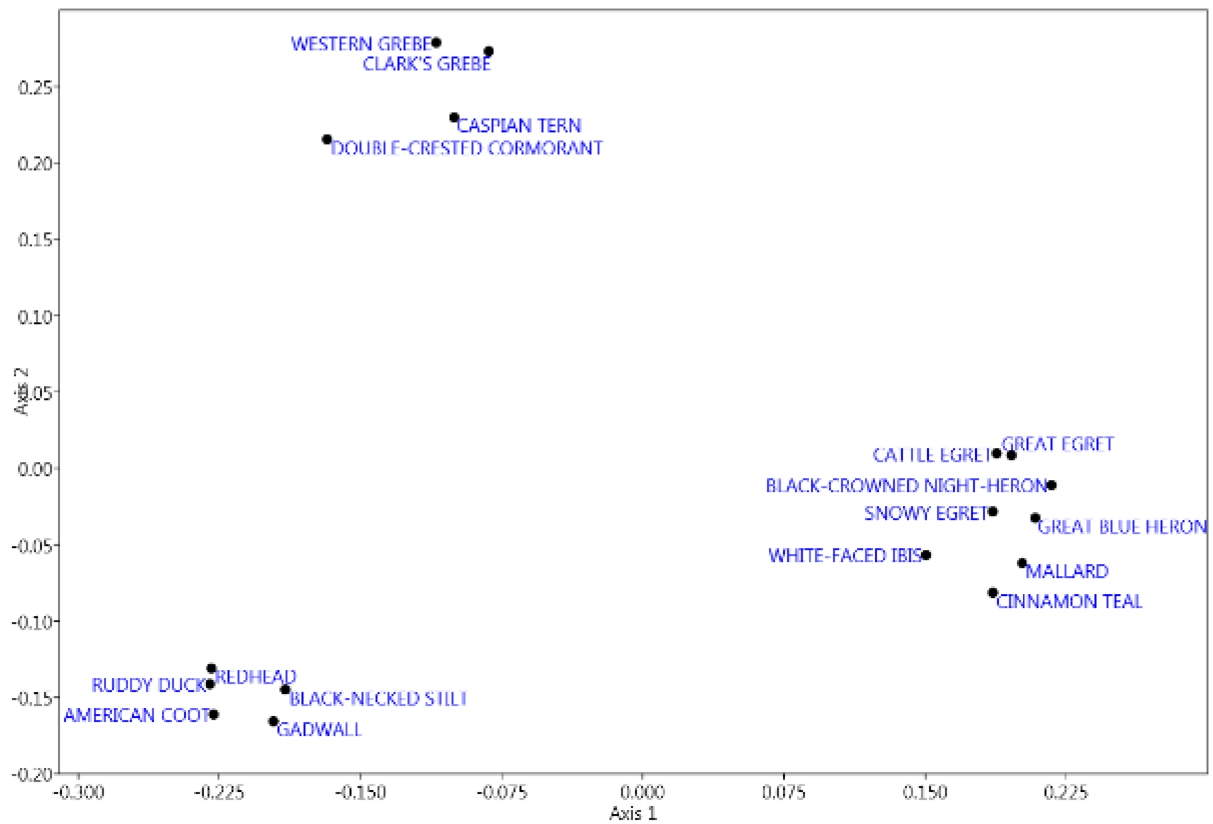
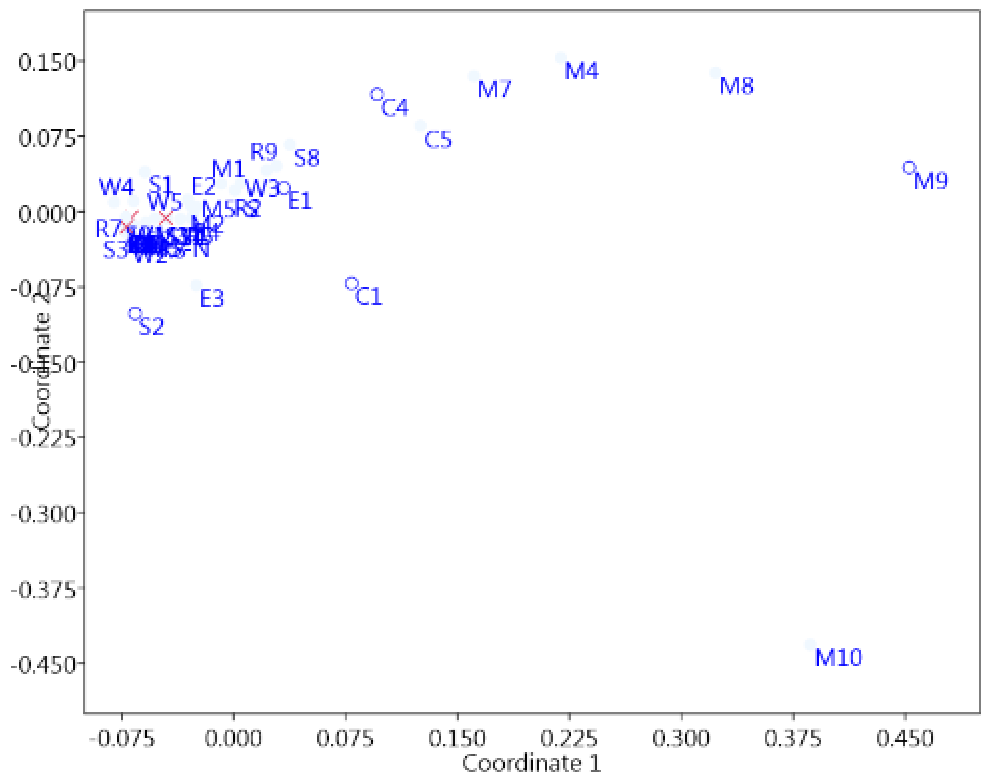
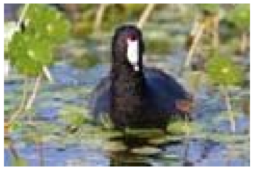
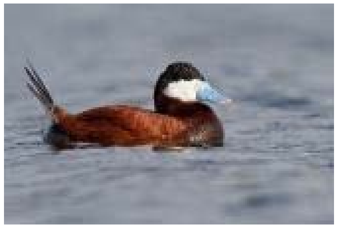
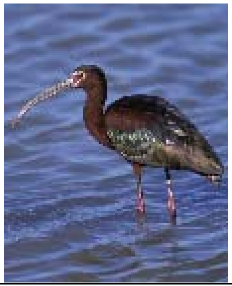
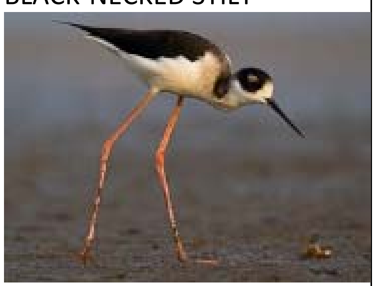


Figure 8. NMDS plot of ponds based on waterbird species assemblages; distances between sites calculated from Jaccard's similarity, which takes in to account species absolute abundances. 'High' waterbird status ponds are designated with open blue symbols. These sites are rather isolated in composition 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.



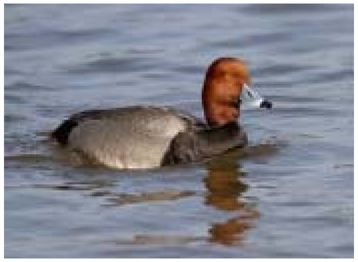
KWB Waterbird Habitats & Diets

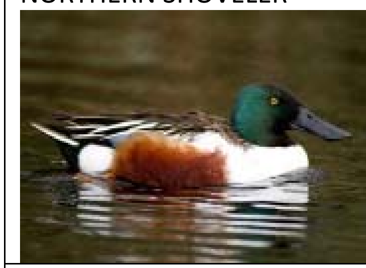
Species	Habitat notes	Aquatic Food	Other Notes
AMERICAN COOT 	Ponds, lakes, marshes Seasonal wetlands used during years of high water, while drought years cause breeding to be limited to permanent wetlands.	Omnivorous. Eats mostly plant material, including stems, leaves, and seeds of pondweeds, sedges, 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.

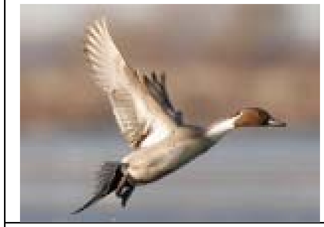
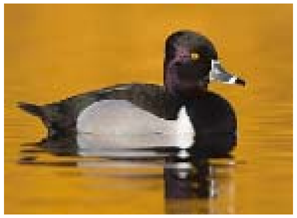
GREAT EGRET 	Lives in freshwater, brackish, and marine wetlands. During the breeding season they live in colonies in trees or shrubs with other waterbirds	Mainly small fish but also eats amphibians, reptiles, birds, small mammals and invertebrates such as crayfish, prawns, shrimp, polychaete worms, isopods, 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
Goodding'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)

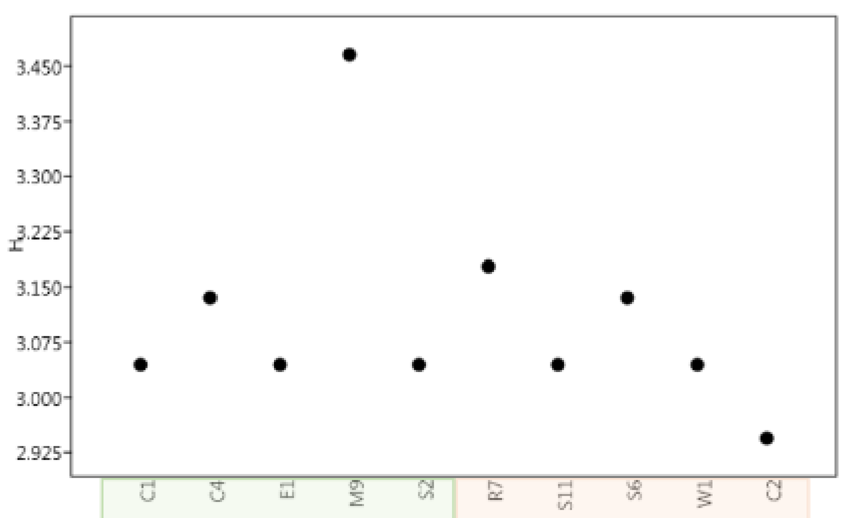


Figure 10. NMDS ordination w/ Jaccard's distance index (for pres/abs data). Open circles and red X are 'High' and 'Low' waterbird ponds respectivley. 'H' & 'L' are centers of the High & Low waterbird ponds. Green lines connect High and Low pond pairs.

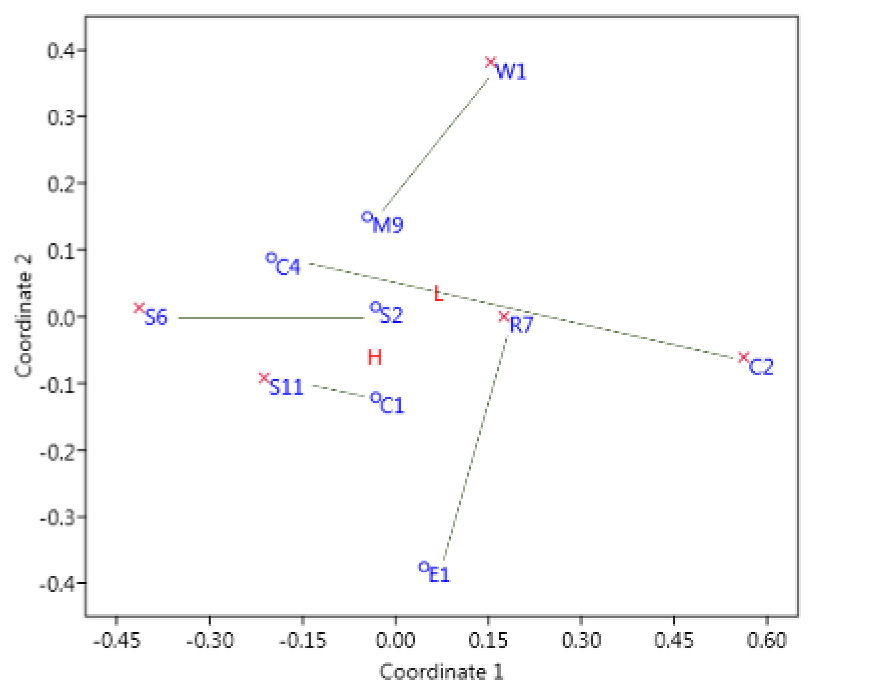


Figure 11. Cluster analysis of ponds based on plant assemblages. Labels are pond code, waterbird status, and pond pair number. This configuration confirms the ordination analysis; there is little grouping by waterbird status or proximity (i.e. pond pairs are not grouped together).

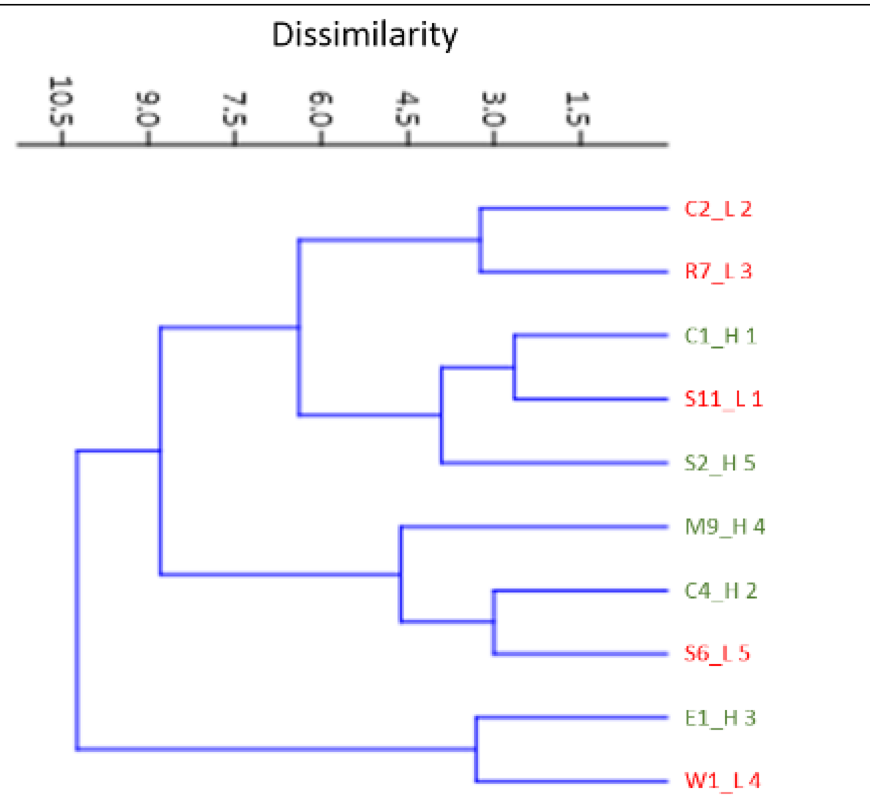
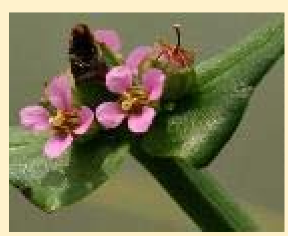
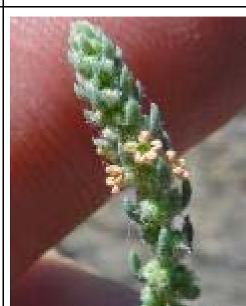
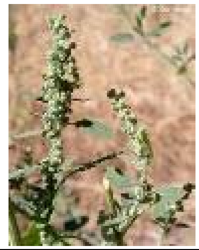
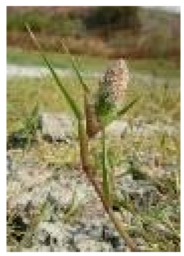


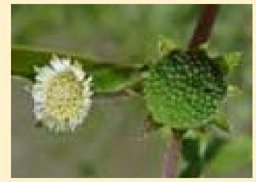
Table 4. Terrestrial Vegetation at Study Pond Margins

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	 

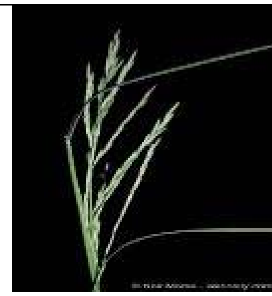
Pitseed goosefoot Chenopodium berlandieri Forb/herb S6 https://www.calflora.org	 
Thistle *(specificity depends on the specific type)* Cirsium species Forb/Herb M9 https://plants.usda.gov	
Swamp pricklegrass Crypsis schoenoides Graminoid M9 https://plants.usda.gov	
Fiveangled dodder Cuscuta campestris 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	 

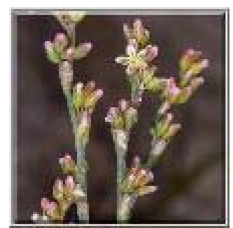
Upright burhead Echinodorus berteroi (submerged) Forb/herb W1 https://plants.usda.gov	 
False daisy Eclipta prostrate Forb/herb W1,R7,C1,S11,S6,M9,E1,C4,S2 https://www.calflora.org	  
Common spikerush Eleocharis palustris (or less likely E. macrostachya) Graminoid C2 https://plants.usda.gov	 
Parish's 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	 

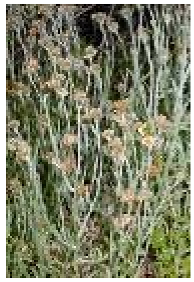
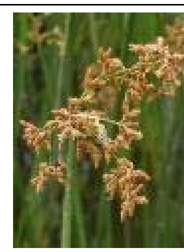
Stork's Bill *(specificity depends on the specific type)* Erodium sp. Forb/herb E1 https://plants.usda.gov	
Great Valley gumweed Grindelia camporum Forb/herb, Subshrub W1, C4 https://plants.usda.gov	
Sunflower Helianthus annuus Forb/herb W1,R7,C2,C1,S11,M9,E1,C4,S2 https://plants.usda.gov	
Salt heliotrope (+ 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	 

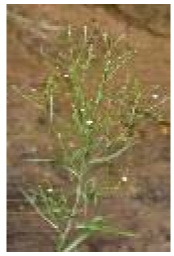
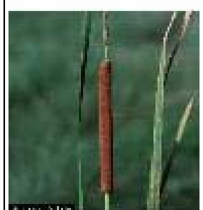
Quillwort *(specificity depends on the specific type)* Isoetes sp. Graminoid C1 https://plants.usda.gov	 
*same as above *(specificity depends on the specific type)* Isoetes sp. (dead, floating on surface) S11,S6	
*same as above *(specificity depends on the specific type)* Isoetes sp. (possibly bolanderi, 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.

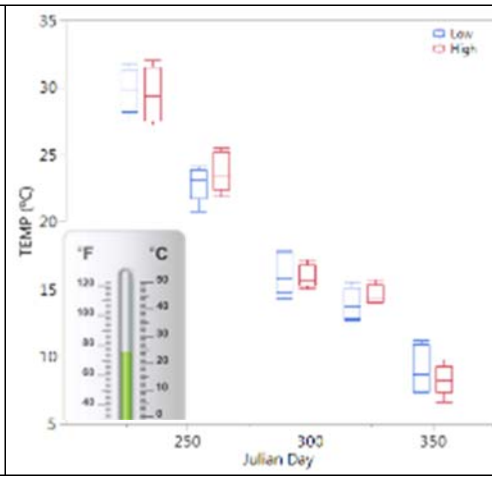


Figure 13. **Water temperature** from continuous monitoring; ponds C4,S2,S6,S11. Lines are smoothed averages from hourly measurements. The very close fit between deep and shallow sensors strongly suggest the mixing of the water column and the even distribution of heat. An

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.

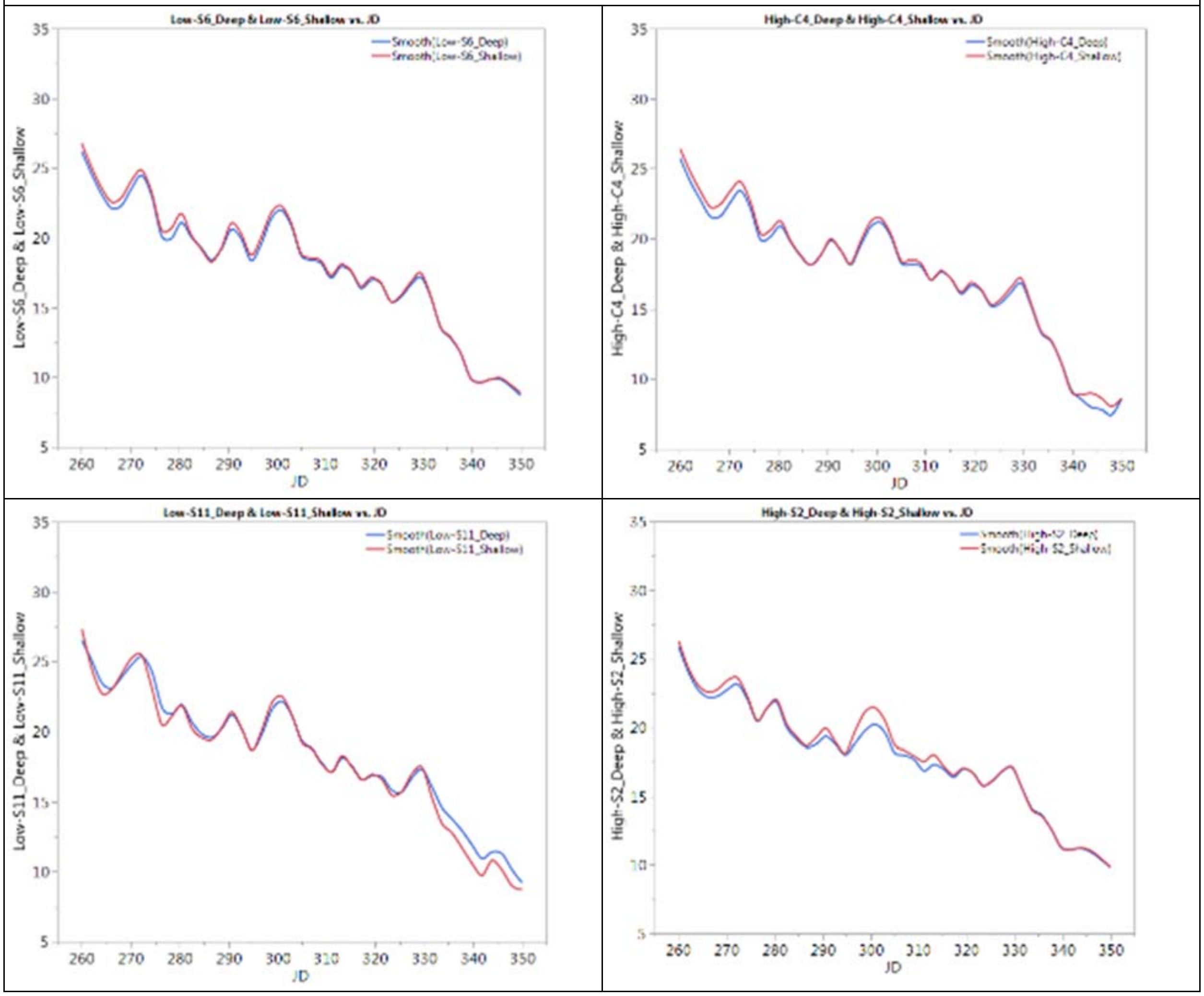


Figure 14. **Air temperatures** (daily average) for comparison with water temperatures.

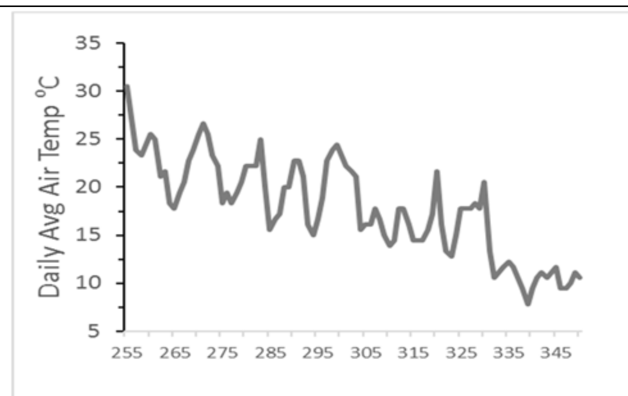
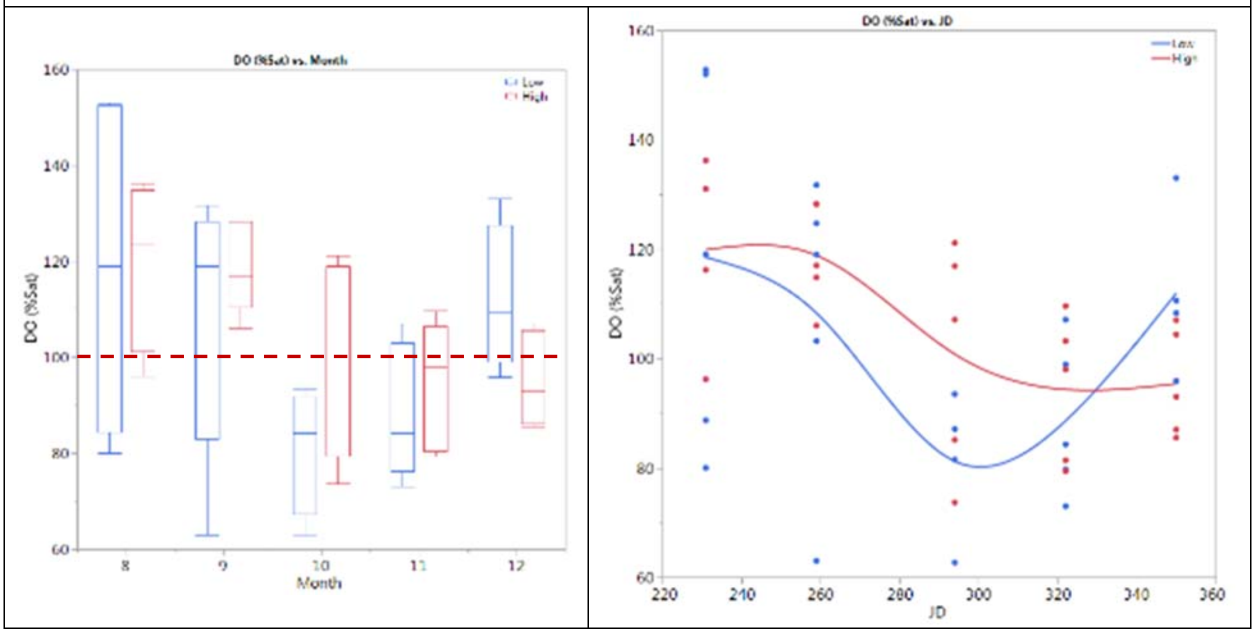
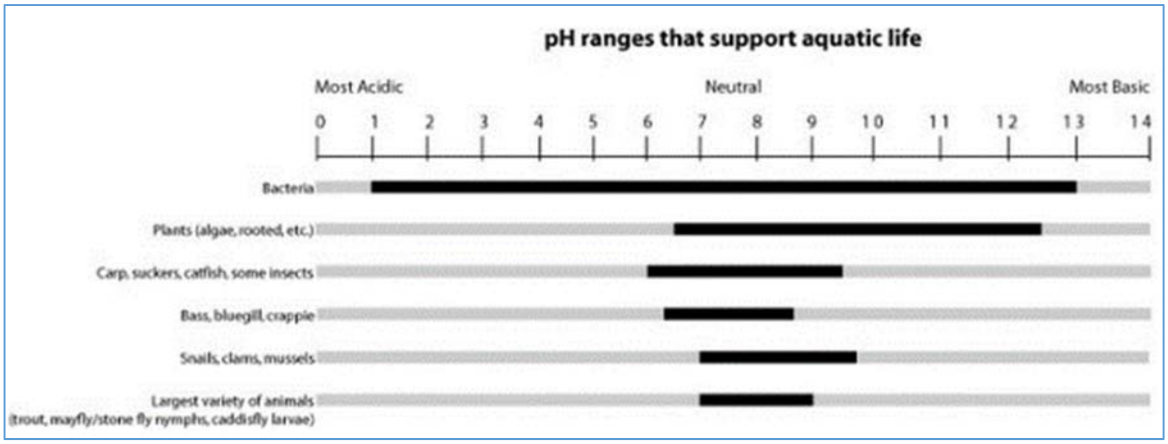


Figure 15. **Dissolved oxygen (as % saturation)** levels across months and pond types. Left panel: Box and whisker plot of DO %Sat showing variation within and among months and pont types. Right panel: Smooted plot of raw data highlighting seasonal patterns and differences between pond types.



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%.

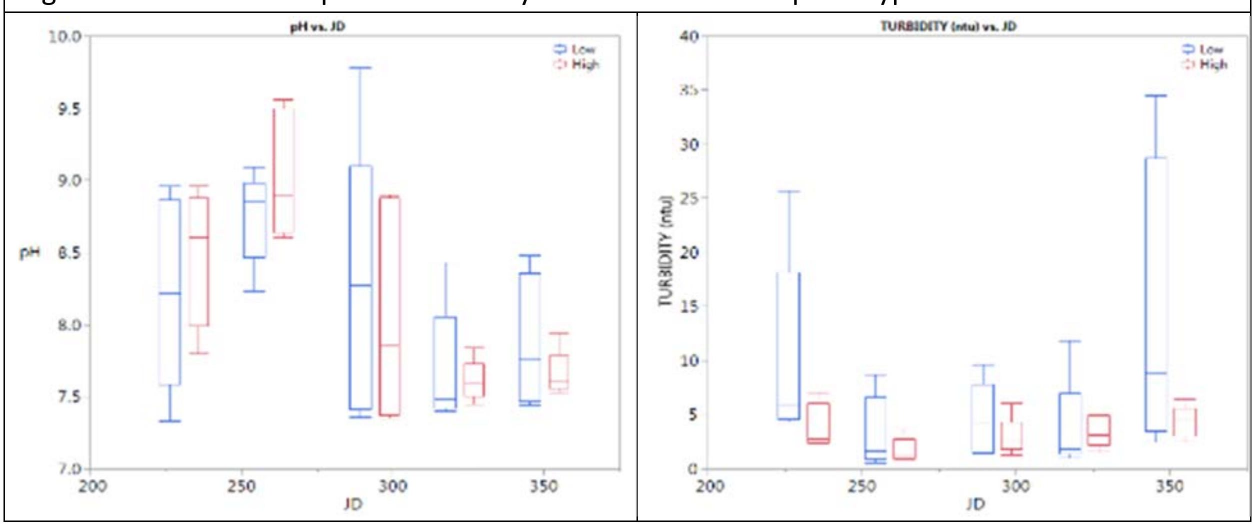


http://www.miseagrant.umich.edu

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		
S2	Oct	Diatoms	Diatoms
		Greens	
		BG	
S2	Nov	Diatoms	Diatoms
S2		Greens	Greens

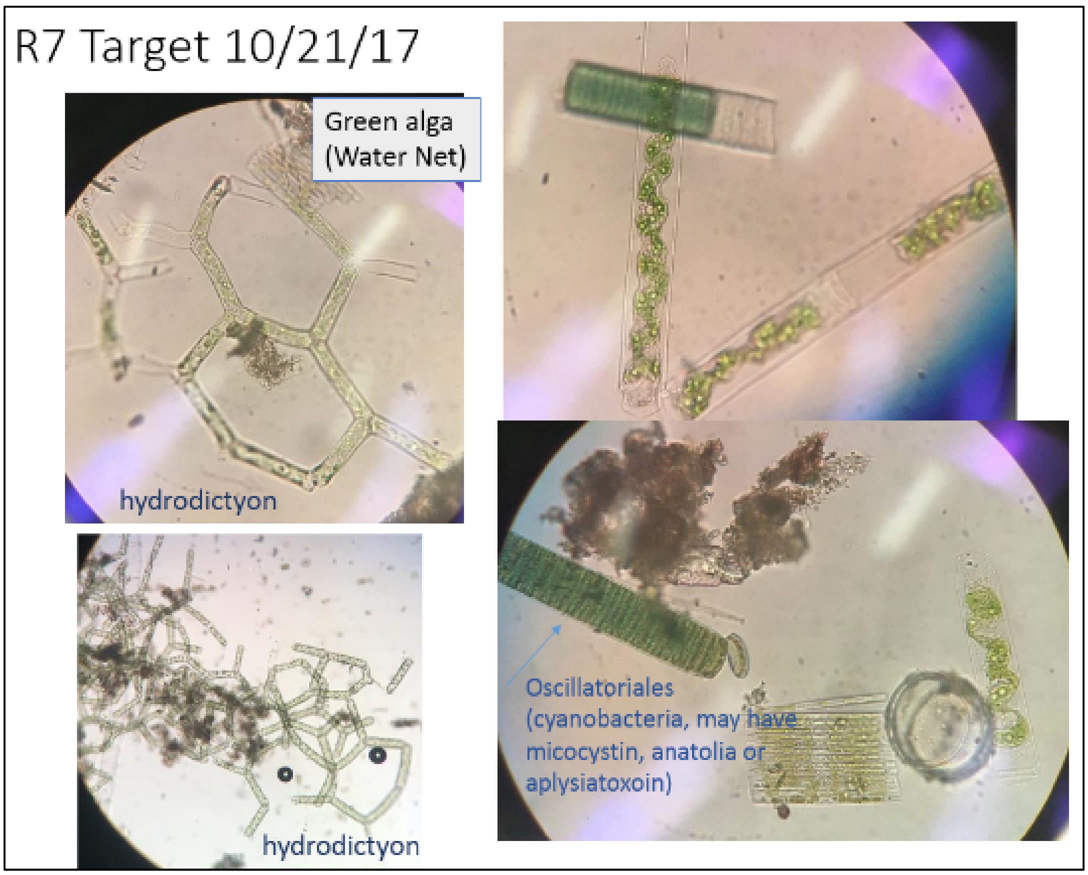
S11	Nov	Diatoms	Diatoms
		Greens	Greens
W1	Aug	Diatoms	Diatoms
		Greens	Greens
	Sept		
	Oct	Greens	Greens
			BG
	Nov	Diatoms	Diatoms
		Greens	Greens

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/zOGBgY6HEkI*
      - *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.

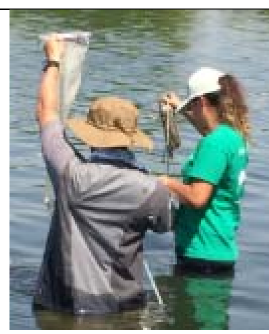
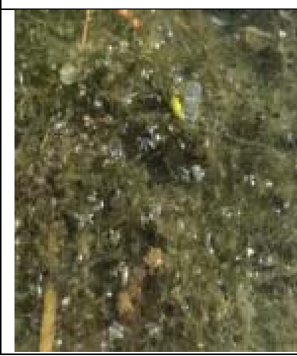
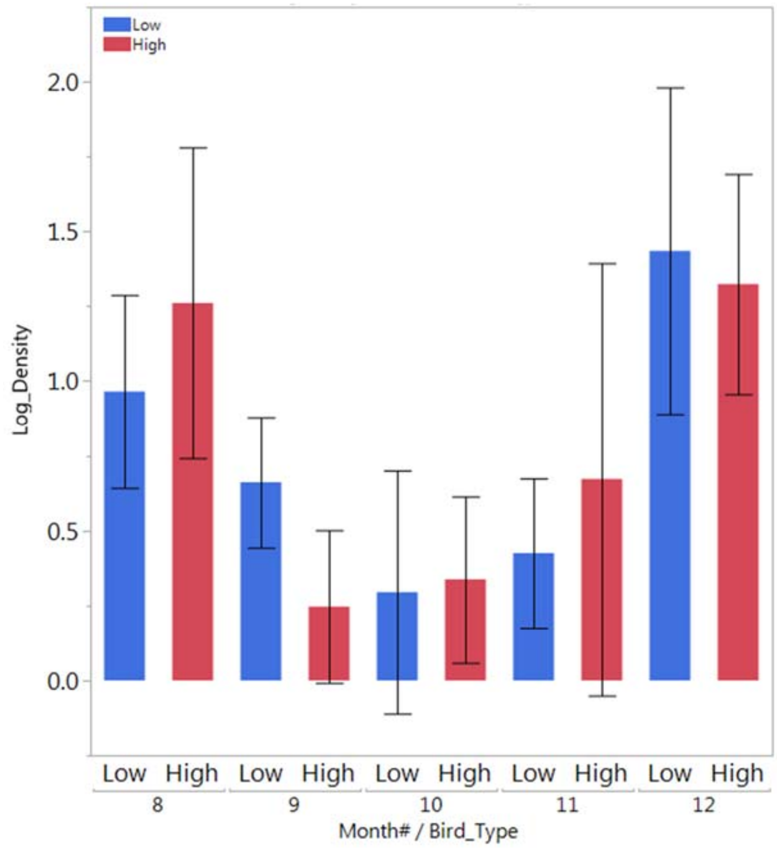
Zooplankton sample collection (Van Dorn) (*click for video*)	Sample water from the Van Dorn bottle were sieved through a plankton net		Collected material (*click for video*)
			

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.

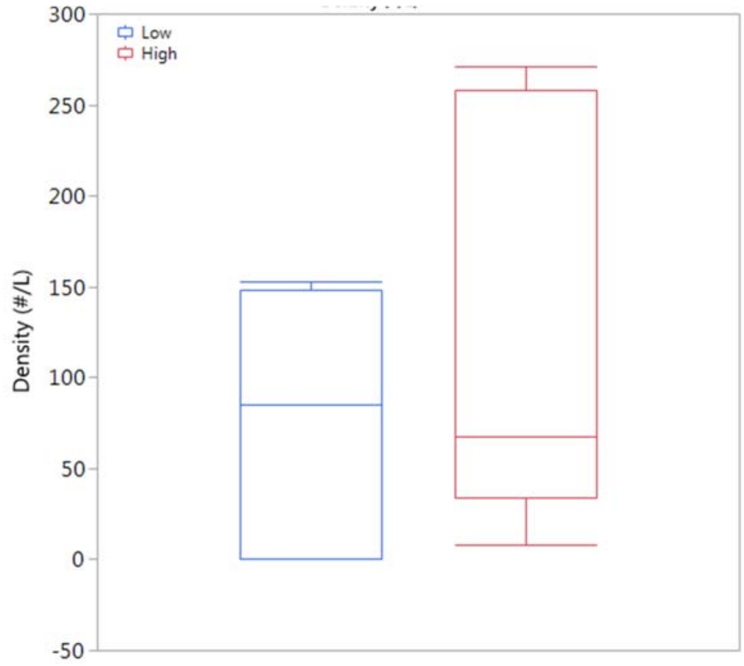
The nets were sampled using a core sampler made from a two-foot section of PVC pipe and a rubber stopper at one end. Parafilm was placed at the open end to allow for pressure to hold water more effectively. A small cut was made in the netting to allow the sampler to be inserted. The stopper would then 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
		

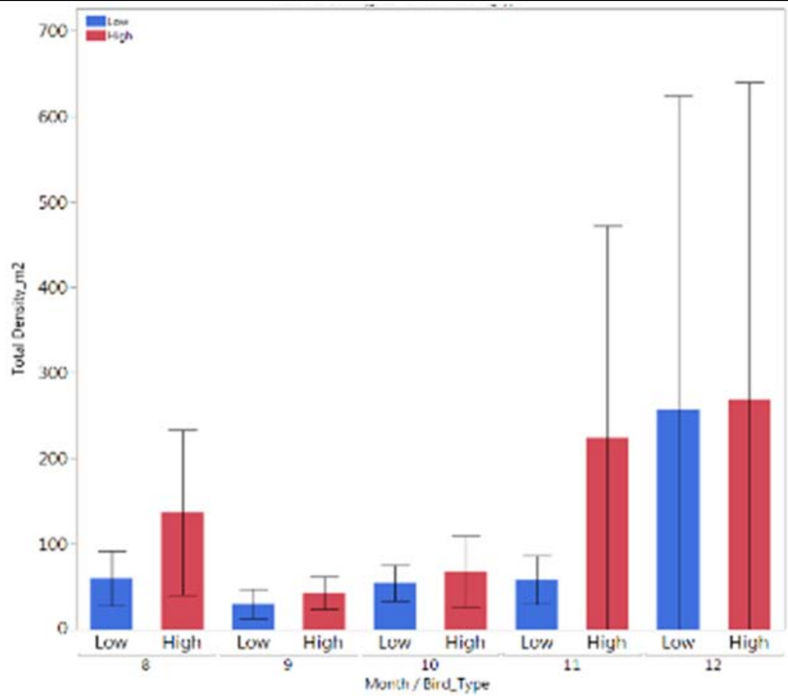
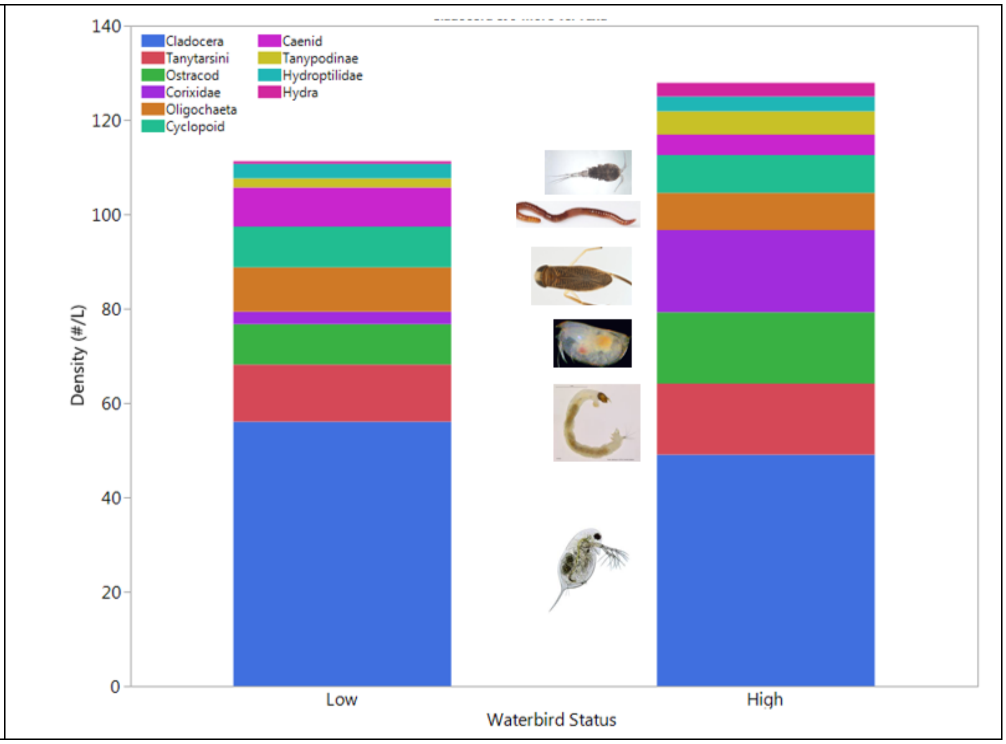


Figure 20. Benthic invertebrate densities (#/m^2) among months and Low vs. High waterbird ponds.

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)

<u>Taxonomic Composition</u>: 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)



<u>**Emergence Traps**</u>

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.

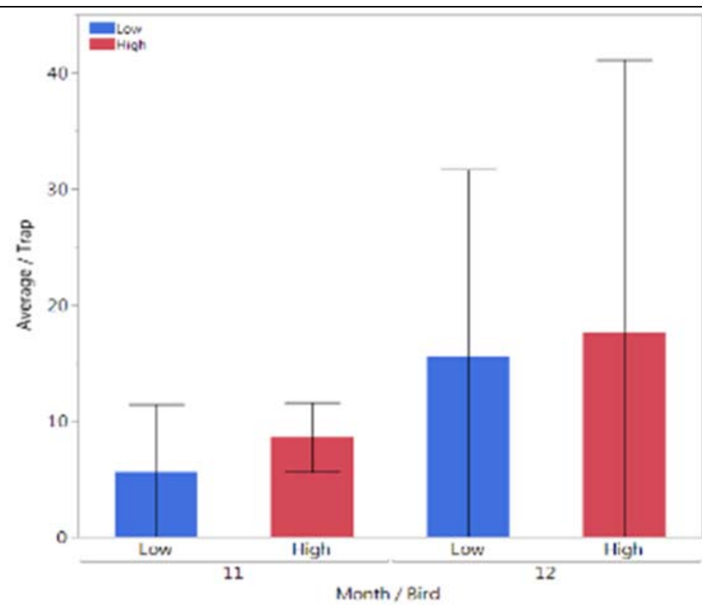
For the month of November, various changes were made in the design of the emergence traps to account for flaws causing them to sink after the October deployment. The deployment trip was conducted on November 11th and a group-sampling trip was conducted on November 18th. Originally, insulation tubes were 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.



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Appendix G

Audubon Checklist - January 27, 2018

Western Scrub-jay (*Aphelocoma californica*)

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Hi Jon

Thanks for allowing us to bird watch on the water bank. I spoke with Steve and he said next weekend after some drying would be better. So Bruce, Denise, and me will be there either March 10 or 11 weather depending. Richard Rudnick might join us.

Here is the summary of birds seen on January 27, 2018. We birded the water bank for around six hours.

eBird Checklist Summary for: Jan 27, 2018 at 12:01 AM to Jan 27, 2018 at 1:59 PM

Number of Checklists: 4

Number of Taxa: 85

8 Cinnamon Teal -- (4)

730 Northern Shoveler -- (4)

46 Gadwall -- (4)

76 American Wigeon -- (4)

14 Mallard -- (4)

60 Northern Pintail -- (4)

9 Green-winged Teal (American) -- (4)

41 Canvasback -- (4)

1 Lesser Scaup -- (4)

72 Bufflehead -- (4)

62 Ruddy Duck -- (4)

13 California Quail -- (2),(3)

7 Pied-billed Grebe -- (4)

7 Eared Grebe -- (4)

4 Western Grebe -- (4)

14 Clark's Grebe -- (4)

12 Double-crested Cormorant -- (1),(3),(4)

143 American White Pelican -- (3),(4)

42 Great Blue Heron -- (1),(3),(4)

73 Great Egret -- (3),(4)

27 Snowy Egret -- (3),(4)

37 Black-crowned Night-Heron -- (3),(4)

551 White-faced Ibis -- (3),(4)

3 Turkey Vulture -- (4)

2 Osprey -- (4)

2 White-tailed Kite -- (3)

4 Northern Harrier -- (2),(3),(4)

1 Sharp-shinned Hawk -- (3)

2 Cooper's Hawk -- (3)

17 Red-tailed Hawk -- (1),(2),(3),(4)

1 Ferruginous Hawk -- (4)

250 American Coot -- (4)

2 Black-necked Stilt -- (4)

1 American Avocet -- (4)

126 Black-bellied Plover -- (4)

12 Killdeer -- (3),(4)

49 Dunlin -- (4)

280 Least Sandpiper -- (4)

4 Western Sandpiper -- (4)

400 Long-billed Dowitcher -- (4)

89 Greater Yellowlegs -- (3),(4)

4 Lesser Yellowlegs -- (4)

14 Ring-billed Gull -- (4)

1 Western Gull -- (4)

200 California Gull -- (4)

40 Herring Gull -- (4)

10 Mourning Dove -- (1),(3)

6 Greater Roadrunner -- (3)

3 Great Horned Owl -- (3),(4)

4 Belted Kingfisher -- (4)

1 Nuttall's Woodpecker -- (3)

2 Northern Flicker (Red-shafted) -- (1)

10 American Kestrel -- (1),(3),(4)

1 Peregrine Falcon -- (4)

19 Black Phoebe -- (1),(2),(3),(4)

5 Say's Phoebe -- (1),(3),(4)

14 Loggerhead Shrike -- (1),(2),(3),(4)

1 California Scrub-Jay -- (1)

1 American Crow -- (3)

9 Common Raven -- (3),(4)

14 Horned Lark -- (1),(4)

10 Marsh Wren -- (1),(3),(4)

1 Bewick's Wren -- (3)

3 Blue-gray Gnatcatcher -- (3)

3 Ruby-crowned Kinglet -- (3)

1 Western Bluebird -- (3)

1 Mountain Bluebird -- (4)

2 California Thrasher -- (3)

16 Northern Mockingbird -- (1),(2),(3),(4)

3 European Starling -- (3)

261 American Pipit -- (1),(2),(3),(4)

1 Orange-crowned Warbler -- (3)

7 Yellow-rumped Warbler (Audubon's) -- (4)

3 Dark-eyed Junco -- (2)

425 White-crowned Sparrow (Gambel's) -- (1),(2),(3),(4)

6 Vesper Sparrow -- (3)

83 Savannah Sparrow -- (1),(2),(3),(4)

2 Song Sparrow -- (4)

6 Lincoln's Sparrow -- (3)

1 Swamp Sparrow -- (4)

74 Western Meadowlark -- (1),(2),(3),(4)

14 Red-winged Blackbird -- (1),(2),(3)

1 Brown-headed Cowbird -- (1)

124 Brewer's Blackbird -- (1),(3)

34 House Finch -- (1),(3),(4)

Appendix H

Terrestrial Species Stressor Monitoring Reports

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Evaluating mammalian diversity in the Mojave Desert and Great Valley ecoregions of California using camera trap surveys

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Executive Summary

1. In response to the drought State of Emergency declared in 2014, California's Department of Fish and Wildlife (CDFW) prioritized monitoring of wildlife populations and their associations with drought stressors and habitat features. As part of this effort, CDFW initiated Terrestrial Species Stressor Monitoring (TSM) surveys in 2016 to collect baseline data on wildlife species in the Mojave Desert and Great Valley ecoregions. In this report, we present our analysis of camera trap data from the 2016-17 TSM surveys. For each ecoregion, our objectives were to estimate the occupancy and richness of terrestrial mammal species weighing >0.5kg and to evaluate community and species-specific responses to climate and habitat variables.
2. We deployed camera traps at 320 and 265 sites across the Mojave Desert and Great Valley ecoregions, respectively, in the springs of 2016 and 2017. We used this camera trap data, in combination with multi-species hierarchical occupancy models, to estimate and evaluate mammal distributions.
3. Sixteen and 22 species of terrestrial mammals (>0.5kg) were photographed in the Mojave Desert and Great Valley ecoregions, respectively, with camera-specific estimates of species richness ranging from 0 – 13. Black-tailed jackrabbits ($\psi = 0.73$) and kit foxes ($\psi = 0.34$) had the highest estimated occupancies in the Mojave, whereas coyotes ($\psi = 0.49$) and raccoons ($\psi = 0.45$) had the highest estimated occupancies in the Great Valley. The mammal community in the Mojave tended to be positively associated with elevation and negatively associated with mean temperature and distance to pinyon juniper forest. The mammal community in the Great Valley, alternatively, tended to be positively associated with crop diversity and negatively associated with natural vegetative cover.
4. Our results suggest projected increases in temperature will negatively influence the Mojave Desert's mammal community, and consequently, that the protection of climate refugia (e.g., high elevations, shaded areas, and permanent water sources) may be an increasingly important conservation strategy. This is particularly true for some species in the region, like deer, Audubon's cottontail, and bobcat, which appeared to be more vulnerable to projected climate changes than species like the kit fox.
5. In the Great Valley, our results suggest that the remnant mammal community is adept at accessing resources and surviving in this human-modified, agricultural landscape. Working with landowners to diversify agricultural practices and maintain habitat heterogeneity is important, however, as heterogeneity within and among croplands positively influences the mammal community.

6. **6.** Biodiversity loss, climate change, and anthropogenic pressures on ecosystems are accelerating. The infrastructure required to monitor changes in biodiversity and species' vulnerability to stressors, however, is often lacking. Our analysis demonstrates the utility of camera traps and multi-species occupancy models for monitoring terrestrial mammals, including elusive species. Expanding beyond our snapshot in time however, requires long-term data. With longer-term data (e.g., >5 years), we can develop an understanding of the processes occurring within these ecoregions including trends in species' occupancy and the influence of climate, environment, and humans on mammal communities. This information in turn, would allow managers to track, improve, and adapt management actions aimed at addressing the loss of wildlife populations.

Introduction

Following the drought State of Emergency declared in 2014, the California Department of Fish and Wildlife (CDFW) was tasked with implementing projects that respond to drought conditions. In order to effectively design and implement these projects, however, additional information on many wildlife populations is needed. Consequently, CDFW has prioritized monitoring wildlife populations including their distributions, abundances, vulnerability to drought stressors, and relationships to other habitat features.

The spatial distributions of wildlife are shaped by a diversity of biotic and abiotic factors. One such factor is water availability. In California, wildlife populations are generally positively associated with the presence of water (Schoenherr 1992). Bobcats (*Lynx rufus*), for example, are positively associated with stream density and riparian areas (Markovchick-Nicholls et al. 2008; Broman et al. 2014), the persistence of bighorn sheep (*Ovis canadensis*) is positively correlated with the presence of dependable springs (Epps et al. 2004), and striped skunks (*Mephitis mephitis*) often select for wetland habitat (Lariviére & Messier 2000). In southwestern USA, including the Mojave Desert, artificial water catchments (hereafter "guzzler") may also influence the distributions of wildlife because they provide permanent or semi-permanent surface water in areas where natural water is scarce (Bleich 1992; Cutler and Morrison 1998; Bleich et al. 2010; Larsen et al. 2012).

The influence of vegetative cover on the occurrence of wildlife, alternatively, is generally species-specific. Black-tailed jackrabbits (*Lepus californicus*) and kit foxes (*Vulpes macrotis*), for example, favor arid and semi-arid grasslands and shrublands (McGrew 1979; Wilson & Ruff 1999), whereas red foxes (*Vulpes vulpes*), California ground squirrels (*Otospermophilus beecheyi*), and opossums (*Didelphis virginiana*) are able to exploit a diversity of habitats (Whitaker 1980; Pérez-Hernandez et al. 2016). Landscape or habitat heterogeneity may also play a role in determining species' distributions. Species richness and landscape heterogeneity tend to be positively related, as heterogeneous landscapes provide more niches and resources (e.g., food, nest sites, den sites, and cover) than homogenous landscapes (MacArthur and MacArthur 1961; Rosenzweig 1995; Benton et al. 2003; Green et al. 2005).

Human disturbance fragments ecosystems, alters animal movements, and increases human activity and persecution, making it an additional driver of wildlife distributions (Forman & Alexander 1998; Crooks 2002; Ordeñana et al. 2010). In southern California, for example, native carnivore richness was negatively associated with urban intensity (Ordeñana et al. 2010). In some instances, however, human disturbance can have a minimal or positive influence of species' distributions, as has been found with generalist carnivores like coyotes (*Canis latrans*), gray foxes (*Urocyon cinereoargenteus*), striped skunks, opossums, and raccoons (*Procyon lotor*; Crooks 2002; Ordeñana et al. 2010; Goad et al. 2014; Kowalski et al. 2015; Wang et al. 2015).

Lastly, climatic variables often influence species' distributions (Grinnell 1917). Warming temperatures over the past 30 years have influenced the function and composition of many ecological communities and, in turn, the distributions of many species (Walther et al. 2002). When climate change decreases habitat quality, the result may be local extinctions or a decrease in the number of available habitat patches, which in turn, may lead to the extirpation of a metapopulation (Hanski 1999). Bighorn sheep populations in hotter, drier environments, for example, are more likely to go extinct (Epps et al. 2004). Kit foxes, alternatively, have adaptations for reducing heat loads and conserving water (Cypher 2003), and consequently, may be more tolerant of increases in temperatures and decreases in precipitation. Climate may also influence a species' probability of detection. Increased movements of mule deer (*Odocoileus hemionus*), for example, were associated with decreased temperatures and increased weekly precipitation (Nicholson et al. 1997).

In 2016, CDFW began a coordinated monitoring process by initiating Terrestrial Species Stressor Monitoring (TSM) surveys. TSM surveys collected baseline data on a wide variety of common wildlife species throughout the drought-stricken Mojave Desert (MD) and Great Valley (GV) ecoregions of California. Survey methods included automated sound recordings, visual encounter surveys, rapid habitat assessments, and camera trap surveys. We began our analysis of the TSM surveys by focusing on data collected via camera traps, a non-invasive survey method that targets medium- to large-sized mammals. We had the specific objectives of: (1) estimating the occupancy and richness of terrestrial mammal species weighing >0.5kg in the MD and GV ecoregions; and (2) elucidating community and species-specific responses to ecological variables. Our overarching goal was to provide a better understanding of how ecological traits, including both climate and habitat features, are influencing mammal distributions and richness in the MD and GV ecoregions. This information will help guide the design and implementation of future drought-response projects.

Methods

Camera trap survey and photo identification

Personnel from CDFW deployed Reconyx PC900 cameras at 320 and 265 sites across the MD and GV ecoregions of California, respectively, between March – August 2016 and March – June 2017 (Fig. 1). To guide the placement of cameras, CDFW calculated the total cover of key lifeforms within each ecoregion (Table 1). For each ecoregion, they then selected a spatially-balanced random sample of hexagons, stratified by lifeform, from the USDA Forest Inventory and Analysis program's hexagon grid (hexagon radius is ~2.6 km) and deployed 1-3 cameras, spaced by 1-2 km, within each hexagon. Exact survey locations within the hexagon were also stratified by lifeform. To do this, CDFW created a finer scale grid of ~2400 points separated by 100m within each hexagon and calculated the lifeform at every point within the fine-scale grids.

Cameras were cable-locked onto T-posts that were securely placed in the ground. If T-post mounting was not possible, cameras were secured to a tree or shrub bole. To maximize detection probabilities, a 1-kg salt lick, 500 ml of oatmeal-peanut butter mixture, and 150 g of fishy cat food were placed on the ground near the center of the camera's field of view. When possible, CDFW personnel positioned cameras to face north in order to avoid direct sunlight and potential false triggers. They programmed cameras to take three photos at each trigger event with a delay of one second between trigger events. Each camera was deployed for 20 to 66 days ($\bar{x}$ = 34, *SD* = 7.6) at sites in the MD ecoregion and 9 – 37 days ($\bar{x}$ = 29, *SD* = 3.5) at sites in the GV ecoregion.

Two observers identified photographic detections to the species-level, unaware of how the other observer had classified photos. Observers only recorded a species once during each 24-hr period that a camera was deployed (e.g., a bobcat photographed 5 times over 24-hrs at camera *j* would result in a single data entry). We then determined when there were mismatches between observers in species identification, and had a third individual decide on the final classification (referred to as 'reconciled data'). We used the reconciled data for all analyses. To evaluate the influence that observer bias may have on estimates of occupancy (Table 4), we carried out a preliminary analysis where we compared occupancy estimates based on identifications by observer 1 vs. observer 2. Estimates did not differ between observers (i.e., estimates' 95% credible intervals overlapped), suggesting there were minimal discrepancies between observers in their classification of photos and in the future, the data entry process can be streamlined by using only a single observer.

Covariates

We hypothesized that climate, elevation, slope, water accessibility, vegetative cover, and human disturbance could influence the occupancy and detection patterns of terrestrial mammalian species. To represent climate, we downloaded 4-km resolution precipitation and temperature data from PRISM (Prism Climate Group 2018) for March – August 2016 and March – June 2017 (i.e., the study periods). We used ArcMAP 10.4.1 (ESRI, Redlands, CA, USA) to determine the mean precipitation, temperature, and maximum temperature at each camera location during the respective survey period. We then used the 30-m resolution National Elevation Dataset (USGS 2016) to calculate and extract slope and elevation values for each site location in ArcMAP.

To evaluate water accessibility in the GV, we used Point Blue's Automated Water Tracking System (http://data.pointblue.org/apps/autowater/), which provides up-to-date assessments of the distribution of open surface water in the Central Valley. Specifically, we downloaded data for the study periods and created a single layer for each year indicating whether water was present at some point during the sampling period or not. We then measured the distance from each camera location to the nearest water source. In the MD, we used Global Surface Water Explorer (Pekel et al. 2016) to identify permanent and seasonal water sources. Again, we measured the distances from each camera to the nearest water source. For the MD, we also included a categorical variable indicating whether the camera was located by a guzzler.

We then placed a buffer radius of 1km around the camera locations. A 1-km buffer size provides information on the general conditions surrounding the camera that is applicable to our suite of variably sized species. We used CDFW's Vegetation Classification and Mapping Program (vegCAMP; https://www.wildlife.ca.gov/Data/VegCAMP) data to calculate percent cover of natural vegetation at the GV sites, percent cover of desert scrub at the MD sites, and distance to the nearest forested area for all sites. In the Mojave where forest cover is limited, forested areas consisted solely of pinyon-juniper woodlands. We then used USDA's cropscape data (USDA CropScape 2016) to calculate the number of crop types within the buffered areas in the GV. Lastly, we estimated human disturbance by extracting values from the U.S. Geological Survey's human footprint model (https://sagemap.wr.usgs.gov/humanfootprint.aspx).

To account for variation in the probability of photographing mammals, we explored maximum temperature, precipitation, human disturbance, and bait status as covariates for detection. Bait status was a categorical variable indicating whether a camera station's bait was disturbed at the end of the sampling period (1) or not (0). In the MD, we also included a categorical variable indicating whether the camera was located by a guzzler (1) or not (0).

Multi-species occupancy modeling

We used multi-species hierarchical occupancy models (Dorazio and Royle 2005), analyzed under a Bayesian framework, to estimate and evaluate the distributions and richness of terrestrial mammal species weighing >0.5kg. Multi-species models link species-specific detection and occupancy using community-level hyper-parameters (Zipkin et al. 2010; Iknayan et al. 2014). These hyper-parameters specify the mean response and variation among species within the community to a respective covariate, thus permitting composite analyses of both communities and individual species (Kéry and Royle 2008). The models also facilitate estimates of species richness (i.e., number of species in the community and at each camera).

To discern non-detection from true absence, we treated each trap day as a repeat survey at a particular camera. We assumed occurrence and detection probabilities differed by species and year (2016 = 1, 2017 = 0), and were influenced by ecological covariates. In the MD ecoregion, we assessed two model structures for occupancy (ψ) and detection (p):

Model 1: ψ(guzzler, precipitation, temperature, slope, year), p(guzzler, maximum temperature, bait status, year)
Model 2: ψ(water, scrub, elevation, pinyon-juniper, year), p(human disturbance, precipitation, bait status, year)

In the GV ecoregion, we also assessed two model structures for occupancy and detection:

Model 1: ψ(water, precipitation, temperature, natural cover, year), p(crop diversity, maximum temperature, bait status, year)
Model 2: ψ(forest, crop diversity, latitude, year), p(human disturbance, precipitation, bait status, year)

We incorporated covariates into the model linearly on the logit-probability scale (Zipkin et al. 2010) and ensured models did not include covariates that were correlated. We estimated posterior distributions of parameters using Markov Chain Monte Carlo implemented in JAGS (Plummer 2011) through program R. We generated three chains of 50,000 iterations thinned by 50 and used uninformative priors.

Next, we projected our model results across each of the ecoregions to estimate species-specific probabilities of occupancy and species richness. We used these model-based inferences, which rely on covariate associations, to ensure our estimates were representative of the ecoregions and not just sampled locations (Gregoire 1998; Furnas and McGrann 2018). To project our results, we overlaid a 1km x 1km grid onto the two ecoregions and calculated covariate values for each grid cell. Using these covariate values and the multi-species occupancy modeling output (e.g., community- and species-level beta values for the model covariates), we projected occupancy probabilities across the MD and GV ecoregions for each detected species. We also summed species' occupancy probabilities within each of the grid cells to generate estimates of species richness at the 1km x 1km scale.

Results

In the MD ecoregion, we photographed 16 and 13 species of mammals over 7,402 and 3,467 trap nights in 2016 and 2017, respectively (Table 2). Black-tailed jackrabbits and kit foxes were the most frequently detected species in both years (Table 2). Among the species photographed the least often were the California ground squirrel, opossum, raccoon, striped skunk, and spotted skunk (*Spilogale gracilis*; Table 2).

In the Great Valley (GV) ecoregion, we photographed 17 and 20 species of mammals over 2,570 and 5,171 trap nights in 2016 and 2017, respectively (Table 2). The most photographed species was the black-tailed jackrabbit in both years (Table 2). Conversely, we photographed gray fox the least often in 2016 and American mink and mountains lions the least often in 2017 (Table 2).

Multi-species occupancy modeling

Black-tailed jackrabbits (ψ = 0.72), kit foxes (ψ = 0.36), and coyotes (ψ = 0.33) had the highest estimated occupancies in the MD ecoregion (Fig. 2). Many species in the MD, conversely, had low estimates of occupancy due to their limited numbers of photographic detections (Table 2; Fig. 2, Appendix S2). Species' occupancy probabilities varied among the key lifeforms, but the majority of species (i.e., 75%) were most likely to occupy upper Mojave desert scrub (Appendix S1). Among the covariates, mean temperature had the greatest influence on community-level occupancy in the MD, with occupancy decreasing as mean temperature increased (Table 3). This negative relationship was most evident for species like deer, bobcat, and Audubon's cottontail (*Sylvilagus audubonii*; Fig. 3; Appendix S2). The kit fox was the only species positively associated with temperature (Fig. 3; Appendix S2). Community-level occupancy in the MD was also related to elevation and distance to pinyon-juniper woodlands, with occupancy tending to increase at higher elevations close to pinyon-juniper habitat (Table 3). The positive influence of elevation also held true for individual species like the badger (*Taxidea taxus*), Audubon's cottontail, bobcat, gray fox, and deer (Fig. 3; Appendix S2). The presence of guzzlers had a weak effect at the community-level, but at the species-level was strongly and positively associated with the occupancy of Audubon's cottontail, bighorn sheep, bobcat, coyote, and gray fox (Fig. 3; Appendix S2). Species' detection probabilities also tended to be positively associated with the presence of a guzzler (Appendix S2). Lastly, precipitation also had a weak effect at the community-level, but was strongly and negatively related to coyote occupancy, and strongly and positively related to Audubon's cottontail and mule deer occupancy (Appendix S2).

Coyotes (ψ = 0.49) and raccoons (ψ = 0.45) had the highest estimated occupancies in the GV ecoregion (Fig. 2). Thirteen of the 22 photographed species, conversely, had occupancy probabilities < 0.10 (Fig. 2). Similar to the MD, this result was a consequence of species having a limited number of photographic detections (Table 2). Among the key lifeforms, human-altered lifeforms like rice fields and orchards/vineyards had the highest mean estimated occupancies for over half of the species (Appendix S1). We note, however, that these lifeforms encompassed a limited number of sampling sites (Table 1). The 95% credible intervals overlapped zero for all community-level hyper-parameters in the GV except natural cover, where species' occupancy probabilities tended to decrease as natural cover increased (i.e., percent natural cover within a 1-km buffered area surrounding the camera trap; Table 3). This was particularly true for opportunistic mammals like California ground squirrel and red fox (Appendix S2). Among the remaining covariates, we found that community-level occupancy tended to increase with crop diversity in the GV and that community-level detection tended to decrease with human disturbance and again, increase with crop diversity (Table 3). Latitude had only a weak, positive influence on community-level occupancy, but at the species-level had a strong, negative influence on the occupancy of, for example, badger, kit fox, and Audubon's cottontail, and a strong, positive influence on the occupancy of, for example, deer, raccoon, and opossum (Fig. 4; Appendix S2). Similarly, precipitation only had a weak influence at the community-level, for both occupancy and detection, but often had a strong influence at the species-level (Fig. 4; Appendix S2).

The distributions of high and low occupancy value areas varied among species (examples shown in Fig. 5, 6). For example, areas with high occupancy values for badger were patchily distributed throughout the MD whereas areas with high occupancy values for kit fox were fairly contiguous in the central part of the ecoregion (Fig. 5). Projected estimates of mammal richness ranged from 0-9 in the MD with a mean of 2.4 (*SD* = 1.13), and 2-13 in the GV with a mean of 6.3 (*SD* = 2.39; Fig. 7). In the MD, estimated species richness appeared to be greatest in the mountainous regions where it was cooler, such as within the Mojave National Preserve. Over 70% of the area with the greatest estimated species richness fell within National Park Service boundaries (Fig. 7). In the GV, species richness appeared to be greatest at higher latitudes (Fig. 7).

Discussion

The California Department of Fish and Wildlife (CDFW) developed Terrestrial Species Stressor Monitoring (TSM) surveys with the goal of collecting baseline data on a wide variety of wildlife species throughout the Mojave Desert and Great Valley ecoregions of California. Having reliable estimates of wildlife populations and methods for detecting wildlife loss are vital in making informed conservation and management decisions (Zipkin et al. 2010). Methods for directly or indirectly monitoring population abundance (e.g., mark-recapture), however, are often time and cost-intensive, particularly for large-scale or long-term monitoring (Bailey et al. 2004). Additionally, abundance estimation generally focuses on a single species. A viable alternative for managers involved in large-scale, multi-species monitoring programs is occupancy, or the probability that a landscape unit is occupied by a species of interest (Bailey et al. 2004; MacKenzie et al. 2005). By analyzing data from the camera trap surveys in an occupancy-modeling framework, we were able to help achieve TSM goals by generating baseline estimates of occupancy for 16 and 22 mammalian species in the Mojave Desert and Great Valley ecoregions, respectively, and empirically evaluate how these estimates were influenced by climate and habitat features. These efforts could form the foundation of a long-term monitoring program and be used to more effectively design said program (e.g., power analyses to determine number of sampling locations and sampling duration). Long-term monitoring is vital as it would allow managers to quantify and detect trends in occupancy, changes in habitat use, and drivers of local colonization and extinction (MacKenzie et al. 2005). This information, in turn, would have innumerable applications including the design of effective and efficient wildlife management strategies, the mitigation of large-scale ecological stressors, and the development of land use plans that minimize adverse impacts on biodiversity.

In addition to estimating occupancy and species richness, we also evaluated potential drivers of these parameters. In the Mojave Desert ecoregion, our results elucidated the influence of artificial water catchments (i.e., guzzlers) and climate on mammal distributions. Water is a critical resource to wildlife populations, particularly in arid ecosystems around the world (Larsen et al. 2012). We found that the occupancy probabilities of close to half the detected species in the Mojave Desert, as well as the probability of photographing these species, was greater at guzzler sites. Some of these species include, for example, bighorn sheep, Audubon's cottontail, and gray fox. Previous research has also found that ungulates (e.g., deer and bighorn sheep) and medium-sized mammals use these artificial water sources, as well as avian species, small mammals, and a variety of herptofauna (Smith and Henry 1985; Bleich 1992; Cutler and Morrison 1998; Bleich et al. 2010). Our results suggest that guzzlers are a viable and important conservation option in the Mojave, and may become increasingly important as habitats continue to be modified by human development (i.e., where wildlife and humans must compete for water) and climate change (Krausman et al. 2006).

Temperatures in southern California deserts are projected to increase 2° C by 2050 (Snyder and Sloan 2005). Our results suggest this will negatively affect the occupancy of medium to large-sized mammals in the Mojave. We found mean temperature was negatively associated with community- and species-level ($n = 6$) occupancy, and that elevation, which was highly correlated with temperature ($r = -0.82$), was positively associated with community- and species-level ($n = 7$) occupancy. There was only one species, the kit fox, which appeared to be well adapted for projected climate changes as their distributions were positively associated with temperature, negatively associated with elevation, and weakly and negatively associated to both precipitation and the presence of a guzzler. For other Mojave mammals, however, extreme heat and drought resulting from climate change may exceed survival thresholds (Bachelet et al. 2016). Deer, Audubon's cottontail, and bobcat, for example, tended to be negatively associated with temperature and positively associated with water (i.e., precipitation and guzzlers). These species may be approaching their physiological thresholds in the Mojave, making them vulnerable to future climate change in the region (Serra-Diaz et al. 2014). Based on these results, we recommend protecting climate refugia including permanent water sources (e.g., guzzlers), shady valleys, high elevations, and north facing slopes in order to help mitigate hypothesized impacts of climate change (Bachelet et al. 2016). We also recommend protecting upper Mojave Desert scrub, which covers just 11.5% of the ecoregion, as 12 of the 16 detected mammals had their highest mean estimated occupancies within this lifeform.

In the Great Valley, one of the most intensely developed agricultural regions in the world (Nelson et al. 2003), heterogeneity within and among croplands had a larger influence on mammal occupancy than did climate. The generally positive influence of crop diversity on mammal occupancy and detection supports the heterogeneity hypothesis, which states that diversity is maximized in heterogeneous landscapes, both farmed and natural, as they provide more niches and complementary resources than homogenous landscapes (MacArthur and MacArthur 1961; Rosenzweig 1995; Benton et al. 2003). Thus, in the Great Valley, working with landowners to diversify agricultural practices (e.g., crop diversity, cultivation practices, rotation planning) may greatly benefit the mammal community. In addition to the influence of crop diversity, we also found that the mammal community was negatively related to natural vegetative cover (i.e., grasslands, shrublands, forests, riparian areas, and wetlands). Supporting this trend, we found 15 of the 22 detected species had their highest mean estimated occupancies in a human-altered lifeform (i.e., crop/fallow fields, orchards/vineyards, or rice fields). While this result may seem surprising, it is not unexpected. Many of the species detected in the Great Valley are opportunistic feeders often associated with humans, such as striped skunks, Virginia opossums, raccoons, and California ground squirrels, or they are species known to be behaviorally plastic and adaptable, like coyotes, bobcats, and mule deer (Crooks 2002; Markovchick-Nichols et al. 2008; Ordeñana et al. 2010; Goad et al. 2014; Kowalski et al. 2015; Wang et al. 2015). In such an intensely developed region, it is likely that mammals sensitive to human disturbance have become locally extinct or rare, leaving behind species adept at accessing resources (e.g., food, cover, den sites) and surviving in agricultural, human-modified landscapes.

Biodiversity loss, climate change, and anthropogenic pressures on ecosystems are accelerating (Walther et al. 2002; Alkemade et al. 2009; Butchart et al. 2010). The infrastructure required to monitor changes in biodiversity and species' vulnerability to stressors, however, is often lacking (Ahumada et al., 2013). Our research demonstrates the utility of camera traps for monitoring terrestrial mammals; they provide records of detections for a wide diversity of species, living in a broad range of ecosystems, at any time of day. We also demonstrate the strength of multi-species hierarchical occupancy models (Dorazio and Royle 2005; Iknayan et al. 2014). Unlike traditional community analyses, our multi-species approach allowed us to: (1) account for observation error (i.e., detection probability) so results can be comparable across species, sites, and, in the future, years; (2) retain species identity; and (3) share data across species, permitting comprehensive assessments of the mammal communities and individual species (Zipkin et al. 2010). Furthermore, many species in our study had low detection probabilities. By integrating data across species, we were able to estimate occupancy probabilities for these rare and elusive species and properly account for them in our estimates of species richness.

We encourage continued, systematic camera trap surveys in both the Mojave Desert and Great Valley ecoregions such that results will expand beyond this snapshot in time. With multi-year data, we can estimate trends in occupancy and evaluate how water availability, climate, vegetation, and human disturbance are influencing mammal communities (MacKenzie et al. 2005; Ahumada et al. 2013). This information would allow policy makers and managers to then track, improve, and adapt policies and management actions aimed at addressing the loss of wildlife populations at both local and landscape scales (Butchart et al., 2010).

Acknowledgements

We thank Misty Nelson, Scott Newton, and the many field technicians that are responsible for this enormous field effort, including the logistics, outreach to private landowners, field data collection, and data entry/organization. We also thank Steve Torres and Karen Miner for their continuous support.

Supplementary Materials

Appendix S1. Mammal species' mean occupancy, and 95% credible intervals, within each of the major habitat strata of the A) Mojave Desert and B) Great Valley ecoregions, 2016-17. The habitat with the largest estimated occupancy for each species is highlighted

Appendix S2. Species names and mean and 95% credible intervals (95% CI) for estimates of species-specific probabilities of occurrence, detection probability (for survey duration), and covariate effects on occupancy (PSI) and detection (P) in the Mojave Desert and Great Valley ecoregions of California, 2016-17. We present results from a) model 1 in the MD, b) model 2 in the MD, c) model 1 in the GV, and d) model 2 in the GV. We highlighted covariate effects that did not overlap 0.0.

Table 1. The number of cameras (*n*) deployed in each of the key lifeforms of the Mojave Desert (A) and Great Valley (B) ecoregions of California, 2016-2017, and the percent coverage (% cover) of each lifeform within the respective ecoregion.

A.

Lifeform	*n*	% cover	Lifeform	*n*	% cover
Desert outcrop & badlands	14	4.7	Riparian	38	2.7
Dunes	15	1.3	Great Basin saltbrush scrub	15	1.5
Grasslands	11	1.0	Upper Mojave desert scrub	50	11.5
Lower Mojave desert scrub	100	69.6	Wetlands/open water	13	0.05
Playa	14	4.3	Guzzler	50	

B.

Lifeform	*n*	% cover	Lifeform	*n*	% cover
Crop/fallow	32	30.1	Rice	7	4.2
Grassland/shrub	93	18.8	Riparian	68	0.3
Orchard/vineyard	11	24.9	Wetlands/open water	54	3.2
Alfalfa	0	7.1			

Table 2. Mammal species detected during TSM 2016-17 camera trap surveys in the Mojave Desert and Great Valley ecoregions, their numbers of detections (# det.), naïve occupancy estimates (naïve ψ), and estimates of occupancy across both years.

Common name	Scientific name	Mojave Desert					Great Valley				
		2016 (*n* = 217)		2017 (*n* = 103)		Both	2016 (*n* = 85)		2017 (*n* = 180)		Both
		# det.	Naïve ψ	# det.	Naïve ψ	ψ	# det.	Naïve ψ	# det.	Naïve ψ	ψ
Ringtail	*Bassariscus astutus*	---	---	---	---	---	---	---	7	0.02	0.01
Coyote	*Canis latrans*	211	0.34	95	0.28	0.33	82	0.41	178	0.42	0.49
Elk	*Cervus canadensis*	---	---	---	---	---	14	0.02	---	---	0.01
Opossum	*Didelphis virginiana*	2	0.005	---	---	0.003	40	0.12	199	0.23	0.20
Wild Burro	*Equus asinus*	18	0.02	74	0.05	0.03	---	---	---	---	---
Common porcupine	*Erethizon dorsatum*	---	---	---	---	---	---	---	7	0.02	0.02
Black-tailed jackrabbit	*Lepus californicus*	1106	0.68	730	0.77	0.72	242	0.32	615	0.36	0.34
Bobcat	*Lynx rufus*	107	0.17	88	0.22	0.25	31	0.13	57	0.09	0.11
Striped skunk	*Mephitis mephitis*	4	0.004	---	---	0.002	56	0.34	272	0.40	0.41
American mink	*Mustela vison*	---	---	---	---	---	---	---	1	0.01	0.02
Mule deer	*Odocoileus hemionus*	92	0.07	32	0.03	0.06	104	0.22	279	0.35	0.32
CA ground squirrel	*Otospermophilus beecheyi*	1	0.005	---	---	0.01	68	0.08	266	0.17	0.14
Rock squirrel	*Otospermophilus variegatus*	10	0.009	---	---	0.01	---	---	---	---	---
Bighorn sheep	*Ovis canadensis*	68	0.03	57	0.05	0.04	---	---	---	---	---
Raccoon	*Procyon lotor*	3	0.005	---	---	0.004	151	0.29	330	0.51	0.45
Mountain lion	*Puma concolor*	---	---	---	---	---	---	---	3	0.01	0.01
Western gray squirrel	*Sciurus griseus*	---	---	---	---	---	4	0.03	93	0.09	0.09
Fox squirrel	*Sciurus niger*	---	---	---	---	---	8	0.05	18	0.06	0.07
Spotted skunk	*Spilogale gracilis*	7	0.03	3	0.01	0.03	---	---	---	---	---
Wild Boar	*Sus scrofa*	---	---	---	---	---	---	---	14	0.02	0.01
Audubon's cottontail	*Sylvilagus audubonii*	485	0.22	196	0.24	0.25	170	0.18	447	0.24	0.22
Brush rabbit	*Sylvilagus bachmani*	---	---	---	---	---	8	0.03	---	---	0.02
American badger	*Taxidea taxus*	45	0.12	28	0.17	0.24	7	0.03	9	0.04	0.06
Gray fox	*Urocyon cinereoargenteus*	48	0.06	47	0.07	0.09	2	0.01	40	0.03	0.03
Kit fox	*Vulpes macrotis*	380	0.45	226	0.34	0.36	11	0.03	20	0.02	0.02
Red fox	*Vulpes vulpes*	---	---	---	---	---	35	0.05	12	0.03	0.04

Table 3. Mean ($\bar{x}$) and 95% credible interval estimates of the community-level hyper-parameters hypothesized to influence the probability of occupancy and detection of terrestrial mammal species in the (A) Mojave Desert and (B) Great Valley ecoregions of California, 2016-2017.

A.

	Occupancy				Detection			
	Covariate	$\bar{x}$	95% CI		Covariate	$\bar{x}$	95% CI	
Model 1	Guzzler site	0.38	-0.675	1.176	Guzzler site	0.63	0.182	1.066
	Precipitation	0.02	-0.411	0.412	Max temp	-0.90	-1.651	-0.307
	Temperature	-0.60	-1.132	-0.101	Bait status	-0.08	-0.566	0.413
	Slope	-0.20	-0.775	0.315	Year	0.42	-0.097	1.004
	Year	0.80	0.086	1.667				
Model 2	Water	-0.01	-0.179	0.129	Human disturb.	0.18	-0.006	0.361
	% scrub	-0.08	-0.450	0.245	Precipitation	0.01	-0.472	0.524
	Elevation	0.41	-0.089	0.934	Bait status	0.06	-0.442	0.563
	Forest	-0.22	-0.585	0.067	Year	-1.02	-1.548	-0.437
	Year	0.08	-0.239	0.397				

B.

	Occupancy				Detection			
	Covariate	$\bar{x}$	95% CI		Covariate	$\bar{x}$	95% CI	
Model 1	Water	-0.04	-0.277	0.138	Crop diversity	0.18	-0.084	0.419
	Precipitation	0.13	-0.233	0.488	Max temp	-0.07	-0.269	0.114
	Temperature	0.05	-0.259	0.324	Bait status	-0.02	-0.184	0.139
	Natural cover	-0.16	-0.301	-0.026	Year	-0.11	-0.619	0.418
	Year	-0.35	-0.844	0.136				
Model 2	Forest	0.07	-0.159	0.291	Human disturb.	-0.06	-0.148	0.047
	Crop diversity	0.19	-0.013	0.385	Precipitation	-0.05	-0.310	0.203
	Latitude	0.28	-0.194	0.753	Bait status	-0.00	-0.140	0.112
	Year	-0.15	-0.513	0.221	Year	-0.24	-0.846	0.357

Table 4. The total number of detections, based on observer 1 vs. observer 2, of each mammal species photographed during TSM 2016 camera trap surveys in the Mojave Desert (A) and Great Valley (B), California, 2016. The total number of detections is the sum of the number of days during which the species was photographed at each camera. The number of differences is the number of discrepancies between observer 1 and observer 2 in their camera-specific recordings of detections (e.g., if observer 1 recorded a coyote on 5 days at camera X and 2 days at camera Y whereas observer 2 recorded a coyote on 2 days at camera X and 5 days at camera Y, the total number of observations would be 7 for both observers but the number of differences would be 6).

A.

Species	**Obs 1**	**Obs 2**	**# diff**	**Species**	**Obs 1**	**Obs 2**	**# diff**
Coyote	213	225	20	Bighorn sheep	69	67	2
Opossum	2	2	0	Raccoon	3	3	0
Black-tailed jackrabbit	1101	1084	67	Western gray squirrel	3	0	3
Bobcat	107	110	7	Spotted skunk	7	7	0
Striped skunk	4	4	0	Audubon's cottontail	485	496	31
Mule deer	92	97	7	American badger	45	48	3
CA ground squirrel	3	10	7	Gray fox	48	68	24
Rock squirrel	6	1	5	Kit fox	379	353	48

B.

Species	**Obs 1**	**Obs 2**	**# diff**	**Species**	**Obs 1**	**Obs 2**	**# diff.**
Coyote	82	81	7	Raccoon	148	145	13
Elk	13	14	1	Western gray squirrel	3	13	10
Opossum	40	34	6	Fox squirrel	8	0	8
Black-tailed jackrabbit	237	218	27	Audubon's cottontail	173	143	50
Bobcat	32	29	3	Brush rabbit	10	18	24
Striped skunk	55	53	6	American badger	5	7	2
Mink	1	1	0	Gray fox	2	6	4
Mule deer	104	101	5	Kit fox	11	5	6
CA ground squirrel	71	65	6	Red fox	34	32	4

Figure 1. Camera traps deployed in the Mojave Desert and Great Valley ecoregions of California, 2016 – 2017, as part of the Terrestrial Species Stressor Monitoring surveys.

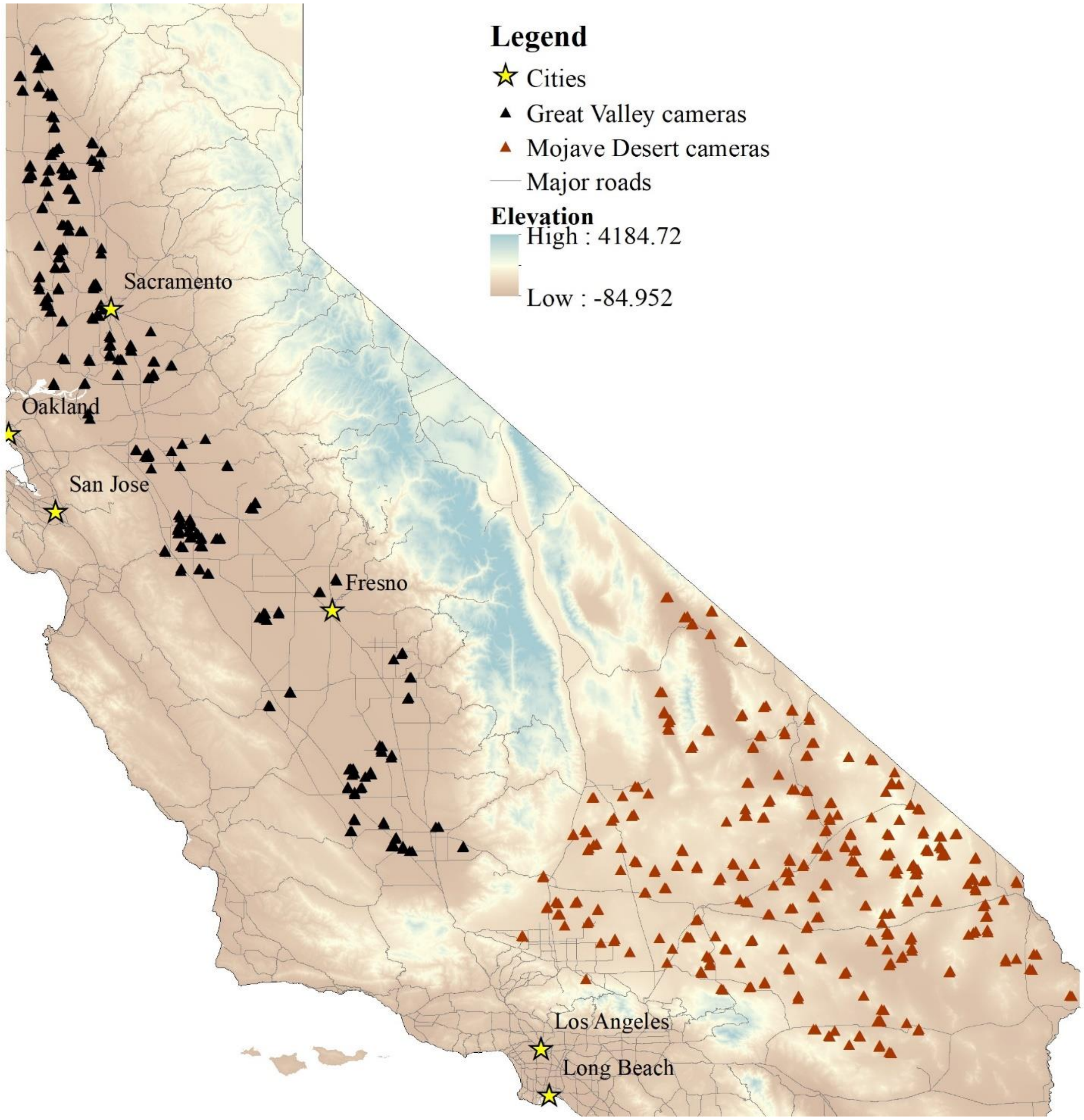
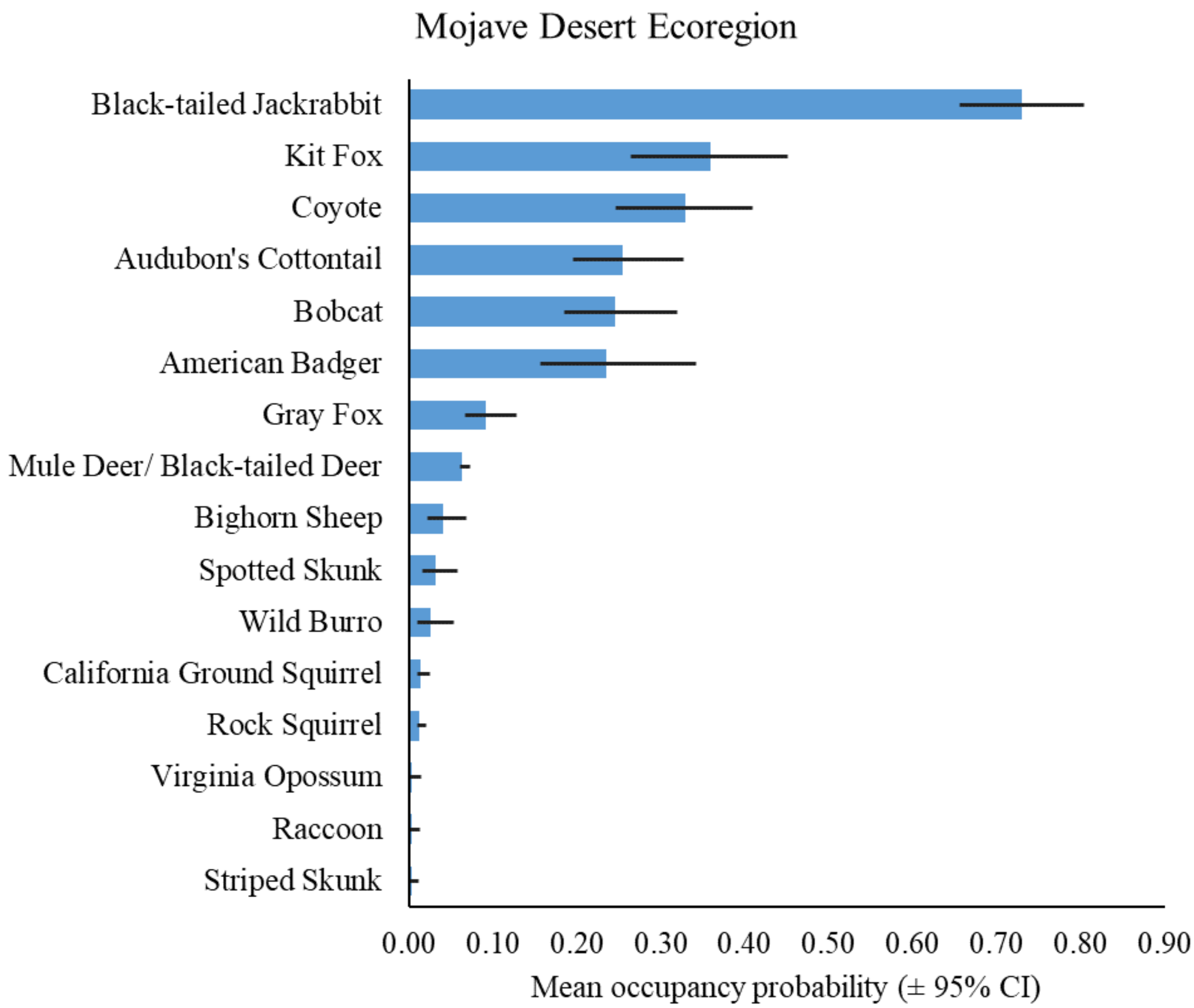
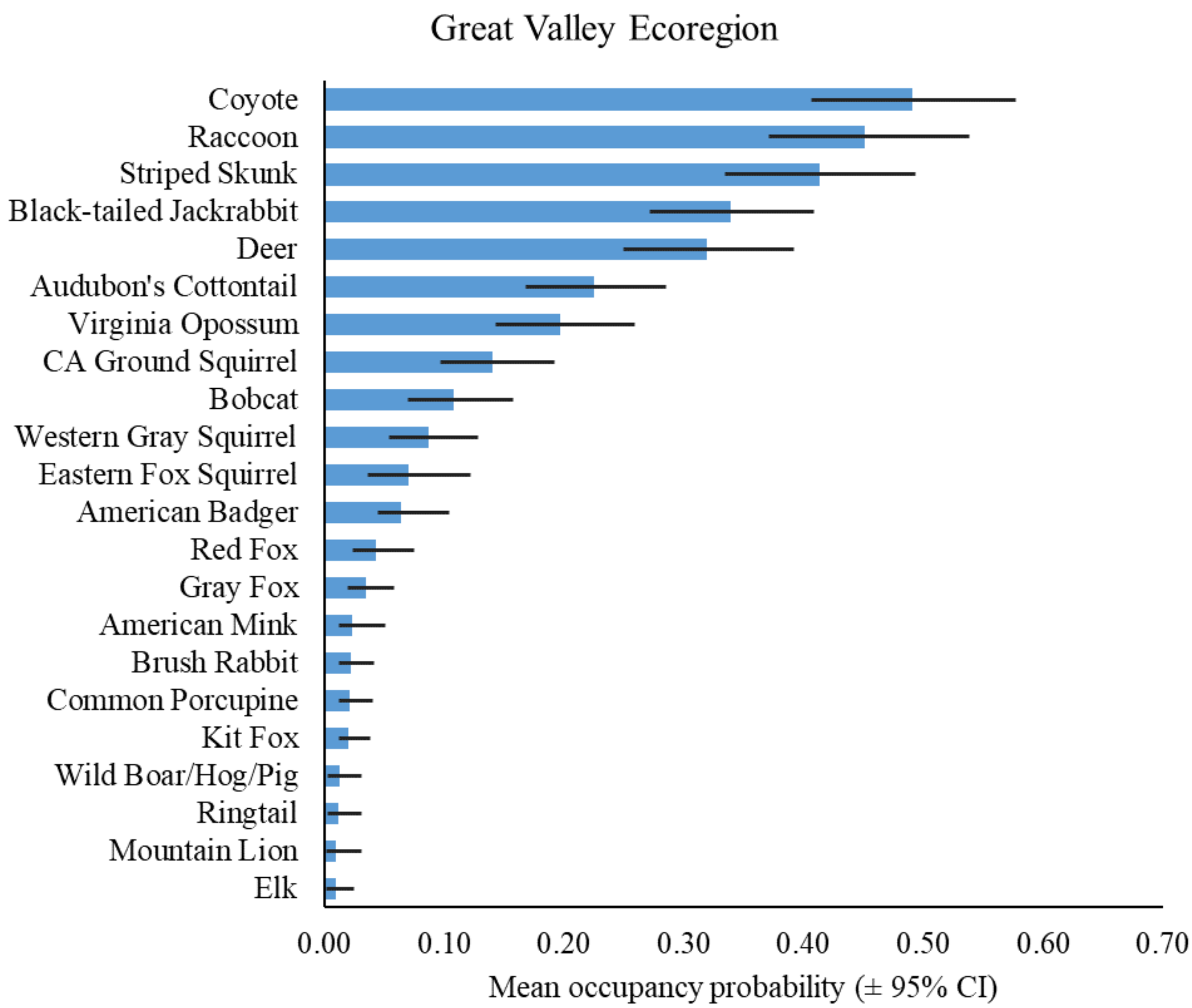


Figure 2. Mean occupancy probabilities for mammal species (> 0.5kg) in the A) Mojave Desert (*n* = 320 sites) and B) Great Valley (*n* = 265 sites) ecoregions of California, 2016-17.

A.



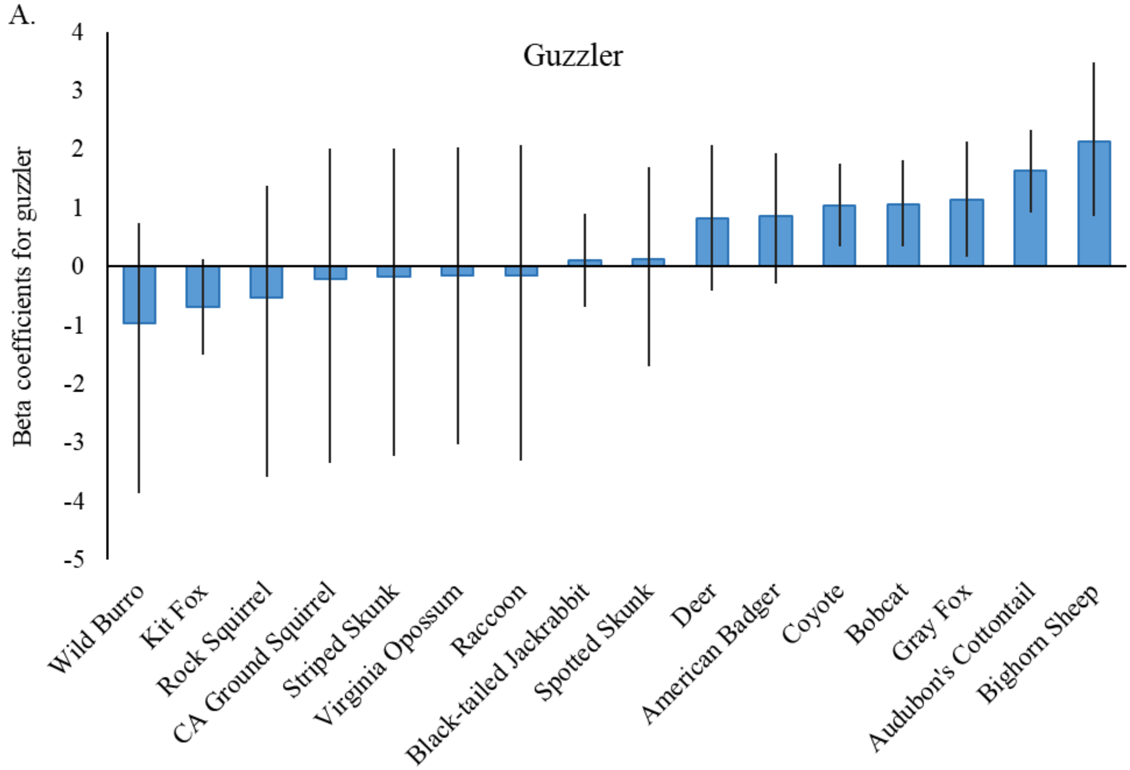
B.



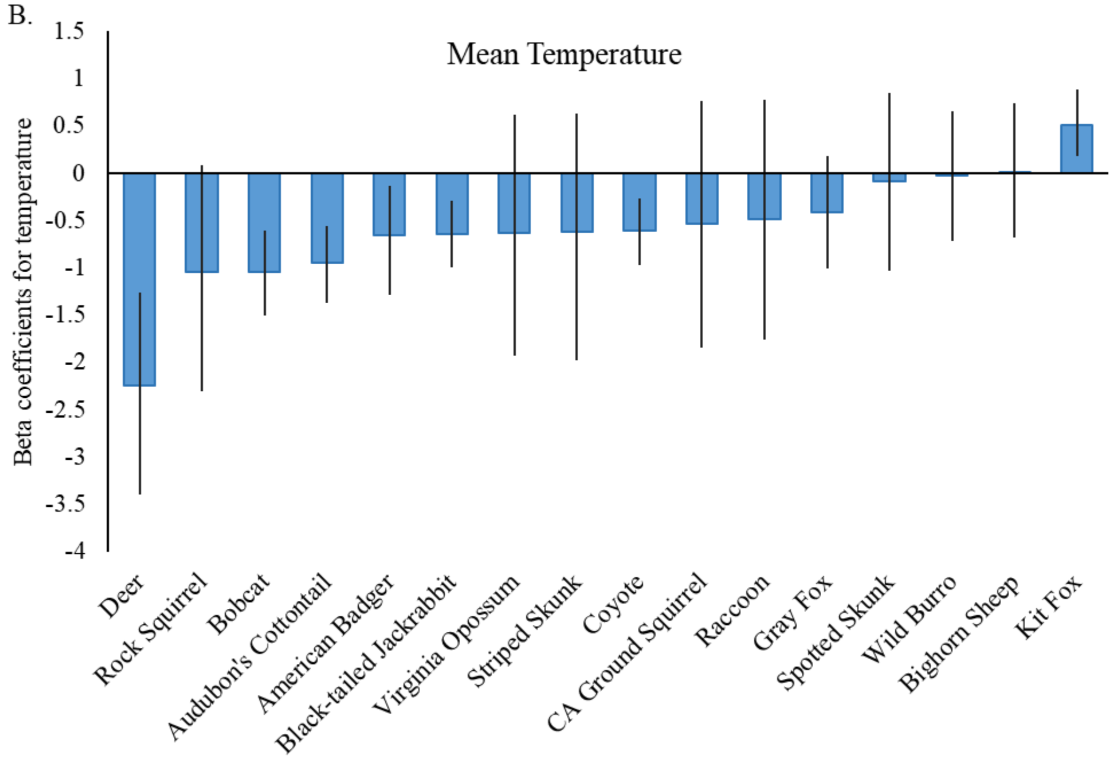
Great Valley Ecoregion
Coyote
Raccoon
Striped Skunk
Black-tailed Jackrabbit
Deer
Audubon's Cottontail
Virginia Opossum
CA Ground Squirrel
Bobcat
Western Gray Squirrel
Eastern Fox Squirrel
American Badger
Red Fox
Gray Fox
American Mink
Brush Rabbit
Common Porcupine
Kit Fox
Wild Boar/Hog/Pig
Ringtail
Mountain Lion
Elk
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
Mean occupancy probability (± 95% CI)

Figure 3. Standardized beta coefficients, and 95% credible intervals, for the influence of A) guzzler classification, B) mean temperature, C) slope, and D) elevation on species' probabilities of occupancy during camera trap surveys in the Mojave Desert ecoregion of California, 2016-17.

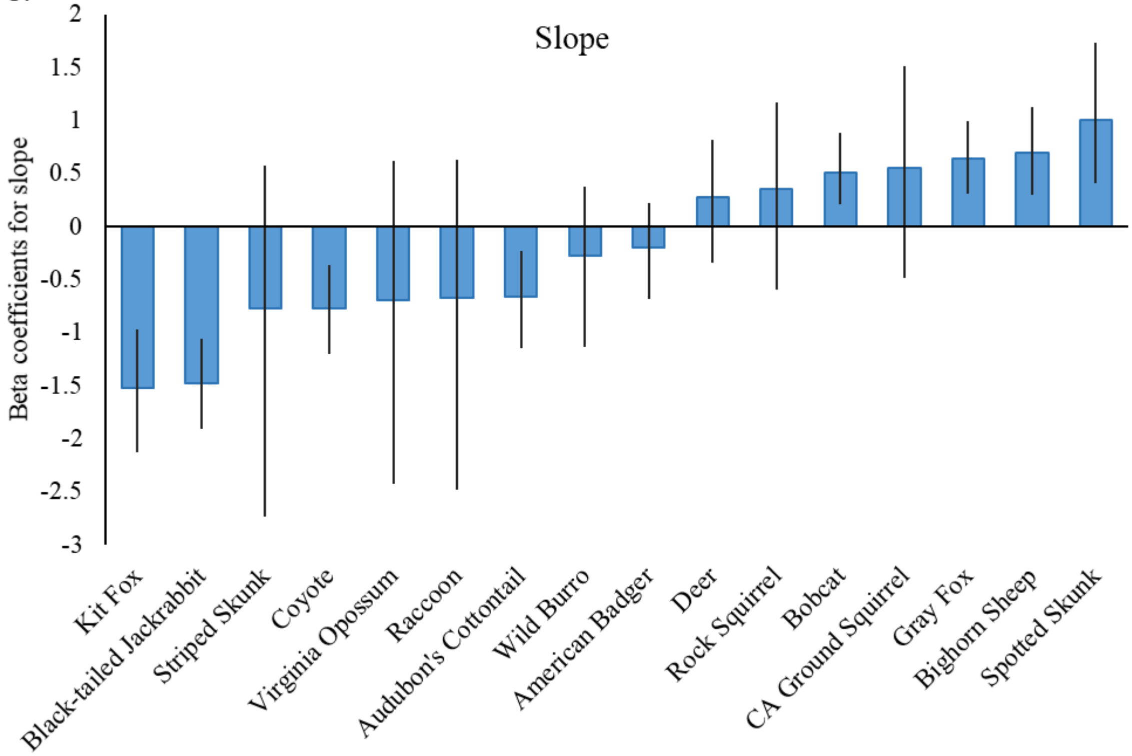
A.



B.



C.


Slope
Beta coefficients for slope
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
Kit Fox
Black-tailed Jackrabbit
Striped Skunk
Coyote
Virginia Opossum
Raccoon
Audubon's Cottontail
Wild Burro
American Badger
Deer
Rock Squirrel
Bobcat
CA Ground Squirrel
Gray Fox
Bighorn Sheep
Spotted Skunk

D.

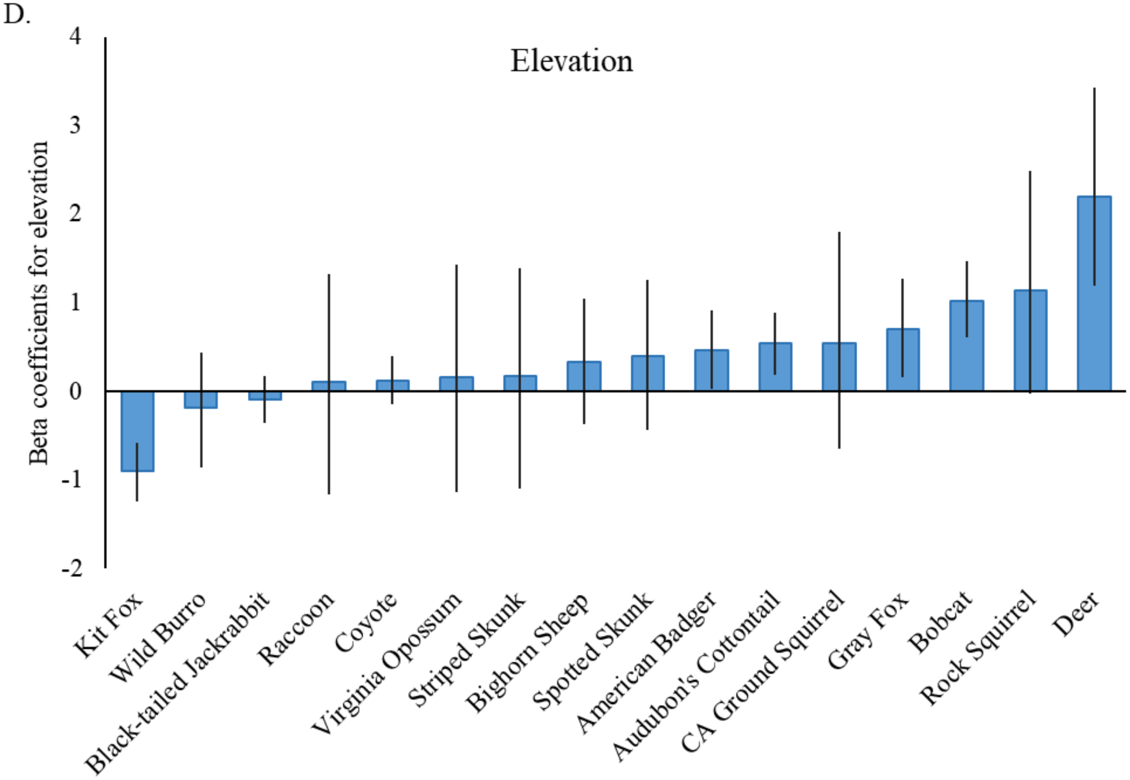
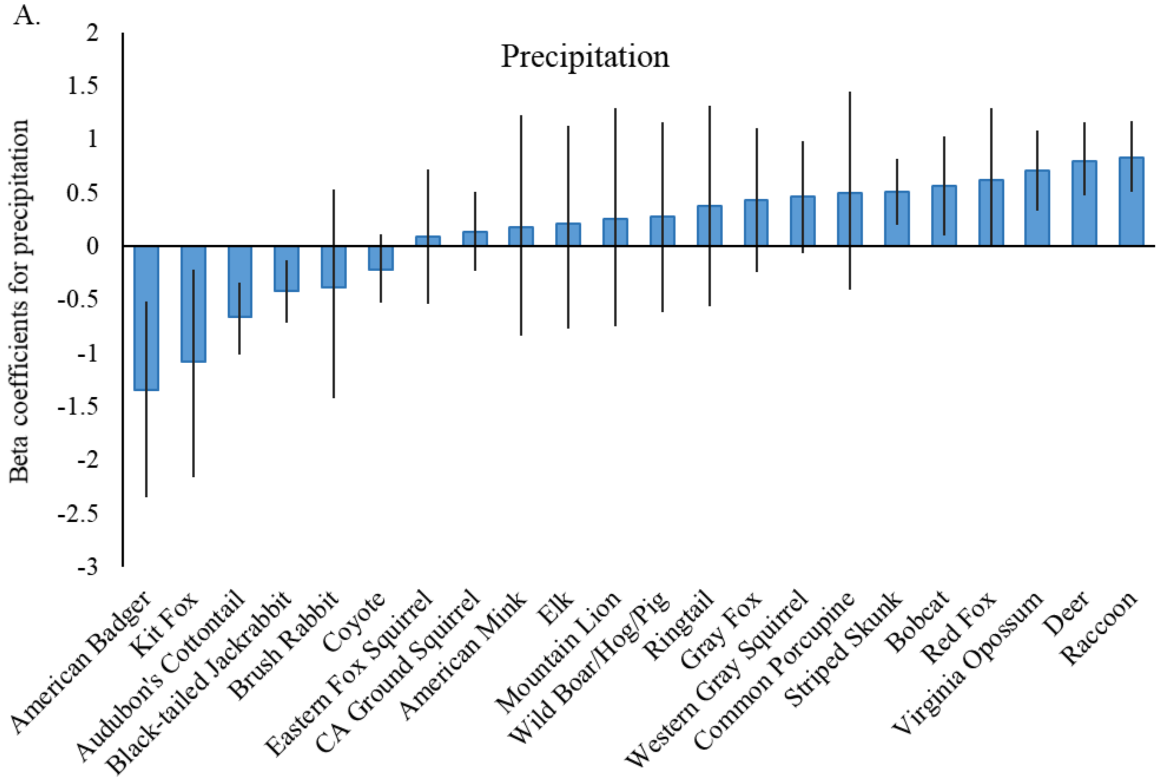
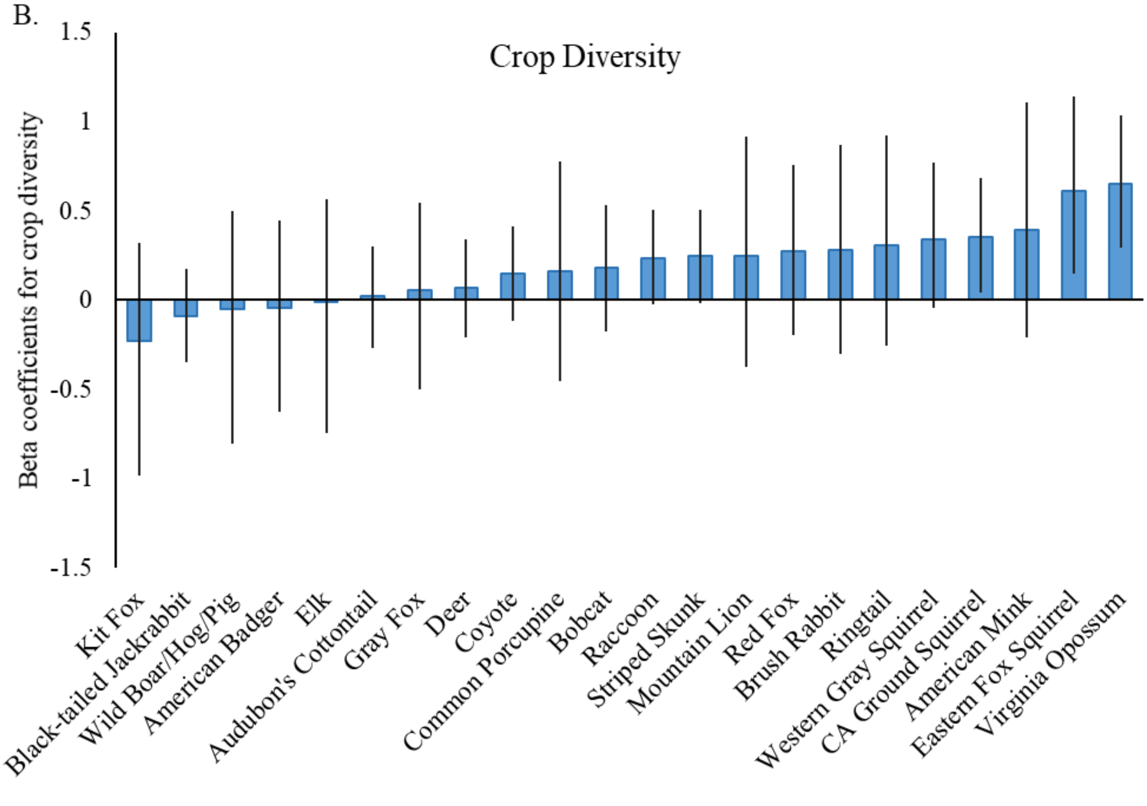

Elevation
Beta coefficients for elevation
4
3
2
1
0
-1
-2
Kit Fox
Wild Burro
Black-tailed Jackrabbit
Raccoon
Coyote
Virginia Opossum
Striped Skunk
Bighorn Sheep
Spotted Skunk
American Badger
Audubon's Cottontail
CA Ground Squirrel
Gray Fox
Bobcat
Rock Squirrel
Deer

Figure 4. Standardized beta coefficients, and 95% credible intervals, for the influence of A) precipitation, B) crop diversity, and C) latitude on species' probabilities of occupancy during the TSM 2016-2017 camera trap surveys in the Great Valley ecoregion of California.

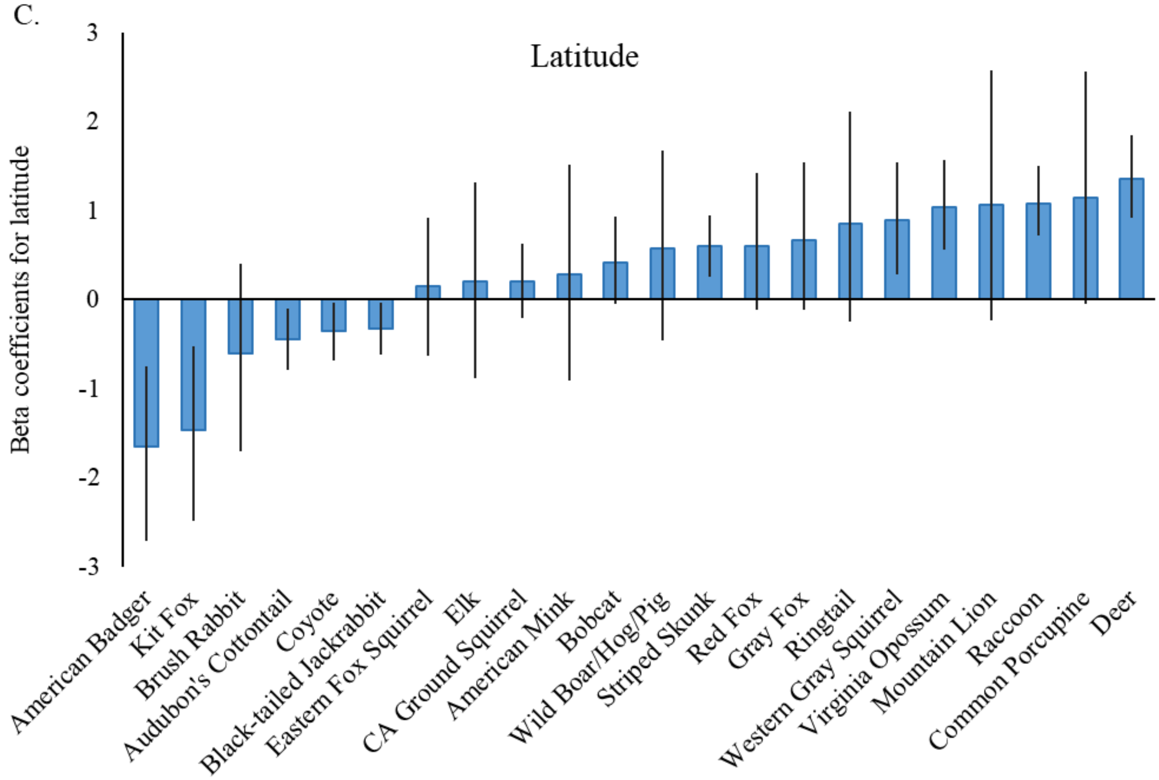
A.



B.



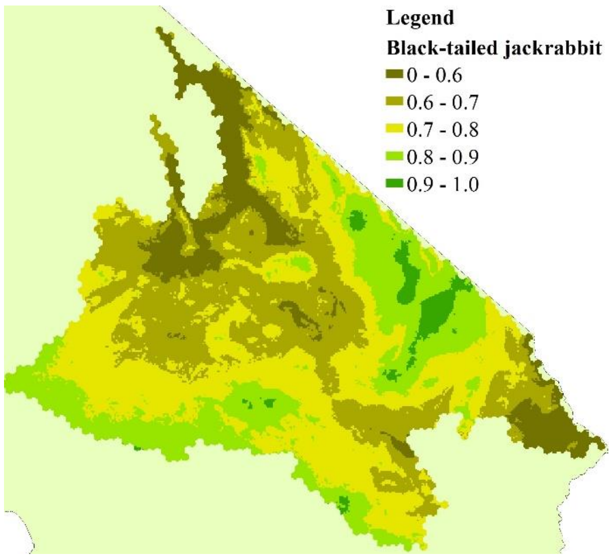
C.



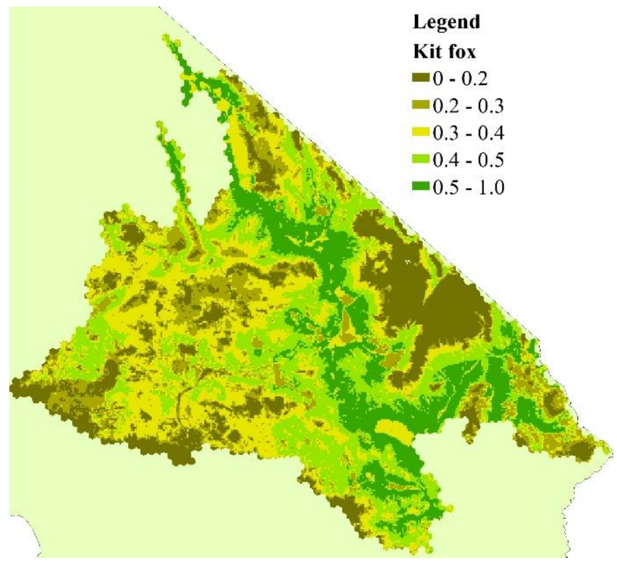
Latitude
Beta coefficients for latitude
3
2
1
0
-1
-2
-3
American Badger
Kit Fox
Brush Rabbit
Audubon's Cottontail
Coyote
Black-tailed Jackrabbit
Eastern Fox Squirrel
Elk
CA Ground Squirrel
American Mink
Bobcat
Wild Boar/Hog/Pig
Striped Skunk
Red Fox
Gray Fox
Ringtail
Western Gray Squirrel
Virginia Opossum
Mountain Lion
Raccoon
Common Porcupine
Deer

Figure 5. Projected occupancy probabilities across the Mojave Desert ecoregion of California, 2017, for A) black-tailed jackrabbits (*Lepus californicus*), B) kit fox (*Vulpes macrotis*), C) coyote (*Canis latrans*), and D) American badger (*Taxidea taxus*). Note that the occupancy scales differ among species.

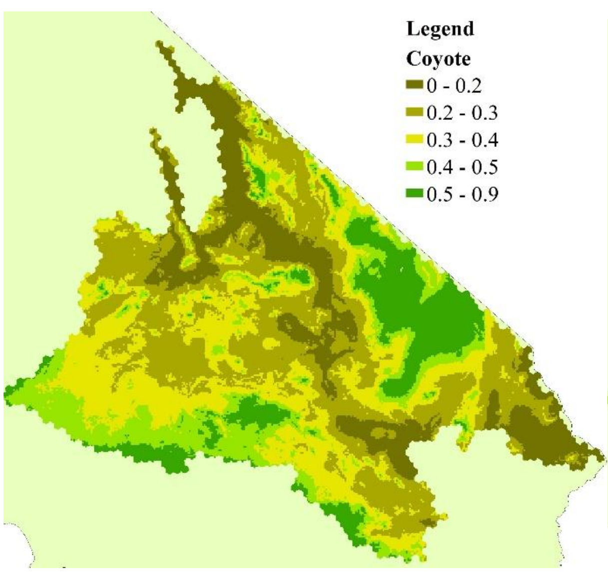
A.



B.



C.



D.

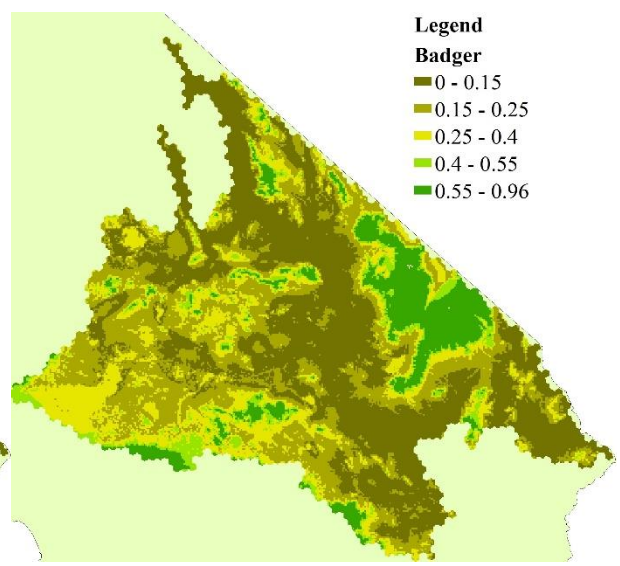
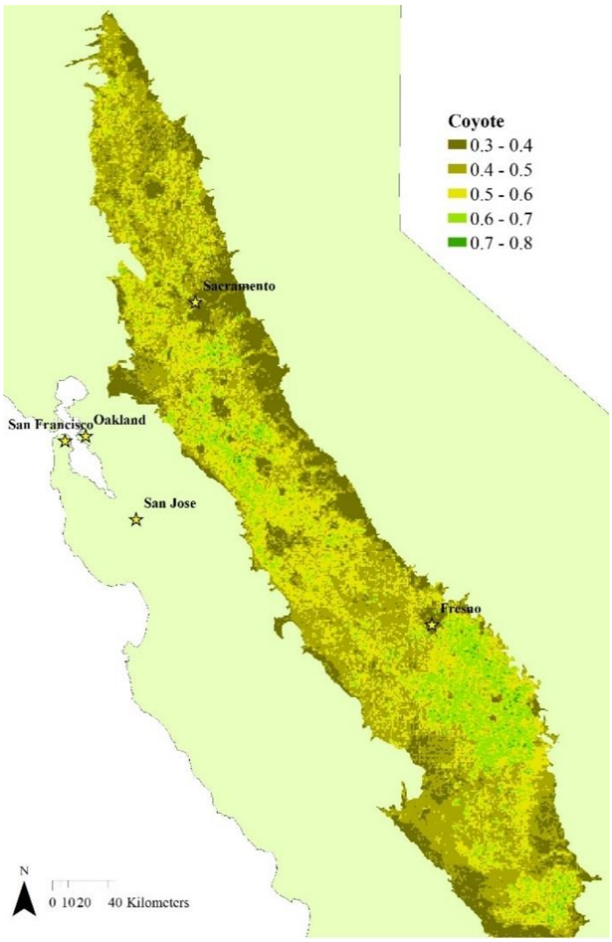
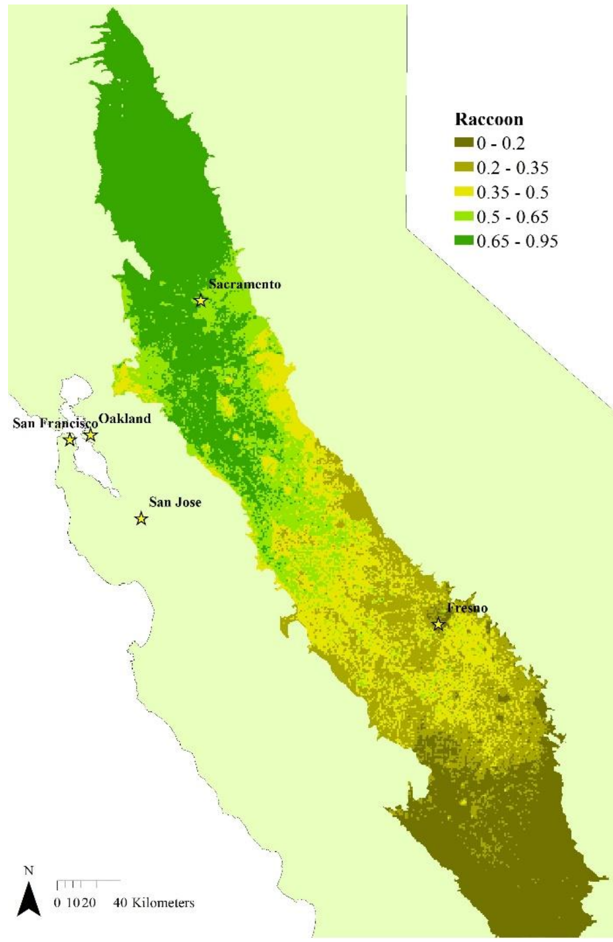


Figure 6. Projected occupancy probabilities across the Great Valley ecoregion of California, 2017, for A) coyotes (*Canis latrans*), B) raccoons (*Procyon lotor*), C) striped skunks (*Mephitis mephitis*), D) black-tailed jackrabbits (*Lepus californicus*), and E) mule deer (*Odocoileus hemionus*). Note that the occupancy scales differ among species.

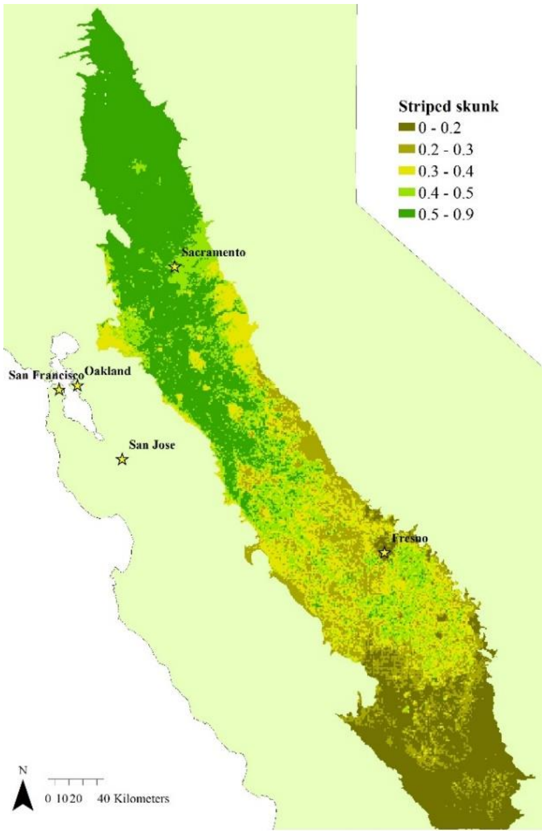
A.



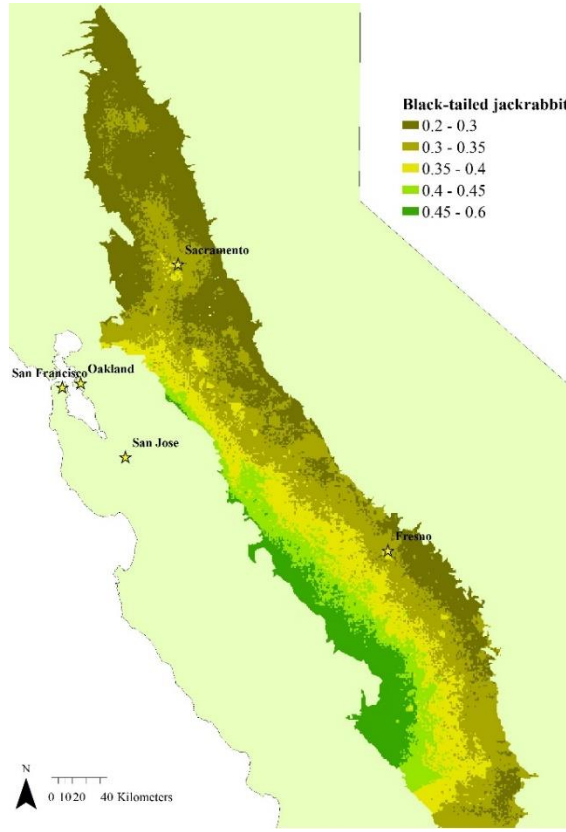
B.



C.


Striped skunk
0 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.9
Sacramento
San Francisco
Oakland
San Jose
Fresno
N
0 10 20 40 Kilometers

D.


Black-tailed jackrabbit
0.2 - 0.3
0.3 - 0.35
0.35 - 0.4
0.4 - 0.45
0.45 - 0.6
Sacramento
San Francisco
Oakland
San Jose
Fresno
N
0 10 20 40 Kilometers

E.

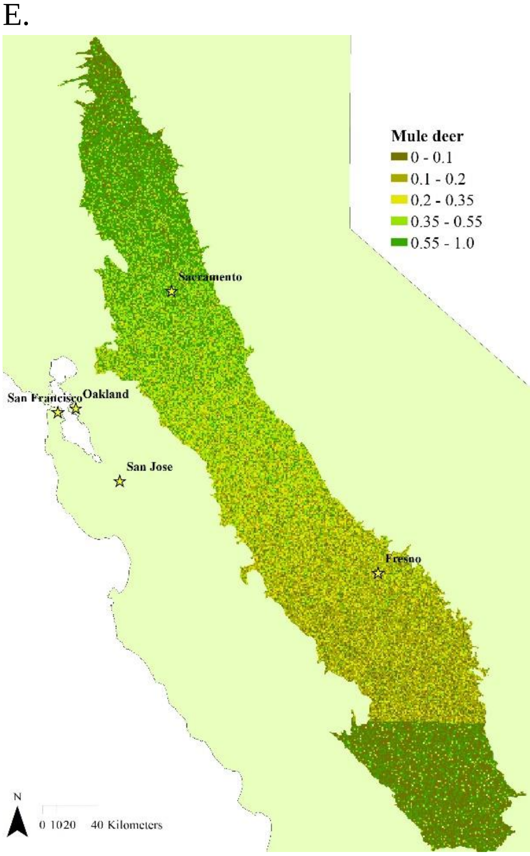
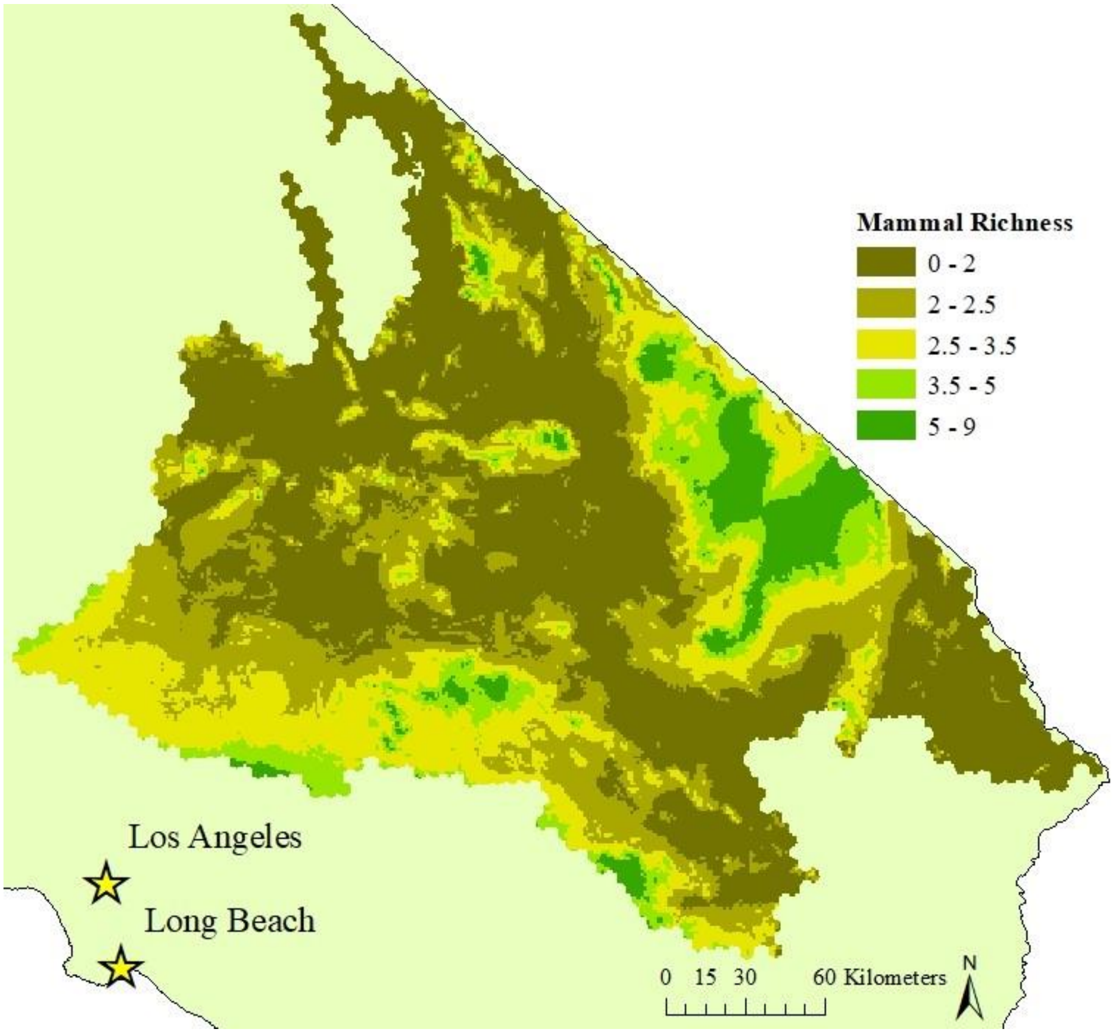
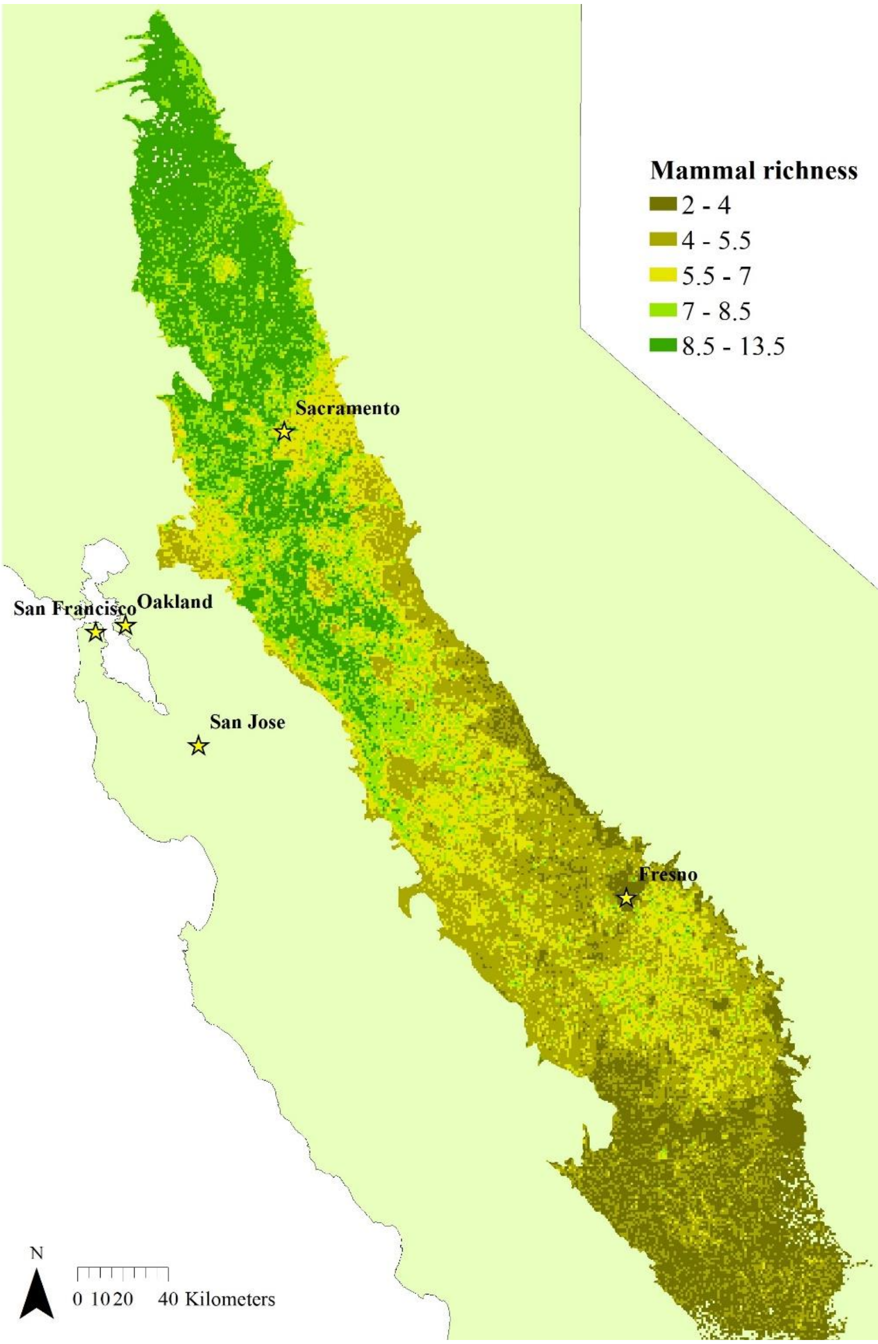

Mule deer
0 - 0.1
0.1 - 0.2
0.2 - 0.35
0.35 - 0.55
0.55 - 1.0
Sacramento
San Francisco
Oakland
San Jose
Fresno
N
0 10 20 40 Kilometers

Figure 7. Estimated mammal richness across the A) Mojave Desert and B) Great Valley ecoregions of California.

A.



B.


Mammal richness
2 - 4
4 - 5.5
5.5 - 7
7 - 8.5
8.5 - 13.5
Sacramento
San Francisco
Oakland
San Jose
Fresno
N
0 10 20 40 Kilometers

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Appendix S1a. Mammal species' mean occupancy, and 95% credible intervals, within each of the major habitat strata of the Mojave Desert ecoregion, 2016-17. The habitat with the largest estimated occupancy for each species is highlighted

	Desert outcrop & badlands		**Lower Mojave Desert Scrub**		**Upper Mojave Desert Scrub**		**Dunes**		**Playa**	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
American badger	0.20	0.073	0.18	0.061	0.38	0.096	0.20	0.070	0.20	0.083
Audubon's cottontail	0.13	0.038	0.12	0.033	0.44	0.063	0.17	0.043	0.16	0.049
Bighorn sheep	0.03	0.014	0.05	0.024	0.04	0.029	0.02	0.013	0.01	0.011
Black-tailed jackrabbit	0.71	0.060	0.71	0.053	0.70	0.062	0.72	0.053	0.72	0.063
Bobcat	0.11	0.037	0.16	0.045	0.45	0.077	0.11	0.034	0.07	0.030
CA ground squirrel	0.00	0.006	0.00	0.006	0.02	0.021	0.00	0.007	0.00	0.008
Coyote	0.32	0.063	0.34	0.058	0.39	0.069	0.34	0.058	0.33	0.067
Gray Fox	0.04	0.019	0.06	0.023	0.13	0.054	0.04	0.017	0.03	0.016
Kit Fox	0.52	0.070	0.55	0.062	0.18	0.041	0.48	0.062	0.51	0.075
Deer	0.00	0.003	0.01	0.004	0.22	0.054	0.00	0.003	0.00	0.003
Raccoon	0.00	0.006	0.00	0.006	0.01	0.012	0.01	0.007	0.01	0.009
Rock Squirrel	0.00	0.003	0.00	0.004	0.02	0.021	0.00	0.004	0.00	0.004
Spotted Skunk	0.02	0.015	0.03	0.023	0.05	0.040	0.02	0.016	0.02	0.016
Striped Skunk	0.00	0.006	0.00	0.005	0.01	0.013	0.00	0.007	0.01	0.008
Virginia Opossum	0.00	0.007	0.00	0.006	0.01	0.015	0.01	0.008	0.01	0.010
Wild Burro	0.05	0.033	0.03	0.019	0.03	0.021	0.04	0.026	0.05	0.033

	Saltbrush scrub		Grassland		Riparian		Wetland		Guzzler	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
American badger	0.25	0.079	0.25	0.080	0.17	0.058	0.23	0.071	0.29	0.076
Audubon's cottontail	0.27	0.058	0.19	0.044	0.14	0.033	0.21	0.039	0.35	0.052
Bighorn sheep	0.02	0.013	0.03	0.017	0.04	0.020	0.03	0.016	0.05	0.028
Black-tailed jackrabbit	0.72	0.054	0.69	0.055	0.72	0.053	0.71	0.056	0.72	0.054
Bobcat	0.14	0.045	0.20	0.056	0.15	0.039	0.17	0.042	0.34	0.061
CA ground squirrel	0.01	0.008	0.01	0.007	0.00	0.006	0.01	0.008	0.01	0.015
Coyote	0.35	0.060	0.35	0.059	0.32	0.057	0.34	0.060	0.37	0.061
Gray Fox	0.04	0.021	0.06	0.025	0.05	0.022	0.05	0.022	0.11	0.041
Kit Fox	0.35	0.061	0.37	0.060	0.55	0.061	0.45	0.059	0.31	0.050
Deer	0.01	0.008	0.01	0.009	0.02	0.007	0.03	0.014	0.13	0.034
Raccoon	0.01	0.007	0.00	0.006	0.00	0.006	0.01	0.007	0.01	0.009
Rock Squirrel	0.00	0.005	0.00	0.005	0.00	0.004	0.00	0.005	0.02	0.013
Spotted Skunk	0.02	0.017	0.02	0.019	0.03	0.020	0.02	0.018	0.05	0.034
Striped Skunk	0.01	0.007	0.00	0.006	0.00	0.005	0.00	0.006	0.01	0.009
Virginia Opossum	0.01	0.008	0.00	0.006	0.00	0.006	0.01	0.008	0.01	0.011
Wild Burro	0.03	0.020	0.04	0.022	0.03	0.019	0.04	0.024	0.02	0.014

Appendix S1b. Mammal species' mean occupancy, and 95% credible intervals, within each of the major habitat strata of the Great Valley ecoregion, 2016-17. The habitat with the largest estimated occupancy for each species is highlighted.

	Crop/Fallow		**Grassland, shrub**		**Orchard, vineyard**	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
American Badger	0.12	0.104	0.04	0.122	0.02	0.116
American Mink	0.01	0.094	0.02	0.090	0.01	0.085
Audubon's Cottontail	0.28	0.000	0.22	0.001	0.09	0.002
Black-tailed Jackrabbit	0.31	0.002	0.37	0.005	0.46	0.011
Bobcat	0.10	0.081	0.11	0.086	0.19	0.084
Brush Rabbit	0.00	0.059	0.01	0.062	0.00	0.051
CA Ground Squirrel	0.19	0.002	0.10	0.002	0.18	0.000
Common Porcupine	0.01	0.066	0.02	0.063	0.01	0.069
Coyote	0.38	0.205	0.51	0.166	0.60	0.144
Eastern Fox Squirrel	0.08	0.124	0.08	0.128	0.11	0.121
Elk	0.00	0.028	0.01	0.028	0.00	0.030
Gray Fox	0.06	0.023	0.02	0.028	0.09	0.013
Kit Fox	0.00	0.027	0.01	0.030	0.00	0.034
Mountain Lion	0.01	0.078	0.02	0.077	0.01	0.074
Deer	0.29	0.071	0.32	0.064	0.28	0.063
Raccoon	0.35	0.068	0.49	0.060	0.56	0.075
Red Fox	0.07	0.056	0.06	0.049	0.00	0.053
Ringtail	0.00	0.058	0.01	0.054	0.00	0.058
Striped Skunk	0.46	0.096	0.46	0.106	0.55	0.057
Virginia Opossum	0.19	0.034	0.17	0.032	0.28	0.040
Western Gray Squirrel	0.05	0.075	0.10	0.062	0.11	0.081
Wild Boar/Hog/Pig	0.03	0.039	0.00	0.039	0.00	0.042

	Rice		Riparian		Wetland, open water	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
American Badger	0.03	0.116	0.08	0.112	0.07	0.103
American Mink	0.01	0.086	0.02	0.087	0.01	0.095
Audubon's Cottontail	0.29	0.000	0.24	0.001	0.20	0.001
Black-tailed Jackrabbit	0.43	0.000	0.29	0.002	0.33	0.006
Bobcat	0.15	0.073	0.13	0.083	0.10	0.077
Brush Rabbit	0.00	0.062	0.00	0.059	0.04	0.060
CA Ground Squirrel	0.14	0.000	0.19	0.002	0.11	0.002
Common Porcupine	0.00	0.057	0.02	0.059	0.02	0.056
Coyote	0.61	0.119	0.46	0.180	0.47	0.178
Eastern Fox Squirrel	0.02	0.133	0.09	0.130	0.02	0.133
Elk	0.00	0.030	0.00	0.028	0.02	0.026
Gray Fox	0.00	0.024	0.00	0.022	0.04	0.029
Kit Fox	0.00	0.019	0.05	0.023	0.04	0.022
Mountain Lion	0.01	0.085	0.02	0.074	0.01	0.078
Deer	0.58	0.068	0.35	0.064	0.26	0.049
Raccoon	0.30	0.104	0.47	0.067	0.44	0.054
Red Fox	0.00	0.039	0.01	0.059	0.06	0.055
Ringtail	0.15	0.048	0.02	0.054	0.00	0.057
Striped Skunk	0.72	0.050	0.37	0.147	0.30	0.157
Virginia Opossum	0.15	0.053	0.16	0.034	0.26	0.032
Western Gray Squirrel	0.15	0.058	0.09	0.073	0.08	0.054
Wild Boar/Hog/Pig	0.00	0.051	0.03	0.037	0.00	0.039

Appendix S2a. Species names and mean and 95% credible intervals (95% CI) for estimates of species-specific probabilities of occurrence, detection probability (for survey duration), and covariate effects on occupancy (PSI) and detection (P) in the Mojave Desert ecoregion of California, 2016-17. Results are presented for model 1; covariate effects that did not overlap 0.0 are highlighted.

Common name	Occupancy			Detection			PSI (guzzler)			PSI (mean precip)		
	Mean	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*	
American Badger	0.19	0.071	0.394	0.63	0.374	0.823	0.86	-0.295	1.932	0.22	-0.333	0.866
Audubon's Cottontail	0.14	0.064	0.245	1.00	0.995	0.999	1.64	0.931	2.340	0.51	0.118	0.923
Bighorn Sheep	0.01	0.002	0.027	1.00	0.963	1.000	2.13	0.871	3.473	-0.65	-1.510	0.061
Black-tailed Jackrabbit	0.73	0.589	0.845	1.00	1.000	1.000	0.12	-0.693	0.893	0.13	-0.238	0.518
Bobcat	0.09	0.040	0.174	0.95	0.871	0.982	1.07	0.342	1.808	0.20	-0.193	0.634
CA Ground Squirrel	0.00	0.000	0.017	0.98	0.191	1.000	-0.21	-3.355	2.009	0.11	-0.934	1.173
Coyote	0.11	0.052	0.208	0.92	0.852	0.961	1.03	0.336	1.747	-0.80	-1.211	-0.401
Gray Fox	0.02	0.007	0.061	1.00	0.991	1.000	1.14	0.166	2.135	-0.11	-0.667	0.387
Kit Fox	0.32	0.196	0.458	1.00	0.995	0.999	-0.69	-1.497	0.120	-0.28	-0.655	0.085
Deer	0.01	0.001	0.024	1.00	0.999	1.000	0.83	-0.401	2.078	1.04	0.407	1.742
Raccoon	0.00	0.000	0.008	1.00	0.556	1.000	-0.16	-3.298	2.066	-0.20	-1.338	0.786
Rock Squirrel	0.00	0.000	0.010	1.00	0.610	1.000	-0.52	-3.592	1.385	0.33	-0.538	1.171
Spotted Skunk	0.01	0.001	0.033	0.97	0.401	1.000	0.13	-1.708	1.705	0.24	-0.513	1.027
Striped Skunk	0.00	0.000	0.009	1.00	0.534	1.000	-0.17	-3.233	2.015	-0.15	-1.346	0.904
Virginia Opossum	0.00	0.000	0.010	1.00	0.400	1.000	-0.16	-3.030	2.033	-0.11	-1.233	0.898
Wild Burro	0.03	0.008	0.082	1.00	1.000	1.000	-0.97	-3.854	0.750	-0.26	-1.084	0.459

Common name	PSI (mean temp)			PSI (slope)			PSI (year)			P (guzzler)		
	Mean	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*	
American Badger	-0.66	-1.287	-0.133	-0.20	-0.688	0.221	0.64	-0.558	1.987	1.17	0.546	1.851
Audubon's Cottontail	-0.95	-1.369	-0.558	-0.66	-1.148	-0.237	0.00	-0.997	0.919	0.89	0.716	1.073
Bighorn Sheep	0.01	-0.676	0.735	0.69	0.300	1.119	1.00	-0.343	2.534	0.77	0.249	1.298
Black-tailed Jackrabbit	-0.64	-0.993	-0.296	-1.47	-1.912	-1.063	-0.04	-0.944	0.816	0.58	0.449	0.714
Bobcat	-1.04	-1.512	-0.610	0.51	0.208	0.883	0.64	-0.295	1.583	0.73	0.408	1.049
CA Ground Squirrel	-0.53	-1.845	0.759	0.56	-0.484	1.513	0.98	-0.816	3.086	0.56	-0.909	1.885
Coyote	-0.61	-0.969	-0.266	-0.77	-1.204	-0.370	1.89	0.880	2.924	0.70	0.436	0.957
Gray Fox	-0.41	-1.009	0.184	0.64	0.311	0.990	1.06	-0.178	2.448	0.03	-0.428	0.478
Kit Fox	0.51	0.174	0.882	-1.52	-2.127	-0.973	0.46	-0.325	1.233	-0.19	-0.591	0.175
Deer	-2.25	-3.405	-1.262	0.27	-0.345	0.819	0.91	-0.723	2.608	1.09	0.618	1.611
Raccoon	-0.49	-1.759	0.774	-0.67	-2.481	0.633	0.84	-0.950	2.890	0.62	-0.656	1.990
Rock Squirrel	-1.04	-2.306	0.081	0.35	-0.592	1.164	1.03	-0.735	3.096	0.62	-0.679	2.001
Spotted Skunk	-0.09	-1.034	0.846	1.01	0.412	1.732	1.60	-0.002	4.000	0.66	-0.472	1.756
Striped Skunk	-0.62	-1.983	0.631	-0.77	-2.734	0.574	0.86	-0.882	2.922	0.62	-0.750	1.915
Virginia Opossum	-0.64	-1.925	0.617	-0.70	-2.431	0.616	0.88	-0.908	2.969	0.60	-0.858	1.898
Wild Burro	-0.03	-0.721	0.648	-0.27	-1.141	0.372	0.09	-1.519	1.448	0.62	-0.725	1.975

Common name	P (max temp)			P (bait status)			P (year)		
	Mean	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*	
American Badger	0.08	-0.240	0.402	-0.47	-1.089	0.103	-0.52	-1.195	0.200
Audubon's Cottontail	-0.03	-0.131	0.072	0.16	-0.061	0.375	0.22	-0.014	0.449
Bighorn Sheep	1.29	0.924	1.676	-0.11	-1.336	1.149	-0.85	-2.150	0.414
Black-tailed Jackrabbit	-0.15	-0.203	-0.088	-0.16	-0.296	-0.032	-0.23	-0.366	-0.084
Bobcat	-0.08	-0.285	0.124	-0.25	-0.638	0.159	-0.32	-0.727	0.087
CA Ground Squirrel	0.39	-1.384	2.214	-0.33	-1.870	1.011	-1.49	-3.819	0.399
Coyote	0.20	0.067	0.332	-0.17	-0.494	0.152	-0.06	-0.408	0.298
Gray Fox	0.84	0.497	1.190	0.70	-0.141	1.588	-2.15	-3.190	-1.195
Kit Fox	-0.06	-0.152	0.025	0.63	0.374	0.902	-1.04	-1.305	-0.786
Deer	2.27	1.488	3.093	-1.13	-1.677	-0.571	-0.78	-1.485	-0.096
Raccoon	0.11	-1.553	1.725	0.00	-1.373	1.435	-0.70	-2.757	1.264
Rock Squirrel	0.79	-0.968	2.711	-0.03	-1.396	1.311	-0.81	-2.635	1.022
Spotted Skunk	0.26	-0.814	1.228	-0.31	-1.659	0.962	-1.68	-3.514	-0.056
Striped Skunk	-0.09	-1.567	1.301	-0.01	-1.405	1.487	-0.69	-2.827	1.409
Virginia Opossum	0.08	-1.398	1.475	-0.10	-1.463	1.313	-0.93	-3.153	1.075
Wild Burro	0.92	0.408	1.449	0.21	-0.303	0.741	-2.48	-3.219	-1.805

Appendix S2b. Species names and mean and 95% credible intervals (95% CI) for estimates of species-specific probabilities of occurrence, detection probability (for survey duration), and covariate effects on occupancy (PSI) and detection (P) in the Mojave Desert ecoregion of California, 2016-17. Results are presented for model 2; covariate effects that did not overlap 0.0 are highlighted.

Common name	Occupancy			Detection			PSI (water)			PSI (scrub)		
	Mean	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*	
American Badger	0.24	0.156	0.342	0.94	0.801	0.988	-0.01	-0.264	0.210	-0.33	-0.725	0.069
Audubon's Cottontail	0.25	0.195	0.328	1.00	1.000	1.000	0.02	-0.194	0.248	-0.61	-0.933	-0.294
Bighorn Sheep	0.04	0.022	0.068	1.00	0.966	1.000	-0.03	-0.363	0.237	0.58	-0.006	1.251
Black-tailed Jackrabbit	0.72	0.655	0.804	1.00	1.000	1.000	0.03	-0.148	0.221	-0.02	-0.273	0.238
Bobcat	0.25	0.185	0.319	1.00	0.993	1.000	-0.02	-0.267	0.186	-0.02	-0.377	0.337
CA Ground Squirrel	0.01	0.010	0.025	0.99	0.545	1.000	-0.03	-0.437	0.253	-0.27	-1.334	0.619
Coyote	0.33	0.247	0.409	0.98	0.955	0.994	-0.06	-0.286	0.127	-0.02	-0.273	0.230
Gray Fox	0.09	0.067	0.129	0.99	0.921	0.999	0.03	-0.221	0.305	0.08	-0.381	0.562
Kit Fox	0.36	0.264	0.452	1.00	0.987	0.998	0.10	-0.083	0.351	0.56	0.260	0.863
Deer	0.06	0.060	0.073	1.00	1.000	1.000	-0.04	-0.421	0.222	-0.69	-1.663	0.081
Raccoon	0.004	0.000	0.013	1.00	0.752	1.000	-0.04	-0.447	0.248	-0.11	-0.994	0.775
Rock Squirrel	0.01	0.010	0.021	1.00	0.829	1.000	-0.01	-0.360	0.291	-0.19	-1.128	0.652
Spotted Skunk	0.03	0.017	0.058	0.99	0.734	1.000	0.02	-0.262	0.314	0.19	-0.462	0.897
Striped Skunk	0.002	0.000	0.012	1.00	0.773	1.000	-0.03	-0.422	0.282	-0.21	-1.180	0.686
Virginia Opossum	0.004	0.000	0.014	1.00	0.624	1.000	-0.03	-0.413	0.278	-0.18	-1.157	0.722
Wild Burro	0.03	0.010	0.054	1.00	0.985	1.000	-0.06	-0.471	0.195	-0.01	-0.568	0.583

Common name	PSI (elevation)			PSI (forest)			PSI (year)			P (human disturbance)		
	Mean	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*	
American Badger	0.46	0.019	0.905	0.09	-0.282	0.494	0.10	-0.441	0.660	0.00	-0.277	0.244
Audubon's Cottontail	0.53	0.183	0.882	-0.43	-0.784	-0.089	-0.06	-0.580	0.346	0.14	0.039	0.244
Bighorn Sheep	0.33	-0.372	1.044	-0.54	-1.226	0.016	-0.01	-0.686	0.564	0.63	0.386	0.893
Black-tailed Jackrabbit	-0.10	-0.363	0.168	-0.13	-0.384	0.130	-0.12	-0.589	0.272	0.26	0.205	0.312
Bobcat	1.02	0.612	1.467	-0.19	-0.525	0.142	0.00	-0.513	0.456	0.42	0.247	0.602
CA Ground Squirrel	0.54	-0.649	1.802	-0.34	-1.339	0.398	0.09	-0.669	0.905	0.18	-0.432	0.770
Coyote	0.12	-0.150	0.398	-0.06	-0.323	0.197	0.19	-0.198	0.619	0.07	-0.061	0.194
Gray Fox	0.70	0.153	1.270	-0.22	-0.709	0.195	0.06	-0.519	0.637	0.05	-0.198	0.278
Kit Fox	-0.90	-1.247	-0.582	0.11	-0.165	0.382	0.33	-0.087	0.856	0.12	0.033	0.214
Deer	2.19	1.183	3.424	-0.58	-1.579	0.068	0.13	-0.465	0.825	0.02	-0.249	0.281
Raccoon	0.11	-1.173	1.320	-0.23	-1.164	0.536	0.08	-0.652	0.834	0.20	-0.375	0.750
Rock Squirrel	1.13	-0.033	2.489	-0.40	-1.415	0.321	0.11	-0.600	0.867	0.12	-0.511	0.659
Spotted Skunk	0.39	-0.432	1.249	-0.54	-1.440	0.089	0.23	-0.367	1.093	0.07	-0.533	0.595
Striped Skunk	0.17	-1.099	1.386	-0.29	-1.232	0.472	0.08	-0.673	0.843	0.21	-0.320	0.753
Virginia Opossum	0.16	-1.134	1.424	-0.30	-1.236	0.476	0.09	-0.689	0.882	0.18	-0.375	0.722
Wild Burro	-0.18	-0.862	0.440	0.50	-0.101	1.144	-0.06	-0.844	0.501	0.21	-0.107	0.517

Common name	P (precipitation)			P (bait status)			P (year)		
	Mean	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*	
American Badger	0.56	0.207	0.887	-0.61	-1.235	-0.007	-1.19	-2.043	-0.369
Audubon's Cottontail	0.87	0.752	1.002	0.52	0.296	0.741	-1.94	-2.335	-1.546
Bighorn Sheep	-0.91	-1.596	-0.300	0.58	-0.583	1.857	-0.51	-1.726	0.703
Black-tailed Jackrabbit	0.48	0.411	0.557	0.00	-0.132	0.143	-1.15	-1.338	-0.956
Bobcat	0.47	0.279	0.673	-0.15	-0.551	0.236	-1.65	-2.263	-1.052
CA Ground Squirrel	-0.16	-1.765	1.325	-0.24	-1.758	1.054	-1.41	-3.054	-0.002
Coyote	0.26	0.115	0.403	-0.36	-0.683	-0.023	-0.26	-0.655	0.148
Gray Fox	-0.45	-0.846	-0.080	0.73	-0.004	1.426	-0.96	-1.766	-0.159
Kit Fox	-0.20	-0.355	-0.042	0.64	0.389	0.908	-0.81	-1.119	-0.495
Deer	-0.20	-0.603	0.173	-0.81	-1.325	-0.335	-0.02	-1.119	1.263
Raccoon	-0.08	-1.649	1.452	0.07	-1.234	1.472	-1.04	-2.430	0.401
Rock Squirrel	-0.21	-0.804	0.294	0.23	-1.014	1.607	-0.86	-2.235	0.545
Spotted Skunk	0.14	-0.581	0.828	-0.28	-1.665	0.918	-1.54	-3.013	-0.227
Striped Skunk	-0.09	-1.705	1.523	0.09	-1.249	1.395	-0.95	-2.407	0.496
Virginia Opossum	-0.06	-1.578	1.565	-0.10	-1.543	1.216	-1.21	-2.761	0.157
Wild Burro	-0.74	-1.511	0.034	0.36	-0.168	0.897	-1.05	-2.197	0.091

Appendix S2c. Species names and mean and 95% credible intervals (95% CI) for estimates of species-specific probabilities of occurrence, detection probability (for survey duration), and covariate effects on occupancy (PSI) and detection (P) in the Great Valley ecoregion of California, 2016-17. Results are presented for model 1; covariate effects that did not overlap 0.0 are highlighted.

Common name	Occupancy			Detection			PSI (dist. to water)			PSI (precipitation)		
	Mean	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*	
American Badger	0.04	0.010	0.089	0.65	0.318	0.890	0.19	-0.286	0.847	-1.34	-2.340	-0.511
American Mink	0.02	0.003	0.061	0.66	0.126	0.978	-0.14	-0.868	0.390	0.18	-0.837	1.225
Audubon's Cottontail	0.22	0.160	0.292	1.00	1.000	1.000	0.13	-0.132	0.402	-0.66	-1.015	-0.334
Black-tailed Jackrabbit	0.37	0.294	0.457	1.00	1.000	1.000	0.26	-0.011	0.586	-0.42	-0.715	-0.132
Bobcat	0.11	0.068	0.171	0.92	0.804	0.975	-0.14	-0.605	0.228	0.56	0.101	1.031
Brush Rabbit	0.01	0.002	0.034	0.92	0.322	1.000	-0.13	-0.851	0.375	-0.38	-1.421	0.536
CA Ground Squirrel	0.14	0.094	0.197	1.00	1.000	1.000	0.25	-0.027	0.591	0.13	-0.229	0.510
Common Porcupine	0.02	0.003	0.039	0.87	0.491	0.988	-0.04	-0.632	0.448	0.50	-0.405	1.453
Coyote	0.51	0.422	0.600	0.89	0.819	0.934	-0.19	-0.542	0.122	-0.21	-0.527	0.110
Eastern Fox Squirrel	0.07	0.030	0.147	0.64	0.318	0.892	-0.24	-0.940	0.231	0.09	-0.539	0.717
Elk	0.01	0.002	0.025	0.99	0.511	1.000	-0.14	-0.861	0.355	0.22	-0.767	1.134
Gray Fox	0.03	0.009	0.052	1.00	0.978	1.000	0.31	-0.017	0.718	0.43	-0.235	1.107
Kit Fox	0.02	0.003	0.038	0.99	0.728	1.000	0.05	-0.479	0.489	-1.07	-2.162	-0.219
Mountain Lion	0.02	0.002	0.047	0.72	0.201	0.979	-0.12	-0.795	0.431	0.26	-0.745	1.289
Deer	0.32	0.242	0.405	0.99	0.980	0.996	-0.24	-0.648	0.062	0.80	0.481	1.161
Raccoon	0.46	0.364	0.555	0.97	0.955	0.986	-0.09	-0.376	0.161	0.83	0.507	1.173
Red Fox	0.03	0.013	0.065	0.88	0.610	0.978	0.31	-0.019	0.700	0.63	0.010	1.296
Ringtail	0.02	0.004	0.049	0.84	0.342	0.993	-0.19	-0.976	0.313	0.38	-0.564	1.312
Striped Skunk	0.43	0.345	0.517	0.98	0.960	0.990	-0.06	-0.335	0.200	0.51	0.207	0.823
Virginia Opossum	0.16	0.107	0.227	0.99	0.980	0.998	-0.41	-1.007	0.007	0.71	0.339	1.086
Western Gray Squirrel	0.08	0.044	0.132	0.99	0.939	0.998	-0.30	-0.995	0.131	0.46	-0.065	0.986
Wild Boar/Hog/Pig	0.01	0.004	0.035	0.99	0.769	1.000	-0.07	-0.686	0.371	0.28	-0.614	1.160

Common name	PSI (temperature)			PSI (natural cover)			PSI (year)			P (crop diversity)		
	Mean	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*	
American Badger	0.19	-0.341	0.787	-0.13	-0.446	0.234	-0.48	-1.466	0.253	0.13	-0.464	0.730
American Mink	-0.03	-0.837	0.673	-0.18	-0.599	0.197	-0.29	-1.106	0.746	0.12	-0.810	0.952
Audubon's Cottontail	-0.02	-0.427	0.372	-0.14	-0.352	0.096	-0.41	-1.158	0.249	0.22	0.109	0.335
Black-tailed Jackrabbit	0.24	-0.128	0.691	-0.09	-0.286	0.143	-0.54	-1.441	0.098	-0.14	-0.237	-0.038
Bobcat	0.45	-0.021	0.994	-0.14	-0.396	0.133	-0.33	-1.082	0.444	0.34	-0.005	0.698
Brush Rabbit	0.44	-0.212	1.283	-0.11	-0.457	0.296	-0.21	-0.964	0.829	-0.07	-1.047	0.757
CA Ground Squirrel	-0.14	-0.629	0.300	-0.28	-0.616	-0.050	-0.38	-1.119	0.368	0.52	0.321	0.718
Common Porcupine	0.01	-0.778	0.728	-0.15	-0.509	0.237	-0.44	-1.503	0.380	0.19	-0.903	1.209
Coyote	0.16	-0.218	0.550	-0.17	-0.396	0.037	-0.39	-1.084	0.276	0.13	-0.030	0.293
Eastern Fox Squirrel	-0.47	-1.381	0.162	-0.22	-0.616	0.048	-0.14	-0.867	1.202	0.37	-0.124	0.881
Elk	0.05	-0.723	0.737	-0.08	-0.407	0.419	-0.21	-0.957	0.992	0.12	-0.734	0.939
Gray Fox	-0.01	-0.703	0.607	-0.16	-0.490	0.187	-0.40	-1.283	0.414	0.66	0.251	1.153
Kit Fox	0.41	-0.167	1.140	-0.06	-0.375	0.418	-0.34	-1.187	0.544	-0.45	-1.181	0.226
Mountain Lion	-0.02	-0.846	0.713	-0.15	-0.519	0.251	-0.43	-1.471	0.428	0.24	-0.610	1.131
Deet	0.04	-0.357	0.462	-0.06	-0.257	0.212	-0.48	-1.278	0.144	0.19	0.052	0.327
Raccoon	-0.35	-0.831	0.055	-0.20	-0.426	0.008	-0.32	-1.001	0.461	0.20	0.079	0.313
Red Fox	0.15	-0.461	0.773	-0.33	-0.911	-0.037	-0.22	-0.936	0.842	-0.54	-1.124	-0.009
Ringtail	0.01	-0.741	0.709	-0.20	-0.615	0.125	-0.45	-1.511	0.352	0.29	-0.628	1.224
Striped Skunk	0.18	-0.230	0.566	-0.07	-0.274	0.198	-0.22	-0.831	0.597	0.19	0.064	0.325
Virginia Opossum	-0.23	-0.732	0.220	-0.23	-0.507	-0.012	-0.30	-0.994	0.526	-0.20	-0.390	-0.007
Western Gray Squirrel	0.00	-0.603	0.553	-0.25	-0.606	0.018	-0.41	-1.245	0.376	0.96	0.576	1.350
Wild Boar/Hog/Pig	-0.05	-0.851	0.613	-0.09	-0.407	0.400	-0.46	-1.549	0.332	0.44	-0.424	1.414

Common name	P (max temp)			P (bait status)			P (year)		
	Mean	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*	
American Badger	-0.04	-0.574	0.470	-0.08	-0.553	0.311	0.49	-0.682	1.660
American Mink	-0.04	-0.649	0.670	-0.06	-0.585	0.405	-0.30	-1.938	1.236
Audubon's Cottontail	-0.05	-0.176	0.080	0.01	-0.169	0.189	-0.06	-0.336	0.214
Black-tailed Jackrabbit	0.22	0.122	0.322	0.10	-0.057	0.270	-0.17	-0.358	0.022
Bobcat	-0.36	-0.631	-0.114	-0.13	-0.506	0.194	0.25	-0.406	0.919
Brush Rabbit	0.13	-0.494	0.792	-0.01	-0.529	0.514	0.18	-1.409	1.749
CA Ground Squirrel	0.40	0.235	0.577	-0.29	-0.586	0.003	-0.96	-1.419	-0.509
Common Porcupine	-0.10	-0.646	0.413	-0.01	-0.500	0.479	-0.34	-2.561	1.787
Coyote	-0.05	-0.196	0.089	-0.03	-0.269	0.204	-0.07	-0.425	0.258
Eastern Fox Squirrel	-0.19	-0.585	0.188	0.02	-0.454	0.514	0.06	-0.879	0.956
Elk	0.06	-0.621	0.803	-0.04	-0.550	0.407	0.81	-0.892	2.649
Gray Fox	-0.54	-1.124	-0.046	0.06	-0.360	0.589	-0.57	-1.981	0.671
Kit Fox	-0.03	-0.503	0.464	-0.07	-0.554	0.327	-0.46	-1.309	0.333
Mountain Lion	-0.06	-0.726	0.583	-0.04	-0.530	0.440	-0.33	-2.507	1.842
Deet	0.09	-0.024	0.195	0.00	-0.205	0.195	0.12	-0.156	0.396
Raccoon	-0.05	-0.151	0.056	-0.04	-0.233	0.139	0.60	0.366	0.826
Red Fox	0.00	-0.529	0.542	0.17	-0.192	0.694	1.82	0.656	3.066
Ringtail	-0.18	-0.882	0.437	-0.05	-0.562	0.398	-0.38	-2.553	1.767
Striped Skunk	-0.03	-0.162	0.092	-0.08	-0.304	0.119	-0.94	-1.330	-0.575
Virginia Opossum	-0.25	-0.401	-0.109	0.11	-0.120	0.406	-0.17	-0.563	0.196
Western Gray Squirrel	0.13	-0.098	0.369	0.19	-0.113	0.594	-1.81	-3.033	-0.810
Wild Boar/Hog/Pig	-0.56	-1.172	-0.056	-0.08	-0.673	0.362	-0.28	-2.608	2.016

Appendix S2d. Species names and mean and 95% credible intervals (95% CI) for estimates of species-specific probabilities of occurrence, detection probability for survey duration, and covariate effects on occupancy (PSI) and detection (P) in the Great Valley ecoregion of California, 2016-17. Results are presented for model 2; covariate effects that did not overlap 0.0 are highlighted.

Common name	**Occupancy**			**Detection**			**PSI (forest cover)**			**PSI (crop diversity)**		
	Mean	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*	
American Badger	0.06	0.044	0.104	0.93	0.596	0.996	0.23	-0.164	0.690	-0.04	-0.624	0.445
American Mink	0.02	0.012	0.051	0.89	0.831	0.933	0.04	-0.619	0.609	0.39	-0.211	1.109
Audubon's Cottontail	0.22	0.167	0.285	0.99	0.520	1.000	0.37	0.043	0.720	0.02	-0.269	0.303
Black-tailed Jackrabbit	0.34	0.271	0.409	1.00	0.987	0.999	0.19	-0.086	0.477	-0.09	-0.347	0.171
Bobcat	0.11	0.069	0.157	0.87	0.473	0.990	-0.19	-0.794	0.253	0.18	-0.175	0.531
Brush Rabbit	0.02	0.012	0.041	1.00	1.000	1.000	-0.10	-0.817	0.373	0.28	-0.305	0.868
CA Ground Squirrel	0.14	0.097	0.192	0.96	0.893	0.989	0.12	-0.248	0.483	0.35	0.044	0.685
Common Porcupine	0.02	0.012	0.040	0.98	0.958	0.989	0.15	-0.413	0.723	0.16	-0.453	0.775
Coyote	0.49	0.407	0.577	0.74	0.217	0.982	-0.08	-0.440	0.233	0.15	-0.114	0.411
Eastern Fox Squirrel	0.07	0.023	0.122	0.97	0.950	0.988	0.08	-0.404	0.530	0.61	0.147	1.140
Elk	0.01	0.006	0.024	1.00	1.000	1.000	-0.04	-0.750	0.458	-0.01	-0.747	0.563
Gray Fox	0.03	0.010	0.058	0.97	0.942	0.981	0.00	-0.596	0.484	0.06	-0.503	0.544
Kit Fox	0.02	0.007	0.039	0.78	0.295	0.976	-0.01	-0.575	0.403	-0.23	-0.983	0.322
Mountain Lion	0.01	0.008	0.031	1.00	0.999	1.000	0.07	-0.533	0.653	0.25	-0.372	0.916
Deer	0.32	0.250	0.392	0.80	0.532	0.940	0.26	-0.094	0.680	0.07	-0.207	0.341
Raccoon	0.45	0.371	0.539	0.97	0.778	0.999	0.18	-0.140	0.507	0.23	-0.026	0.506
Red Fox	0.04	0.023	0.075	1.00	1.000	1.000	-0.15	-0.909	0.332	0.28	-0.197	0.758
Ringtail	0.01	0.002	0.031	0.91	0.280	1.000	0.07	-0.564	0.630	0.31	-0.257	0.920
Striped Skunk	0.41	0.334	0.493	0.66	0.286	0.909	0.10	-0.230	0.425	0.25	-0.017	0.505
Virginia Opossum	0.20	0.142	0.259	1.00	0.992	1.000	0.16	-0.201	0.565	0.65	0.294	1.035
Western Gray Squirrel	0.09	0.054	0.129	0.99	0.687	1.000	0.10	-0.367	0.584	0.34	-0.043	0.769
Wild Boar/Hog/Pig	0.01	0.003	0.031	0.93	0.602	0.997	0.14	-0.378	0.754	-0.05	-0.804	0.501

Common name	PSI (latitude)			PSI (year)			P (human dist.)			P (precipitation)		
	Mean	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*	
American Badger	-1.65	-2.707	-0.745	-0.23	-1.031	0.461	-0.07	-0.380	0.202	0.04	-0.564	0.650
American Mink	0.29	-0.907	1.520	-0.11	-0.852	0.753	-0.06	-0.375	0.252	-0.10	-1.081	0.853
Audubon's Cottontail	-0.45	-0.788	-0.095	-0.12	-0.671	0.489	-0.06	-0.154	0.030	0.24	0.146	0.334
Black-tailed Jackrabbit	-0.32	-0.621	-0.030	-0.12	-0.633	0.419	0.02	-0.078	0.117	-0.18	-0.267	-0.102
Bobcat	0.41	-0.049	0.928	0.03	-0.539	0.820	-0.17	-0.379	0.011	0.03	-0.249	0.315
Brush Rabbit	-0.60	-1.696	0.401	0.02	-0.630	1.052	-0.07	-0.369	0.235	-0.30	-1.100	0.393
CA Ground Squirrel	0.21	-0.203	0.631	-0.32	-1.030	0.211	-0.08	-0.201	0.046	-0.23	-0.395	-0.070
Common Porcupine	1.15	-0.041	2.554	-0.22	-1.051	0.471	-0.06	-0.358	0.239	0.03	-0.768	0.846
Coyote	-0.35	-0.683	-0.034	-0.21	-0.821	0.327	0.02	-0.104	0.165	-0.08	-0.226	0.059
Eastern Fox Squirrel	0.15	-0.627	0.924	-0.14	-0.814	0.559	-0.02	-0.291	0.339	0.32	-0.545	1.365
Elk	0.20	-0.875	1.321	-0.03	-0.701	0.931	-0.09	-0.393	0.173	-0.01	-0.975	0.952
Gray Fox	0.67	-0.113	1.543	-0.21	-1.060	0.481	0.10	-0.126	0.432	-0.21	-0.620	0.204
Kit Fox	-1.46	-2.482	-0.527	-0.09	-0.831	0.733	-0.07	-0.317	0.168	-0.36	-1.209	0.388
Mountain Lion	1.06	-0.236	2.578	-0.20	-1.006	0.551	-0.07	-0.373	0.256	-0.22	-1.294	0.720
Deer	1.36	0.924	1.846	-0.10	-0.629	0.461	-0.20	-0.339	-0.065	0.38	0.205	0.573
Raccoon	1.08	0.720	1.497	-0.34	-0.984	0.151	-0.06	-0.149	0.035	0.21	0.079	0.354
Red Fox	0.61	-0.108	1.418	-0.09	-0.751	0.675	0.03	-0.232	0.410	-0.26	-1.125	0.500
Ringtail	0.86	-0.248	2.109	-0.23	-1.109	0.486	-0.06	-0.346	0.257	-0.05	-0.937	0.835
Striped Skunk	0.60	0.259	0.942	0.09	-0.436	0.812	-0.01	-0.118	0.117	0.14	0.001	0.287
Virginia Opossum	1.04	0.563	1.563	-0.25	-0.868	0.259	-0.17	-0.322	-0.036	-0.05	-0.248	0.145
Western Gray Squirrel	0.89	0.285	1.539	-0.14	-0.846	0.629	-0.08	-0.306	0.150	-0.91	-1.373	-0.481
Wild Boar/Hog/Pig	0.57	-0.462	1.668	-0.22	-1.123	0.455	-0.05	-0.317	0.261	0.43	-0.079	1.026

Common name	PSI (bait status)			PSI (year)		
	Mean	*95% CI*		*Mean*	*95% CI*	
American Badger	-0.02	-0.373	0.258	0.51	-0.630	1.591
American Mink	-0.02	-0.386	0.275	-0.43	-2.128	1.182
Audubon's Cottontail	0.04	-0.115	0.196	0.03	-0.199	0.250
Black-tailed Jackrabbit	0.12	-0.027	0.298	-0.02	-0.202	0.170
Bobcat	-0.07	-0.425	0.161	-0.25	-0.808	0.272
Brush Rabbit	0.00	-0.349	0.317	-0.12	-1.757	1.568
CA Ground Squirrel	-0.10	-0.355	0.090	-0.27	-0.653	0.105
Common Porcupine	0.00	-0.348	0.315	-0.46	-2.774	1.887
Coyote	-0.01	-0.238	0.175	-0.10	-0.431	0.233
Eastern Fox Squirrel	0.04	-0.253	0.393	-0.07	-1.031	0.855
Elk	-0.01	-0.364	0.281	0.72	-0.811	2.442
Gray Fox	0.01	-0.326	0.317	-1.37	-2.812	-0.176
Kit Fox	-0.01	-0.345	0.264	-0.56	-1.348	0.210
Mountain Lion	-0.01	-0.408	0.309	-0.44	-2.718	1.821
Deet	0.02	-0.150	0.195	0.21	-0.050	0.457
Raccoon	0.01	-0.156	0.161	0.67	0.441	0.879
Red Fox	0.08	-0.173	0.466	1.45	0.417	2.476
Ringtail	-0.01	-0.376	0.295	-0.51	-2.851	1.746
Striped Skunk	-0.05	-0.272	0.120	-0.86	-1.226	-0.522
Virginia Opossum	0.06	-0.127	0.284	-0.39	-0.787	-0.005
Western Gray Squirrel	0.05	-0.194	0.320	-2.51	-3.721	-1.396
Wild Boar/Hog/Pig	-0.11	-0.602	0.156	-0.44	-2.879	1.863

An evaluation of avifaunal diversity in California's Great Valley

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Executive Summary

1. Reconciliation ecology focuses on modifying human-dominated landscapes to maximize their ability to support wildlife, recognizing that wildlife habitat can be improved and expanded without losing human habitat. This approach may be applicable to songbird management in the Great Valley ecoregion of California, an intensely modified agricultural area. Developing management actions aimed at reconciling the Great Valley for a specific songbird of interest or native songbird diversity, however, requires reliable estimates and evaluations of species distributions and richness. In this study, we aimed to help provide this information using songbird data collected as part of California Department of Fish and Wildlife's Terrestrial Species Stressor Monitoring surveys.
2. We deployed automated recorders at 263 sites across the Great Valley ecoregion between March and July of 2016 and 2017. We identified recordings to the species-level, and used multi-species hierarchical occupancy models to estimate and evaluate the occupancy and richness of songbird species.
3. We recorded 84 species of songbirds, with estimated occupancies ranging from 0.01 for the black-throated gray warbler to 0.65 for the red-winged blackbird. Mean estimated richness ranged from 5 – 34 songbird species ($\bar{x}$ = 16.10) and was greatest in mixed habitats. Overall, our results suggest Great Valley's songbird community was positively associated with heterogeneous landscapes, both natural and agricultural, that were close to a forested area.
4. We used data collected by automated recorders to generate baseline estimates of occupancy for >80 songbird species in the Great Valley. Site-level detection probabilities were high for the majority of songbirds, providing support for the effectiveness of automated recorders as a monitoring tool. Further, our research highlights potential starting points for reconciling the Great Valley when the goal is to increase the distribution and richness of songbirds. These include increasing natural and agricultural heterogeneity, and conserving remnant forests and natural vegetation throughout the region. We encourage CDFW to use our estimates as baselines, thus setting the stage for long-term monitoring of songbird communities in the region. A long-term monitoring program would provide the agency with the empirical data needed to evaluate the processes driving the songbird populations, such as trends in occupancy and drivers of local colonization and extinction probabilities.

Introduction

Reservation ecology, restoration ecology, and reconciliation ecology describe three approaches for addressing ecosystem change and potential, corresponding losses and degradation of natural habitat and wildlife populations. Reservation ecology focuses on protecting areas from further development by designating them as preserves (Rosenzweig 2003). If the size of protected areas is small, however, then long-term maintenance of a diversity of species is unlikely (Rosenzweig 2003). Restoration ecology, alternatively, focuses on restoring an area to its historic state including the biota and ecosystem conditions (Rosenzweig 2001; Jackson and Hobbs 2009; Bullock et al. 2011). Restoring ecosystems to their historical conditions, however, is unlikely when considered in the light of rapid environmental and human-mediated change (Choi et al. 2008; Seastedt et al. 2008; Hobbs et al. 2009). Lastly, reconciliation ecology focuses on modifying and diversifying human-dominated landscapes so they can harbor a wide variety of wildlife, recognizing that we can improve and expand wildlife habitat without having to lose human habitat (Rosenzweig 2003). Reconciliation ecology acknowledges the relevance of new and novel ecosystems, which have often been irreversibly changed by modifications to abiotic conditions or biotic compositions (Fox 2007; Seastedt et al. 2008; Hobbs et al. 2009).

Some of the most important cases of reconciliation ecology are agricultural landscapes (Daily et al. 2001). Croplands and pastures occupy approximately 40% of the world's land surface, a number that will likely surge given projected two- to threefold increases in food demand by 2050 (Foley et al. 2005; Green et al. 2005). Agricultural landscapes' ability to serve as wildlife habitat ranges widely depending on a multitude of factors such as land tenure, crop species, the size of crop fields, cultivation practices, agrochemical usage, and rotation planning (Benton et al. 2003; Fahrig et al. 2011). For example, areas with low to intermediate-intensity land use can positively impact native wildlife (Daily et al. 2001) while areas experiencing rapid agricultural intensification tend to negatively impact native wildlife (McKinney 2002; Benton et al. 2003; Green et al. 2005). The negative effects of rapid agricultural intensification are likely due to large-scale transitions from heterogeneous (i.e., in structure, time, and space) to homogeneous agricultural landscapes that provide fewer niches and resources, such as food, nest sites, den sites, and cover (MacArthur and MacArthur 1961; Rosenzweig 1995; Benton et al. 2003; Green et al. 2005). The positive relationship between the richness of wildlife populations and landscape heterogeneity is widely supported (Benton et al. 2003; Lee and Martin 2017). Our understanding of the degree to which heterogeneity in croplands and pastures benefits wildlife and specific taxa, however, is limited (Benton et al. 2003; Fahrig et al. 2011). Improving this understanding would not only inform the conservation and management of wildlife in farmlands, but also provide a potentially feasible method in which to reconcile these human-dominated landscapes (Benton et al. 2003; Foley et al. 2005; Fahrig et al. 2011; Lee and Martin 2017). Reconciling agricultural areas in a way that maximizes their potential as wildlife habitat is imperative, given their increasing coverage globally and because the fate of many species depends on their ability to use human-modified landscapes (Green et al. 2005; Ewers and Didham 2006; Fahrig et al. 2011).

In this study, we explored the ecological drivers of songbird distributions in a human-modified, agricultural landscape. We focused on songbird species, specifically, as farming serves as one of the biggest threats to globally threatened and near-threatened birds (McKinney 2002; Green et al. 2005). We applied our question to the Great Valley of California, an area that has been transformed from seasonal wetlands and alkali scrub to one of the most intensely developed agricultural regions in the world (Frayer et al. 1989; Nelson et al. 2003). A better understanding of how to maximize the distributions of specific species of interest or overall songbird diversity in a landscape like the Great Valley, could have local to global relevance due to the loss of wildlife populations and increasing coverage of croplands and pastures worldwide (Alkemade et al. 2009; Fahrig et al. 2011). Additionally, our research was motivated by the lack of studies in areas of high-intensity agricultural land use (Haslem and Bennett 2008; Prevedello and Vieira 2010; Mendoza et al. 2014; Kennedy et al. 2017). Studies that sample outside of native habitats tend to take place in urban areas or areas of low-intensity land uses (Daily et al. 2001; Haslem and Bennett 2008; Prevedello and Vieira 2010; Mendoza et al. 2014).

Prioritizing management actions aimed at reconciling the Great Valley ecoregion for one or more bird species requires reliable estimates and evaluations of species richness and species distributions (Yoccoz et al. 2001; Lindenmayer and Hobbs 2007; Zipkin et al. 2009; Furnas and Callas 2015). Thus, our specific objectives for the Great Valley ecoregion and each of its major habitat strata were threefold. First, we determined baseline estimates of occupancy for songbird species. Species' estimates of occupancy are based on repeated detection-nondetection data, and are considered an informative index to population status (MacKenzie et al. 2002; Royle et al. 2005). Second, we identified habitats that support the greatest richness of songbirds. Third, to help determine which ecological variables should be targeted by reconciliation efforts, we evaluated community and species-specific responses to landscape heterogeneity, water, and land cover variables, all of which have been found to influence avian richness (Gill 1995; McKinney 2002; Benton et al. 2003; Billeter et al. 2008; Lee and Martin 2017). We considered anthropogenic-driven heterogeneity (e.g., different field crops, types of grazed lands, orchards) and natural heterogeneity (e.g., woodlands, wetlands, grasslands) separately, as the strength of their influences on avifaunal diversity may differ. We hypothesized that increasing water availability and landscape heterogeneity, both anthropogenic and natural, would have the greatest, positive influence on species-specific occupancy and overall songbird richness because of increased niche and resource availability (MacArthur and MacArthur 1961; Rosenzweig 1995).

Methods

Automated recorder survey and bird call classifications

In 2016, California Department of Fish and Wildlife (CDFW) initiated Terrestrial Species Stressor Monitoring (TSM) surveys in the Great Valley (GV) ecoregion of California. TSM surveys employ noninvasive survey techniques, including automated sound recordings, visual encounter surveys, and camera trap surveys, to collect baseline data on a wide variety of common wildlife species. In this study, we focused on songbird data collected via automated recorders, an increasingly common tool for surveying bird communities (Furnas and Callas 2015; Shonfield and Bayne 2017).

We surveyed 263 sites across the GV ecoregion between March and July of 2016 and 2017 (Fig. 1). We identified survey locations by first selecting a spatially balanced random sample of hexagons, stratified by vegetative community, from the USDA Forest Inventory and Analysis program's hexagon grid (hexagon radius is ~2.6 km). We then randomly selected 1-3 survey locations within each hexagon, which were spaced by 1-2 km and stratified by vegetative community. At each survey location, we deployed an SM3-BAT bioacoustic recorder with microphone (Wildlife Acoustics, Inc., Maynard, MA, USA, hereafter termed ARU). We cable-locked ARUs to securely placed T-posts 2-m above the ground and if T-post mounting was not possible, we secured devices to a tree or other vegetation. We programmed ARUs to record three, 5-min sessions on three consecutive days during the survey period. The first session was at 30 minutes before sunrise, the second at sunrise, and the third at 30 minutes after sunrise (Furnas & Callas, 2015).

After the field season, we reviewed the recordings and identified bird species by song or call. To aid in bird identification, we examined spectrograms in Raven Pro software (v. 1.5; Cornell Lab of Ornithology Bioacoustics Research Program, Ithaca, NY, USA). We omitted recordings that could not be identified to the species-level and in an effort to ensure species were similar ecologically, we restricted our analysis to songbirds (i.e., species in the order Passeriformes; Barker, Cibois, Schikler, Feinstein, & Cracraft, 2004). We also classified the level of background noise (e.g., wind, rain, vehicle and air traffic) during each recording using an ordinal variable ranging from zero, indicating no noise, to four, indicating loud noise.

Covariates

We expected that land cover, water accessibility, and landscape heterogeneity would influence songbird distributions in the GV. To represent land cover, we buffered each sampling location by 500m in ArcMAP 10.4.1 (ESRI, Redlands, CA, USA). We used this buffer size because in our preliminary analyses, we found that the direction of covariate relationships was consistent across buffer sizes (i.e., 1km, 500m, and 100m) but the strength of the relationships tended to be greatest when using the 500m buffer. We used data from CDFW's Vegetation Classification and Mapping Program (CDFW 2017)) to calculate percent cover of natural vegetation (i.e., within each 500m buffered area), percent cover of agricultural vegetation, and distances from each sampling location to the nearest forested area and urban area. We used data from Point Blue's Automated Water Tracking System (Point Blue 2017) to identify areas that had open surface water during the survey period, and then measured the distance from each ARU to the nearest available water source.

To represent landscape heterogeneity, we calculated the number of crop types and number of natural vegetation types within each 500m buffered area. To quantify crop types, we used USDA cropscape data (USDA 2017) and to quantify natural vegetation types, we used the regional dominance types identified in the vegCAMP data. We also represented landscape heterogeneity by calculating Simpson's measure of evenness, which accounts for the relative abundance of different species making up the richness of an area (Simpson 1949):

$$\frac{-\sum_{i=0}^{n} P(i) \times lnP(i)}{\ln(\#\ vegetation\ types)},\ \text{where } P(i) = \frac{area\ covered\ by\ vegetation\ type\ i}{total\ area}$$

When estimating natural and agricultural evenness, vegetation types included each natural dominance type and each crop species, respectively, and total area included natural and agricultural cover within the buffered areas, respectively.

To account for the influence that temperature may have on the vocal activity of songbirds, we included maximum daily temperature as a covariate for species' detection probabilities (McGrann and Furnas 2016). To estimate maximum temperatures, we downloaded 4-km resolution temperature data from PRISM (Prism Climate Group 2017) for the survey period. We then determined the mean maximum temperature at each sampling location over the 3-day survey period. We also included background noise and Julian day and its quadratic term as covariates for detection. Background noise can impede the audibility and identification of bird species while the phenology of birds' vocal behaviors can change over the course of the breeding season (Slagsvold 1977; Strebel et al. 2014).

Multi-species occupancy modeling

We used multispecies hierarchical occupancy models to estimate the probability songbird *i* occurred within the area sampled by an ARU during our survey period (i.e., occurrence; Dorazio & Royle 2005; Iknayan et al. 2014). Multi-species models link species-specific detection and occupancy using community-level hyper-parameters, which specify the mean response and variation among species within the community to a respective covariate (Kéry and Royle 2008; Zipkin et al. 2010). Linking occurrence models for individual species together within a hierarchical model results in a more efficient use of data, increased precision in estimates of occupancy, and assessments of ecological variables at both the species- and community-level (Kéry and Royle 2008; Zipkin et al. 2009; Iknayan et al. 2014). The models also produces estimates of species richness (i.e., number of species in the community and at each sampling location). To produce estimates of songbird richness that accounted for songbird species that were not recorded during sampling but may have occupied areas of the GV, we augmented the dataset by adding ten all-zero observations.

Occupancy models distinguish the true absence of a species from the non-detection of a species (i.e., species present but not recorded) using spatially or temporally replicated survey data. For each sampling location, we treated each 5-minute acoustic recording (n = 9) as a repeat survey at that particular site. We assumed occurrence and detection probabilities differed between years and among species, and were influenced by ecological covariates. To avoid overparameterizing our models and ensure all parameters were estimable, we restricted the number of covariates included in each model. We assessed two model structures for occupancy (ψ) and detection (*p*):

Model 1	Occupancy	# natural types, # agricultural types, forest, water, year
	Detection	Max temperature, Julian day, Julian day^2, noise, year
Model 2	Occupancy	Crop cover, natural evenness, crop evenness, urban, year
	Detection	Max temperature, Julian day, temp * Julian day, noise, year

We incorporated covariates into the model linearly on the logit-probability scale (Zipkin et al. 2010) and ensured models did not include covariates that were correlated. We then linked species-specific models using a mixed modelling approach where we assumed species-specific parameters were random effects derived from a normally distributed, community-level hyper-parameter (Iknayan et al. 2014).

We estimated posterior distributions of parameters using Markov Chain Monte Carlo implemented in JAGS (Plummer 2011) through program R. We generated three chains of 50,000 iterations thinned by 50 and used uninformative priors. We assessed model convergence using the Gelman-Rubin statistic, where values < 1.1 indicated convergence (Gelman et al. 2004). During each model iteration, we summed the number of estimated species at recorder *j* to generate probability distributions representing site-specific estimates of species richness (Zipkin et al. 2010). We also used our model output to estimate mean, habitat-specific estimates of occupancy and songbird richness. To classify habitat, we used vegCAMP data to quantify the percent cover of (1) urban and agriculture, (2) grassland and oak savannah, (3) riparian and wetland, (4) forest, and (5) shrub within each 500m buffered sampling locations. We then categorized each sampling location based on the dominant habitat type. When a single habitat type did not cover >60% of the area, we categorized the habitat type as ‘mixed’.

Results

We recorded 84 songbird species during our 2,367 sampling occasions (i.e., 5-minute recordings) in the Great Valley ecoregion (Table 1). Eight species were recorded on over 500 occasions, including western meadowlarks and red-winged blackbirds, whereas 20 species were recorded on less than 10 occasions (Table 1). Among the covariates, natural and agricultural cover were correlated ($|r| > 0.6$) as were measures of habitat heterogeneity, both natural (i.e., number of natural vegetation types and natural evenness) and agricultural (i.e., number of agricultural vegetation types and agricultural evenness).

Mean estimated richness ranged from 5 – 34 songbird species ($\bar{x}$ = 16.10) with red-winged blackbirds (ψ = 0.65), brown-headed cowbirds (ψ = 0.65), and western meadowlarks (ψ = 0.65) having the highest estimated occupancies (Table 1; Appendix S1). Many species, conversely, had low estimates of occupancy due to their limited numbers of detections (Table 1;

Appendix S1). Site-level detection probabilities were > 0.3 for every species but the Lincoln's sparrow, and > 0.6 for the majority of species (Table 1; Appendix S2). At the community-level, and for close to half of the songbird species, detection probability had a quadratic relationship with Julian day (Table 2; Appendix S3). We were also more likely to detect songbirds on cooler days and at sites with reduced levels of noise (Table 2; Appendix S3).

Overall, our results suggest Great Valley's songbird community was more likely to use heterogeneous landscapes, both natural and agricultural, that were close to a forested area (Table 2). Among the covariates, natural heterogeneity, as measured by Simpson's measure of evenness, had the largest positive influence on community-level occupancy while distance to forest had the largest negative influence (Table 2). At the species-level, natural evenness was positively related to the distributions of 25 songbirds, including Bewick's wren, song sparrow, and wrentit, and distance to forest was negatively related to the distributions (i.e., species more likely to occupy areas close to forest) of 29 songbirds, including the black-headed grosbeak, bushtit, and oak titmouse (Table 2; Appendix S3). Six and seven songbird species had the converse relationship with natural evenness and distance to forest, respectively (Table 2; Appendix S3). Our alternative measure of habitat heterogeneity, which was the number of natural and agricultural vegetation types, also tended to have a positive influence on songbird occupancy at both the community and species level (Table 2). Specifically, 13 and 11 songbird species were positively related to the number of natural and agricultural vegetation types, respectively, whereas only 3 and 2 species had a negative relationship with these variables (Table 2; Appendix S3). Lastly, in general, songbirds were more likely to occupy areas close to water but this relationship tended to be weak (Table 2; Appendix S3). Water availability appeared to be most important to common yellowthroat, marsh wren, song sparrow, and tree swallow (Appendix S3).

The greatest number of sampling locations fell within urban and agricultural habitat (n = 105), followed by mixed habitat (n = 60), grassland and oak savannah (n = 52), riparian areas and wetlands (n = 38), and shrublands (n = 7). At the community and species-levels, occupancy probabilities varied among the major habitat strata but tended to be greatest in mixed habitat (n = 27 species; Fig. 3; Appendix S1). We note, however, that among the various habitat strata, error estimates for mean and species-specific occupancy probabilities tended to overlap. This limits our ability to determine if the community or a particular species was more or less likely to occupy riparian and wetland habitat than mixed habitat, for example. Songbird richness also appeared to be greatest in mixed habitat ($\bar{x}$ = 17.48), followed by urban and agricultural habitat ($\bar{x}$ = 17.13; Fig. 4). Error bars associated with our estimates of songbird richness also tended to overlap, however (Fig. 4).

Discussion

Effectively prioritizing actions aimed at conserving wildlife requires reliable estimates of species richness, species distributions, and an understanding of how these parameters are driven by ecological factors (Yoccoz et al. 2001; Lindenmayer and Hobbs 2007; Zipkin et al. 2009; Furnas and Callas 2015). The distribution and habitat requirements of species within an ecosystem are rarely known, however, making it difficult to discern optimal management strategies (White et al. 2013). In this study, we applied a field technique that was developed in forested regions as part of the Ecoregion Biodiversity (EBM) surveys, and applied it in the Great Valley, an intensely modified agricultural region. Despite the dramatically different landscapes, similar to Furnas and Callas (2015), we found that detection probabilities using ARUs were high for most species. Further, because the ARUs collected data on a numerous species simultaneously, we were able to estimate the distributions and richness of over 80 songbird species in the Great Valley (Fig. 2; Appendix S1). Our research provides additional support for the effectiveness of automated recorders as a tool for collecting detection-nondetection data on multiple species (Furnas and Callas 2015).

It is challenging and often infeasible to create new protected areas or to implement major restoration efforts in intensely developed regions like the Great Valley (Rosenzweig 2003; Seastedt et al. 2008; Choi et al. 2008; Jackson and Hobbs 2009). Thus, efforts must focus on reconciling these ecosystems in a way that maximizes their ability to function as suitable habitat for both endemic wildlife species and humans (Rosenzweig 2003; Seastedt et al. 2008; Hobbs et al. 2009). In addition to providing baseline estimates of occupancy for songbirds, our research also produced a number of key findings relevant to prioritizing actions aimed at reconciling the Great Valley. Specifically, our evaluation of community and species-specific responses to ecological variables suggests that increasing natural and agricultural heterogeneity, and conserving remnant forests and natural vegetation throughout the region, offer potential starting points for reconciling the Great Valley when the goal is to increase the distribution and richness of songbirds.

We found that songbird richness was greatest in mixed habitat (i.e., areas encompassing multiple habitat types), that over 30% of the songbird species were most likely to occupy mixed habitat, and that songbirds, both the community and individual species, tended to be positively associated with natural and agricultural heterogeneity. Similar to prior studies, these results support that diversity is maximized in heterogeneous landscapes, likely because they provide more niches and complementary resources than homogeneous landscapes (MacArthur and MacArthur 1961; Benton et al. 2003; Haslem and Bennett 2008; Lee et al. 2017). Increasing landscape heterogeneity by actively managing natural areas and encouraging landowners to tailor their agricultural practices (e.g., crop diversity, cultivation practices, rotation planning) may therefore be a viable approach for reconciling the Great Valley. While the songbird community tended to be positively associated with both natural and agricultural heterogeneity, the strength of these relationships varied. Natural evenness, for example, had the largest positive influence on the songbird community (Table 4; Appendix S2). Thus, even in this intensely modified landscape, native vegetation played a vital role in maintaining songbird populations (Haslem and Bennett 2008). These results suggest actions aimed at increasing landscape heterogeneity should not be done in isolation, but rather in parallel with the protection of remnant natural habitats.

Our multi-species model also illustrated the importance of forested habitats, specifically, to songbirds in the Great Valley. Forest had the largest influence on the occupancy of avian species, at both the community- and species-levels, where species were more likely to occupy areas close to forest cover (Table 2). Forested areas generally have high species diversity, including bird diversity, as they provide critical resources like foraging and roosting sites and help facilitate the movement of individuals (Gill 1995; Haslem and Bennett 2008; Mendoza et al. 2014). Despite their role in supporting terrestrial wildlife, however, forested landscapes continue to be converted into agricultural, mining, and urban areas (White et al. 2013). Our results highlight the importance of conserving forests within the Great Valley and that maximizing landscape heterogeneity should not be considered a replacement for reducing the loss and degradation of native forests (Kennedy et al. 2017).

Climate and land use change will continue to transform many of the world's ecosystems (Rosenzweig 2003; Millenium Ecosystem Assessment 2005; Seastedt et al. 2008; Hobbs et al. 2009; Walther et al. 2009; Bullock et al. 2011; Steffen et al. 2015). Methods for reconciling these novel landscapes in a way that maximizes their potential as wildlife habitat is imperative, as the fate of many species depends on their ability to utilize human-modified landscapes (Green et al. 2005; Ewers and Didham 2006; Fahrig et al. 2011). This is particularly true for agricultural landscapes given their increasing coverage globally (Daily et al. 2001; Foley et al. 2005; Green et al. 2005). Our research employed automated recorders and multispecies occupancy models to estimate and evaluate the distributions of 84 songbird species and to identify plausible ways in which the Great Valley, an intensely developed agricultural region, could be reconciled for the benefit of the songbird community. Our findings underscore the importance of conserving natural vegetation, forested areas in particular, and of promoting landscape heterogeneity in both natural and agricultural areas. If done in isolation, however, these results will represent only a snapshot in time. We encourage CDFW to use our estimates as baselines, thus setting the stage for long-term monitoring of songbird communities in the region. A long-term monitoring program would allow CDFW to develop an understanding of the processes driving the songbird populations, such as trends in occupancy, changes in habitat use, and drivers of local colonization and extinction probabilities (MacKenzie et al. 2005; Tingley and Beissinger 2013). Furthermore, this information would allow managers to test, track, improve, and adapt management actions aimed reconciling the Great Valley for the benefit of endemic songbird species.

Supplementary Material

Appendix S1. Songbird species in the Great Valley ecoregion of California and their occupancy probabilities overall, and within each of the major habitat strata. The habitat strata in which each species had the highest occupancy probability is highlighted.

Appendix S2. Songbird species in the Great Valley ecoregion of California and their site-level detection probabilities (± 95 credible intervals).

Appendix S3. Mean and 95% credible interval estimates for covariate effects on occupancy (PSI) and detection (P) for 84 songbird species in the Great Valley ecoregion of California, 2016-17. Results are based on model 1 (3a) and model 2 (3b); covariate effects that do not overlap 0.0 are highlighted in yellow.

Table 1. Songbird species detected during TSM 2016-17 automated recorder surveys in the Great Valley ecoregion of California, numbers of detections (# det.), proportion of sites at which the species was detected (naïve ψ), occupancy probabilities (ψ), and site-level detection probabilities (p^*).

Common name	Scientific name	# det.	Naïve ψ	ψ	p^*
American Crow	*Corvus brachyrhynchos*	156	0.25	0.24	0.90
American Goldfinch	*Spinus tristis*	186	0.32	0.29	0.89
American Pipit	*Anthus rubescens*	76	0.12	0.15	0.44
American Robin	*Turdus migratorius*	423	0.40	0.33	0.99
Ash-throated Flycatcher	*Myiarchus cinerascens*	343	0.34	0.29	0.98
Bank Swallow	*Riparia riparia*	1	0.00	0.01	0.50
Barn Swallow	*Hirundo rustica*	37	0.10	0.19	0.52
Bell’s Sparrow	*Artemisiospiza belli*	40	0.03	0.01	0.99
Bewick's Wren	*Thryomanes bewickii*	350	0.29	0.27	1.00
Blue-gray Gnatcatcher	*Polioptila caerulea*	1	0.00	0.01	0.53
Brown-headed Cowbird	*Molothrus ater*	505	0.61	0.65	0.97
Black-headed Grosbeak	*Pheucticus melanocephalus*	205	0.20	0.12	0.97
Blue Grosbeak	*Passerina caerulea*	86	0.13	0.19	0.71
Black Phoebe	*Sayornis nigricans*	273	0.38	0.37	0.95
Brewer's Blackbird	*Euphagus cyanocephalus*	258	0.44	0.51	0.88
Black-throated Gray Warbler	*Setophaga nigrescens*	4	0.00	0.00	0.94
Bullock's Oriole	*Icterus bullockii*	318	0.39	0.39	0.98
Bushtit	*Psaltriparus minimus*	130	0.20	0.12	0.91
Cassin's Kingbird	*Tyrannus vociferans*	10	0.01	0.01	0.98
California Towhee	*Melozone crissalis*	303	0.30	0.24	0.99
California Thrasher	*Toxostoma redivivum*	4	0.02	0.05	0.34
Cassin's Vireo	*Vireo cassinii*	1	0.00	0.01	0.50
Cedar Waxwing	*Bombycilla cedrorum*	16	0.04	0.05	0.57
Chipping Sparrow	*Spizella passerina*	2	0.01	0.02	0.46
Cliff Swallow	*Petrochelidon pyrrhonota*	107	0.21	0.29	0.70
Common Raven	*Corvus corax*	222	0.34	0.38	0.93
Common Yellowthroat	*Geothlypis trichas*	343	0.27	0.24	1.00
Dark-eyed Junco	*Junco hyemalis*	6	0.02	0.03	0.37
European Starling	*Sturnus vulgaris*	321	0.39	0.34	0.97
Fox Sparrow	*Passerella iliaca*	1	0.00	0.01	0.51
Golden-crowned Sparrow	*Zonotrichia atricapilla*	65	0.11	0.15	0.38
Grasshopper Sparrow	*Ammodramus savannarum*	10	0.02	0.01	0.91
Great-tailed Grackle	*Quiscalus mexicanus*	40	0.07	0.08	0.87
Hermit Thrush	*Catharus guttatus*	12	0.02	0.03	0.41
House Finch	*Haemorhous mexicanus*	632	0.63	0.64	0.99
Horned Lark	*Eremophila alpestris*	283	0.21	0.15	1.00
House Sparrow	*Passer domesticus*	96	0.13	0.13	0.90
House Wren	*Troglodytes aedon*	436	0.31	0.18	1.00
Hutton's Vireo	*Vireo huttoni*	6	0.01	0.01	0.73
Lark Sparrow	*Chondestes grammacus*	27	0.06	0.05	0.75
Lazuli Bunting	*Passerina amoena*	19	0.05	0.10	0.47

Le Conte's Thrasher	*Toxostoma lecontei*	7	0.01	0.01	0.93
Lesser Goldfinch	*Spinus psaltria*	90	0.16	0.10	0.86
Lincoln's Sparrow	*Melospiza lincolnii*	12	0.03	0.07	0.24
Loggerhead Shrike	*Lanius ludovicianus*	119	0.15	0.12	0.96
Marsh Wren	*Cistothorus palustris*	404	0.23	0.21	1.00
MacGillivray's Warbler	*Geothlypis tolmiei*	3	0.01	0.02	0.42
Nashville Warbler	*Oreothlypis ruficapilla*	1	0.00	0.01	0.54
Northern Mockingbird	*Mimus polyglottos*	643	0.53	0.53	1.00
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	39	0.07	0.07	0.52
Oak Titmouse	*Baeolophus inornatus*	107	0.14	0.08	0.78
Orange-crowned Warbler	*Oreothlypis celata*	45	0.10	0.15	0.96
Phainopepla	*Phainopepla nitens*	7	0.02	0.02	0.51
Pacific-slope Flycatcher	*Empidonax difficilis*	20	0.02	0.01	0.65
Purple Finch	*Haemorhous purpureus*	4	0.01	0.02	0.95
Ruby-crowned Kinglet	*Regulus calendula*	12	0.02	0.02	0.50
Rufous-crowned Sparrow	*Aimophila ruficeps*	6	0.00	0.01	0.44
Rock Wren	*Salpinctes obsoletus*	4	0.01	0.01	0.98
Red-winged Blackbird	*Agelaius phoeniceus*	970	0.65	0.65	0.67
Sage Sparrow	*Artemisiospiza nevadensis/belli*	1	0.00	0.01	1.00
Savannah Sparrow	*Passerculus sandwichensis*	192	0.21	0.19	0.58
Song Sparrow	*Melospiza melodia*	527	0.36	0.34	0.74
Spotted Towhee	*Pipilo maculatus*	419	0.32	0.14	1.00
Swainson's Thrush	*Catharus ustulatus*	1	0.00	0.01	1.00
Tricolored Blackbird	*Agelaius tricolor*	16	0.02	0.03	0.51
Tree Swallow	*Tachycineta bicolor*	534	0.50	0.47	0.83
Warbling Vireo	*Vireo gilvus*	19	0.05	0.04	1.00
White-breasted Nuthatch	*Sitta carolinensis*	77	0.11	0.08	0.55
White-crowned Sparrow	*Zonotrichia leucophrys*	248	0.22	0.33	0.92
Western Bluebird	*Sialia mexicana*	31	0.07	0.05	0.41
Western Kingbird	*Tyrannus verticalis*	660	0.57	0.58	0.72
Western Meadowlark	*Sturnella neglecta*	921	0.61	0.65	1.00
Western Scrub-Jay	*Aphelocoma californica*	278	0.35	0.29	1.00
Western Tanager	*Piranga ludoviciana*	11	0.03	0.06	0.96
Western Wood-Pewee	*Contopus sordidulus*	87	0.09	0.06	0.46
Wilson's Warbler	*Cardellina pusilla*	39	0.09	0.09	0.84
Wrentit	*Chamaea fasciata*	42	0.06	0.03	0.61
White-throated Swift	*Aeronautes saxatalis*	1	0.00	0.01	0.89
Yellow-breasted Chat	*Icteria virens*	9	0.01	0.01	0.53
Yellow-billed Magpie	*Pica nuttalli*	31	0.05	0.04	0.96
Yellow Warbler	*Setophaga petechia*	24	0.05	0.04	0.94
Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*	55	0.10	0.09	0.74
Yellow-rumped Warbler	*Setophaga coronata*	50	0.09	0.15	0.88

Table 2. Mean ($\bar{x}$) and 95% credible interval estimates for the community-level parameters hypothesized to influence songbird species' occupancy (ψ) and detection (*p*) probabilities in the Great Valley ecoregion, California, 2016-17. Bolded beta values have credible intervals that did not include zero.

	Covariate		Community-level		Species-level	
			$\bar{x}$	95% CI	+	–
Model 1	ψ_1	# natural vegetation types	0.09	-0.007 – 0.195	13	3
	ψ_2	# agricultural vegetation types	**0.11**	0.018 – 0.191	11	2
	ψ_3	Distance to forest	**-0.57**	-0.799 - -0.345	7	29
	ψ_4	Distance to water	-0.04	-0.139 – 0.053	2	4
	ψ_5	Year	**0.24**	0.097 – 0.405	12	2
	p_1	Maximum temperature	**-0.10**	-0.192 - -0.018	3	11
	p_2	Julian day	**0.88**	0.526 – 1.212	34	0
	p_3	Julian day^2	**-0.93**	-1.279 - -0.574	0	32
	p_4	Noise level	**-0.13**	-0.214 - -0.050	3	15
	P_5	Year	0.03	-0.029 – 0.104	7	3
Model 2	ψ_1	Crop cover (%)	0.10	-0.010 – 0.206	14	3
	ψ_2	Natural evenness	**0.20**	0.080 – 0.322	25	6
	ψ_3	Agricultural evenness	**0.14**	0.064 – 0.217	11	1
	ψ_4	Distance to urban	-0.07	-0.153 – 0.003	0	4
	ψ_5	Year	**0.24**	0.102 – 0.404	12	2
	p_1	Maximum temperature	**0.17**	0.013 – 0.339	2	0
	p_2	Julian day	**0.32**	0.111 – 0.521	21	0
	p_3	Temperature * Julian day	**-0.58**	-0.888 - -0.287	0	22
	p_4	Noise level	**-0.13**	-0.215 - -0.049	2	15
	p_5	Year	0.05	-0.009 – 0.116	9	2

Figure 1. Automated recorder locations during Terrestrial Species Stressor Monitoring surveys in the Great Valley ecoregion of California, 2016-2017.

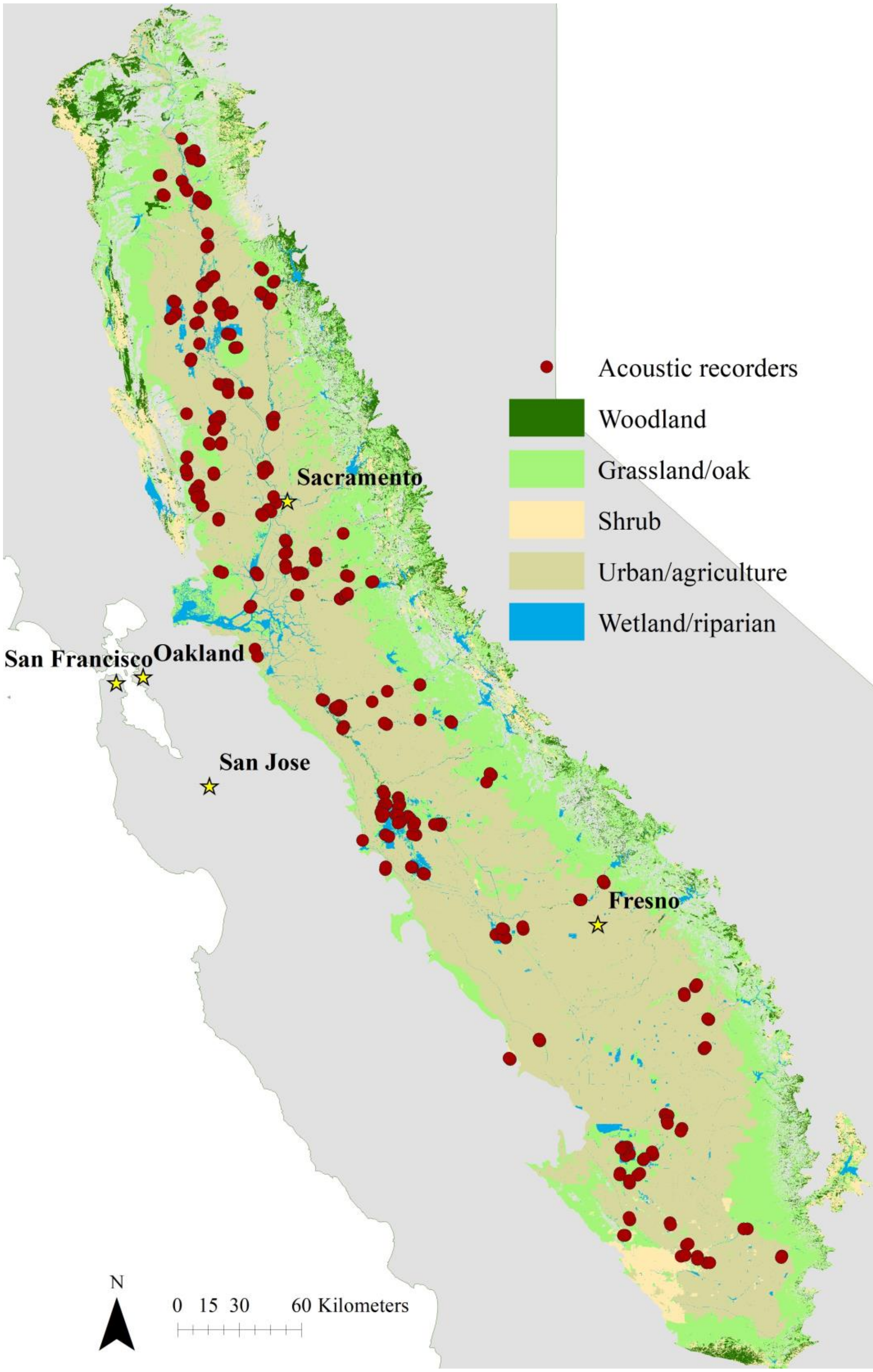


Figure 2. Mean occupancy probabilities (± 95% credible intervals) for songbird species across the Great Valley ecoregion, California, 2016-17. We present species with occupancy estimates > 0.05.

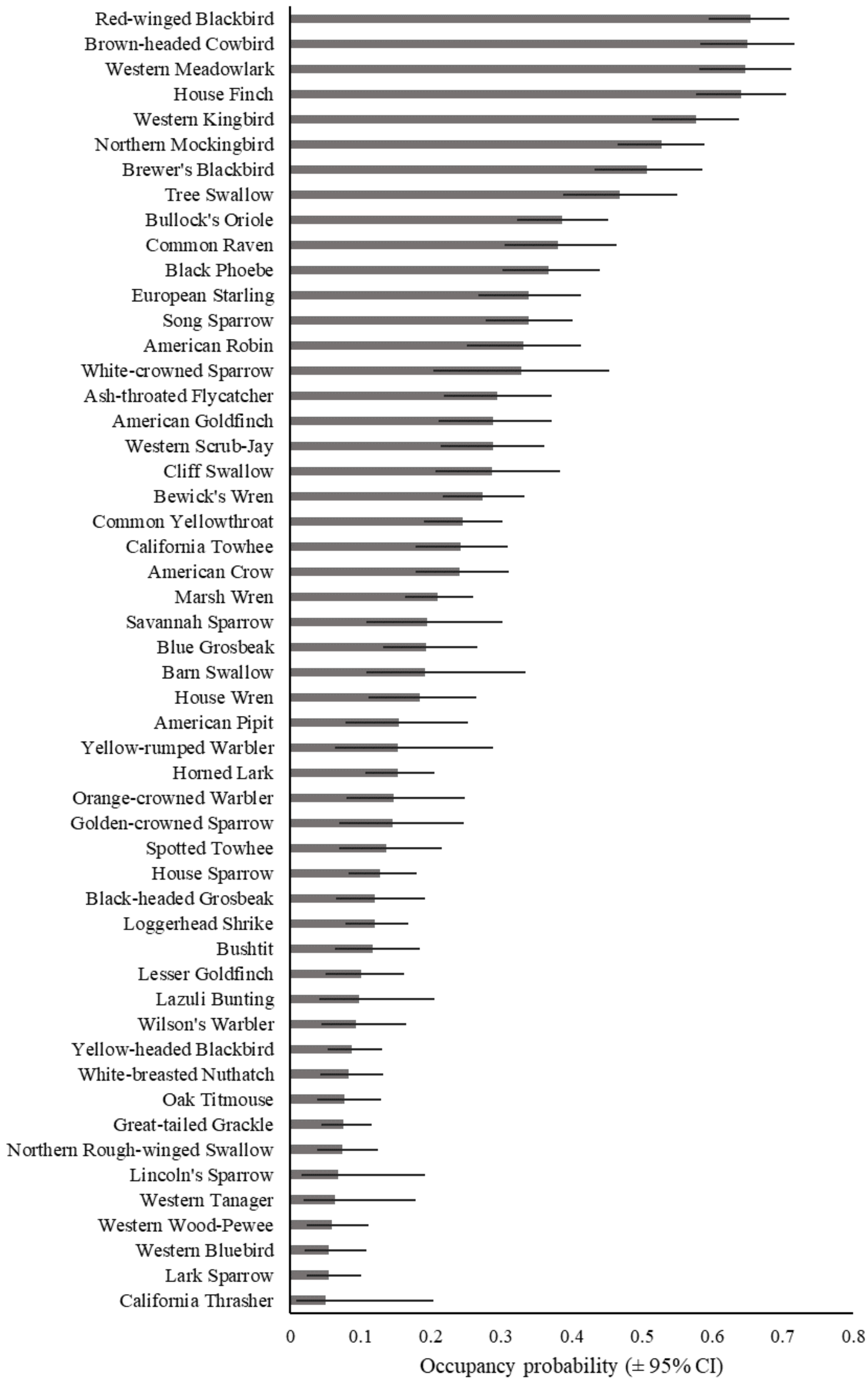


Figure 3. Region-wide and habitat-specific mean estimated occupancy probabilities (± 1 standard deviation) for songbird species in the Great Valley ecoregion of California, 2016-17.

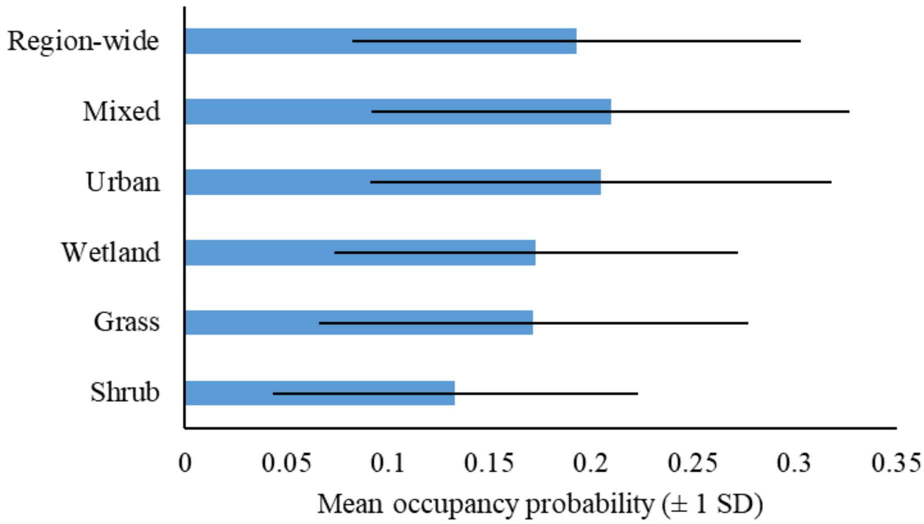
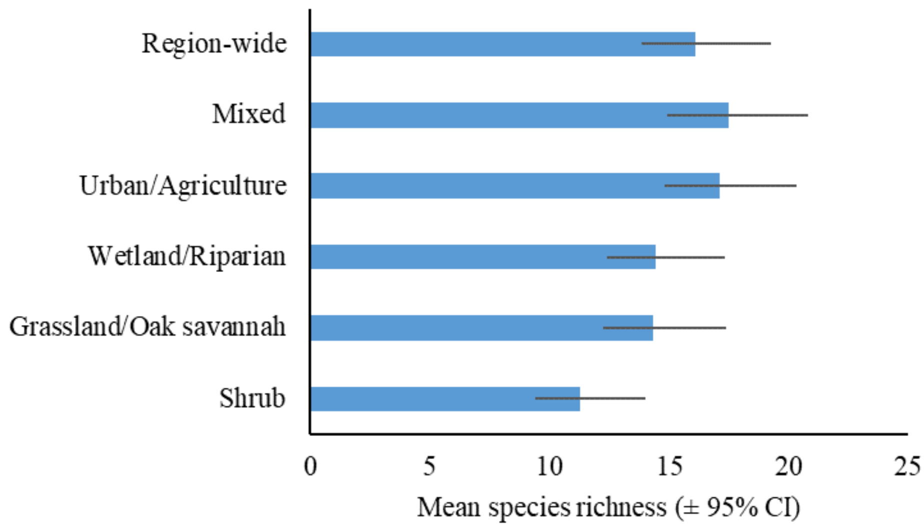


Figure 4. Overall and habitat-specific estimates (± 95% credible interval) of songbird richness in the Great Valley ecoregion, California, 2016-17.



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Appendix S1. Songbird species in the Great Valley ecoregion of California and their occupancy probabilities overall, and within each of the major habitat strata . The habitat strata in which each species had the highest occupancy probability is highlighted.

Species Code	Common Name	OCCUPANCY: Overall		Grass/Oak Savannah		Mixed		Riparian & Wetland		Urban & Agriculture		Shrub	
		Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
AMCR	American Crow	0.24	0.034	0.16	0.138	0.41	0.118	0.17	0.150	0.31	0.144	0.17	0.126
AMGO	American Goldfinch	0.29	0.042	0.16	0.174	0.42	0.152	0.34	0.111	0.47	0.133	0.03	0.131
AMPI	American Pipit	0.15	0.045	0.24	0.241	0.24	0.238	0.24	0.240	0.21	0.238	0.09	0.238
AMRO	American Robin	0.33	0.041	0.20	0.058	0.50	0.062	0.24	0.042	0.55	0.044	0.14	0.017
ATFL	Ash-throated Flycatcher	0.29	0.039	0.37	0.058	0.37	0.106	0.19	0.057	0.40	0.089	0.43	0.031
BANS	Bank Swallow	0.01	0.012	0.01	0.090	0.03	0.107	0.01	0.088	0.01	0.103	0.01	0.071
BARS	Barn Swallow	0.19	0.058	0.26	0.252	0.16	0.288	0.26	0.295	0.21	0.277	0.21	0.369
BESP	Bell's Sparrow	0.01	0.006	0.02	0.021	0.07	0.016	0.05	0.027	0.00	0.024	0.29	0.028
BEWR	Bewick's Wren	0.27	0.030	0.14	0.035	0.44	0.040	0.21	0.013	0.32	0.038	0.43	0.017
BGGN	Blue-gray Gnatcatcher	0.01	0.014	0.01	0.092	0.03	0.100	0.01	0.103	0.01	0.094	0.01	0.103
BHCO	Brown-headed Cowbird	0.65	0.035	0.54	0.090	0.60	0.117	0.84	0.019	0.67	0.088	0.17	0.116
BHGR	Black-headed Grosbeak	0.12	0.033	0.17	0.070	0.30	0.126	0.11	0.033	0.27	0.112	0.30	0.043
BLGR	Blue Grosbeak	0.19	0.033	0.15	0.189	0.24	0.219	0.20	0.200	0.22	0.218	0.22	0.224
BLPH	Black Phoebe	0.37	0.036	0.31	0.107	0.39	0.112	0.35	0.068	0.49	0.114	0.16	0.095
BRBL	Brewer's Blackbird	0.51	0.039	0.56	0.158	0.42	0.194	0.50	0.189	0.55	0.172	0.48	0.156
BTYW	Black-throated Gray Warbler	0.00	0.004	0.00	0.036	0.00	0.039	0.00	0.028	0.01	0.039	0.00	0.019
BUOR	Bullock's Oriole	0.39	0.033	0.27	0.095	0.50	0.084	0.38	0.086	0.43	0.083	0.29	0.060
BUSH	Bushtit	0.12	0.032	0.18	0.113	0.28	0.138	0.11	0.068	0.28	0.126	0.02	0.086
CAKI	Cassin's Kingbird	0.01	0.006	0.02	0.030	0.02	0.033	0.00	0.037	0.00	0.039	0.00	0.036
CALT	California Towhee	0.24	0.034	0.20	0.057	0.31	0.058	0.06	0.044	0.44	0.064	0.29	0.021
CATH	California Thrasher	0.05	0.052	0.04	0.200	0.07	0.213	0.08	0.213	0.06	0.210	0.19	0.201
CAVI	Cassin's Vireo	0.01	0.014	0.03	0.094	0.01	0.111	0.01	0.090	0.01	0.104	0.01	0.075
CEDW	Cedar Waxwing	0.05	0.024	0.08	0.171	0.08	0.184	0.03	0.154	0.10	0.183	0.15	0.089

Species Code	Common Name	OCCUPANCY Overall Mean	Overall SD	Grass/Oak Savannah Mean	Grass/Oak Savannah SD	Mixed Mean	Mixed SD	Riparian & Wetland Mean	Riparian & Wetland SD	Urban & Agriculture Mean	Urban & Agriculture SD	Shrub Mean	Shrub SD
CHSP	Chipping Sparrow	0.02	0.024	0.04	0.123	0.02	0.141	0.04	0.130	0.02	0.131	0.02	0.125
CLSW	Cliff Swallow	0.29	0.045	0.39	0.219	0.26	0.246	0.29	0.225	0.29	0.265	0.26	0.281
CORA	Common Raven	0.38	0.041	0.45	0.079	0.25	0.105	0.33	0.125	0.41	0.127	0.73	0.072
COYE	Common Yellowthroat	0.24	0.029	0.19	0.028	0.19	0.041	0.71	0.009	0.21	0.049	0.00	0.029
DEJU	Dark-eyed Junco	0.03	0.026	0.06	0.169	0.08	0.198	0.03	0.153	0.06	0.185	0.01	0.107
EUST	European Starling	0.34	0.038	0.30	0.085	0.50	0.078	0.25	0.087	0.46	0.066	0.01	0.088
FOSP	Fox Sparrow	0.01	0.013	0.01	0.092	0.01	0.110	0.01	0.087	0.02	0.106	0.01	0.081
GCSP	Golden-crowned Sparrow	0.15	0.046	0.16	0.252	0.19	0.273	0.17	0.232	0.31	0.222	0.06	0.207
GRSP	Grasshopper Sparrow	0.01	0.008	0.06	0.059	0.02	0.066	0.00	0.049	0.01	0.069	0.00	0.043
GTGR	Great-tailed Grackle	0.08	0.018	0.09	0.101	0.10	0.102	0.06	0.089	0.10	0.127	0.01	0.084
HETH	Hermit Thrush	0.03	0.020	0.03	0.146	0.06	0.178	0.02	0.137	0.08	0.159	0.01	0.097
HOFI	House Finch	0.64	0.032	0.49	0.058	0.71	0.033	0.45	0.058	0.75	0.029	0.29	0.026
HOLA	Horned Lark	0.15	0.025	0.44	0.003	0.18	0.006	0.08	0.012	0.14	0.013	0.43	0.005
HOSP	House Sparrow	0.13	0.025	0.09	0.098	0.12	0.104	0.18	0.118	0.20	0.129	0.03	0.150
HOWR	House Wren	0.18	0.039	0.19	0.012	0.45	0.005	0.11	0.011	0.37	0.007	0.14	0.006
HUVI	Hutton's Vireo	0.01	0.008	0.02	0.065	0.04	0.093	0.01	0.064	0.01	0.082	0.00	0.054
LASP	Lark Sparrow	0.05	0.020	0.06	0.135	0.11	0.135	0.02	0.122	0.10	0.148	0.01	0.100
LAZB	Lazuli Bunting	0.10	0.044	0.14	0.233	0.12	0.248	0.08	0.209	0.13	0.242	0.05	0.209
LCTH	Le Conte's Thrasher	0.01	0.006	0.00	0.042	0.02	0.045	0.00	0.046	0.00	0.047	0.14	0.032
LEGO	Lesser Goldfinch	0.10	0.029	0.08	0.135	0.32	0.136	0.07	0.090	0.21	0.144	0.01	0.080
LISP	Lincoln's Sparrow	0.07	0.050	0.14	0.241	0.12	0.271	0.07	0.230	0.13	0.255	0.03	0.151
LOSH	Loggerhead Shrike	0.12	0.023	0.23	0.080	0.17	0.064	0.25	0.091	0.09	0.075	0.21	0.178
MAWR	Marsh Wren	0.21	0.025	0.13	0.000	0.15	0.000	0.76	0.000	0.13	0.000	0.00	0.000
MGWA	MacGillivray's Warbler	0.02	0.025	0.04	0.146	0.05	0.168	0.02	0.134	0.04	0.159	0.01	0.099
NAWA	Nashville Warbler	0.01	0.011	0.01	0.088	0.01	0.109	0.01	0.087	0.02	0.093	0.01	0.074
NOMO	Northern Mockingbird	0.53	0.032	0.58	0.022	0.50	0.021	0.37	0.024	0.56	0.026	0.57	0.028

		OCCUPANCY											
	Common Name	Overall		Grass/Oak Savannah		Mixed		Riparian & Wetland		Urban & Agriculture		Shrub	
		Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
NRWS	Northern Rough-winged Swallow	0.07	0.022	0.10	0.122	0.15	0.145	0.02	0.117	0.09	0.169	0.29	0.055
OATI	Oak Titmouse	0.08	0.023	0.05	0.076	0.24	0.072	0.06	0.047	0.19	0.078	0.00	0.038
OCWA	Orange-crowned Warbler	0.15	0.041	0.18	0.246	0.17	0.247	0.10	0.219	0.21	0.258	0.33	0.150
PHAI	Phainopepla	0.02	0.013	0.05	0.104	0.03	0.115	0.01	0.096	0.01	0.106	0.15	0.062
PSFL	Pacific-slope Flycatcher	0.01	0.007	0.00	0.049	0.02	0.052	0.00	0.038	0.03	0.048	0.00	0.028
PUFI	Purple Finch	0.02	0.016	0.02	0.114	0.06	0.139	0.01	0.105	0.03	0.131	0.01	0.073
RCKI	Ruby-crowned Kinglet	0.02	0.016	0.03	0.137	0.08	0.175	0.02	0.129	0.06	0.135	0.01	0.084
RCSP	Rufous-crowned Sparrow	0.01	0.004	0.02	0.024	0.00	0.026	0.00	0.024	0.00	0.031	0.00	0.010
ROWR	Rock Wren	0.01	0.008	0.03	0.073	0.01	0.080	0.01	0.085	0.02	0.073	0.02	0.117
RWBL	Red-winged Blackbird	0.65	0.030	0.65	0.004	0.58	0.007	0.84	0.003	0.65	0.007	0.29	0.006
SAGS	Sage Sparrow	0.01	0.012	0.01	0.083	0.01	0.090	0.01	0.093	0.02	0.084	0.02	0.116
SAVS	Savannah Sparrow	0.19	0.051	0.34	0.189	0.25	0.207	0.34	0.197	0.30	0.179	0.05	0.183
SOSP	Song Sparrow	0.34	0.032	0.23	0.014	0.37	0.021	0.82	0.001	0.27	0.028	0.14	0.012
SPTO	Spotted Towhee	0.14	0.038	0.17	0.011	0.50	0.014	0.13	0.004	0.35	0.014	0.14	0.005
SWTH	Swainson's Thrush	0.01	0.015	0.01	0.094	0.03	0.115	0.01	0.090	0.01	0.104	0.01	0.078
TRBL	Tricolored Blackbird	0.03	0.012	0.06	0.068	0.04	0.087	0.04	0.083	0.01	0.090	0.01	0.092
TRES	Tree Swallow	0.47	0.041	0.46	0.029	0.61	0.030	0.40	0.021	0.52	0.034	0.14	0.022
WAVI	Warbling Vireo	0.04	0.022	0.06	0.174	0.12	0.188	0.05	0.133	0.11	0.172	0.01	0.092
WBNU	White-breasted Nuthatch	0.08	0.023	0.15	0.081	0.19	0.098	0.03	0.064	0.14	0.123	0.01	0.059
WCSP	White-crowned Sparrow	0.33	0.064	0.34	0.271	0.51	0.252	0.36	0.255	0.46	0.200	0.21	0.295
WEBL	Western Bluebird	0.05	0.022	0.06	0.139	0.13	0.175	0.05	0.123	0.14	0.161	0.02	0.102
WEKI	Western Kingbird	0.58	0.032	0.62	0.027	0.59	0.035	0.48	0.029	0.60	0.044	0.29	0.038
WEME	Western Meadowlark	0.65	0.034	0.94	0.003	0.52	0.007	0.84	0.002	0.42	0.006	0.71	0.007
WESJ	Western Scrub-Jay	0.29	0.038	0.22	0.080	0.41	0.098	0.15	0.099	0.48	0.075	0.29	0.032
WETA	Western Tanager	0.06	0.046	0.09	0.205	0.07	0.213	0.05	0.217	0.11	0.216	0.17	0.143

		OCCUPANCY											
	Common Name	Overall		Grass/Oak Savannah		Mixed		Riparian & Wetland		Urban & Agriculture		Shrub	
		Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
WEWP	Western Wood-Pewee	0.06	0.023	0.05	0.115	0.22	0.154	0.10	0.066	0.13	0.163	0.15	0.045
WIWA	Wilson's Warbler	0.09	0.031	0.18	0.179	0.16	0.200	0.09	0.172	0.13	0.186	0.05	0.168
WREN	Wrentit	0.03	0.013	0.01	0.083	0.15	0.094	0.04	0.068	0.07	0.084	0.01	0.055
WTSW	White-throated Swift	0.01	0.010	0.01	0.083	0.03	0.096	0.01	0.081	0.01	0.096	0.01	0.076
YBCH	Yellow-breasted Chat	0.01	0.006	0.00	0.039	0.02	0.045	0.03	0.036	0.00	0.039	0.14	0.014
YBMA	Yellow-billed Magpie	0.04	0.013	0.04	0.052	0.02	0.061	0.03	0.049	0.08	0.075	0.00	0.050
YEWA	Yellow Warbler	0.04	0.016	0.09	0.113	0.10	0.148	0.04	0.115	0.05	0.132	0.15	0.062
YHBL	Yellow-headed Blackbird	0.09	0.020	0.17	0.099	0.14	0.115	0.21	0.124	0.04	0.107	0.02	0.135
YRWA	Yellow-rumped Warbler	0.15	0.059	0.20	0.303	0.24	0.309	0.16	0.281	0.34	0.277	0.05	0.200

Appendix S2. Songbird species in the Great Valley ecoregion of California and their site-level detection probabilities (± 95 credible intervals).

Species Code	Common Name	P* Mean	95% CI		Species Code	Common Name	P* Mean	95% CI	
AMCR	American Crow	0.90	0.842	0.938	HOFI	House Finch	0.99	0.990	0.995
AMGO	American Goldfinch	0.89	0.839	0.926	HOLA	Horned Lark	1.00	0.999	1.000
AMPI	American Pipit	0.44	0.247	0.644	HOSP	House Sparrow	0.90	0.806	0.957
AMRO	American Robin	0.99	0.985	0.995	HOWR	House Wren	1.00	0.999	1.000
ATFL	Ash-throated Flycatcher	0.98	0.964	0.991	HUVI	Hutton's Vireo	0.73	0.314	0.955
BANS	Bank Swallow	0.50	0.080	0.927	LASP	Lark Sparrow	0.75	0.526	0.885
BARS	Barn Swallow	0.52	0.318	0.696	LAZB	Lazuli Bunting	0.47	0.226	0.712
BESP	Bell's Sparrow	0.99	0.939	0.999	LCTH	Le Conte's Thrasher	0.93	0.567	0.998
BEWR	Bewick's Wren	1.00	0.995	0.999	LEGO	Lesser Goldfinch	0.86	0.769	0.924
BGGN	Blue-gray Gnatcatcher	0.53	0.067	0.950	LISP	Lincoln's Sparrow	0.24	0.066	0.526
BHCO	Brown-headed Cowbird	0.97	0.961	0.981	LOSH	Loggerhead Shrike	0.96	0.916	0.981
BHGR	Black-headed Grosbeak	0.97	0.935	0.984	MAWR	Marsh Wren	1.00	1.000	1.000
BLGR	Blue Grosbeak	0.71	0.569	0.820	MGWA	MacGillivray's Warbler	0.42	0.078	0.802
BLPH	Black Phoebe	0.95	0.930	0.970	NAWA	Nashville Warbler	0.54	0.069	0.962
BRBL	Brewer's Blackbird	0.88	0.835	0.915	NOMO	Northern Mockingbird	1.00	0.998	0.999
BTYW	Black-throated Gray Warbler	0.94	0.483	1.000	NRWS	Northern Rough-winged Swallow	0.52	0.212	0.807
BUOR	Bullock's Oriole	0.98	0.962	0.984	OATI	Oak Titmouse	0.78	0.594	0.897
BUSH	Bushtit	0.91	0.853	0.947	OCWA	Orange-crowned Warbler	0.96	0.916	0.980
CAKI	Cassin's Kingbird	0.98	0.638	1.000	PHAI	Phainopepla	0.51	0.318	0.694
CALT	California Towhee	0.99	0.982	0.995	PSFL	Pacific-slope Flycatcher	0.65	0.246	0.925
CATH	California Thrasher	0.34	0.054	0.764	PUFI	Purple Finch	0.95	0.651	0.998
CAVI	Cassin's Vireo	0.50	0.078	0.919	RCKI	Ruby-crowned Kinglet	0.50	0.133	0.842
CEDW	Cedar Waxwing	0.57	0.283	0.797	RCSP	Rufous-crowned Sparrow	0.44	0.102	0.878
CHSP	Chipping Sparrow	0.46	0.068	0.892	ROWR	Rock Wren	0.98	0.694	1.000
CLSW	Cliff Swallow	0.70	0.570	0.812	RWBL	Red-winged Blackbird	0.67	0.208	0.956
CORA	Common Raven	0.93	0.893	0.951	SAGS	Sage Sparrow	1.00	1.000	1.000
COYE	Common Yellowthroat	1.00	0.995	0.999	SAVS	Savannah Sparrow	0.58	0.082	0.964
DEJU	Dark-eyed Junco	0.37	0.081	0.797	SOSP	Song Sparrow	0.74	0.533	0.903
EUST	European Starling	0.97	0.960	0.984	SPTO	Spotted Towhee	1.00	1.000	1.000
FOSP	Fox Sparrow	0.51	0.069	0.946	SWTH	Swainson's Thrush	1.00	0.998	1.000
GCSP	Golden-crowned Sparrow	0.38	0.205	0.577	TRBL	Tricolored Blackbird	0.51	0.068	0.939
GRSP	Grasshopper Sparrow	0.91	0.408	0.999	TRES	Tree Swallow	0.83	0.528	0.963
GTGR	Great-tailed Grackle	0.87	0.730	0.949	WAVI	Warbling Vireo	1.00	0.993	0.997
HETH	Hermit Thrush	0.41	0.102	0.831	WBNU	White-breasted Nuthatch	0.55	0.285	0.798

Species Code	Common Name	P* Mean	95% CI	
WCSP	White-crowned Sparrow	0.92	0.844	0.963
WEBL	Western Bluebird	0.41	0.250	0.572
WEKI	Western Kingbird	0.72	0.508	0.865
WEME	Western Meadowlark	1.00	0.995	0.998
WESJ	Western Scrub-Jay	1.00	1.000	1.000
WETA	Western Tanager	0.96	0.945	0.978
WEWP	Western Wood-Pewee	0.46	0.149	0.749
WIWA	Wilson's Warbler	0.84	0.646	0.954
WREN	Wrentit	0.61	0.420	0.786
WTSW	White-throated Swift	0.89	0.718	0.968
YBCH	Yellow-breasted Chat	0.53	0.093	0.938
YBMA	Yellow-billed Magpie	0.96	0.684	0.999
YEWA	Yellow Warbler	0.94	0.844	0.984
YHBL	Yellow-headed Blackbird	0.74	0.487	0.904
YRWA	Yellow-rumped Warbler	0.88	0.781	0.945

Appendix S3a. Mean and 95% credible interval estimates for covariate effects on occupancy (PSI) and detection (P) for 84 songbird species in the Great Valley ecoregion of California, 2016-17. Results are based on model 1; covariate effects that do not overlap 0.0 are highlighted in yellow.

Species Code	**Common Name**	**PSI (# natural types)**			**PSI (# agricultural types)**			**PSI (distance to forest)**		
		Mean	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*	
AMCR	American Crow	0.38	0.100	0.694	0.38	0.102	0.672	-0.60	-1.117	-0.155
AMGO	American Goldfinch	0.13	-0.160	0.428	0.32	0.031	0.609	-1.35	-2.058	-0.752
AMPI	American Pipit	-0.26	-0.668	0.151	0.00	-0.352	0.367	0.26	-0.194	0.730
AMRO	American Robin	0.29	0.003	0.581	0.54	0.278	0.840	-1.37	-2.038	-0.819
ATFL	Ash-throated Flycatcher	0.36	0.070	0.661	0.07	-0.189	0.331	-1.15	-1.794	-0.625
BANS	Bank Swallow	0.15	-0.460	0.755	0.18	-0.322	0.692	-0.78	-2.500	0.623
BARS	Barn Swallow	-0.07	-0.507	0.333	0.04	-0.330	0.381	0.50	0.059	0.984
BESP	Bell's Sparrow	0.08	-0.501	0.660	-0.19	-0.673	0.252	1.19	0.671	1.778
BEWR	Bewick's Wren	0.63	0.335	0.949	0.04	-0.199	0.282	-0.23	-0.598	0.110
BGGN	Blue-gray Gnatcatcher	0.04	-0.618	0.662	0.05	-0.449	0.554	0.14	-1.174	1.278
BHCO	Brown-headed Cowbird	0.32	0.010	0.658	0.12	-0.136	0.372	-0.47	-0.779	-0.172
BHGR	Black-headed Grosbeak	0.56	0.211	0.906	0.22	-0.073	0.508	-1.80	-2.889	-0.864
BLGR	Blue Grosbeak	0.23	-0.119	0.610	0.19	-0.128	0.497	0.11	-0.324	0.535
BLPH	Black Phoebe	0.07	-0.210	0.340	0.30	0.048	0.558	-0.87	-1.307	-0.459
BRBL	Brewer's Blackbird	-0.24	-0.527	0.030	-0.03	-0.274	0.228	-0.04	-0.351	0.290
BTYW	Black-throated Gray Warbler	0.12	-0.489	0.733	0.04	-0.442	0.532	-0.74	-2.375	0.589
BUOR	Bullock's Oriole	0.15	-0.111	0.429	0.15	-0.095	0.398	-0.32	-0.656	-0.002
BUSH	Bushtit	0.24	-0.075	0.578	0.17	-0.127	0.468	-1.98	-3.113	-1.007
CAKI	Cassin's Kingbird	0.09	-0.516	0.702	-0.01	-0.549	0.454	0.05	-1.084	0.947
CALT	California Towhee	-0.02	-0.288	0.243	0.32	0.061	0.579	-1.20	-1.835	-0.639
CATH	California Thrasher	0.03	-0.570	0.583	0.15	-0.336	0.611	0.26	-0.725	1.192
CAVI	Cassin's Vireo	0.11	-0.539	0.711	0.08	-0.430	0.554	-0.69	-2.231	0.657
CEDW	Cedar Waxwing	0.06	-0.415	0.545	0.03	-0.379	0.442	-0.81	-1.938	0.082
CHSP	Chipping Sparrow	0.10	-0.521	0.693	0.03	-0.484	0.506	-0.09	-1.347	0.973
CLSW	Cliff Swallow	-0.15	-0.524	0.197	-0.15	-0.459	0.149	0.01	-0.374	0.379
CORA	Common Raven	-0.17	-0.491	0.149	0.23	-0.056	0.525	1.22	0.799	1.742
COYE	Common Yellowthroat	0.24	-0.031	0.506	-0.06	-0.312	0.189	-0.30	-0.693	0.025
DEJU	Dark-eyed Junco	0.18	-0.323	0.693	0.12	-0.350	0.586	-1.28	-2.922	0.062
EUST	European Starling	0.39	0.117	0.683	0.22	-0.025	0.472	-1.17	-1.762	-0.678
FOSP	Fox Sparrow	-0.03	-0.655	0.583	0.19	-0.307	0.708	-0.76	-2.369	0.621
GCSP	Golden-crowned Sparrow	-0.09	-0.498	0.304	0.42	0.048	0.825	-0.73	-1.529	-0.071

Species Code	Common Name	PSI (# natural types)			PSI (# agricultural types)			PSI (distance to forest)		
		Mean	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*	
GRSP	Grasshopper Sparrow	-0.16	-0.738	0.381	-0.05	-0.523	0.408	-0.99	-2.479	0.145
GTGR	Great-tailed Grackle	-0.19	-0.628	0.206	0.22	-0.140	0.563	-0.25	-0.872	0.280
HETH	Hermit Thrush	0.06	-0.472	0.572	0.27	-0.181	0.734	-1.17	-2.712	0.041
HOFI	House Finch	0.01	-0.266	0.287	0.39	0.137	0.657	-0.69	-1.014	-0.392
HOLA	Horned Lark	-0.40	-0.816	-0.018	-0.33	-0.683	-0.003	0.93	0.620	1.256
HOSP	House Sparrow	-0.47	-0.887	-0.099	0.52	0.211	0.845	0.25	-0.148	0.632
HOWR	House Wren	0.45	0.159	0.740	0.09	-0.168	0.350	-1.98	-3.017	-1.135
HUVI	Hutton's Vireo	0.45	-0.089	1.009	0.10	-0.372	0.573	-1.00	-2.538	0.285
LASP	Lark Sparrow	-0.12	-0.580	0.306	0.01	-0.371	0.374	-1.25	-2.448	-0.309
LAZB	Lazuli Bunting	0.10	-0.389	0.571	-0.04	-0.458	0.362	-0.60	-1.472	0.136
LCTH	Le Conte's Thrasher	0.07	-0.540	0.653	-0.03	-0.519	0.448	0.46	-0.461	1.307
LEGO	Lesser Goldfinch	0.38	0.047	0.715	0.19	-0.111	0.494	-1.66	-2.810	-0.719
LISP	Lincoln's Sparrow	-0.03	-0.535	0.475	-0.06	-0.525	0.392	-1.29	-2.681	-0.101
LOSH	Loggerhead Shrike	-0.21	-0.625	0.163	-0.17	-0.514	0.153	0.74	0.399	1.086
MAWR	Marsh Wren	0.10	-0.193	0.377	-0.11	-0.384	0.157	-0.18	-0.561	0.161
MGWA	MacGillivray's Warbler	0.11	-0.476	0.686	-0.01	-0.499	0.444	-1.01	-2.562	0.223
NAWA	Nashville Warbler	0.26	-0.340	0.895	0.11	-0.381	0.582	-0.69	-2.318	0.689
NOMO	Northern Mockingbird	-0.35	-0.623	-0.094	0.08	-0.144	0.315	0.19	-0.092	0.479
NRWS	Northern Rough-winged Swallow	0.13	-0.266	0.532	0.33	-0.012	0.691	-0.56	-1.419	0.124
OATI	Oak Titmouse	0.20	-0.111	0.516	0.12	-0.179	0.418	-1.87	-3.018	-0.835
OCWA	Orange-crowned Warbler	-0.14	-0.527	0.255	0.08	-0.298	0.446	-0.97	-1.888	-0.253
PHAI	Phainopepla	0.13	-0.421	0.654	-0.06	-0.557	0.403	-0.71	-1.978	0.387
PSFL	Pacific-slope Flycatcher	-0.04	-0.601	0.487	-0.01	-0.489	0.438	-1.09	-2.576	0.070
PUFI	Purple Finch	0.17	-0.380	0.733	0.23	-0.242	0.722	-1.06	-2.574	0.219
RCKI	Ruby-crowned Kinglet	0.40	-0.110	0.916	0.12	-0.330	0.586	-1.22	-2.780	0.045
RCSP	Rufous-crowned Sparrow	0.02	-0.595	0.625	0.00	-0.507	0.492	-0.34	-1.785	0.797
ROWR	Rock Wren	0.06	-0.563	0.678	-0.02	-0.539	0.463	0.69	-0.238	1.592
RWBL	Red-winged Blackbird	-0.08	-0.328	0.186	0.12	-0.112	0.362	0.04	-0.236	0.315
SAGS	Sage Sparrow	0.02	-0.607	0.628	0.14	-0.356	0.646	0.54	-0.610	1.672
SAVS	Savannah Sparrow	-0.50	-0.883	-0.139	-0.10	-0.429	0.228	0.10	-0.305	0.501
SOSP	Song Sparrow	0.35	0.087	0.607	0.10	-0.136	0.350	-0.10	-0.413	0.198
SPTO	Spotted Towhee	0.77	0.428	1.114	0.29	0.016	0.570	-2.50	-3.732	-1.468
SWTH	Swainson's Thrush	0.19	-0.444	0.814	0.11	-0.390	0.622	-0.72	-2.278	0.647
TRBL	Tricolored Blackbird	0.05	-0.472	0.566	0.06	-0.373	0.499	0.31	-0.384	0.942
TRES	Tree Swallow	0.72	0.393	1.067	0.34	0.071	0.606	-1.04	-1.533	-0.600
WAVI	Warbling Vireo	0.23	-0.202	0.682	-0.09	-0.513	0.314	-1.60	-3.043	-0.415

Species Code	Common Name	PSI (# natural types)			PSI (# agricultural types)			PSI (distance to forest)		
		Mean	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*	
WBNU	White-breasted Nuthatch	0.09	-0.242	0.437	0.13	-0.197	0.450	-1.42	-2.485	-0.531
WCSP	White-crowned Sparrow	0.08	-0.303	0.486	0.36	-0.012	0.723	-0.02	-0.455	0.478
WEBL	Western Bluebird	0.21	-0.183	0.613	0.16	-0.203	0.527	-1.63	-3.036	-0.511
WEKI	Western Kingbird	-0.13	-0.399	0.126	0.05	-0.174	0.287	-0.32	-0.605	-0.056
WEME	Western Meadowlark	-0.10	-0.366	0.160	-0.43	-0.698	-0.180	0.83	0.436	1.260
WESJ	Western Scrub-Jay	0.21	-0.071	0.497	0.32	0.065	0.587	-1.31	-1.963	-0.757
WETA	Western Tanager	-0.14	-0.684	0.371	0.01	-0.421	0.433	-0.22	-1.145	0.549
WEWP	Western Wood-Pewee	0.30	-0.086	0.702	0.11	-0.246	0.441	-1.84	-3.159	-0.680
WIWA	Wilson's Warbler	0.16	-0.228	0.538	0.05	-0.315	0.406	-0.43	-1.123	0.149
WREN	Wrentit	0.49	0.090	0.909	0.26	-0.107	0.636	-1.61	-3.113	-0.362
WTSW	White-throated Swift	0.04	-0.579	0.677	0.06	-0.439	0.536	-0.64	-2.215	0.669
YBCH	Yellow-breasted Chat	0.09	-0.438	0.644	0.07	-0.411	0.525	-0.98	-2.497	0.236
YBMA	Yellow-billed Magpie	-0.05	-0.510	0.383	0.21	-0.162	0.604	-0.62	-1.615	0.154
YEWA	Yellow Warbler	0.40	-0.023	0.843	-0.04	-0.464	0.337	-0.87	-1.969	0.014
YHBL	Yellow-headed Blackbird	0.09	-0.298	0.491	0.04	-0.314	0.383	0.62	0.247	0.996
YRWA	Yellow-rumped Warbler	-0.21	-0.656	0.211	0.31	-0.104	0.745	-1.23	-2.339	-0.333

Species Code	Common Name	PSI (distance to water)			PSI (year)			P (max temperature)		
		Mean	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*	
AMCR	American Crow	0.15	-0.204	0.540	0.17	-0.156	0.491	-0.33	-0.604	-0.070
AMGO	American Goldfinch	0.03	-0.283	0.317	0.07	-0.236	0.371	0.07	-0.170	0.333
AMPI	American Pipit	-0.18	-0.661	0.260	1.20	0.519	2.020	-0.18	-0.532	0.177
AMRO	American Robin	0.00	-0.320	0.295	0.20	-0.092	0.489	-0.11	-0.270	0.063
ATFL	Ash-throated Flycatcher	-0.20	-0.575	0.134	-0.28	-0.578	0.005	-0.25	-0.452	-0.050
BANS	Bank Swallow	-0.04	-0.631	0.498	0.34	-0.580	1.347	-0.11	-0.655	0.437
BARS	Barn Swallow	-0.21	-0.680	0.215	-0.19	-0.698	0.307	-0.22	-0.656	0.208
BESP	Bell’s Sparrow	0.22	-0.181	0.597	0.83	0.111	1.667	-0.33	-0.920	0.208
BEWR	Bewick's Wren	-0.07	-0.411	0.218	-0.09	-0.366	0.192	0.06	-0.148	0.272
BGGN	Blue-gray Gnatcatcher	0.00	-0.555	0.536	0.34	-0.567	1.296	-0.11	-0.669	0.443
BHCO	Brown-headed Cowbird	-0.23	-0.526	0.039	0.00	-0.293	0.295	0.23	0.070	0.397
BHGR	Black-headed Grosbeak	-0.13	-0.578	0.253	-0.18	-0.520	0.165	0.10	-0.144	0.347
BLGR	Blue Grosbeak	-0.20	-0.627	0.173	-0.12	-0.487	0.262	0.13	-0.184	0.466
BLPH	Black Phoebe	0.16	-0.112	0.448	-0.06	-0.351	0.213	-0.01	-0.200	0.182
BRBL	Brewer's Blackbird	-0.11	-0.382	0.154	0.08	-0.215	0.368	-0.33	-0.550	-0.115

Species Code	Common Name	PSI (distance to water)			PSI (year)			P (max temperature)		
		Mean	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*	
BTYW	Black-throated Gray Warbler	-0.07	-0.623	0.439	0.32	-0.593	1.257	-0.03	-0.577	0.527
BUOR	Bullock's Oriole	-0.24	-0.580	0.052	0.11	-0.152	0.375	0.20	-0.001	0.407
BUSH	Bushtit	-0.18	-0.618	0.208	-0.24	-0.586	0.111	-0.06	-0.349	0.224
CAKI	Cassin's Kingbird	-0.14	-0.728	0.355	0.44	-0.416	1.430	-0.15	-0.706	0.373
CALT	California Towhee	0.19	-0.082	0.481	-0.03	-0.317	0.258	0.09	-0.109	0.295
CATH	California Thrasher	0.04	-0.485	0.592	0.23	-0.570	1.132	-0.19	-0.742	0.326
CAVI	Cassin's Vireo	-0.08	-0.686	0.479	0.35	-0.601	1.327	-0.10	-0.656	0.458
CEDW	Cedar Waxwing	0.24	-0.217	0.792	0.88	0.145	1.710	-0.01	-0.433	0.421
CHSP	Chipping Sparrow	-0.06	-0.633	0.462	0.46	-0.453	1.426	-0.10	-0.659	0.444
CLSW	Cliff Swallow	-0.10	-0.440	0.235	-0.41	-0.766	-0.058	0.15	-0.157	0.475
CORA	Common Raven	0.55	0.072	1.054	-0.18	-0.507	0.156	-0.28	-0.504	-0.070
COYE	Common Yellowthroat	-0.47	-0.922	-0.090	0.16	-0.112	0.455	-0.48	-0.709	-0.253
DEJU	Dark-eyed Junco	0.07	-0.496	0.625	0.64	-0.175	1.604	-0.17	-0.686	0.353
EUST	European Starling	0.23	-0.034	0.544	-0.13	-0.423	0.167	-0.03	-0.216	0.162
FOSP	Fox Sparrow	-0.07	-0.645	0.470	0.35	-0.583	1.352	-0.11	-0.676	0.443
GCSP	Golden-crowned Sparrow	0.18	-0.140	0.569	1.20	0.491	2.064	-0.20	-0.544	0.140
GRSP	Grasshopper Sparrow	-0.02	-0.537	0.431	0.54	-0.271	1.435	0.05	-0.494	0.625
GTGR	Great-tailed Grackle	-0.23	-0.739	0.159	0.13	-0.325	0.615	0.12	-0.290	0.546
HETH	Hermit Thrush	-0.09	-0.660	0.430	0.65	-0.181	1.561	-0.36	-0.938	0.177
HOFI	House Finch	0.13	-0.134	0.417	-0.14	-0.426	0.128	0.20	0.052	0.338
HOLA	Horned Lark	0.09	-0.179	0.362	-0.14	-0.464	0.185	-0.43	-0.699	-0.163
HOSP	House Sparrow	-0.06	-0.414	0.262	0.26	-0.131	0.669	-0.13	-0.470	0.197
HOWR	House Wren	0.10	-0.211	0.388	-0.02	-0.309	0.275	-0.17	-0.375	0.031
HUVI	Hutton's Vireo	-0.06	-0.622	0.466	0.16	-0.602	0.979	-0.15	-0.678	0.413
LASP	Lark Sparrow	0.08	-0.351	0.522	0.00	-0.500	0.514	0.13	-0.293	0.585
LAZB	Lazuli Bunting	0.33	0.005	0.733	0.27	-0.369	0.913	0.12	-0.364	0.578
LCTH	Le Conte's Thrasher	0.16	-0.332	0.632	0.45	-0.399	1.395	-0.18	-0.755	0.385
LEGO	Lesser Goldfinch	-0.03	-0.447	0.333	0.26	-0.140	0.652	0.10	-0.195	0.408
LISP	Lincoln's Sparrow	-0.22	-0.822	0.285	0.74	-0.094	1.694	-0.39	-0.922	0.080
LOSH	Loggerhead Shrike	0.23	-0.048	0.547	-0.27	-0.626	0.087	0.21	-0.112	0.542
MAWR	Marsh Wren	-0.45	-0.895	-0.058	0.00	-0.288	0.290	0.02	-0.237	0.305
MGWA	MacGillivray's Warbler	-0.12	-0.732	0.427	0.52	-0.311	1.448	-0.06	-0.595	0.469
NAWA	Nashville Warbler	-0.07	-0.671	0.466	0.34	-0.570	1.338	-0.11	-0.630	0.430

Species Code	Common Name	PSI (distance to water)			PSI (year)			P (max temperature)		
		Mean	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*	
NOMO	Northern Mockingbird	0.01	-0.232	0.277	0.02	-0.222	0.266	-0.12	-0.284	0.044
NRWS	Northern Rough-winged Swallow	-0.18	-0.703	0.252	0.32	-0.154	0.857	-0.08	-0.500	0.337
OATI	Oak Titmouse	0.19	-0.140	0.524	-0.07	-0.408	0.281	-0.16	-0.447	0.133
OCWA	Orange-crowned Warbler	0.19	-0.137	0.545	-0.10	-0.619	0.421	-0.48	-0.915	-0.088
PHAI	Phainopepla	-0.10	-0.657	0.407	0.18	-0.571	1.010	-0.07	-0.577	0.457
PSFL	Pacific-slope Flycatcher	-0.12	-0.695	0.354	0.50	-0.299	1.441	-0.43	-0.938	0.044
PUFI	Purple Finch	-0.09	-0.655	0.454	0.51	-0.330	1.426	-0.04	-0.551	0.494
RCKI	Ruby-crowned Kinglet	-0.13	-0.710	0.372	0.69	-0.148	1.655	-0.35	-0.821	0.100
RCSP	Rufous-crowned Sparrow	-0.04	-0.617	0.442	0.33	-0.551	1.274	-0.19	-0.752	0.356
ROWR	Rock Wren	-0.12	-0.701	0.384	-0.32	-1.157	0.519	-0.09	-0.648	0.446
RWBL	Red-winged Blackbird	-0.08	-0.324	0.169	0.28	0.024	0.532	0.23	0.077	0.389
SAGS	Sage Sparrow	-0.06	-0.652	0.464	-0.11	-1.036	0.780	-0.09	-0.645	0.482
SAVS	Savannah Sparrow	-0.36	-0.818	0.022	1.41	0.768	2.214	-0.12	-0.383	0.138
SOSP	Song Sparrow	-0.55	-1.004	-0.165	-0.08	-0.350	0.178	-0.59	-0.814	-0.357
SPTO	Spotted Towhee	-0.18	-0.640	0.206	-0.30	-0.618	0.029	-0.08	-0.293	0.127
SWTH	Swainson's Thrush	-0.06	-0.635	0.523	0.35	-0.559	1.325	-0.09	-0.621	0.445
TRBL	Tricolored Blackbird	-0.11	-0.643	0.325	0.14	-0.504	0.832	0.02	-0.520	0.561
TRES	Tree Swallow	-0.35	-0.729	-0.026	0.14	-0.150	0.438	-0.06	-0.236	0.098
WAVI	Warbling Vireo	0.23	-0.154	0.584	0.89	0.165	1.758	-0.15	-0.545	0.258
WBNU	White-breasted Nuthatch	-0.06	-0.489	0.331	0.11	-0.273	0.515	-0.03	-0.380	0.312
WCSP	White-crowned Sparrow	0.12	-0.206	0.523	1.69	1.042	2.509	-0.50	-0.732	-0.258
WEBL	Western Bluebird	0.03	-0.435	0.451	-0.13	-0.606	0.339	0.00	-0.408	0.391
WEKI	Western Kingbird	-0.13	-0.397	0.115	-0.28	-0.550	-0.030	0.03	-0.129	0.190
WEME	Western Meadowlark	-0.24	-0.558	0.037	0.31	0.050	0.573	-0.07	-0.224	0.084
WESJ	Western Scrub-Jay	0.11	-0.179	0.404	-0.27	-0.560	0.013	-0.35	-0.564	-0.127
WETA	Western Tanager	0.00	-0.497	0.490	0.82	0.032	1.732	-0.07	-0.529	0.392
WEWP	Western Wood-Pewee	-0.27	-0.844	0.193	0.19	-0.242	0.650	-0.04	-0.405	0.310
WIWA	Wilson's Warbler	0.30	-0.021	0.667	1.09	0.397	1.948	0.02	-0.326	0.360
WREN	Wrentit	0.00	-0.480	0.465	-0.44	-0.958	0.048	-0.12	-0.604	0.376
WTSW	White-throated Swift	-0.08	-0.680	0.461	0.35	-0.574	1.360	-0.11	-0.666	0.463

Species Code	Common Name	PSI (distance to water)			PSI (year)			P (max temperature)		
		Mean	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*	
YBCH	Yellow-breasted Chat	-0.14	-0.760	0.358	0.11	-0.669	0.943	-0.05	-0.602	0.503
YBMA	Yellow-billed Magpie	0.16	-0.269	0.619	-0.08	-0.582	0.428	-0.27	-0.780	0.202
YEWA	Yellow Warbler	0.01	-0.493	0.462	0.93	0.240	1.767	-0.06	-0.495	0.372
YHBL	Yellow-headed Blackbird	-0.41	-0.933	0.027	0.38	-0.065	0.873	0.07	-0.353	0.507
YRWA	Yellow-rumped Warbler	-0.13	-0.662	0.387	1.10	0.352	1.950	-0.51	-0.906	-0.140

Species Code	Common Name	P (Julian day)			P (Julian day²)			P (Noise)		
		Mean	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*	
AMCR	American Crow	0.96	0.165	1.733	-0.63	-1.448	0.189	0.21	-0.045	0.469
AMGO	American Goldfinch	0.58	-0.260	1.397	-0.54	-1.329	0.285	0.06	-0.156	0.269
AMPI	American Pipit	0.25	-0.694	1.214	-1.63	-2.743	-0.654	-0.60	-0.952	-0.283
AMRO	American Robin	0.22	-0.558	0.936	-0.53	-1.275	0.260	-0.07	-0.222	0.085
ATFL	Ash-throated Flycatcher	1.53	0.647	2.549	-1.08	-1.984	-0.293	-0.06	-0.217	0.088
BANS	Bank Swallow	0.87	-0.323	2.105	-0.92	-2.149	0.263	-0.14	-0.656	0.390
BARS	Barn Swallow	1.09	0.179	2.025	-0.70	-1.600	0.189	0.10	-0.211	0.417
BESP	Bell's Sparrow	1.18	0.203	2.129	-0.75	-1.697	0.255	-0.03	-0.482	0.430
BEWR	Bewick's Wren	0.87	0.141	1.675	-1.17	-1.998	-0.424	-0.44	-0.625	-0.260
BGGN	Blue-gray Gnatcatcher	0.86	-0.274	2.045	-0.92	-2.113	0.189	-0.13	-0.663	0.424
BHCO	Brown-headed Cowbird	0.82	0.082	1.537	-0.81	-1.511	-0.084	-0.19	-0.317	-0.074
BHGR	Black-headed Grosbeak	1.77	0.873	2.817	-1.03	-1.968	-0.191	-0.54	-0.772	-0.321
BLGR	Blue Grosbeak	1.52	0.589	2.487	-0.52	-1.370	0.364	-0.10	-0.422	0.221
BLPH	Black Phoebe	0.60	-0.212	1.359	-0.70	-1.470	0.100	-0.14	-0.302	0.015
BRBL	Brewer's Blackbird	0.80	0.010	1.591	-0.75	-1.557	0.054	0.05	-0.119	0.217
BTYW	Black-throated Gray Warbler	0.80	-0.497	2.043	-1.05	-2.367	0.166	-0.20	-0.752	0.334
BUOR	Bullock's Oriole	0.78	-0.036	1.536	-0.65	-1.416	0.161	0.08	-0.076	0.234
BUSH	Bushtit	0.78	-0.007	1.570	-0.90	-1.737	-0.100	-0.38	-0.627	-0.151
CAKI	Cassin's Kingbird	1.39	0.122	2.765	-0.48	-1.646	0.804	-0.05	-0.576	0.473
CALT	California Towhee	1.35	0.602	2.189	-1.07	-1.890	-0.328	-0.19	-0.360	-0.018
CATH	California Thrasher	0.76	-0.300	1.805	-1.04	-2.134	-0.007	-0.15	-0.645	0.322
CAVI	Cassin's Vireo	0.90	-0.278	2.148	-0.93	-2.134	0.235	-0.15	-0.687	0.399
CEDW	Cedar Waxwing	1.03	-0.111	2.132	-0.90	-1.977	0.186	-0.20	-0.635	0.233
CHSP	Chipping Sparrow	0.87	-0.349	2.068	-0.95	-2.041	0.207	-0.14	-0.658	0.390

Species Code	Common Name	P (Julian day)			P (Julian day²)			P (Noise)		
		Mean	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*	
CLSW	Cliff Swallow	1.33	0.483	2.250	-0.96	-1.820	-0.142	-0.28	-0.473	-0.086
CORA	Common Raven	1.35	0.589	2.189	-1.09	-1.960	-0.303	-0.11	-0.290	0.075
COYE	Common Yellowthroat	1.09	0.279	1.937	-0.65	-1.472	0.161	-0.33	-0.518	-0.137
DEJU	Dark-eyed Junco	0.60	-0.418	1.596	-1.15	-2.223	-0.146	-0.18	-0.653	0.295
EUST	European Starling	1.01	0.257	1.792	-1.18	-1.982	-0.416	0.15	0.016	0.288
FOSP	Fox Sparrow	0.84	-0.323	2.047	-0.95	-2.137	0.207	-0.13	-0.653	0.407
GCSP	Golden-crowned Sparrow	0.20	-0.770	1.180	-1.64	-2.809	-0.588	-0.19	-0.498	0.121
GRSP	Grasshopper Sparrow	0.80	-0.478	2.053	-1.06	-2.305	0.109	-0.28	-0.840	0.251
GTGR	Great-tailed Grackle	0.84	-0.062	1.790	-1.11	-2.093	-0.199	-0.311	-0.738	0.095
HETH	Hermit Thrush	0.40	-0.765	1.438	-1.31	-2.511	-0.265	-0.075	-0.553	0.425
HOFI	House Finch	1.15	0.433	1.914	-1.42	-2.185	-0.685	0.070	-0.041	0.181
HOLA	Horned Lark	1.37	0.518	2.318	-1.19	-2.170	-0.370	-0.038	-0.198	0.114
HOSP	House Sparrow	1.29	0.400	2.255	-0.67	-1.561	0.152	0.211	-0.113	0.557
HOWR	House Wren	0.46	-0.324	1.212	-0.60	-1.367	0.169	0.077	-0.084	0.236
HUVI	Hutton's Vireo	1.12	0.143	2.208	-0.70	-1.797	0.381	-0.188	-0.733	0.330
LASP	Lark Sparrow	1.10	0.110	2.122	-0.88	-1.808	0.019	0.183	-0.220	0.607
LAZB	Lazuli Bunting	0.99	-0.011	2.005	-1.00	-2.090	0.001	-0.269	-0.697	0.151
LCTH	Le Conte's Thrasher	1.01	-0.244	2.385	-0.85	-2.201	0.469	-0.242	-0.821	0.308
LEGO	Lesser Goldfinch	0.87	0.040	1.712	-0.96	-1.857	-0.115	-0.334	-0.570	-0.099
LISP	Lincoln's Sparrow	0.46	-0.589	1.465	-1.25	-2.346	-0.265	-0.102	-0.549	0.340
LOSH	Loggerhead Shrike	0.80	-0.075	1.654	-0.61	-1.463	0.261	0.367	0.142	0.589
MAWR	Marsh Wren	1.43	0.584	2.390	-1.22	-2.207	-0.344	0.043	-0.186	0.275
MGWA	MacGillivray's Warbler	0.94	-0.210	2.143	-0.90	-2.043	0.251	-0.169	-0.698	0.368
NAWA	Nashville Warbler	0.85	-0.311	2.009	-0.97	-2.135	0.155	-0.110	-0.632	0.402
NOMO	Northern Mockingbird	1.25	0.482	2.015	-0.83	-1.623	-0.094	-0.022	-0.144	0.094
NRWS	Northern Rough-winged Swallow	1.14	0.244	2.080	-0.81	-1.784	0.097	-0.379	-0.848	0.096
OATI	Oak Titmouse	0.34	-0.628	1.140	-0.34	-1.178	0.670	-0.198	-0.423	0.025
OCWA	Orange-crowned Warbler	0.66	-0.204	1.554	-1.22	-2.247	-0.303	-0.062	-0.349	0.243
PHAI	Phainopepla	0.59	-0.463	1.656	-1.14	-2.276	-0.130	-0.126	-0.611	0.371
PSFL	Pacific-slope Flycatcher	0.23	-0.866	1.312	-1.42	-2.647	-0.383	-0.280	-0.844	0.242
PUFI	Purple Finch	0.97	-0.060	2.030	-0.83	-1.910	0.247	-0.223	-0.745	0.316
RCKI	Ruby-crowned Kinglet	0.40	-0.684	1.435	-1.31	-2.522	-0.281	-0.038	-0.523	0.462

Species Code	Common Name	P (Julian day)			P (Julian day²)			P (Noise)		
		Mean	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*	
RCSP	Rufous-crowned Sparrow	0.98	-0.328	2.347	-0.89	-2.222	0.337	-0.247	-0.800	0.289
ROWR	Rock Wren	1.12	0.066	2.334	-0.71	-1.816	0.437	-0.260	-0.774	0.226
RWBL	Red-winged Blackbird	0.02	-0.853	0.789	-0.05	-0.844	0.857	-0.147	-0.267	-0.027
SAGS	Sage Sparrow	0.86	-0.344	2.101	-0.96	-2.184	0.187	-0.104	-0.622	0.414
SAVS	Savannah Sparrow	0.59	-0.303	1.578	-1.90	-3.042	-0.835	-0.29	-0.537	-0.046
SOSP	Song Sparrow	0.69	-0.120	1.426	-0.41	-1.164	0.427	-0.51	-0.683	-0.354
SPTO	Spotted Towhee	1.20	0.462	2.006	-1.05	-1.876	-0.285	-0.20	-0.356	-0.047
SWTH	Swainson's Thrush	0.92	-0.256	2.153	-0.90	-2.123	0.290	-0.14	-0.673	0.383
TRBL	Tricolored Blackbird	1.39	0.424	2.433	-0.39	-1.315	0.643	-0.17	-0.688	0.349
TRES	Tree Swallow	0.76	-0.014	1.514	-0.72	-1.503	0.101	-0.09	-0.230	0.050
WAVI	Warbling Vireo	0.88	-0.119	1.914	-0.99	-2.000	0.018	-0.27	-0.730	0.178
WBNU	White-breasted Nuthatch	1.04	0.126	1.895	-0.42	-1.227	0.476	-0.23	-0.519	0.051
WCSP	White-crowned Sparrow	-0.16	-1.183	0.828	-2.14	-3.374	-0.968	-0.06	-0.259	0.122
WEBL	Western Bluebird	0.92	0.036	1.815	-0.69	-1.586	0.180	0.00	-0.436	0.408
WEKI	Western Kingbird	0.84	0.072	1.578	-0.67	-1.398	0.093	-0.25	-0.367	-0.136
WEME	Western Meadowlark	0.70	-0.041	1.409	-0.64	-1.359	0.124	0.09	-0.021	0.198
WESJ	Western Scrub-Jay	0.97	0.172	1.725	-0.48	-1.237	0.304	0.23	0.072	0.378
WETA	Western Tanager	1.08	0.040	2.162	-0.86	-1.882	0.180	-0.01	-0.444	0.429
WEWP	Western Wood-Pewee	1.63	0.701	2.664	-0.70	-1.643	0.133	-0.75	-1.092	-0.412
WIWA	Wilson's Warbler	0.58	-0.371	1.544	-1.30	-2.352	-0.390	-0.30	-0.729	0.104
WREN	Wrentit	0.59	-0.285	1.457	-1.13	-2.100	-0.196	0.01	-0.336	0.351
WTSW	White-throated Swift	0.91	-0.356	2.221	-0.91	-2.113	0.244	-0.13	-0.656	0.419
YBCH	Yellow-breasted Chat	0.66	-0.529	1.821	-1.19	-2.453	-0.126	0.11	-0.386	0.636
YBMA	Yellow-billed Magpie	1.41	0.499	2.403	-0.85	-1.860	0.056	-0.02	-0.332	0.300
YEWA	Yellow Warbler	1.07	-0.003	2.156	-0.89	-1.954	0.161	-0.07	-0.516	0.388
YHBL	Yellow-headed Blackbird	0.81	-0.091	1.718	-0.88	-1.811	0.021	0.13	-0.270	0.561
YRWA	Yellow-rumped Warbler	-0.04	-1.068	0.914	-1.64	-2.809	-0.609	-0.24	-0.610	0.111

Appendix S3b. Mean and 95% credible interval estimates for covariate effects on occupancy (PSI) and detection (P) for 84 songbird species in the Great Valley ecoregion of California, 2016-17. Results are based on model 2; covariate effects that do not overlap 0.0 are highlighted in yellow.

Species Code	**Common Name**	**PSI (crop cover)**			**PSI (natural evenness)**			**PSI (agricultural evenness)**		
		Mean	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*	
AMCR	American Crow	0.22	-0.089	0.543	0.38	0.070	0.708	0.36	0.068	0.653
AMGO	American Goldfinch	0.44	0.133	0.766	0.42	0.119	0.736	0.23	-0.028	0.514
AMPI	American Pipit	-0.17	-0.592	0.207	-0.64	-1.099	-0.197	0.17	-0.157	0.488
AMRO	American Robin	0.51	0.235	0.804	0.35	0.074	0.632	0.34	0.080	0.601
ATFL	Ash-throated Flycatcher	0.22	-0.083	0.513	0.71	0.432	1.012	-0.05	-0.315	0.208
BANS	Bank Swallow	0.11	-0.522	0.760	0.17	-0.673	0.981	0.19	-0.242	0.635
BARS	Barn Swallow	-0.09	-0.502	0.302	-0.34	-0.777	0.100	0.06	-0.272	0.398
BESP	Bell's Sparrow	-0.46	-1.025	0.038	0.08	-0.469	0.650	0.45	0.081	0.872
BEWR	Bewick's Wren	0.25	-0.048	0.556	0.89	0.573	1.211	0.35	0.090	0.627
BGGN	Blue-gray Gnatcatcher	0.11	-0.554	0.750	0.42	-0.378	1.264	0.15	-0.299	0.597
BHCO	Brown-headed Cowbird	0.31	0.028	0.613	0.81	0.513	1.142	-0.08	-0.349	0.186
BHGR	Black-headed Grosbeak	0.36	0.021	0.704	0.78	0.462	1.145	0.22	-0.077	0.518
BLGR	Blue Grosbeak	0.17	-0.223	0.548	0.41	0.041	0.813	0.16	-0.158	0.485
BLPH	Black Phoebe	0.38	0.100	0.667	0.26	-0.023	0.549	0.14	-0.120	0.385
BRBL	Brewer's Blackbird	0.15	-0.150	0.444	-0.13	-0.416	0.168	-0.06	-0.339	0.197
BTYW	Black-throated Gray Warbler	0.20	-0.425	0.852	0.39	-0.370	1.204	0.14	-0.288	0.569
BUOR	Bullock's Oriole	0.09	-0.186	0.378	0.27	0.009	0.534	0.27	0.021	0.513
BUSH	Bushtit	0.21	-0.119	0.543	0.48	0.155	0.814	0.21	-0.088	0.490
CAKI	Cassin's Kingbird	-0.13	-0.769	0.471	0.02	-0.747	0.735	0.10	-0.339	0.513
CALT	California Towhee	0.60	0.304	0.907	0.39	0.120	0.674	0.19	-0.079	0.458
CATH	California Thrasher	-0.12	-0.704	0.467	-0.08	-0.823	0.644	0.21	-0.206	0.631
CAVI	Cassin's Vireo	0.01	-0.634	0.660	0.12	-0.714	0.951	0.10	-0.335	0.535
CEDW	Cedar Waxwing	0.28	-0.208	0.798	0.20	-0.335	0.741	0.06	-0.351	0.450
CHSP	Chipping Sparrow	-0.07	-0.720	0.565	0.18	-0.575	0.952	-0.01	-0.466	0.400
CLSW	Cliff Swallow	-0.19	-0.539	0.169	-0.34	-0.702	0.035	-0.01	-0.324	0.281
CORA	Common Raven	-0.16	-0.447	0.125	-0.49	-0.790	-0.207	0.21	-0.041	0.461
COYE	Common Yellowthroat	-0.09	-0.399	0.208	0.51	0.230	0.805	-0.20	-0.489	0.076
DEJU	Dark-eyed Junco	0.17	-0.408	0.736	0.06	-0.677	0.739	0.16	-0.246	0.589
EUST	European Starling	0.33	0.037	0.615	0.65	0.370	0.945	0.21	-0.042	0.465
FOSP	Fox Sparrow	0.10	-0.587	0.774	-0.04	-0.881	0.790	0.17	-0.259	0.615
GCSP	Golden-crowned Sparrow	0.49	0.075	0.937	0.03	-0.433	0.457	0.16	-0.184	0.510

Species Code	Common Name	PSI (crop cover)			PSI (natural evenness)			PSI (agricultural evenness)		
		Mean	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*	
GRSP	Grasshopper Sparrow	-0.20	-0.820	0.372	0.05	-0.386	0.486	0.01	-0.406	0.404
GTGR	Great-tailed Grackle	0.05	-0.386	0.458	0.08	-0.564	0.742	0.11	-0.242	0.455
HETH	Hermit Thrush	0.36	-0.197	0.952	0.21	-0.063	0.483	0.23	-0.173	0.659
HOFI	House Finch	0.34	0.069	0.617	-0.80	-1.186	-0.460	0.34	0.095	0.596
HOLA	Horned Lark	-0.37	-0.680	-0.053	-0.11	-0.479	0.247	-0.10	-0.378	0.172
HOSP	House Sparrow	0.19	-0.157	0.544	0.69	0.407	0.966	0.16	-0.143	0.458
HOWR	House Wren	0.31	0.014	0.607	0.50	-0.243	1.256	0.33	0.069	0.593
HUVI	Hutton's Vireo	0.03	-0.561	0.624	-0.11	-0.620	0.354	0.16	-0.262	0.604
LASP	Lark Sparrow	0.16	-0.295	0.642	0.44	-0.095	0.985	0.21	-0.140	0.593
LAZB	Lazuli Bunting	0.26	-0.228	0.745	0.04	-0.745	0.796	0.00	-0.395	0.357
LCTH	Le Conte's Thrasher	-0.14	-0.785	0.480	0.58	0.221	0.970	0.06	-0.362	0.480
LEGO	Lesser Goldfinch	0.28	-0.072	0.659	-0.30	-0.943	0.319	0.26	-0.044	0.565
LISP	Lincoln's Sparrow	0.21	-0.321	0.753	-0.45	-0.812	-0.094	0.07	-0.328	0.450
LOSH	Loggerhead Shrike	-0.49	-0.861	-0.146	0.48	0.152	0.794	0.25	-0.035	0.533
MAWR	Marsh Wren	-0.32	-0.648	0.020	0.36	-0.392	1.134	-0.22	-0.524	0.052
MGWA	MacGillivray's Warbler	0.14	-0.480	0.759	0.35	-0.485	1.159	0.10	-0.337	0.508
NAWA	Nashville Warbler	0.17	-0.474	0.822	-0.23	-0.497	0.007	0.15	-0.288	0.582
NOMO	Northern Mockingbird	0.04	-0.222	0.310	0.16	-0.274	0.592	0.12	-0.116	0.347
NRWS	Northern Rough-winged Swallow	-0.04	-0.483	0.395	0.63	0.275	1.006	0.21	-0.131	0.562
OATI	Oak Titmouse	0.37	0.008	0.749	0.07	-0.383	0.534	0.33	0.027	0.653
OCWA	Orange-crowned Warbler	0.12	-0.313	0.526	0.22	-0.489	0.891	0.12	-0.204	0.462
PHAI	Phainopepla	-0.18	-0.799	0.387	0.11	-0.565	0.778	0.03	-0.402	0.435
PSFL	Pacific-slope Flycatcher	0.35	-0.218	0.951	0.22	-0.520	0.988	0.13	-0.284	0.559
PUFI	Purple Finch	0.09	-0.525	0.693	0.60	-0.053	1.252	0.24	-0.172	0.682
RCKI	Ruby-crowned Kinglet	0.38	-0.187	0.964	0.39	-0.371	1.209	0.20	-0.218	0.605
RCSP	Rufous-crowned Sparrow	-0.02	-0.667	0.609	-0.11	-0.882	0.655	0.05	-0.388	0.463
ROWR	Rock Wren	0.07	-0.534	0.663	0.09	-0.171	0.344	0.03	-0.404	0.443
RWBL	Red-winged Blackbird	0.03	-0.243	0.296	-0.05	-0.868	0.766	0.01	-0.230	0.255
SAGS	Sage Sparrow	0.16	-0.485	0.842	-0.61	-0.979	-0.240	0.17	-0.254	0.602
SAVS	Savannah Sparrow	0.04	-0.317	0.379	0.66	0.392	0.928	0.07	-0.228	0.358
SOSP	Song Sparrow	-0.18	-0.472	0.105	0.87	0.569	1.176	0.03	-0.227	0.280
SPTO	Spotted Towhee	0.27	-0.039	0.586	0.26	-0.564	1.105	0.31	0.038	0.593
SWTH	Swainson's Thrush	0.04	-0.647	0.695	0.10	-0.542	0.717	0.17	-0.281	0.616
TRBL	Tricolored Blackbird	-0.16	-0.712	0.372	0.73	0.463	1.016	0.14	-0.247	0.535
TRES	Tree Swallow	0.18	-0.103	0.458	0.21	-0.331	0.729	0.18	-0.066	0.425
WAVI	Warbling Vireo	0.32	-0.144	0.808	0.21	-0.331	0.729	0.15	-0.225	0.516

Species Code	Common Name	PSI (crop cover)			PSI (natural evenness)			PSI (agricultural evenness)		
		Mean	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*	
WBNU	White-breasted Nuthatch	0.08	-0.286	0.454	0.30	-0.085	0.674	0.12	-0.184	0.427
WCSP	White-crowned Sparrow	0.40	0.001	0.794	0.23	-0.170	0.663	0.38	0.061	0.718
WEBL	Western Bluebird	0.41	-0.020	0.869	0.68	0.224	1.168	0.15	-0.214	0.530
WEKI	Western Kingbird	0.02	-0.252	0.278	0.08	-0.167	0.340	0.19	-0.049	0.423
WEME	Western Meadowlark	-0.75	-1.052	-0.454	-0.56	-0.867	-0.276	-0.34	-0.634	-0.061
WESJ	Western Scrub-Jay	0.42	0.110	0.715	0.47	0.182	0.759	0.17	-0.077	0.434
WETA	Western Tanager	0.27	-0.239	0.835	0.23	-0.337	0.813	0.04	-0.368	0.424
WEWP	Western Wood-Pewee	0.09	-0.334	0.523	0.81	0.371	1.294	0.27	-0.058	0.624
WIWA	Wilson's Warbler	0.06	-0.359	0.471	0.28	-0.139	0.727	0.07	-0.260	0.385
WREN	Wrentit	0.12	-0.367	0.596	0.97	0.416	1.550	0.39	0.006	0.791
WTSW	White-throated Swift	0.10	-0.547	0.718	0.27	-0.539	1.150	0.13	-0.321	0.557
YBCH	Yellow-breasted Chat	-0.18	-0.808	0.424	0.35	-0.367	1.092	0.09	-0.327	0.500
YBMA	Yellow-billed Magpie	0.23	-0.250	0.687	-0.08	-0.597	0.423	0.22	-0.144	0.610
YEWA	Yellow Warbler	-0.09	-0.573	0.413	0.67	0.136	1.210	-0.03	-0.410	0.329
YHBL	Yellow-headed Blackbird	-0.42	-0.849	0.001	0.32	-0.100	0.750	0.26	-0.058	0.594
YRWA	Yellow-rumped Warbler	0.63	0.133	1.137	-0.02	-0.510	0.472	0.19	-0.180	0.569

Species Code	Common Name	PSI (distance to urban)			PSI (year)			P (max temperature)		
		Mean	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*	
AMCR	American Crow	-0.30	-0.580	-0.027	0.17	-0.142	0.503	-0.04	-0.463	0.334
AMGO	American Goldfinch	-0.34	-0.623	-0.081	0.10	-0.182	0.394	0.28	-0.085	0.664
AMPI	American Pipit	0.17	-0.141	0.496	1.16	0.502	1.978	0.15	-0.242	0.558
AMRO	American Robin	-0.33	-0.585	-0.082	0.20	-0.076	0.473	0.09	-0.240	0.400
ATFL	Ash-throated Flycatcher	-0.02	-0.271	0.214	-0.24	-0.501	0.017	0.14	-0.221	0.504
BANS	Bank Swallow	-0.11	-0.552	0.323	0.34	-0.569	1.319	0.18	-0.343	0.671
BARS	Barn Swallow	-0.12	-0.458	0.206	-0.22	-0.745	0.260	0.13	-0.339	0.572
BESP	Bell’s Sparrow	-0.18	-0.583	0.183	0.76	0.096	1.553	0.02	-0.522	0.506
BEWR	Bewick's Wren	-0.03	-0.288	0.212	-0.13	-0.401	0.160	0.36	0.018	0.731
BGGN	Blue-gray Gnatcatcher	-0.09	-0.532	0.355	0.34	-0.587	1.304	0.17	-0.319	0.693
BHCO	Brown-headed Cowbird	-0.09	-0.342	0.157	0.01	-0.280	0.290	0.33	0.015	0.675
BHGR	Black-headed Grosbeak	0.08	-0.187	0.346	-0.22	-0.542	0.085	0.35	-0.003	0.734
BLGR	Blue Grosbeak	0.13	-0.160	0.432	-0.13	-0.510	0.238	0.28	-0.096	0.723
BLPH	Black Phoebe	-0.22	-0.474	0.030	-0.04	-0.328	0.235	0.20	-0.122	0.525
BRBL	Brewer's Blackbird	0.03	-0.217	0.288	0.11	-0.180	0.380	0.05	-0.311	0.408

Species Code	Common Name	PSI (distance to urban)			PSI (year)			P (max temperature)		
		Mean	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*	
BTYW	Black-throated Gray Warbler	-0.11	-0.556	0.320	0.34	-0.531	1.332	0.25	-0.235	0.791
BUOR	Bullock's Oriole	0.01	-0.220	0.248	0.11	-0.142	0.366	0.29	-0.055	0.647
BUSH	Bushtit	-0.24	-0.524	0.030	-0.18	-0.482	0.147	0.18	-0.185	0.540
CAKI	Cassin's Kingbird	0.03	-0.373	0.469	0.40	-0.420	1.267	0.14	-0.362	0.617
CALT	California Towhee	-0.04	-0.299	0.207	-0.03	-0.299	0.243	0.37	0.023	0.743
CATH	California Thrasher	-0.09	-0.519	0.336	0.21	-0.539	1.025	0.12	-0.364	0.603
CAVI	Cassin's Vireo	-0.10	-0.563	0.342	0.35	-0.578	1.355	0.17	-0.340	0.686
CEDW	Cedar Waxwing	0.01	-0.360	0.387	0.84	0.103	1.687	0.24	-0.179	0.704
CHSP	Chipping Sparrow	-0.07	-0.501	0.358	0.44	-0.428	1.456	0.17	-0.330	0.668
CLSW	Cliff Swallow	0.07	-0.207	0.345	-0.39	-0.766	-0.044	0.37	-0.018	0.824
CORA	Common Raven	-0.01	-0.257	0.242	-0.19	-0.485	0.097	0.20	-0.139	0.554
COYE	Common Yellowthroat	0.13	-0.106	0.382	0.16	-0.114	0.434	-0.02	-0.393	0.335
DEJU	Dark-eyed Junco	-0.21	-0.650	0.188	0.61	-0.180	1.568	0.14	-0.353	0.638
EUST	European Starling	-0.21	-0.462	0.033	-0.10	-0.369	0.167	0.20	-0.114	0.529
FOSP	Fox Sparrow	-0.12	-0.567	0.318	0.35	-0.563	1.335	0.17	-0.313	0.677
GCSP	Golden-crowned Sparrow	-0.30	-0.655	0.035	1.15	0.473	2.012	0.13	-0.287	0.540
GRSP	Grasshopper Sparrow	0.04	-0.352	0.470	0.52	-0.284	1.383	0.27	-0.214	0.804
GTGR	Great-tailed Grackle	-0.14	-0.486	0.189	0.18	-0.279	0.666	0.33	-0.104	0.812
HETH	Hermit Thrush	-0.24	-0.676	0.144	0.63	-0.129	1.542	-0.01	-0.554	0.444
HOFI	House Finch	-0.16	-0.391	0.062	-0.12	-0.387	0.153	0.47	0.148	0.830
HOLA	Horned Lark	0.21	-0.058	0.474	-0.15	-0.449	0.150	0.00	-0.402	0.365
HOSP	House Sparrow	-0.01	-0.310	0.286	0.22	-0.157	0.621	0.15	-0.242	0.554
HOWR	House Wren	-0.21	-0.471	0.043	-0.02	-0.296	0.251	0.05	-0.300	0.391
HUVI	Hutton's Vireo	-0.11	-0.550	0.300	0.15	-0.603	0.952	0.14	-0.387	0.642
LASP	Lark Sparrow	-0.12	-0.490	0.218	0.03	-0.462	0.547	0.33	-0.090	0.820
LAZB	Lazuli Bunting	-0.01	-0.371	0.375	0.28	-0.330	0.907	0.32	-0.091	0.817
LCTH	Le Conte's Thrasher	-0.16	-0.611	0.257	0.41	-0.380	1.353	0.10	-0.420	0.596
LEGO	Lesser Goldfinch	-0.12	-0.419	0.171	0.24	-0.156	0.649	0.31	-0.065	0.722
LISP	Lincoln's Sparrow	0.09	-0.298	0.511	0.72	-0.093	1.634	-0.01	-0.494	0.434
LOSH	Loggerhead Shrike	-0.05	-0.349	0.234	-0.25	-0.573	0.077	0.29	-0.120	0.725
MAWR	Marsh Wren	0.08	-0.158	0.343	0.02	-0.265	0.299	0.28	-0.077	0.688
MGWA	MacGillivray's Warbler	-0.05	-0.496	0.359	0.53	-0.279	1.495	0.19	-0.290	0.686
NAWA	Nashville Warbler	-0.10	-0.536	0.328	0.34	-0.544	1.302	0.16	-0.331	0.680

Species Code	Common Name	PSI (distance to urban)			PSI (year)			P (max temperature)		
		Mean	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*	
NOMO	Northern Mockingbird	-0.08	-0.299	0.135	0.05	-0.196	0.292	0.21	-0.091	0.551
NRWS	Northern Rough-winged Swallow	-0.12	-0.472	0.222	0.33	-0.163	0.851	0.19	-0.237	0.637
OATI	Oak Titmouse	0.00	-0.305	0.284	-0.08	-0.414	0.280	0.05	-0.339	0.416
OCWA	Orange-crowned Warbler	-0.22	-0.584	0.106	-0.01	-0.511	0.482	-0.06	-0.543	0.368
PHAI	Phainopepla	-0.08	-0.495	0.325	0.21	-0.530	1.016	0.20	-0.264	0.660
PSFL	Pacific-slope Flycatcher	-0.16	-0.585	0.227	0.51	-0.236	1.400	-0.07	-0.623	0.380
PUFI	Purple Finch	-0.14	-0.556	0.269	0.52	-0.298	1.492	0.22	-0.257	0.733
RCKI	Ruby-crowned Kinglet	-0.09	-0.513	0.308	0.64	-0.136	1.563	0.00	-0.507	0.423
RCSP	Rufous-crowned Sparrow	0.04	-0.378	0.495	0.29	-0.549	1.218	0.10	-0.440	0.587
ROWR	Rock Wren	0.01	-0.411	0.452	-0.32	-1.178	0.514	0.18	-0.317	0.694
RWBL	Red-winged Blackbird	0.04	-0.182	0.269	0.27	0.027	0.515	0.16	-0.168	0.487
SAGS	Sage Sparrow	-0.07	-0.533	0.383	-0.11	-1.036	0.795	0.17	-0.323	0.660
SAVS	Savannah Sparrow	0.28	-0.010	0.592	1.39	0.794	2.144	0.24	-0.122	0.639
SOSP	Song Sparrow	0.11	-0.117	0.356	-0.07	-0.336	0.194	-0.15	-0.568	0.233
SPTO	Spotted Towhee	-0.27	-0.551	-0.016	-0.24	-0.523	0.034	0.31	-0.018	0.704
SWTH	Swainson's Thrush	-0.12	-0.585	0.306	0.34	-0.547	1.305	0.19	-0.302	0.718
TRBL	Tricolored Blackbird	0.05	-0.324	0.437	0.14	-0.479	0.815	0.28	-0.212	0.836
TRES	Tree Swallow	-0.15	-0.383	0.089	0.10	-0.155	0.356	0.19	-0.139	0.518
WAVI	Warbling Vireo	-0.03	-0.413	0.332	0.88	0.169	1.776	0.14	-0.296	0.562
WBNU	White-breasted Nuthatch	-0.14	-0.453	0.150	0.12	-0.249	0.521	0.20	-0.177	0.608
WCSP	White-crowned Sparrow	-0.27	-0.591	0.042	1.64	1.036	2.399	0.02	-0.381	0.417
WEBL	Western Bluebird	-0.28	-0.670	0.067	-0.09	-0.554	0.385	0.24	-0.173	0.664
WEKI	Western Kingbird	-0.01	-0.240	0.210	-0.25	-0.502	-0.001	0.12	-0.180	0.436
WEME	Western Meadowlark	0.12	-0.130	0.379	0.33	0.059	0.599	-0.04	-0.387	0.271
WESJ	Western Scrub-Jay	-0.40	-0.673	-0.137	-0.21	-0.473	0.054	-0.03	-0.400	0.323
WETA	Western Tanager	0.12	-0.268	0.527	0.79	0.043	1.667	0.20	-0.225	0.650
WEWP	Western Wood-Pewee	0.14	-0.173	0.468	0.12	-0.305	0.539	0.18	-0.241	0.589
WIWA	Wilson's Warbler	-0.04	-0.347	0.271	1.06	0.410	1.875	0.28	-0.117	0.683
WREN	Wrentit	-0.22	-0.624	0.144	-0.41	-0.923	0.075	0.16	-0.317	0.631
WTSW	White-throated Swift	0.01	-0.433	0.442	0.32	-0.522	1.299	0.17	-0.353	0.692

Species Code	Common Name	PSI (distance to urban)			PSI (year)			P (max temperature)		
		Mean	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*	
YBCH	Yellow-breasted Chat	-0.06	-0.475	0.339	0.12	-0.622	0.906	0.22	-0.248	0.732
YBMA	Yellow-billed Magpie	-0.21	-0.604	0.157	-0.08	-0.579	0.432	0.11	-0.370	0.569
YEWA	Yellow Warbler	-0.01	-0.359	0.339	0.87	0.191	1.686	0.20	-0.239	0.629
YHBL	Yellow-headed Blackbird	0.22	-0.103	0.553	0.35	-0.078	0.812	0.28	-0.166	0.770
YRWA	Yellow-rumped Warbler	-0.32	-0.715	0.033	1.09	0.371	1.952	-0.06	-0.528	0.372

Species Code	Common Name	P (Julian day)			P (temp * JD)			P (Noise)		
		Mean	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*	
AMCR	American Crow	0.60	0.208	1.014	-0.53	-1.167	0.108	0.17	-0.078	0.432
AMGO	American Goldfinch	0.25	-0.200	0.687	-0.39	-1.028	0.264	0.05	-0.164	0.273
AMPI	American Pipit	-0.43	-1.155	0.275	-0.98	-1.833	-0.216	-0.58	-0.915	-0.268
AMRO	American Robin	-0.11	-0.498	0.263	-0.38	-0.975	0.250	-0.08	-0.231	0.069
ATFL	Ash-throated Flycatcher	0.69	0.255	1.142	-0.69	-1.314	-0.082	-0.05	-0.197	0.095
BANS	Bank Swallow	0.32	-0.718	1.284	-0.58	-1.557	0.345	-0.14	-0.666	0.366
BARS	Barn Swallow	0.69	0.098	1.339	-0.67	-1.445	0.050	0.06	-0.254	0.390
BESP	Bell's Sparrow	0.71	-0.028	1.488	-0.80	-1.710	0.078	-0.03	-0.465	0.437
BEWR	Bewick's Wren	0.08	-0.310	0.476	-0.63	-1.271	-0.031	-0.46	-0.647	-0.277
BGGN	Blue-gray Gnatcatcher	0.29	-0.713	1.315	-0.59	-1.540	0.296	-0.13	-0.650	0.417
BHCO	Brown-headed Cowbird	0.10	-0.276	0.460	-0.18	-0.785	0.422	-0.19	-0.314	-0.074
BHGR	Black-headed Grosbeak	0.97	0.465	1.491	-0.51	-1.167	0.108	-0.55	-0.773	-0.331
BLGR	Blue Grosbeak	1.01	0.440	1.582	-0.21	-0.888	0.438	-0.09	-0.405	0.203
BLPH	Black Phoebe	0.16	-0.270	0.582	-0.43	-1.070	0.182	-0.14	-0.303	0.014
BRBL	Brewer's Blackbird	0.51	0.077	0.946	-0.79	-1.434	-0.137	0.04	-0.133	0.206
BTYW	Black-throated Gray Warbler	0.24	-0.872	1.334	-0.48	-1.471	0.536	-0.21	-0.748	0.307
BUOR	Bullock's Oriole	0.23	-0.188	0.636	-0.17	-0.795	0.471	0.07	-0.078	0.223
BUSH	Bushtit	0.18	-0.273	0.649	-0.51	-1.162	0.112	-0.38	-0.630	-0.138
CAKI	Cassin's Kingbird	0.79	-0.254	1.872	-0.50	-1.505	0.430	-0.07	-0.592	0.473
CALT	California Towhee	0.61	0.211	1.037	-0.58	-1.226	0.030	-0.19	-0.356	-0.025
CATH	California Thrasher	0.23	-0.665	1.118	-0.69	-1.623	0.166	-0.14	-0.627	0.344
CAVI	Cassin's Vireo	0.33	-0.727	1.349	-0.57	-1.494	0.378	-0.14	-0.664	0.376
CEDW	Cedar Waxwing	0.42	-0.498	1.304	-0.46	-1.328	0.376	-0.20	-0.642	0.222
CHSP	Chipping Sparrow	0.29	-0.683	1.293	-0.58	-1.483	0.357	-0.13	-0.628	0.379

Species Code	Common Name	P (Julian day)			P (temp * JD)			P (Noise)		
		Mean	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*	
CLSW	Cliff Swallow	0.57	0.040	1.103	-0.42	-1.074	0.190	-0.28	-0.473	-0.087
CORA	Common Raven	0.76	0.328	1.217	-0.88	-1.555	-0.298	-0.11	-0.288	0.077
COYE	Common Yellowthroat	0.85	0.431	1.304	-0.85	-1.487	-0.214	-0.32	-0.509	-0.123
DEJU	Dark-eyed Junco	0.11	-0.791	1.021	-0.74	-1.677	0.109	-0.18	-0.646	0.258
EUST	European Starling	0.17	-0.216	0.568	-0.50	-1.150	0.098	0.14	0.004	0.272
FOSP	Fox Sparrow	0.31	-0.731	1.304	-0.60	-1.539	0.305	-0.13	-0.659	0.394
GCSP	Golden-crowned Sparrow	-0.46	-1.176	0.255	-0.94	-1.797	-0.197	-0.18	-0.504	0.122
GRSP	Grasshopper Sparrow	0.20	-0.840	1.257	-0.48	-1.398	0.466	-0.26	-0.805	0.258
GTGR	Great-tailed Grackle	0.10	-0.583	0.750	-0.45	-1.204	0.297	-0.308	-0.721	0.085
HETH	Hermit Thrush	-0.03	-0.980	0.917	-0.97	-1.970	-0.135	-0.094	-0.586	0.390
HOFI	House Finch	0.09	-0.235	0.447	-0.57	-1.208	-0.012	0.061	-0.053	0.172
HOLA	Horned Lark	0.68	0.227	1.173	-0.86	-1.493	-0.240	-0.033	-0.182	0.109
HOSP	House Sparrow	0.81	0.204	1.436	-0.45	-1.111	0.179	0.222	-0.095	0.559
HOWR	House Wren	0.08	-0.314	0.468	-0.39	-0.993	0.234	0.070	-0.087	0.229
HUVI	Hutton's Vireo	0.58	-0.247	1.462	-0.56	-1.488	0.380	-0.177	-0.680	0.345
LASP	Lark Sparrow	0.39	-0.393	1.172	-0.31	-1.031	0.446	0.161	-0.225	0.569
LAZB	Lazuli Bunting	0.31	-0.458	1.062	-0.40	-1.249	0.465	-0.260	-0.672	0.155
LCTH	Le Conte's Thrasher	0.40	-0.670	1.579	-0.68	-1.725	0.275	-0.238	-0.790	0.292
LEGO	Lesser Goldfinch	0.23	-0.258	0.734	-0.49	-1.222	0.209	-0.335	-0.571	-0.101
LISP	Lincoln's Sparrow	0.03	-0.811	0.890	-0.96	-1.909	-0.148	-0.102	-0.538	0.331
LOSH	Loggerhead Shrike	0.12	-0.373	0.629	-0.02	-0.641	0.587	0.344	0.126	0.557
MAWR	Marsh Wren	0.55	0.093	1.009	-0.55	-1.210	0.077	0.032	-0.200	0.271
MGWA	MacGillivray's Warbler	0.34	-0.668	1.337	-0.52	-1.488	0.374	-0.165	-0.667	0.349
NAWA	Nashville Warbler	0.30	-0.698	1.307	-0.61	-1.542	0.269	-0.114	-0.640	0.422
NOMO	Northern Mockingbird	0.78	0.407	1.165	-0.65	-1.274	-0.058	-0.018	-0.134	0.104
NRWS	Northern Rough-winged Swallow	0.61	-0.078	1.301	-0.55	-1.328	0.191	-0.342	-0.826	0.113
OATI	Oak Titmouse	0.17	-0.338	0.640	-0.34	-1.006	0.375	-0.199	-0.421	0.019
OCWA	Orange-crowned Warbler	0.10	-0.486	0.722	-1.05	-1.906	-0.269	-0.049	-0.345	0.253
PHAI	Phainopepla	0.05	-0.823	0.932	-0.68	-1.574	0.161	-0.108	-0.594	0.379
PSFL	Pacific-slope Flycatcher	-0.17	-1.222	0.743	-1.13	-2.077	-0.326	-0.300	-0.831	0.214
PUFI	Purple Finch	0.39	-0.493	1.283	-0.46	-1.335	0.422	-0.205	-0.715	0.300

Species Code	Common Name	P (Julian day)			P (temp * JD)			P (Noise)		
		Mean	*95% CI*		*Mean*	*95% CI*		*Mean*	*95% CI*	
RCKI	Ruby-crowned Kinglet	-0.06	-0.935	0.834	-0.99	-1.934	-0.162	-0.048	-0.526	0.432
RCSP	Rufous-crowned Sparrow	0.38	-0.708	1.517	-0.73	-1.811	0.217	-0.272	-0.831	0.250
ROWR	Rock Wren	0.49	-0.484	1.516	-0.49	-1.443	0.454	-0.284	-0.779	0.183
RWBL	Red-winged Blackbird	-0.15	-0.527	0.198	0.20	-0.406	0.827	-0.152	-0.267	-0.037
SAGS	Sage Sparrow	0.29	-0.679	1.307	-0.58	-1.556	0.370	-0.107	-0.632	0.415
SAVS	Savannah Sparrow	-0.22	-0.866	0.541	-1.04	-1.908	-0.286	-0.28	-0.530	-0.027
SOSP	Song Sparrow	0.67	0.256	1.090	-0.77	-1.437	-0.100	-0.51	-0.680	-0.348
SPTO	Spotted Towhee	0.62	0.239	1.032	-0.82	-1.484	-0.236	-0.21	-0.358	-0.056
SWTH	Swainson's Thrush	0.33	-0.709	1.329	-0.54	-1.529	0.359	-0.16	-0.671	0.365
TRBL	Tricolored Blackbird	0.84	0.074	1.625	-0.10	-0.898	0.767	-0.17	-0.690	0.336
TRES	Tree Swallow	0.34	-0.007	0.709	-0.51	-1.106	0.107	-0.08	-0.218	0.054
WAVI	Warbling Vireo	0.34	-0.477	1.135	-0.63	-1.413	0.136	-0.29	-0.720	0.151
WBNU	White-breasted Nuthatch	0.74	0.220	1.261	-0.34	-1.054	0.329	-0.24	-0.513	0.040
WCSP	White-crowned Sparrow	-1.08	-1.666	-0.467	-1.41	-2.339	-0.583	-0.06	-0.262	0.124
WEBL	Western Bluebird	0.43	-0.163	1.042	-0.43	-1.162	0.299	-0.01	-0.439	0.411
WEKI	Western Kingbird	0.22	-0.130	0.581	-0.13	-0.671	0.419	-0.26	-0.375	-0.146
WEME	Western Meadowlark	0.06	-0.322	0.394	-0.01	-0.560	0.600	0.08	-0.021	0.193
WESJ	Western Scrub-Jay	0.77	0.343	1.190	-0.57	-1.222	0.078	0.23	0.069	0.380
WETA	Western Tanager	0.49	-0.313	1.311	-0.50	-1.330	0.331	-0.01	-0.415	0.429
WEWP	Western Wood-Pewee	1.08	0.469	1.708	-0.51	-1.227	0.162	-0.69	-1.020	-0.377
WIWA	Wilson's Warbler	-0.21	-0.929	0.504	-0.63	-1.411	0.132	-0.27	-0.680	0.114
WREN	Wrentit	0.00	-0.623	0.623	-0.79	-1.644	-0.003	-0.01	-0.337	0.344
WTSW	White-throated Swift	0.36	-0.677	1.382	-0.57	-1.542	0.396	-0.14	-0.663	0.404
YBCH	Yellow-breasted Chat	0.08	-0.926	1.062	-0.59	-1.522	0.339	0.13	-0.342	0.639
YBMA	Yellow-billed Magpie	0.94	0.172	1.714	-0.73	-1.510	-0.031	-0.03	-0.356	0.296
YEWA	Yellow Warbler	0.37	-0.518	1.252	-0.58	-1.422	0.265	-0.05	-0.486	0.407
YHBL	Yellow-headed Blackbird	0.16	-0.510	0.820	-0.41	-1.159	0.359	0.16	-0.233	0.573
YRWA	Yellow-rumped Warbler	-0.52	-1.324	0.212	-1.26	-2.241	-0.410	-0.23	-0.595	0.114

Appendix I

Financial Statements

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Kern Water Bank Authority

Financial Statements

December 31, 2018 and 2017

C O N T E N T S

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BROWN ARMSTRONG
Certified Public Accountants

INDEPENDENT AUDITOR'S REPORT

Board of Directors
Kern Water Bank Authority
Bakersfield, California

Report on the Financial Statements

We have audited the accompanying financial statements of the Kern Water Bank Authority (the Authority) as of and for the years ended December 31, 2018 and 2017, and the related notes to the financial statements, which collectively comprise the Authority's basic financial statements as listed in the table of contents.

Management's Responsibility for the Financial Statements

Management is responsible for the preparation and fair presentation of these financial statements in accordance with accounting principles generally accepted in the United States of America; this includes the design, implementation, and maintenance of internal control relevant to the preparation and fair presentation of financial statements that are free from material misstatement, whether due to fraud or error.

Auditor's Responsibility

Our responsibility is to express opinions on these financial statements based on our audits. We conducted our audits in accordance with auditing standards generally accepted in the United States of America and the standards applicable to financial audits contained in *Government Auditing Standards*, issued by the Comptroller General of the United States. Those standards require that we plan and perform the audits to obtain reasonable assurance about whether the financial statements are free from material misstatement.

An audit involves performing procedures to obtain audit evidence about the amounts and disclosures in the financial statements. The procedures selected depend on the auditor's judgment, including the assessment of the risks of material misstatement of the financial statements, whether due to fraud or error. In making those risk assessments, the auditor considers internal control relevant to the Authority's preparation and fair presentation of the financial statements in order to design audit procedures that are appropriate in the circumstances, but not for the purpose of expressing an opinion on the effectiveness of the Authority's internal control. Accordingly, we express no such opinion. An audit also includes evaluating the appropriateness of accounting policies used and the reasonableness of significant accounting estimates made by management, as well as evaluating the overall presentation of the financial statements.

We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our audit opinion.

Opinions

In our opinion, the financial statements referred to above present fairly, in all material respects, the respective financial position of the Authority as of December 31, 2018 and 2017, and the respective changes in financial position and cash flows thereof for the years then ended in accordance with accounting principles generally accepted in the United States of America.

Other Matters

Required Supplementary Information

Accounting principles generally accepted in the United States of America require that the management's discussion and analysis on pages 4 through 10 be presented to supplement the basic financial statements. Such information, although not a part of the basic financial statements, is required by the Governmental Accounting Standards Board who considers it to be an essential part of financial reporting for placing the basic financial statements in an appropriate operational, economic, or historical context. We have applied certain limited procedures to the required supplementary information in accordance with auditing standards generally accepted in the United States of America, which consisted of inquiries of management about the methods of preparing the information and comparing the information for consistency with management's responses to our inquiries, the basic financial statements, and other knowledge we obtained during our audit of the basic financial statements. We do not express an opinion or provide any assurance on the information because the limited procedures do not provide us with sufficient evidence to express an opinion or provide any assurance.

Other Supplementary Information

Our audits were conducted for the purpose of forming an opinion on the financial statements that collectively comprise the Authority's basic financial statements. The other supplementary information, as noted in the table of contents, are presented for purposes of additional analysis and are not a required part of the basic financial statements.

The other supplementary information is the responsibility of management and was derived from and relates directly to the underlying accounting and other records used to prepare the basic financial statements. Such information has been subjected to the auditing procedures applied in the audit of the basic financial statements and certain additional procedures, including comparing and reconciling such information directly to the underlying accounting and other records used to prepare the basic financial statements or to the basic financial statements themselves, and other additional procedures in accordance with auditing standards generally accepted in the United States of America. In our opinion, other supplementary information, as noted in the table of contents, is fairly stated, in all material respects, in relation to the basic financial statements as a whole.

Other Reporting Required by *Government Auditing Standards*

In accordance with *Government Auditing Standards*, we have also issued our report dated May 2, 2019, on our consideration of the Authority's internal control over financial reporting and on our tests of its compliance with certain provisions of laws, regulations, contracts, and grant agreements and other matters. The purpose of that report is to describe the scope of our testing of internal control over financial reporting and compliance and the results of that testing, and not to provide an opinion on internal control over financial reporting or on compliance. That report is an integral part of an audit performed in accordance with *Government Auditing Standards* and should be considered in assessing the results of our audits.

BROWN ARMSTRONG
ACCOUNTANCY CORPORATION

Brown Armstrong Accountancy Corporation

Bakersfield, California
May 2, 2019

Management's Discussion and Analysis

As management of the Kern Water Bank Authority (the Authority), we offer readers of the Authority's financial statements this narrative overview and analysis of the Authority's financial performance during the fiscal years ended December 31, 2018 and 2017. Please read it in conjunction with the Authority's financial statements, which follow this section.

The Authority is a Joint Powers Authority, established October 16, 1995, under the Joint Exercise of Powers Act. The Authority operates the Kern Water Bank, which is an area of land (approximately 20,000 acres) located in the southwest portion of the San Joaquin Valley uniquely suited for water recharge, water recovery and habitat preservation.

The Authority is a public agency, whose participants are the Kern County Water Agency, water storage districts, water districts and a mutual water company. The Authority oversees the day-to-day operations of the Kern Water Bank on behalf of the Participants.

The Authority recharges, recovers and stores water on behalf of the Participants. The Authority's governing body is a seven-member Board of Directors, comprised of Participant representatives, which includes a Chairman and a Vice-Chairman.

Participants receive water from a number of sources including the State Water Project (SWP), the Central Valley Project via the Friant-Kern Canal, and the Kern River. Participants recognized the benefit of developing the Kern Water Bank lands and constructed recharge basins, recovery wells, canals and other banking facilities on a portion of the Kern Water Bank lands while preserving the land for habitat conservation. Participants, under the Authority, utilize these banking facilities to create a more reliable water supply.

Hydrological patterns tend to be cyclical, often creating multiple years of abundant water supply followed by multiple years of water supply shortage. Participants have, or acquire, water surplus to accommodate their needs in wet years and place it in storage in the Kern Water Bank for future recovery in dry years. This provides Participants with a unique water supply regulation tool.

Significant precipitation in the winter of 2017 resulted in a substantial snowpack throughout the Sierra Nevada. As a result, the Authority was able to recharge a record 566,000 acre-feet of water, with recharge operations continuing from January through the end of 2017 and into early 2018.

Conditions in 2018 were dry, but water available from the previous year helped alleviate conditions. The Authority recharged approximately 13,000 acre-feet of water in January and February and recovered approximately 38,000 acre-feet of water from March through September 2018.

Financial Highlights

The Authority's total assets decreased by $2.9 million, or 3.86%, over the course of 2018, largely due to decreased Participant assessments and an associated decrease of accounts receivable at year end.

The Authority's total revenues decreased from $14.7 million to $8.3 million because of decreased assessments from Participants in 2018 as capital improvements and land purchases that were assessed in 2017 were not required in 2018. Total expenses increased from $7.5 million to $7.8 million because of increased general and administrative (G&A) expenses, primarily due to an increase in legal fees.

The Authority's long-term debt decreased by $1.6 million from $12.5 million to $10.9 million. This was due to principal payments paid to the variable rate bond investors and to the State of California Department of Water Resources (DWR) of $1,080,000 and $289,985, respectively, and a decrease in the fair value of the interest rate swap of $238,559.

Overview of the Financial Statements

This annual financial report includes this management's discussion and analysis, the independent auditor's report, the basic financial statements of the Authority and selected supplementary information. The financial statements also include notes that explain in more detail some of the information in the financial statements.

Required Financial Statements

The financial statements of the Authority report information of the Authority using accounting methods similar to those used by private sector companies. These statements offer short and long-term financial information about its activities. The Statement of Net Position includes all of the Authority's assets, deferred outflows of resources, liabilities and deferred inflows of resources and provides information about the nature and amounts of investments in resources (assets) and the obligations to Authority creditors (liabilities). It also provides the basis for evaluating the capital structure of the Authority and assessing the liquidity and financial flexibility of the Authority.

All of the current year's revenues and expenses are accounted for in the Statement of Revenues and Expenses and Changes in Net Position. This statement can be used to determine whether the Authority has successfully recovered all of its costs through its user fees and other charges, its profitability, and its credit worthiness. It also reconciles the beginning net position balance to the ending net position balance.

The final required financial statement is the Statement of Cash Flows. This statement reports cash receipts, cash payments, and net changes in cash resulting from operations, financing, and investing activities and provides answers to such questions as where did cash come from, what was cash used for, and what was the change in the cash balance during the reporting period.

Financial Analysis of the Authority

One of the most important questions asked about the Authority's finances is, "Has the Authority met all of its financial obligations in 2018?" The Statement of Net Position and the Statement of Revenues and Expenses and Changes in Net Position report information about the Authority's activities in a way that will help answer this question. These statements report the net position of the Authority and the changes in it. One can think of the Authority's net position - the difference between assets, deferred inflows of resources, deferred outflows of resources and liabilities - as one way to measure financial health or financial position. However, one will need to consider other non-financial factors such as changes in economic conditions, population growth, and new or changed government legislation.

Net Position

To begin our analysis, a summary of the Authority's Statements of Net Position is presented in the following table.

Condensed Statements of Net Position
December 31, 2018 and 2017
(000's)

	2018	2017	Dollar Change	Percentage Change
Current Assets	$ 8,233	$ 14,328	$ (6,095)	(42.54) %
Capital Assets - Net	63,092	59,725	3,367	5.64 %
Restricted Assets	1,614	1,812	(198)	(10.93) %
Total Assets	72,939	75,865	(2,926)	(3.86) %
Deferred Outflows of Resources	372	610	(238)	(39.02) %
	$ 73,311	$ 76,475	$ (3,164)	(4.14) %
Current Liabilities	$ 5,900	$ 7,903	$ (2,003)	(25.34) %
Long-Term Debt	10,873	12,489	(1,616)	(12.94) %
Total Liabilities	16,773	20,392	(3,619)	(17.75) %
Net Investment in Capital Assets	50,842	45,866	4,976	10.85 %
Restricted	1,614	1,812	(198)	(10.93) %
Unrestricted	4,082	8,405	(4,323)	(51.43) %
Total Net Position	56,538	56,083	455	0.81 %
	$ 73,311	$ 76,475	$ (3,164)	(4.14) %

The decrease in current assets from the year ended 2017 to 2018 of 42.54% is largely due to no additional Participant assessments and the associated decrease of accounts receivable owed to the Authority due to completion of capital asset improvements throughout 2018. The increase in capital assets is due to offsetting investments in facilities and depreciation, and the decrease in restricted assets is due to reduced assessment requirements for the variable rate bonds interest. The decrease in total liabilities of 17.75% is due, primarily, to a decrease in Participant reimbursement payable and a decrease in Long-Term Debt.

The following chart summarizes the Comparative Statements of Revenues and Expenses and Changes in Net Position.

Condensed Statements of Revenues and Expenses and Changes in Net Position
For the Years Ended December 31, 2018 and 2017
(000's)

	2018	*2017*	*Dollar Change*	*Percentage Change*
Operating Revenues, Net	$ 7,110	$ 14,004	$ (6,894)	(49.23) %
Nonoperating Revenues	1,163	646	517	80.03 %
Total Revenues	8,273	14,650	(6,377)	(43.53) %
Operating Expenses	7,227	6,862	365	5.32 %
Nonoperating Expenses	591	640	(49)	(7.66) %
Total Expenses	7,818	7,502	316	4.21 %
Change in Net Position	455	7,148	(6,693)	
Net Position, Beginning of Year	56,083	48,935	7,148	
Net Position, End of Year	$ 56,538	$ 56,083	$ 455	

Operating revenues in 2018 were $7.1 million compared to $14.0 million in 2017. Operating expenses in 2018 of $7.2 million represent an increase of 5.32% from the 2017 expenses reported of $6.9 million. The decrease in revenues is because no additional assessments from the Participants were required for capital improvements and land purchase in 2018, and due to a decrease in fees charged for operations. The increase in expenses is because of increased legal fees. Total expenses did not exceed total revenues in 2018, thus, the Authority was able to meet all of its financial obligations for 2018.

Budgetary Highlights

The Authority adopts an annual budget each year to project the expected coming year's administrative, land management, and general maintenance operations. The budget includes these proposed expenses and the means of financing them. The Authority's budget remains in effect the entire year. Budget-to-actual comparisons were analyzed by management throughout the year; however, it is not reported on, nor shown in, the financial statements section of this report.

A December 31, 2018 budget-to-actual comparison is presented in the following table:

General and Administrative
Budget vs. Actual Comparison
For the Year Ended December 31, 2018
(000's)

	Actual	Budget	Variance
G&A Revenues	$ 2,958	$ 2,790	$ 168
Other G&A Revenues	184	45	139
Total G&A Revenues	3,142	2,835	307
G&A Expenses	2,697	2,835	(138)
Net Income	$ 445	$ -	$ 445

The Authority collected both semi-annual G&A assessments for the year ended December 31, 2018. The G&A revenues were over budget by $307,000, which is due to an increase in grazing income, an increase in interest revenue, and the sale of 9 conservation credits when no conservation credit income was budgeted for 2018. The G&A expenses are administrative expenses, such as payroll and benefits, equipment and supplies, general maintenance and legal fees. The 2018 G&A actual expenses were lower than expected because of lower than anticipated lab analysis costs for recovery well sampling and lower than anticipated electricity charges due to the wells being used to recover water and those costs being charged to Participants for operations.

The Authority collects estimated fees from Participants for their recharge and recovery activity based on usage. These fees and the expenses, in addition to offsetting debt service assessments and payments, are not included in the annual G&A budget.

Capital Assets

As of December 31, 2018, the Authority had invested $87.6 million in total capital assets as shown in the following table:

Capital Assets
December 31, 2018 and 2017
(000's)

	2018	2017	Dollar Change	Percentage Change
Land	$ 25,916	$ 23,614	$ 2,302.00	9.75 %
Wells - Recovery	40,058	35,971	4,087	11.36 %
Canals and Related Facilities	12,900	12,487	413	3.31 %
Earthwork - Recharge	6,087	4,338	1,749	40.32 %
Pumps - Recharge	568	568	-	- %
Roads and Fences	972	972	-	- %
Equipment	160	6	154	2,566.67 %
Office Equipment and Furniture	51	51	-	- %
Trucks and Autos	216	128	88	68.75 %
Buildings and Structures	207	-	207	100.00 %
Construction in Progress	479	4,476	(3,997)	(89.30) %
Total Capital Assets	87,614	82,611	5,003	6.06 %
Less: Accumulated Depreciation	24,522	22,886	1,636	7.15 %
Total Net Capital Assets	$ 63,092	$ 59,725	$ 3,367	5.64 %

Total capital assets net of depreciation increased from $59.7 million at December 31, 2017 to $63.1 million at December 31, 2018. This change reflects the balance of investments in facilities and depreciation.

Debt Service Requirements

Between 1999 and 2002, the Authority received a $5 million loan from the DWR. The proceeds of this loan were used to complete a portion of the Master Plan Construction Project, and the Authority makes monthly deposits into a fiscal service agent account for semi-annual principal and interest payments. As of December 31, 2018, the outstanding principal on this loan was approximately $1.08 million.

On November 25, 2003, the Authority received $27 million in proceeds from the issuance of two series of variable rate demand bonds, Series 2003A (tax exempt) and Series 2003B (taxable). The proceeds from this bond issuance were designated to pay off a 1999 Bank of America loan, fund the Authority's 50% match for a DWR Proposition 13 grant to construct the River Area well and pipeline project, enhance recharge basin capacities, expand security fencing and roads, and possibly build an office facility on the Kern Water Bank property.

As part of the bond issuance, Zions First National Bank, Trustee, established restricted cash accounts, including a $1 million Reserve Fund. The remainder of the bond proceeds was placed, primarily, in the Project Fund to be used for the construction projects. The final requisition was drawn in 2007.

The principal amount owed on this bond issuance as of December 31, 2018 was approximately $11.88 million. Principal is payable in annual installments, or mandatory redemptions, of $1.08 million due on July 1, beginning in 2004 and ending in 2028 (maturity). Variable interest on the two series of bonds is accrued weekly and paid monthly.

On July 27, 2005, the Authority entered into an Interest Rate Master Agreement with Wells Fargo Bank, N.A. which established a fixed interest rate swap on the outstanding balance of the Series A and Series B bonds through July 1, 2023, in which the Authority pays interest at 3.86% and 4.75%, respectively, in exchange for receiving a Bond Market Association (BMA) rate and a London Interbank Offered Rate (LIBOR), respectively. Payments are made monthly.

Kern Integrated Regional Water Management Implementation Grant

In 2014, the Kern Integrated Regional Water Management project proposal received final approval by the DWR. The Authority's portion of the project had an estimated cost of $3 million, of which a 25% match was provided by the Authority. The Authority is the lead agency with the DWR on the project. For the year ended December 31, 2018, $569,731 of grant funds were approved by DWR and received by the Authority.

Contacting the Authority's Management

This annual financial report is designed to provide our customers and creditors with a general overview of the Authority's finances and to demonstrate the Authority's accountability for the money it receives. If you have questions about this report or need additional financial information, contact the Kern Water Bank Authority, 1620 Mill Rock Way, Suite 500, Bakersfield, CA 93311.

Kern Water Bank Authority

Statements of Net Position
December 31, 2018 and 2017

ASSETS AND DEFERRED OUTFLOWS OF RESOURCES	***2018***	***2017***
Current Assets		
Cash and cash equivalents	$ 7,818,288	$ 9,788,541
Accounts receivable	395,546	4,405,782
Prepaid expenses	6,250	106,146
Interest receivable	12,695	27,447
	8,232,779	14,327,916
Capital Assets, net of accumulated depreciation	63,091,743	59,724,571
Restricted Assets	1,613,950	1,811,741
Total Assets	72,938,472	75,864,228
Deferred Outflows of Resources		
Deferred outflow of interest rate swap	371,834	610,393
	$ 73,310,306	$ 76,474,621

See Notes to Basic Financial Statements.

LIABILITIES AND NET POSITION	*2018*	*2017*
Current Liabilities		
Current maturities of long-term debt	$ 1,377,796	$ 1,369,915
Accounts payable	1,212,293	1,396,136
Accounts payable, water transfers	934,823	588,380
Participant reimbursements payable	2,029,990	4,289,860
Accrued interest payable	7,284	9,241
Mitigation funds payable	338,076	249,314
	5,900,262	7,902,846
Long-Term Liabilities		
Long-term debt, less current maturities	10,500,638	11,878,504
Fair value of interest rate swap	371,834	610,393
	10,872,472	12,488,897
Total Liabilities	16,772,734	20,391,743
Net Position		
Net investment in capital assets	50,841,475	45,865,759
Restricted for debt service	1,613,950	1,811,741
Unrestricted	4,082,147	8,405,378
	56,537,572	56,082,878
	$ 73,310,306	$ 76,474,621

Kern Water Bank Authority

Statements of Revenues, Expenses and Changes in Net Position
For the Years Ended December 31, 2018 and 2017

	2018	***2017***
Operating revenues, net of participant refunds	$ 7,110,452	$ 14,004,277
Operating expenses	(7,227,352)	(6,862,209)
Operating income	(116,900)	7,142,068
Nonoperating revenues	1,162,703	646,244
Nonoperating expenses	(591,109)	(640,013)
Nonoperating income	571,594	6,231
Change in net position	454,694	7,148,299
Net Position, beginning of year	56,082,878	48,934,579
Net Position, end of year	$ 56,537,572	$ 56,082,878

See Notes to Basic Financial Statements.

Kern Water Bank Authority

Statements of Cash Flows
For the Years Ended December 31, 2018 and 2017

	2018	2017
Cash flows from operating activities:		
Receipts from customers and participants	$ 8,949,580	$ 13,782,476
Payments to other suppliers for goods and services	(5,494,014)	(4,238,165)
Payments to employees for services	(645,933)	(667,691)
Net cash provided by operating activities	2,809,633	8,876,620
Cash flows from capital and related financing activities:		
Payments on long-term debt	(1,369,985)	(1,362,342)
Payments for construction of water banking facilities and capital assets	(4,327,565)	(1,802,639)
Interest paid on long-term debt	(425,167)	(460,644)
Reimbursement from Participants for interest on construction loan	36,506	44,149
Reimbursement from Participants for annual bond fees	339,480	425,140
Grant payments from DWR	569,731	40,074
Net cash used by capital and related financing activities	(5,177,000)	(3,116,262)
Cash flows from investing activities:		
Receipt of interest	199,323	109,488
Net increase (decrease) in cash and cash equivalents	(2,168,044)	5,869,846
Cash and cash equivalents at beginning of the year	11,600,282	5,730,436
Cash and cash equivalents at end of the year	$ 9,432,238	$ 11,600,282

See Notes to Basic Financial Statements.

	2018	2017
Reconciliation of operating income (loss) to net cash provided (used) by operating activities:		
Operating income	$ (116,900)	$ 7,142,068
Adjustments to reconcile operating income (loss) to net cash provided by operating activities:		
Depreciation	1,665,612	1,576,811
Other expense	(135,484)	(165,848)
Change in operating assets and liabilities:		
Accounts receivable	4,010,236	(3,692,083)
Prepaid expenses	99,896	(100,198)
Accounts payable	(3,148,932)	4,518,483
Accounts payable, water transfers	346,443	(230,902)
Advanced well replacement and refurbishment	-	(62,390)
Advanced mitigation funds	88,762	(109,321)
Net cash provided by operating activities	$ 2,809,633	$ 8,876,620
Supplemental disclosures of cash flow information:		
Reconciliation of cash and cash equivalents:		
Unrestricted cash	$ 7,818,288	$ 9,788,541
Restricted cash	1,613,950	1,811,741
	$ 9,432,238	$ 11,600,282
Noncash capital, investing and financing activities:		
Capital assets purchased through issuance of accounts payable	$ 858,240	$ 153,021
Participant refund through issuance of accounts payable	$ 2,029,990	$ 4,289,860
Change in fair value of interest rate swap liability	$ 238,559	$ 310,858

Note 1. Summary of Significant Accounting Policies

The reporting entity:

In 1995, the Monterey Agreement was signed which, among other things, modified how State Water Project water supplies are allocated and how users are charged. One of the components of the Monterey Agreement was the transfer of Kern Fan Element lands from the California Department of Water Resources (DWR) to local ownership.

Kern Water Bank Authority (the Authority) was established October 16, 1995 under the Joint Exercise of Powers Act, as amended by the First Amended and Restated Joint Powers Agreement signed July 19, 1999. The Authority is a public agency comprised of the Kern County Water Agency, water storage districts, water districts, and a mutual water company (Participants). Water is stored in aquifers during times of surplus and recovered during times of shortage. The Authority oversees all day-to-day operations of these facilities. As organized, the Authority does not own the stored water, but rather, acts on behalf of the Participants.

Kern Water Bank Authority Participants:

The Participants and their percentage of ownership are:

Tejon-Castac Water District	2.00%
Semitropic Water Storage District	6.67%
Dudley Ridge Water District	9.62%
Kern County Water Agency	9.62%
Wheeler Ridge-Maricopa Water Storage District	24.03%
Westside Mutual Water Company	48.06%

Management and Board of Directors:

The Authority has a full time staff to administer the day-to-day operations. The Authority's governing body is its seven-member Board of Directors (Board), which includes a Chairman and a Vice-Chairman. The joint powers agreement directs that voting is based on each member's ownership in the Authority.

Financial reporting:

The Authority prepares its financial statements in accordance with the provisions of Governmental Accounting Standards Board (GASB) Statement No. 34, "Basic Financial Statements - and Management's Discussion and Analysis - for State and Local Governments," as amended by GASB Statement No. 63 requires the classification of net position into three components – net investment in capital assets, restricted components of net position, and unrestricted components of net position. These classifications are defined as follows:

Net investment in capital assets - This component of net position consists of capital assets, including restricted capital assets, net of accumulated depreciation and reduced by the outstanding balances of any bonds, mortgages, notes, or other borrowings that are attributable to the acquisition, construction, or improvement of those assets. If there are significant unspent related debt proceeds at year end, the portion of the debt attributable to the unspent proceeds is not included in the calculation of investment in capital assets, net of related debt. Rather, that portion of the debt is included in the same net position component as the unspent proceeds.

Restricted component of net position - This component of net position consists of constraints placed on net position use through external constraints imposed by creditors (such as through debt covenants), grantors, contributors, or laws or regulations of other governments or constraints imposed by the law through constitutional provisions or enabling legislation.

Unrestricted component of net position - This component of net position consists of net position that does not meet the definition of “restricted” or “net investment in capital assets.”

Derivatives:

The Authority reports its interest rate swap in accordance with the provisions of GASB Statement No. 53, “Accounting and Financial Reporting for Derivative Instruments,” as amended by GASB Statement No. 64. Requires governments to measure derivative instruments, which include interest rate swaps, at fair value.

Deferred outflows/inflows of resources:

The Authority reports increases/decreases in net assets that relate to future periods as deferred outflows/inflows of resources in a separate section of the statements of net position. Deferred outflow and inflow of resources reported in the statements of net position are the results of value adjustments made for the fair value of the interest swap rate after the year end and will be recognized as a reduction of the fair value of interest rate swap liability in the following year.

Fund accounting:

The Authority utilizes a proprietary enterprise fund category to account for its activities. Enterprise funds are used to account for operations (a) that are financed and operated in a manner similar to private business enterprises - where the intent of the governing body is that the costs (expenses, including depreciation) of providing goods or services to the general public on a continuing basis be financed or recovered primarily through user charges or (b) where the governing body has decided that periodic determination of revenues earned, expenses incurred, and/or net income is appropriate for capital maintenance, public policy, management control, accountability or other purposes. Other items not properly included among operating revenues are reported as nonoperating revenues. All assets and liabilities associated with an enterprise fund's activities are included on its statement of net position.

Notes to Basic Financial Statements

Basis of accounting:

The accompanying financial statements are reported using the economic resources measurement focus and the accrual basis of accounting, in conformity with the uniform system of accounts prescribed for water districts by the Controller of the State California. Revenues are recognized when earned and expenses are recognized when a liability is incurred regardless of the timing of related cash flows.

When the Authority has both unrestricted and restricted resources available for Authority purposes, in is the Authority's practice to first expend restricted resources, subsequently utilizing unrestricted resources as needed.

Use of estimates:

The preparation of financial statements in conformity with accounting principles generally accepted in the United States of America requires management to make estimates and assumptions that affect the reporting of assets and liabilities and revenue and expenses in the financial statements and accompanying notes. Actual results could differ from those estimates.

Retirement plan:

Employees of the Authority may participate in the 457 deferred compensation plan, and employees with at least one year of service are eligible for the 401(a) employer match program. Maximum annual contributions to the 457 plan are established by the Internal Revenue Service. The employer match by the Authority is 100% of the employee's annual deferred compensation, up to 6% of the employee's annual salary. Subject to eligibility requirements, employees are vested in the 401(a) employer match contribution at 25% per year of employment, whereby they are fully vested at the end of the fourth year of employment. For the years ended 2018 and 2017, the plan expense was $31,397 and $30,298, respectively.

Capital assets and depreciation:

Capital assets are capitalized at cost and updated for additions and retirements during the year. The straight-line method has been used to determine depreciation based on the following estimated useful lives:

	Years
Wells - recovery	39
Canals and related facilities	20-50
Earthwork - recharge	20-50
Pumps - recharge	20-25
Roads and fences	10-50
Equipment	7
Office equipment and furniture	5
Trucks/autos	5

The Authority maintains a capitalization threshold of $10,000. Maintenance and repairs of capital assets that do not add to the value of the asset or materially extend the asset's life are charged to operations; major improvements are capitalized. Upon retirement, sale or other disposition of capital assets, the cost and accumulated depreciation are eliminated from the accounts, and the gain or loss is included in operations.

Deposits and investments:

Cash and cash equivalents

For purposes of reporting cash flows, the Authority considers highly liquid investments (including restricted assets) with an original maturity of three months or less when purchased to be cash equivalents. The Authority utilizes a financial institution to service bonded debt as principal and interest payments come due. The balances in these accounts are presented on the statement of net position as Restricted Assets. Cash and cash equivalents also include cash on hand and amounts deposited with banks and the County of Kern's (the County) investment pool money fund. Investments are reported at fair value, which is based on quoted market prices.

Cash deposits

The Authority's cash deposits at December 31, 2018 and 2017 were either entirely insured by appropriate federal depository insurance, partially insured up to the federal limit and the remainder collateralized, or fully collateralized with collateral held by the pledging financial institution's trust department or agent in the Authority's name in accordance with provisions of the California Government Code.

The carrying amount and bank balance of the Authority's deposits at December 31, 2018 and 2017 are as follows:

	2018		***2017***	
	Carrying Amount	***Bank Balance***	***Carrying Amount***	***Bank Balance***
Insured	$ 250,000	$ 250,000	$ 250,000	$ 250,000
Uninsured and collateralized with securities held by the pledging financial institution	1,415,655	1,530,877	1,594,333	1,701,505
County of Kern's investment pool	7,766,583	7,810,116	9,755,949	9,570,352
	$ 9,432,238	$ 9,590,993	$ 11,600,282	$ 11,521,857

Cash funds deposited with the County of Kern are in a pooled money fund. Funds are pooled with other agencies in the County. Investments are made in accordance with California Government Code Section 53601 and 53635.

Pooled funds may be invested in: (1) direct obligations of the United States government, the payment of which the full faith and credit of the United States government is pledged, (2) certificates of deposit at savings and loan associations and federally insured banks when secured by acceptable collateral, and (3) savings accounts at savings and loan associations and banks, to the extent fully insured.

Cash flows

GASB Statement No. 9, "Reporting Cash Flows of Proprietary and Nonexpendable Trust Funds and Governmental Entities That Use Proprietary Fund Accounting" states, for all purposes of preparing the statement of cash flows, all transactions not classified as capital and related financing activities or investing activities are classified as operating activities. The adjustments to reconcile operating income (loss) to net cash provided by (used in) operating activities include other income (expense) which consists of nonoperating revenues and expenses.

Concentration of credit risk:

Credit is extended, in the form of accounts receivable, to landowners who are located in the Authority's service area.

Accounts receivable:

Trade accounts receivable are stated at the amount management expects to collect from balances outstanding at year-end. Consistent with established policy and California Water Code, the Authority can initiate statutory proceedings to obtain a certificate of sale for accounts considered delinquent which are represented by liens on the respective property. There were no such delinquent accounts for the 2018 and 2017 calendar year. Accordingly, no allowance for doubtful accounts is required.

Water banking revenue and assessments:

Water banking revenue

Water banking revenue, to cover the costs of recharging and recovering water, is recognized upon receipt from the Participants. The amount charged per acre-foot recharged or recovered is set after considering actual cost incurred in the most recent year for recharge and recovery operations. Any revenue collected in excess of actual expenses is refunded to the Participants in the following year. If the amount collected is less than the recharge and recovery expenses incurred by the Authority, the Participants will be billed for their proportionate share of the shortage.

In 1999, the Authority began billing the Participants capital fees for their recharge and recovery use of the facilities. These fees are distributed annually to the Participants based on their ownership shares in the Authority.

General administrative assessment revenue

General administrative assessment revenue, for general and administrative, general maintenance, and land management expenses, is recognized upon receipt from the Participants. The amount of the assessment is determined by the Board based on the operating budget and the amount of cash that is available. Each Participant pays its proportionate share of the operating assessments based on ownership shares. For the years ended 2018 and 2017, the Authority recorded general administrative assessment revenue of $2,750,000 and $9,250,000, respectively.

Note 2. Capital Assets

Capital assets consist of land and the accumulated costs to build the basins and roads used for collection and storage of the water; wells used for recovery of the water; canals, pump station, pipelines, pumps, and equipment used for transportation of the water; and office equipment and furniture.

Title transfer of assets from the DWR to the Authority was completed on August 9, 1996. Upon the exchange of water entitlements by the Participants to the DWR, reflected as contribution of capital in the amount of $27,858,500 by the respective Participants, the Participants received Kern Fan Element lands and 42,830 acre-feet of banked water. The 42,830 acre-feet of water was subsequently transferred to each of the Participants in proportion to their ownership shares in the Authority.

Notes to Basic Financial Statements

The following is a summary of changes in the Authority's capital assets for the years ended December 31, 2018 and 2017:

	Assets-At Cost			
	Balance 12/31/17	***Additions***	***Transfers/ Retirements***	***Balance 12/31/18***
Land	$ 23,613,500	$ 2,302,806	$ -	$ 25,916,306
Wells-recovery	35,971,109	4,087,004	-	40,058,113
Canals and related facilities	12,487,266	412,667	-	12,899,933
Earthwork – recharge	4,338,427	1,748,399	-	6,086,826
Pumps – recharge	568,841	-	-	568,841
Roads and fences	971,423	-	-	971,423
Equipment	6,235	153,519	-	159,754
Office equipment and furniture	51,027	-	-	51,027
Trucks/autos	127,616	117,427	(29,491)	215,552
Building/structures	-	206,902	-	206,902
Construction in progress	4,475,589	442,824	(4,438,764)	479,649
	$ 82,611,033	$ 9,471,548	$ (4,468,255)	$ 87,614,326

	Accumulated Depreciation			
	Balance 12/31/17	***Expense***	***Retirements***	***Balance 12/31/18***
Wells-recovery	$ 13,332,414	$ 975,347	$ -	$ 14,307,761
Canals and related facilities	7,354,160	465,892	-	7,820,052
Earthwork – recharge	1,325,161	105,543	-	1,430,704
Pumps – recharge	246,140	24,117	-	270,257
Roads and fences	474,761	62,158	-	536,919
Equipment	6,235	3,838	-	10,073
Office equipment and furniture	49,831	1,197	-	51,028
Building/structures	-	6,897	-	6,897
Trucks/autos	97,760	20,623	(29,491)	88,892
	$ 22,886,462	$ 1,665,612	$ (29,491)	$ 24,522,583

	Assets-At Cost			
	Balance 12/31/16	***Additions***	***Transfers/ Retirements***	***Balance 12/31/17***
Land	$ 23,613,500	$ -	$ -	$ 23,613,500
Wells-recovery	36,072,451	-	(101,342)	35,971,109
Canals and related facilities	12,487,266	-	-	12,487,266
Earthwork – recharge	4,178,356	160,071	-	4,338,427
Pumps – recharge	533,105	35,736	-	568,841
Roads and fences	971,423	-	-	971,423
Equipment	6,235	-	-	6,235
Office equipment and furniture	51,027	-	-	51,027
Trucks/autos	126,262	33,725	(32,371)	127,616
Construction in progress	2,680,228	1,795,361	-	4,475,589
	$ 80,719,853	$ 2,024,893	$ (133,713)	$ 82,611,033

	Accumulated Depreciation			
	Balance 12/31/16	***Expense***	***Retirements***	***Balance 12/31/17***
Wells-recovery	$ 12,407,164	$ 925,250	$ -	$ 13,332,414
Canals and related facilities	6,889,101	465,059	-	7,354,160
Earthwork – recharge	1,238,460	86,701	-	1,325,161
Pumps – recharge	223,810	22,330	-	246,140
Roads and fences	406,760	68,001	-	474,761
Equipment	6,235	-	-	6,235
Office equipment and furniture	47,780	2,051	-	49,831
Trucks/autos	105,987	7,419	(15,646)	97,760
	$ 21,325,297	$ 1,576,811	$ (15,646)	$ 22,886,462

Note 3. Restricted Assets

Restricted assets are cash and cash equivalents whose use is limited by legal requirements.

Restricted cash:

As part of the Authority's 2000 loan agreement with the DWR, the Authority executed a Fiscal Services Agent Agreement with Bank of America to collect monthly deposits for the semi-annual principal and interest payments to DWR. The Authority also agreed to accumulate a Reserve Fund equal to at least two semi-annual payments within the first ten years of the repayment period. In 2015, Bank of America discontinued offering Fiscal Services Agent services for clients. When Zions First National Bank agreed to perform the services, the cash was transferred to accounts at that bank.

As part of the Authority's 2003 Bond Indenture for two series of variable rate demand bonds, the Authority agreed to maintain a debt service reserve of $1,000,000 with the bond trustee, Zions First National Bank. This reserve was funded as part of the bond closing in November 2003.

The following schedule summarizes the restricted assets at December 31, 2018 and 2017:

	2018	***2017***
Cash, Wells Fargo Bank - debt retirement	$ 147,577	$ 365,086
Cash, Zions First National Bank - debt retirement	25,300	11,420
Cash, Zions First National Bank - reserve fund	1,000,000	1,000,000
Cash, Zions First National Bank - debt retirement	110,137	108,780
Cash, Zions First National Bank - reserve	330,936	326,455
	$ 1,613,950	$ 1,811,741

Note 4. Long-Term Debt

Loans for Master Plan:

DWR Proposition 204 Construction Loan:

In March 2000, the Authority and the DWR executed a contract for a $5,000,000 "Groundwater Recharge Construction Loan under the Safe, Clean, Reliable Water Supply Act."

After all conditions were met, the DWR began disbursing the loan commitment to the Authority in 2001. At December 31, 2002, the DWR had advanced the full loan commitment to the Authority. For the years ended December 31, 2018 and 2017, interest expense on the loan principal balance was $33,040 and $40,736, respectively.

The interest rate is 2.7% per annum on the unpaid balance, and the DWR bills the Authority's Fiscal Services Agent, Zions First National Bank, for semi-annual principal and interest payments until the principal is repaid. Principal repayment commenced upon completion of the initial project and will continue at semi-annual intervals for a period not to exceed 20 years.

Variable Rate Demand Revenue Bonds - Series "A" and "B":

On November 25, 2003, the Authority issued Series 2003A (tax exempt) and Series 2003B (taxable) variable rate demand revenue bonds, pursuant to an Indenture of Trust dated November 1, 2003 between the Authority and Zions First National Bank, as Trustee. The 2003 Bonds were identified in the Official Statement as:

A. Series 2003A	$10,800,000 – CUSIP: 492291 AA7
B. Series 2003B	$16,200,000 – CUSIP: 492291 AB5

The 2003 Bonds were issued to provide funds to (a) prepay in full the principal amount owed by the Authority to Bank of America under the 1999 Loan Agreement; (b) finance certain capital expenditures of the Authority; (c) fund a $1,000,000 Reserve Fund; (d) fund a deposit to the Interest Fund to pay capitalized interest on the bonds; and (e) pay costs of issuance. The bonds will mature in 2028.

The Indenture of Trust, executed by the Authority and Zions First National Bank, as Trustee, documented that the Trustee received $27,870,412 on the date of closing as the aggregate purchase price of the bonds, including $1,000,000 relating to repayment of the Bank of America loan. The Trustee transferred $19,000,000 as repayment of the principal for the Bank of America loan, and the remaining proceeds were deposited by the Trustee as follows:

Project Fund	$ 6,166,332
Reserve Fund	$ 1,000,000
Costs of Issuance Fund	$ 704,080
Interest Fund	$ 1,000,000

The bonds bear interest at variable rates determined weekly which is paid semi-annually to the Trustee for the benefit of the bond holders. The Participants are assessed semi-annually for their proportionate share of the interest due to bond holders. Interest expense for the years ended December 31, 2018 and 2017 was $390,169 and $418,002, respectively. The interest rates in effect as of December 31, 2018 and 2017 for Series 2003A (tax exempt) bonds were 1.55% and 1.31%, respectively. The interest rates in effect as of December 31, 2018 and 2017 for Series 2003B (taxable) bonds were 2.40% and 1.50%, respectively.

On July 27, 2005, the Authority entered into an Interest Rate Master Agreement with Wells Fargo Bank, N.A. which established a fixed interest rate swap on the outstanding balance of the Series 2003A and Series 2003B bonds through July 1, 2023 at 3.86% and 4.75%, respectively. These rates were used to calculate the interest rate swap, net in the "Summary of long-term debt" schedule of this note. Also, see Note 5 regarding derivatives.

Equal portions of the bonds are subject to mandatory redemption annually, on July 1, until they reach maturity in 2028. The bonds are selected by lot and are redeemed by Authority revenues at a redemption price equal to the principal amount to be redeemed. The annual redemption amount for Series 2003A (tax exempt) and Series 2003B (taxable) bonds is $432,000 and $648,000, respectively.

While the bonds are outstanding, the Authority is required, with certain exceptions, to maintain a Letter of Credit, currently provided by Wells Fargo Bank, or alternate credit facility to provide security and/or liquidity. The Wells Fargo Letter of Credit (LOC) was issued for $27,434,959. The LOC is automatically extended every year on November 1 unless notice is given by Wells Fargo Bank to the contrary. The Authority is required to meet certain loan covenants. At December 31, 2018, the Authority was in compliance with these covenants.

Summary of long-term liabilities:

The following summarizes long-term liabilities transactions for the years ended December 31, 2018 and 2017:

	Payable 12/31/17	***Additions***	***Deletions***	***Payable 12/31/18***	***Amount Due Within One Year***
Bond principal	$ 11,880,000	$ -	$ (1,080,000)	$ 10,800,000	$ 1,080,000
Loan, DWR	1,368,419	-	(289,985)	1,078,434	297,796
Fair value of interest rate swap	610,393	-	(238,559)	371,834	-
	$ 13,858,812	$ -	$ (1,608,544)	$ 12,250,268	$ 1,377,796

	Payable 12/31/16	***Additions***	***Deletions***	***Payable 12/31/17***	***Amount Due Within One Year***
Bond principal	$ 12,960,000	$ -	$ (1,080,000)	$ 11,880,000	$ 1,080,000
Loan, DWR	1,650,761	-	(282,342)	1,368,419	289,915
Fair value of interest rate swap	921,251	-	(310,858)	610,393	-
	$ 15,532,012	$ -	$ (1,673,200)	$ 13,858,812	$ 1,369,915

The annual requirements to amortize all debt outstanding as of December 31, 2018 are as follows:

Years Ending December 31,	***Principal***	***Interest***	***Interest Rate Swap, net***	***Total Debt Service***
2019	$ 1,377,796	$ 238,496	$ 137,743	$ 1,754,035
2020	1,385,890	208,154	107,133	1,701,177
2021	1,394,205	177,591	76,524	1,648,320
2022	1,240,543	146,789	45,914	1,433,246
2023	1,080,000	122,364	15,305	1,217,669
2024-2028	5,400,000	278,100	-	5,678,100
	$ 11,878,434	$ 1,171,494	$ 382,619	$ 13,432,547

Note 5. Derivatives

The Authority accounts for derivatives under GASB Statement No. 53. The objectives and terms of the Authority's hedging derivative instruments outstanding at December 31, 2018 are listed below:

Type	***Objective***	***Notional Amount***	***Effective Date***	***Maturity Date***	***Terms***	***Fair Value***
Pay-fixed interest rate swap	Hedge of changes in interest rates of the Series 2003A Bonds	$ 2,700,000	8/1/2005	7/1/2023	Pay 3.86%, receive BMA	$ (140,172)
Pay-fixed interest rate swap	Hedge of changes in interest rates of the Series 2003B Bonds	$ 4,050,000	8/1/2005	7/1/2023	Pay 4.75%, receive LIBOR	(231,662)
						$ (371,834)

The objectives and terms of the Authority's hedging derivative instruments outstanding at December 31, 2017 are listed below:

Type	***Objective***	***Notional Amount***	***Effective Date***	***Maturity Date***	***Terms***	***Fair Value***
Pay-fixed interest rate swap	Hedge of changes in interest rates of the Series 2003A Bonds	$ 3,240,000	8/1/2005	7/1/2023	Pay 3.86%, receive BMA	$ (220,789)
Pay-fixed interest rate swap	Hedge of changes in interest rates of the Series 2003B Bonds	$ 4,860,000	8/1/2005	7/1/2023	Pay 4.75%, receive LIBOR	(389,604)
						$ (610,393)

The fair values of the interest rate swaps were estimated using the zero-coupon method. This method calculates the future net settlement payments required by the swap, assuming that the current forward rates implied by the yield curve correctly anticipate future spot interest rates. These payments are then discounted using the spot rates implied by the current yield curve for hypothetical zero-coupon bonds due on the date of each future net settlement on the swaps. The above swaps were classified as deferred outflows of resources on the Statements of Net Position. The total change in fair value for the years ended December 31, 2018 and 2017 was $(238,559) and $(310,858), respectively, and the balances at December 31, 2018 and 2017 are $371,834 and $610,393, respectively.

Risks:

Credit Risk - Credit risk is the risk that Wells Fargo Bank cannot fulfill the terms and obligations specified in the swap agreements. Because the swaps had a negative fair value as of December 31, 2018 and 2017, the Authority did not have exposure related to credit risk on its swaps with Wells Fargo Bank. However, the Authority would have exposure related to credit risk in the amount of the swaps' positive fair value if interest rates increased to cause the fair value of the swaps to become positive. The credit ratings of Wells Fargo Bank are A+ and Aa2 by Standard and Poor's and Moody's Investors Service, respectively.

Basis Risk - The Authority is exposed to basis risk on its pay-fixed interest rate swaps because the variable rate payments received are based on an index other than the interest rates the Authority pays on its Series 2003A and 2003B revenue bonds. As of December 31, 2018, the weighted average interest rate on the Authority's hedged variable rate bonds was 1.67% and 2.43%, respectively, while the Bond Market Association (BMA) rate was 1.55% and London Interbank Offered Rate (LIBOR) was 2.40%. As of December 31, 2017, the weighted average interest rate on the Authority's hedged variable rate bonds was 1.22% and 1.47%, respectively, while the BMA rate was 1.31% and LIBOR was 1.50%.

Termination Risk - Neither party may terminate the transaction prior to its maturity date, unless the Authority or Wells Fargo Bank fails to make any payment when due or otherwise fails to perform any of its obligations with respect to the swap agreement. The non-defaulting party may terminate the swap agreement. If at the time of termination, a derivative instrument is in a liability position, the Authority would be liable to Wells Fargo Bank for a payment equal to the liability, plus interest.

Market Access Risk - At this time, the Authority will most likely not issue variable rate debt to coincide with the Wells Fargo fair value interest swap.

Rollover Risk - At this time, the Authority is not exposed to rollover risk.

Foreign Currency Risk - All derivatives are denominated in U.S. dollars and therefore, the Authority is not exposed to foreign currency risk.

Note 6. Self-Insurance

The Authority is a member of the Association of California Water Agencies, Joint Powers Insurance Authority (JPIA). JPIA is a group of California Water Districts who have pooled funds to provide self-insurance coverage as follows:

	Limits per Occurrence			
Type of Coverage	***Self-Insurance***		***Excess Insurance***	
General, automobile and public officials liability	$	5,000,000	$	55,000,000
Buildings, fixed equipment, personal property and licensed vehicles	$	100,000	$	150,000,000
Fidelity coverage	$	100,000	$	-
Workers' compensation	$	2,000,000	$	2,000,000

The Authority is in a group that has a $2,500 retention level (deductible) per occurrence for property damage due to theft and natural causes. Property includes buildings, personal property, fixed equipment, mobile equipment, licensed vehicles, and turbine generators and transformers. For mechanical damages to turbines, generators and transformers, the deductible ranges from $25,000 to $50,000. For fidelity coverage, the deductible is $1,000. Claims over the retention levels are insured by the group up to the self-insurance limits (see above) and by policies purchased by JPIA from the Lloyd's Brit-Scion Insurance Company, Great American Insurance Company of New York, Great American E&S Insurance Company, Lloyd's Hiscox, Endurance Risk Solutions Assurance Company, General Security Indemnity Company of Arizona, and Evanston Insurance Company for the excess.

JPIA bills the Authority a deposit premium at the beginning of each policy year, which is placed in a reserve fund to cover the self-insurance portion of any claim. Settlements and/or expenses related to claims during the year are charged against the reserve. If the balance of the reserve at the end of the year is deemed too low in relation to the amount of outstanding claims, the Authority is retrospectively billed for additional premiums. When the claims are fully settled, any amounts remaining in the reserve are refunded to the Authority.

Note 7. Commitments

Leases:

The Authority leases office space under an agreement that expires in 2023. Total rent expense for the years ended December 31, 2018 and 2017 was $75,001 and $73,317, respectively.

Future minimum lease payments are as follows:

Years Ending December 31,		
2019	$	63,786
2020		65,413
2021		67,366
2022		69,319
2023		58,037
	$	323,921

Note 8. Contingent Liabilities

Covered Species Viability Fund:

On October 2, 1997, the Authority received a 75-year Federal Fish and Wildlife Permit, the purpose of which is to authorize incidental "take" of endangered species subject to the terms and conditions of the Kern Water Bank Authority Habitat Conservation Plan/Natural Community Conservation Plan (KWBA HCP/NCCP) and the California Endangered Species Act Management Authorization, also executed on October 2, 1997. In accordance with the Implementation Agreement (IA) of the KWBA HCP/NCCP, in 1997 the Authority established the KWBA Covered Species Viability Fund (Viability Fund) with the Treasurer of Kern County for $50,000. The Wildlife Agencies may draw up to $10,000 per year, not to exceed $75,000, from this account to fund preservation of covered species not undertaken by the Authority. If necessary, on January 1 of each year during the term of the KWBA HCP/NCCP, the Authority will deposit up to $10,000 to restore this fund to $50,000, however, the Authority is not obligated to make additional deposits above a cumulative contribution of $75,000. As of December 31, 2018, the Wildlife Agencies had made no withdrawals from this fund and no additional principal had been deposited by the Authority. Interest earned on the required $50,000 principal may be withdrawn by the Authority annually. No withdrawals were made during the years ended December 31, 2018 or 2017. In 2018 and 2017, interest earned was $804 and $638, respectively.

Financial guarantees:

The KWBA HCP/NCCP is designed to achieve both water conservation and environmental objectives, including protection of the sensitive habitat. In addition to the agreement with the United States Fish and Wildlife Service and the California Department of Fish and Game (Wildlife Agencies), and in accordance with the KWBA HCP/NCCP and IA, the Authority executed financial guarantees with the Wildlife Agencies in 1997. The purpose of the guarantees is to ensure the Authority's performance of mutually agreed upon covenants, conditions, and obligations. The guarantees include two promissory notes with principal amounts of $200,000 and $300,000 which are secured by Deeds of Trust and Subordination Agreements.

The $200,000 Ongoing Management Note requires the Authority to pay principal and interest on demand if the Authority violates any provision of the KWBA HCP/NCCP or IA while the 75-year permit is in effect.

The $300,000 Permanent Management Note requires the Authority to pay principal and interest if the Wildlife Agencies choose to call the note after the 75-year permit terminates, or following revocation of the permit, or following the Authority’s relinquishment of the permit, whichever occurs first.

Litigation:

The Authority was involved in the mediation phase process regarding litigation involving the propriety of a series of amendments to the contracts between the State Water Project contractors and the DWR in 1995. In 2003, the trial court (the Court) approved a settlement agreement which, among other things, confirms that the Authority will continue to own and control the Kern Water Bank. Pursuant to the settlement, the Plaintiffs agreed to dismiss the validation cause of action without prejudice and to not re-file it if conditions of the settlement agreement were fulfilled. A new Environmental Impact Report (EIR) was finalized in May 2010 by the DWR. Litigation challenging the new EIR and amendments was filed. The first phase of that litigation, again challenging the propriety of the contract amendments and transfer of the Kern Fan Element lands to the Kern County Water Agency (which was in turn transferred to the Authority), was dismissed by the Court on January 25, 2013 for not being timely filed. The second phase was regarding the adequacy of the EIR and on March 5, 2014, the Court rejected all Plaintiff's claims that the new EIR was deficient, except as to a claim that the EIR was deficient in not adequately evaluating future impacts of operation of the Kern Water Bank on groundwater. On September 5, 2014, the Court held a hearing on the remedy for the deficient EIR. On October 2, 2014, the Court issued its ruling and subsequently issued a writ of mandate (2014 Writ) confirming that DWR would prepare a Revised EIR to address the groundwater issues and that the Kern Water Bank could continue to operate pursuant to an interim operating plan that was developed by the Authority and neighboring districts that were Plaintiffs in the action. Certain of the Plaintiffs appealed the Court decision. The Authority and others filed a protective cross-appeal. The appeals were fully briefed. In September 2016, DWR certified a Revised EIR and filed its return to the 2014 Writ. On October 21, 2016, Plaintiffs filed a new lawsuit against DWR challenging the Revised EIR. On February 10, 2017, the Court issued an order for briefing and a joint hearing on August 18, 2017, to resolve all issues raised by the Plaintiffs concerning the adequacy of the Revised EIR and any objections to the Court discharging the 2014 Writ. After considering the parties’ briefs and arguments at the August 18, 2017 hearing on the merits, the Court issued a ruling denying the Center for Food Safety (CFS) petition in its entirety, and subsequently discharged the writ of mandate and issued judgment in favor of DWR and the real parties in interest including the Authority and its member entities. Near the end of 2017, certain Plaintiffs filed an appeal of the judgment.

No party filed a cross-appeal. In early 2018, DWR filed a motion to consolidate the Central Delta 1 and appeals and cross-appeal, which Plaintiffs/Appellants opposed. The Authority joined in support of the motion to consolidate. The motion to consolidate was granted, consolidating the appeals for purposes of oral argument and decision only. All appeals have been fully briefed. Oral argument has not yet been scheduled by the Court of Appeal.

On January 14, 2019, Buena Vista Water Storage District filed a Petition for Writ of Mandate against the Authority and its member entities, challenging the Authority's final EIR for its Conservation and Storage Project relating to its application to appropriate Kern River water. The member entities have been dismissed. The case was transferred from Kern County Superior Court to Ventura County Superior Court on April 15, 2019. The administrative record is being prepared by the Authority. No briefing schedule or trial date has been set. Because the ultimate outcome of the litigation and the impact on the Authority are unknown at this time, no specific reserve for any potential liability has been recorded.

Note 9. Fair Value of Financial Instruments

The Authority categorizes its fair value measurements within the fair value hierarchy established by generally accepted accounting principles. Fair value is the price that would be received to sell an asset or paid to transfer a liability in an orderly transaction between market participants at the measurement date. The hierarchy is based on the valuation inputs used to measure the fair value of the assets. Level 1 inputs are quoted prices in active markets for identical assets or liabilities; Level 2 inputs are quoted market prices for similar assets or liabilities, quoted market prices in markets that are not active, or other inputs that are observable or can be corroborated by observable market data of substantially the full term of the assets or liabilities; Level 3 inputs are significant unobservable inputs for assets or liabilities. The Authority's recurring fair value measurements as of December 31, 2018 and 2017 consist of its interest rate swaps which were estimated using the zero-coupon method with observable inputs (Level 2).

Note 10. Kern Integrated Regional Water Management Implementation Grant

In 2014, the Kern Integrated Regional Water Management project proposal received final approval by the DWR. The Authority's portion of the project had an estimated cost of $3 million. The Authority requested $2,311,458 in grant funding and provided a 25% match of $770,572. The Authority is the lead agency with the DWR on the project. During the year ended December 31, 2018, $569,731 of grant funds were approved by the DWR and were received by the Authority in 2018, including the project retention, which closed out the grant for the Authority's project. During the year ended December 31, 2017, $33,375 of grant funds were approved by the DWR and were received by the Authority in 2017.

Note 11. Subsequent Events

The date to which events occurring after December 31, 2018 have been evaluated for possible adjustments to the financial statements or disclosures is May 2, 2019, which is the date that the financial statements were available to be issued.

On April 1, 2019, the DWR loan was paid in full. On April 4, 2019, the Wells Fargo interest rate swap agreement was terminated. On April 5, 2019, a long-term line of credit agreement was signed with Union Bank for $25 million. On that same day, approximately $9.8 million of this line of credit was drawn and along with $1 million cash in the debt reserve fund, the bond holders were paid in full. In addition, a revolving line of credit was opened with Union Bank for $5 million, of which no amount has been drawn as of the auditor's report date.

Supplementary Information

Kern Water Bank Authority

Schedules of Revenues
For the Years Ended December 31, 2018 and 2017

	2018	2017
Operating revenues:		
Recharge/recovery revenues:		
Water banking O & M	$ 496,630	$ 2,658,645
Water banking capital use fees	861,317	2,313,863
Energy fees	3,367,327	1,320,383
Third party conveyance	87,045	849,156
	4,812,319	7,142,047
Other operating revenues:		
Assessments - general and administrative	2,750,000	9,250,000
Assessments - well replacement and refurbishment	-	62,390
Cattle and sheep grazing	41,564	8,232
Easements	26,574	34,126
Conservation credits	140,000	435,000
Loan principal charges received from Participants	1,369,985	1,362,342
	4,328,123	11,152,090
Total operating revenues	9,140,442	18,294,137
Participant refunds:		
Participant refund	(2,029,990)	(4,289,860)
Net operating revenues	7,110,452	14,004,277
Nonoperating revenues:		
Grant revenue	569,731	33,375
Loan interest charges received from Participants	36,506	44,149
Line of credit bond fees from Participants	339,480	425,140
Interest income	184,571	128,157
Other nonoperating income	32,415	15,423
Total nonoperating revenues	1,162,703	646,244
Total revenues	$ 8,273,155	$ 14,650,521

Kern Water Bank Authority

Schedules of Expenses
For the Years Ended December 31, 2018 and 2017

	2018	2017
Operating expenses:		
General and administrative	$ 1,467,038	$ 1,031,233
Depreciation	1,665,612	1,576,811
Operating and maintenance - Participants	2,782,327	2,058,866
Operating and maintenance - general	1,312,375	2,195,299
Total operating expenses	7,227,352	6,862,209
Nonoperating expenses:		
Interest expense	423,210	458,739
Finance charges	167,899	181,274
Total nonoperating expenses	591,109	640,013
Total expenses	$ 7,818,461	$ 7,502,222

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INDEPENDENT AUDITOR'S REPORT ON INTERNAL CONTROL OVER FINANCIAL REPORTING AND ON COMPLIANCE AND OTHER MATTERS BASED ON AN AUDIT OF THE BASIC FINANCIAL STATEMENTS PERFORMED IN ACCORDANCE WITH *GOVERNMENT AUDITING STANDARDS*

Board of Directors
Kern Water Bank Authority
Bakersfield, California

We have audited, in accordance with the auditing standards generally accepted in the United States of America and the standards applicable to financial audits contained in *Government Auditing Standards* issued by the Comptroller General of the United States, the financial statements of the Kern Water Bank Authority (the Authority) as of and for the year ended December 31, 2018, and the related notes to the financial statements, and have issued our report thereon dated May 2, 2019.

Internal Control Over Financial Reporting

In planning and performing our audit of the financial statements, we considered the Authority's internal control over financial reporting (internal control) to determine the audit procedures that are appropriate in the circumstances for the purpose of expressing our opinion on the financial statements, but not for the purpose of expressing an opinion on the effectiveness of the Authority's internal control. Accordingly, we do not express an opinion on the effectiveness of the Authority's internal control.

A *deficiency in internal control* exists when the design or operation of a control does not allow management or employees, in the normal course of performing their assigned functions, to prevent, or detect and correct, misstatements on a timely basis. A *material weakness* is a deficiency, or a combination of deficiencies, in internal control, such that there is a reasonable possibility that a material misstatement of the entity's financial statements will not be prevented, or detected and corrected, on a timely basis. A *significant deficiency* is a deficiency, or a combination of deficiencies, in internal control that is less severe than a material weakness, yet important enough to merit attention by those charged with governance.

Our consideration of internal control was for the limited purpose described in the first paragraph of this section and was not designed to identify all deficiencies in internal control that might be material weaknesses or significant deficiencies. Given these limitations, during our audit we did not identify any deficiencies in internal control that we consider to be material weaknesses. However, material weaknesses may exist that have not been identified.

Compliance and Other Matters

As part of obtaining reasonable assurance about whether the Authority's financial statements are free of material misstatement, we performed tests of its compliance with certain provisions of laws, regulations, contracts, and grant agreements, noncompliance with which could have a direct and material effect on the determination of financial statement amounts. However, providing an opinion on compliance with those provisions was not an objective of our audit and, accordingly, we do not express such an opinion. The results of our tests disclosed no instances of noncompliance or other matters that are required to be reported under *Government Auditing Standards*.

Purpose of this Report

The purpose of this report is solely to describe the scope of our testing of internal control and compliance and the results of that testing, and not to provide an opinion on the effectiveness of the Authority's internal control or on compliance. This report is an integral part of an audit performed in accordance with *Government Auditing Standards* in considering the Authority's internal control and compliance. Accordingly, this communication is not suitable for any other purpose.

BROWN ARMSTRONG
ACCOUNTANCY CORPORATION

Brown Armstrong
Accountancy Corporation

Bakersfield, California
May 2, 2019