HOW WATER LEVEL AND IRRIGATION PRACTICES AFFECT WATERBIRD COMMUNITY, NESTING, AND FORAGING HABITAT USE ON THE DUCK VALLEY INDIAN RESERVATION

by

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The following individuals read and discussed the thesis submitted by student Jamie L. Burke, and they evaluated her presentation and response to questions during the final oral examination. They found that the student passed the final oral examination.

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ABSTRACT

Loss of habitat continues to threaten all bird populations. Despite efforts for conservation of wetlands, waterbirds continue to face habitat threats especially in western North America where water resources are limited across the landscape. The White-faced Ibis (*Plegadis chihi*) is a colonial nesting waterbird of conservation concern that builds nests in emergent vegetation of freshwater wetlands throughout the western United States. An ibis breeding colony site located at the Blue Creek Wetland complex on Duck Valley Indian Reservation may face habitat threats in the future due to plans intended to increase irrigation water use efficiency. Plans include manipulation of water levels in the wetland and conversion of flood irrigation practices to sprinkler irrigation which may alter nesting and foraging habitat quality and availability for waterbirds. We conducted an assessment of waterbird populations, especially including the White-faced Ibis, to add critical information that could help conservation planning at this important bird site. We compared secretive marsh bird density, local nesting habitat changes, and ibis breeding success during two years with naturally different water levels, and in 2019, we modeled ibis nesting success with habitat variables we predicted might influence nesting success. We did not see a difference in density of secretive marsh birds or abundance of ibis from 2018 to 2019. However, higher natural water levels in 2019 decreased availability of emergent vegetation in the wetland needed by ibis for nest building and we observed catastrophic nest failures due to exposure to harsh weather events. As a result, apparent nest survival for ibis was lower in 2019 than 2018. Additionally, we investigated foraging habitat selection by ibis of agricultural fields with different irrigation practices surrounding the breeding colony. We found ibis foraged most often in the natural wetland areas but frequently used flooded agricultural fields as additional foraging sites. We modeled habitat selection and our results suggest the presence of water, resulting in saturation of a field with standing water, is the main predictor of selection. We also investigated differences in macro-invertebrate abundance and diversity of agricultural fields with different irrigation practices which may also drive foraging habitat selection. Our results suggest no differences in diversity between irrigation practices, but abundance was higher in naturally flooded areas and in flood-irrigated fields than sprinkler irrigated fields. Given the importance of this wetland site to a variety of wetland birds, understanding the effects of changes to irrigation practices and water management on waterbird community structure, nesting habitat, and foraging habitat availability is necessary to help shape adaptive management practices. Overall, our results provide information for future waterbird conservation planning and will be especially informative in increasingly human-controlled environments.

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CHAPTER 1: DOES VARIATION IN WATER LEVELS AFFECT WATERBIRD COMMUNITY AND NESTING?

Abstract

The historic loss and degradation of wetlands in North America has likely contributed to population declines of many waterbird species. The White-faced Ibis is a large, colonial nesting waterbird of conservation concern that nests in freshwater wetlands of western North America. The Blue Creek Wetland complex on The Duck Valley Indian Reservation is one of six known ibis nesting colony sites in Idaho. We conducted an assessment of waterbirds at this site where future water use plans include manipulation of water levels which could alter the hydrology and thus the habitat used by many waterbird species each year. We estimated density of secretive marsh birds and surveyed the White-faced Ibis nesting colony for nesting timing, habitat use, and survival. We did not see a difference in density of secretive marsh birds or abundance of ibis from 2018 to 2019. However, higher natural water levels in 2019 decreased availability of emergent vegetation in the wetland needed by ibis for nest building and some catastrophic nest failures were observed due to exposure to harsh weather events. As a result, apparent nest survival for ibis was lower in 2019 than 2018. Given the changes in habitat availability and quality with high levels of water, understanding ibis nesting timing, habitat requirements, and density of other important marsh birds is necessary to inform management decisions in order to ensure habitat availability and persistence of waterbird species.

Introduction

Birds in North America are threatened by habitat loss in almost every type of ecosystem which has resulted in a net loss of 29% of our birdlife since 1970 (Rosenberg et al. 2019). Although certain species, including many waterfowl, are recovering due to wetlands conservation efforts, 20% of waterbirds are still considered of high conservation concern (NABCI 2016). Additionally, though the life history for most bird species in North America have been well researched, including their habitat requirements for breeding, migration, and foraging, further research aiming to understand the effects of habitat loss, natural variation in water levels, and conservation efforts will continue to be a critical component of conservation plans for declining waterbird species.

Wetlands provide important habitat for a variety of birds including waterfowl, shorebirds, and waterbirds. These habitats are especially important for waterbirds during breeding as their habitat requirements include a variety of wetland habitats, ranging from continually inundated marshes to seasonally flooded wetlands such as irrigated rangelands and agricultural fields. The United States lost an estimated 53% of total wetland acreage from the 1780s to the 1980s with both Idaho and Nevada losing over half of historical acreage of wetlands in that time (Dahl 1990). According to more recent USFWS Wetland Status and Trends reports, since 1980 wetland loss has slowed and even shown a net gain in some areas (Dahl 2006). However, loss of freshwater emergent marsh has continued (Dahl 2006), and these reports only provide estimates of wetland extent and type, not condition. Human water use can drastically change water levels in wetland systems and disturb water dynamics by diverting water for agriculture, urbanization, and other human water needs. The National Wetland Condition Assessment found that 61%

of all wetland types in the western U.S. are considered in poor biological condition (USEPA 2011). Wetland areas in the West are especially important for birds since there are fewer wetland areas in an arid landscape, and these wetlands are prone to more dynamic changes (Donnelly and Vest 2012). In addition, about 40 waterbird species are known to breed or migrate through this region (Ivey and Herziger 2006).

The White-faced Ibis (*Plegadis chihi)* is a migratory waterbird species that breeds in freshwater wetlands throughout the Intermountain West (Ryder and Manry 1994). They nest colonially in shallow freshwater marshes by building nests above the water surface out of emergent vegetation like bulrush (*Scirpus* sp.) which is preferred by ibis in the Great Basin (Ryder and Manry 1994). Sites hosting breeding colonies are often returned to each year and reused by ibis (Ivey, Stern, and Carey 1988, Moulton, Carlisle, Brenner, and Cavallaro 2013). Nest building and egg laying are usually highly synchronized although in large colonies, distinct subcolonies may initiate nesting up to 40 days apart (Ryder and Manry 1994). Clutch completion dates range from late April-early July depending on location (Ryder and Manry 1994). During breeding, adults often forage in shallow pools, marshes, and edges of reservoirs within a few miles of the nesting colony (Bray and Klebenow 1988) and return to feed chicks at or near the nest. Chicks start moving away from the nest by day 8 and spend most of their time away from the nest but within the nesting colony until fledging around 6 weeks after hatching (Ryder and Manry 1994). Thus, the breeding colony site is important to nesting and chick development for several months during a breeding season.

White-faced ibis are recognized as a Species of Greatest Conservation Need (SGCN) in 8 states (USGS SWAP 2017), including most states within their breeding range, due to threats to habitat and productivity although regional population trend studies have shown an increase in populations since 1984 (Earnst, Neel, Ivey, and Zimmerman 1998, Cavitt et al. 2014, IDFG 2017). Idaho currently supports up to 50% of the known ibis breeding population in the western U.S. with the Blue Creek Wetland area on Duck Valley Indian Reservation being one of six known breeding sites in Idaho (Cavitt et al. 2014). The Duck Valley area is recognized as an important waterbird site of the Intermountain West Region (Ivey and Herziger 2006), in part because it's a known breeding site of a large colony of ibis and other waterbirds (Gossett 2008). It also supports migrating waterfowl and shorebirds, but the area also lacks consistent and long-term data for all bird populations. Baseline species occurrence and population abundance estimates are needed for this important bird area to add to local and regional waterbird population trends especially for birds with conservation needs.

Basic population data along with local habitat requirements is also needed because the Shoshone-Paiute Tribes of the Duck Valley Indian Reservation are considering an irrigation structure upgrade to be installed in the near future which might impact water levels of the wetland complex at critical times of year for breeding waterbirds. Specifically, the idea is that water will be charged ("stored") in the wetlands for irrigation water calls downstream, likely causing water levels to increase for storing in the spring and then lowered when releasing water for irrigation purposes later in the summer. Managers of this wetland complex need guidelines for water level management in the wetlands to produce the least amount of change to this ecosystem and ensure quality habitat for the birds that rely on it every year. Thus, we set out to describe important waterbird use, including key time periods of breeding when water level changes would be the most destructive to breeding success, in this wetland system.

We conducted an assessment of wetland bird populations, especially including the White-faced ibis (hereafter "ibis") breeding colony and secretive marsh birds, at the Blue Creek Wetland complex, to establish baseline population estimates and habitat requirements for ibis and other important breeding waterbird species. We conducted weekly observations of the ibis colony in order to estimate breeding population size, nesting timing and success, and habitat requirements specific to the Blue Creek colony. We compared secretive marsh bird density, local nesting habitat changes and ibis breeding success during two years with naturally different water levels in a natural experiment and in 2019 we modeled ibis nesting success with measured habitat variables we predicted might influence nesting success.

Study Area

The Duck Valley Indian Reservation straddles the Idaho and Nevada border and is comprised of about 290,000 acres and home to 1,700 Shoshone-Paiute Tribal members. The primary land use is agriculture, mainly cattle ranching with many fields used for growing alfalfa and hay while cattle are grazed in some irrigated fields but mostly in natural meadows and sagebrush rangeland. The Blue Creek Wetland complex lies in a broad floodplain completely on the Idaho side of the reservation (Figure 1.1) and stretches north to south running parallel to and west of Highway 51, totaling about 4,400 acres (Gossett 2008). This palustrine system is characterized by persistent, emergent vegetation and extends into areas of wet meadows dominated by grasses (USFWS 2011). The primary wetland communities include sagebrush with braided channels, grass/spike rush, open water, bulrush, and sedge/grass (Gossett 2008). The primary open water areas are located just west of Mountain View Reservoir and are separated by a dike that also serves as a road. The western side of the wetland complex is bounded by a rocky plateau with areas of sagebrush uplands. The wetland seasonally floods and is fed by springs mostly originating in plateaus on the eastern boundary. The Owyhee River at the southern end of the wetland area seasonally floods and feeds the wetland through culverts under Blue Creek Road. These culverts are proposed to be replaced by an irrigation structure designed to be able to hold water in the wetlands later in the summer to better provide irrigation water for the Pleasant Valley agricultural fields just downstream of the wetland complex.

The ibis colony historically located on the Duck Valley Indian Reservation is typically established in the Blue Creek wetlands directly west of highway 51 in a large Hardstem bulrush (*Scirpus acutus*) stand about 10.5 miles north of Owyhee, Nevada (Gossett 2008). The bulrush patch can be clearly seen on aerial imagery and totals about 100 acres (Figure 1.2). In 2018, we observed the colony established at this location. In 2019, after higher than average winter snowfall and spring rains, some ibis nested at this historic location, but we also observed a second colony established approximately one mile north of the usual colony in a small patch of bulrush (Figure 1.2).

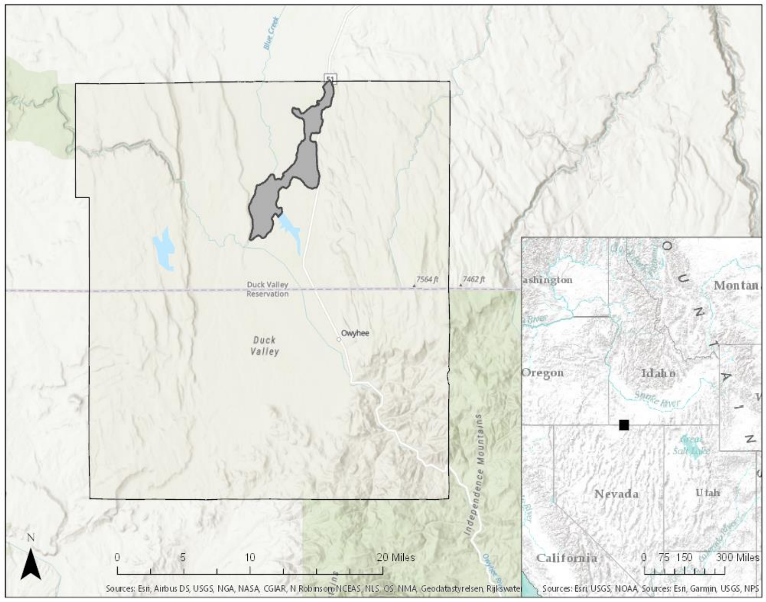

Figure 1.1 Blue Creek Wetland complex study site on the Duck Valley Indian Reservation.

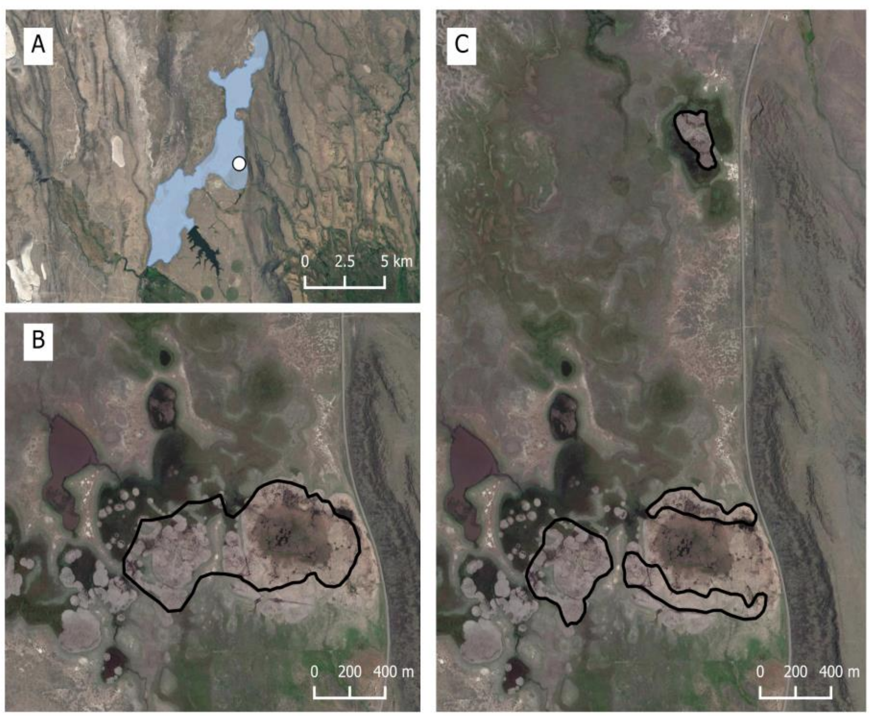

Figure 1.2 A) Location of ibis nesting colony within Blue Creek Wetland complex;
B) Extent of ibis nesting colony in 2018;
C) Extent of ibis nesting colony in 2019, including the northern area that wasn't used in 2018.

Methods

Field Methods

Point Count Surveys for all bird species and Secretive Marsh Bird Surveys

To assess waterbird use and to quantify abundance of all bird species in the study area, we conducted standardized point counts at a series of sites to completely cover the wetland area and adjacent upland habitats of the study area. Following standardized breeding bird survey protocols recommended by Ralph, Droege, and Sauer (1995), we conducted unlimited radius point-transect counts and estimated exact distances using a laser rangefinder to all birds detected by sight or sound in 5 minutes. Points were spaced approximately 400m apart and mostly located along the emergent vegetation zone around Blue Creek Wetland (Figure 1.3). We included Mountain View Reservoir to serve possibly as a comparison since the water levels of the reservoir are managed and consistent. We divided the points into 4 main routes which we could travel to and cover in a single morning: (1) western boundary of the Blue Creek Wetland complex from the southern boundary north to extended wet meadows, (2) eastern boundary of main open water area of Blue Creek Wetland, (3) northern area of extended emergent vegetation and wet meadows running parallel to Idaho state highway 51, and (4) Mountain View Reservoir. We traveled between the routes by vehicle (truck or ATV) for the routes around the wetland and by boat for the reservoir points. We conducted counts in 2018 during the first two weeks of June to correspond with peak breeding season and started our counts 30 minutes before sunrise and ended no later than 4 hours after sunrise.

We conducted secretive marsh bird surveys separately from point counts following the Standardized North American Marsh Bird Protocol (Conway 2011). We conducted these surveys to target bird species that are easily missed during regular point counts because they are rarely observed and do not vocalize frequently (Conway 2011). We chose four focal species for these surveys following Idaho Department of Fish and Game's Idaho Bird Inventory and Survey methods (Moulton 2010): American Bittern (*Botaurus lentiginosus*), Sora (*Porzana carolina*), Virginia Rail (*Rallus limicola*), and Pied-billed Grebe (*Podilymbus podiceps*). The protocol requires an initial 5-minute passive survey to record all focal species seen or heard, similar to standard point counts, then continues with a series of broadcast calls ("call playback") followed by 1-minute listening periods for each focal species. We selected a subset of points from our overall point counts and established 4 routes along the emergent vegetation of the wetland complex (Figure 1.3): (1) western boundary of main open water area, (2) eastern boundary of main open water area, (3) northern area of extended emergent vegetation and wet meadows including the ibis colony site, and (4) Mountain View Reservoir to serve as a comparison. Each route consisted of 8-12 points spaced about 400m apart. We traveled between points depending on the location of the route either by vehicle (truck or ATV) or boat. Secretive marsh birds are more likely to vocalize in the hours around sunrise or sunset (Conway 2011) and the protocol allows for conducting surveys around either sunrise or sunset. We did not conduct surveys during sustained heavy rain, fog, or wind speeds over 12mph (greater than force 3 on the Beaufort Scale) following the National and Idaho protocol (Conway 2011, Moulton 2010) to limit weather effects on detection probability. For many survey attempts in 2018, we were unable to conduct surveys during the hours around sunset due to high evening winds so for all replicate surveys in 2018 after the first survey for each route, we conducted morning surveys and started 30 minutes before sunrise and finished no later than 3 hours after sunrise. In 2019, we conducted morning surveys for all routes and replicates. We conducted replicate surveys during three main time frames both in 2018 and 2019: May 15-31, June 1-15, and June 16-30.

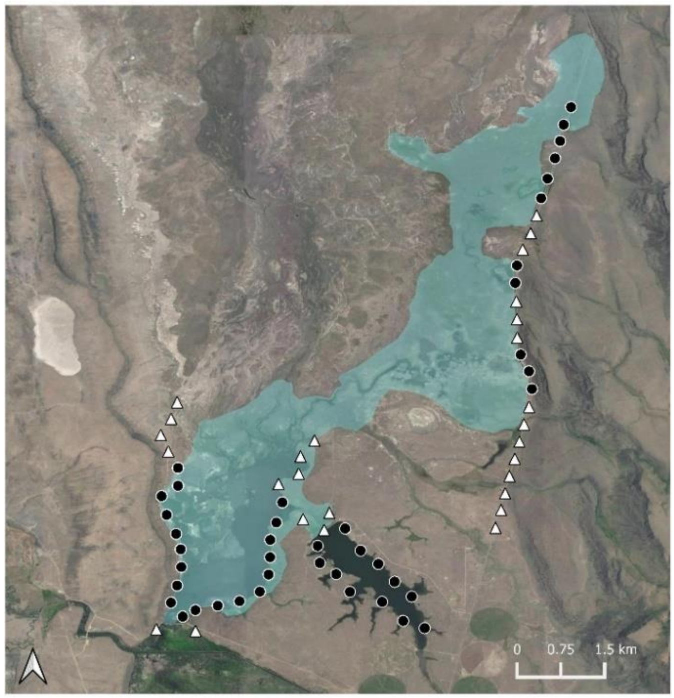

Figure 1.3 Map of Blue Creek Wetland complex (larger light blue area) and Mountain View Reservoir (smaller dark blue area) showing secretive marsh bird point count locations (black circles) and overall bird point count locations (black circles and white triangles).

<u>Ibis Nest Success, Timing, and Habitat</u>

We observed and described the behavior of birds in the ibis breeding colony with weekly observations of the colony during both 2018 and 2019 from the first week in May to mid-August. We used a perimeter survey approach recommended by Steinkamp et al. (2003) for surveying colonial nesting waterbirds and observed the colony with a telescope from a set location just outside the eastern boundary of the breeding colony, from which we could observe much of the entire colony. For each observation event, we recorded an estimated total count of ibis (rounding by 100s) and counts of other birds nesting in the colony. We included details of behavior and nesting stage by a quick approximate percentage of behaviors over the entire colony and a more detailed behavior assessment by recording individual behaviors of a sample (aiming for at least 100 individuals) of the ibis in the colony. Behaviors we quantified included foraging, roosting, nest building, mating, and incubating.

While colony-level surveys provided overall population and nesting stage estimates, we also collected nest timing information and success at the individual nest level. In both 2018 and 2019, we placed remote motion activated trail cameras (Reconyx PC800) at 5 individual nests and monitored additional nearby nests by collecting GPS locations and visiting at least once a week. To minimize abandonment during egg laying, we placed cameras and began monitoring nests after we observed incubation had begun for most pairs in the colony. We placed the cameras randomly at accessible nest locations and at least 50m apart. We checked the cameras each week, only entering the colony once to minimize disturbances. During checks, we recorded the status of the nests including number of eggs, chicks, or failures. In 2018, we also recorded general habitat characteristics around each nest cluster including water height, vegetation height and type, and height of nest above the water. In 2019, we focused our measures on each individual nest (not clusters) and recorded these environmental characteristics along with nesting status for each individual nest. We considered a nest successful if at least one egg survived to hatch. We continued to monitor nests after hatching to gain more information about timing of chick development. We removed cameras and stopped checking individual nests after at least two weeks of inactivity due to either chick dispersal or abandonment.

Analysis Methods

Quantifying local habitat change

We used open access spatial data acquired and classified in Google Earth Engine (Gorelick et al. 2017), and further analyzed with ArcGIS Pro (ESRI 2019) to quantify areas of surface water and wetland vegetation over a time series from April to August of 2018 and 2019. In Google Earth Engine, we acquired Sentinel-2 images (ImageCollection ID: COPERNICUS/S2) filtered for our study area and for images taken in May 2018 and 2019 to correspond with the ibis colony establishment and nest building. We then further filtered the image collection using the QA60 band to mask out cloud cover. We classified each image using a supervised classification method: classification and regression tree (CART) classifier (Breiman, Friedman, Olshen, and Stone 1984) into classes of surface water, emergent vegetation, bulrush, and sage/dry grass. After training and running the classifier, we used the error matrix to assess overall accuracy of the classification. Lastly, we reduced the classified pixels to a polygon layer in order to calculate total area for each class.

Quantifying Overall Bird Density and Diversity

We used the "Distance" package in R (Miller 2019, R Core Team 2019) to calculate bird density estimates for species detected in the Blue Creek Wetland complex and surrounding upland habitats. Following the rule of thumb of Buckland, Marsden, and Green (2008), we only modeled species-specific probability of detection and obtained density estimates for species in which we had at least 60 detections. Similarly, for overall bird density estimates, we grouped detections of species by their taxonomic order and modeled detection for the orders of birds in which we had at least 60 detections. Alldredge, Pollock, Simons, and Shriner (2007) recommended that groupings in multispecies detection models be based on characteristics likely to affect the detection process and suggested for surveys in open habitats that visibility, activity patterns, and size could be appropriate ways to classify characteristics. We divided detections of birds into taxonomic order, because we felt taxonomic order incorporated these suggested detectability characteristics, although caution must be taken when interpreting these estimates since some differences in detectability were likely overlooked in grouping species in this way. For all detection probability modeling, we tested half-normal and hazard rate key functions with covariates that may affect detection: temperature, wind, and cloud cover, region (reservoir or wetland), and species. We used AIC to rank competing detection probability models and tested goodness of fit with Cramer-von Mises tests. We calculated adjusted abundance and density based on the detection probability obtained from the best-supported model. As a baseline for future monitoring, we also calculated relative abundance for each species detected and overall bird diversity measurements of diversity indices.

Quantifying Secretive Marsh Bird Density

We used the 'Distance' package in R (Miller 2019, R Core Team 2019) to calculate secretive marsh bird density estimates in Blue Creek Wetland and Mountain View Reservoir. We combined all detections of the focal species from both years and routes and used a multi-species approach to modeling detectability since we did not have the recommended 60 detections (Buckland et al. 2008) per species to model detectability individually. We tested species, year, and site (Mountain View Reservoir or Blue Creek Wetland) as covariates in the detection model to avoid the assumption of equal detectability between species and habitat difference between the reservoir and wetland routes (Marques, Thomas, Fancy, and Buckland 2007). This approach allowed for increased detections in our model, thus improving estimates (Marques et al. 2007). We also tested additional covariates that may affect detection: wind, cloud cover, and background noise (all scaled). We only had a few detections of American Bittern each year, so we decided to remove those observations from the model. We used Cramer-von Mises tests to check for goodness-of-fit for hazard rate and half-normal key functions and used AIC to rank competitive models (Akaike 1981, Table 1.1). We then used the detection probability obtained from the best-supported model to obtain adjusted density estimates and post-stratified estimates to get unique density estimates for each species, year, and region.

Table 1.1 Candidate model set for multiple covariate distance sampling analysis of secretive marsh bird species at Blue Creek Wetland complex and Mountain View Reservoir in 2018 and 2019 combined. P_a is the estimated percentage of detection.

key function	formula	Cv-M *p* -value	P_a	se(P_a)	Δ AIC_c
hazard-rate	~Species + Region	0.97037	0.078	0.025	0.000
hazard-rate	~ Species + Region + Wind	0.96933	0.072	0.026	2.919
hazard-rate	~ Species + Region + Wind + Year	0.93704	0.068	0.027	3.740
hazard-rate	~ Species	0.71804	0.080	0.027	10.810
hazard-rate	~ Species + Wind	0.70098	0.071	0.030	12.520
half-normal	~ Species + Wind	0.03238	0.215	0.017	32.050
half-normal	~ Species + Wind + Region	0.02124	0.213	0.017	32.920

Ibis Nest Success Modeling

We modeled 2019 nest success using a generalized linear mixed model with logistic exposure link (Shaffer 2004) with the lme4 package in R (Bates, Maechler, Bolker, and Walker 2015, R Core Team 2019). Nest survival was the binomial response and we used predictor variables measured in the field and that we hypothesized might affect nest survival: water level, average height of vegetation above water level around nest, and height of nest bowl above water. We focused on environmental predictors because these variables can be more directly manipulated by managers as the wetland complex may be more controlled based on needs of irrigators in the future. As a random effect, we included nest subsite which corresponds to the two different nesting colonies in 2019. The two colony sites showed different characteristics in extent and habitat, including amount of emergent vegetation available for nesting, amount of open surface water in the colony area, and density of nests - each of which may have influenced nest survival. In ecological systems, environmental variables are often correlated and their effects on the response variable can be difficult to analyze (Graham 2003). In this system, our environmental variables of water height and vegetation height were significantly correlated (Pearson's correlation; $r \geq 0.7$), so we did not include these correlated variables in the same model. We used AICc and AICc weight to rank and evaluate our candidate models within 2 AICc of the top ranked model (Burnham and Anderson 2002, Table 1.2).

Although we did not collect individual nest variables in 2018 and therefore could not model success dependent on environmental variables, we did monitor individual nest success for a sample of nests (n=15). We calculated apparent nest success for 2018 and 2019 to provide a broad nest survival comparison between years with different natural water levels.

Table 1.2 Candidate models for 2019 ibis nest survival using generalized linear models with logistic exposure links.

parameters	k	Δ AICc	ω	loglik
bowl	2	0.0	0.36	-16.32
bowl+site	3	0.45	0.29	-15.52
water	2	1.94	0.14	-17.29
veg+site	3	2.49	0.11	-16.54
water+site	3	3.88	0.05	-17.23

Results

Habitat Changes and Ibis Nesting Timing

In 2018, the average water depth in the main colony area was 0.84m when ibis began building nests in mid-May and the average height of the bulrush above the water level was 0.60m. In 2019, the average water depth in the main colony during nest building was 1.74m with very sparse old bulrush or new growth with an average height of 0.18m above the water in the main colony area. In 2018, we calculated the area of surface water with minimal emergent vegetation in mid-May to be approximately 0.69km^2 and there was approximately 0.82 km^2 of bulrush available. In 2019, surface water covered approximately 1.71km^2 at the main colony area after a higher than average winter snowfall and spring rain, and only 0.34km^2 of bulrush was available for nesting (Table 1.3).

In 2019, some ibis nested at the historic location, but we also observed a second colony established approximately one mile north of the usual colony site in a small patch of bulrush (Figure 1.2). This bulrush patch was less flooded than the main colony site with an average water depth of 0.76m thus providing some protection from terrestrial predators. In 2018, the approximate area of the colony was 0.55 km^2. In 2019, the area of the colony was only about 0.36km^2 in the main colony location with the northern colony location area just 0.04 km^2 (Table 1.3) Along with the second colony just north of the main colony, we also observed ibis trying to nest in a few small patches of bulrush surrounding Mountain View Reservoir although these patches were unable to support more than a few nests.

Despite differences in water levels and nesting vegetation availability in 2018 and 2019, we observed very similar timeframe (timeframe for N colony) for ibis nesting with ibis arriving at the nesting site in early May, followed by nest building and incubation from mid-May to June, hatching ending by the first week of July, and fledging and foraging away from the colony in early August. We observed about a one week difference in nesting timing at the northern satellite colony in 2019 which was established after many nests failed in the main colony. We also recorded similar estimates of nesting ibis from our colony counts (Table 1.3) and recorded other colonial nesters like Black-crowned Night Herons (*Nycticorax nycticorax*), Great Egrets (*Ardea alba*), and Forster's Terns (*Sterna forsteri*) nesting in the colony in 2018 and 2019. In addition, though we did not see any using the colony in 2018, we recorded at least five nesting pairs of Black Terns (*Chlidonias niger*) nesting in the ibis colony in the same general area as the Forster's Terns in 2019.

Table 1.3 Estimates for maximum count of adult ibis, area of colony, area of surface water, and area of bulrush in primary colony area during May 2018 and 2019.

	maximum count of ibis	area of colony (km^2)	Area of surface water in May (km^2)	Area of Bulrush in May (km^2)
2018	8,000	0.55	0.69	0.82
2019	10,000	0.40	1.71	0.34

Overall Bird Diversity and Density

During 2018 point count surveys, we detected 93 bird species at our study site with 1,677 total detections (Appendix 1). We had enough detections of six species in which we were able to calculate unique detection function and density estimates for: American Coot (*Fulica americana*), Marsh Wren (*Cistothorus palustris*), Western Grebe (*Aechmophorus occidentalis*), Western Meadowlark (*Sturnella neglecta*), White-faced Ibis, and Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*) (Table 1.4). American coots, Marsh wrens, Western grebes, and Yellow-headed blackbirds were all more abundant at Mountain View Reservoir although they also occurred on all three routes around the wetland. Western Meadowlarks were generally recorded at points around the wetland at the interface between emergent vegetation or wet meadow and sagebrush uplands. White-faced Ibis occurred on all routes although were most abundant in the northern wetland route where the colony is located. Although the density estimates suggest more Marsh Wrens and Yellow-headed Blackbirds than White-faced Ibis (Table 1.4), with the ibis occurring more clustered in the colony area and leaving the wetland complex to forage in agricultural fields, we believe the density estimate for ibis was likely underestimated.

Similar to individual species detection models, we had enough detections for six orders of birds: Anseriformes, Charadriiformes, Gruiformes, Passeriformes, Pelecaniformes, and Podicipediformes. Passeriformes had the highest density estimate while the lowest density estimate was Pelecaniformes which included White-faced Ibis (Table 1.5). Again, this estimate may have been underestimated as detections for only three species were incorporated into the model, most of which being ibis, whereas for passerines, detections for 42 species were grouped for the model which resulted in a higher estimate. For other groups, number of species grouped for modeling ranged from four species for both Gruiformes and Podicipediformes, 13 for Charadriiforms, and 15 for Anseriformes. The probability of detection for each group ranged from 0.173 to 0.579 (Table 1.5) which should be considered when interpreting these estimates.

Overall, we recorded the occurrence of many species currently on Idaho's species of greatest conservation need list (IDFG 2017): Clark's Grebe (*Aechmophorus clarkii*), Western Grebe (*Aechmophorus occidentalis*), Grasshopper Sparrow (*Ammodramus savannarum*), Short-eared Owl (*Asio flammeus*), Common Nighthawk (*Chordeiles minor*), Bobolink (*Dolichonyx oryzivorus*), Sandhill Crane (*Antigone canadensis*), Long-billed Curlew (*Numenius americanus*), Sage Thrasher (*Oreoscoptes montanus*), American White Pelican (*Pelecanus erythrorhynchos*), American Bittern (*Botaurus lentiginosus*), Black Tern (*Chlidonias niger*), and California Gull (*Larus californicus*). Additionally, without effort focused on this, we observed evidence of breeding for Western Grebe, Sandhill Crane, Long-billed Curlew, and Black Terns.

Table 1.4 Species specific model selection results and respective density estimates from point count surveys for six species of birds at Blue Creek Wetland and Mountain View Reservoir on The Duck Valley Indian Reservation in 2018. Density estimates are reported as birds/km^2. 95% CI are associated with density estimates.

Species	Best supported model	Cv-M *p*-value	P_a	density	se	cv	95% CI
American Coot	Hazard rate ~ Region	0.681	0.299	7.065	1.673	0.237	4.43-11.27
Marsh Wren	Hazard rate ~ Wind	0.867	0.031	171.314	65.960	0.385	81.74-359.06
Western Grebe	Hazard rate ~ Region	0.907	0.361	7.717	2.032	0.263	4.59-12.95
Western Meadowlark	Hazard rate ~ 1	0.122	0.511	10.940	1.330	0.120	8.61-13.89
White-faced Ibis	Hazard rate ~ Wind	0.720	0.517	63.100	14.820	0.230	25.72-154.79
Yellow-headed Blackbird	Hazard rate ~ Wind +Region	0.858	0.026	188.849	70.055	0.371	92.65-384.94

Table 1.5 Model selection results and respective density estimates from point count surveys for six orders of birds at Blue Creek Wetland and Mountain View Reservoir on The Duck Valley Indian Reservation in 2018. Density estimates are reported as birds/km2. 95% CI are associated with density estimates.

Order	Best supported model	Cv-M *p* -value	P_a	density	se	cv	95% CI
Anseriformes	Hazard-rate ~ Region	0.828	0.369	19.618	5.055	0.257	11.89-32.36
Charadriiformes	Hazard-rate ~ Species	0.678	0.190	35.698	18.850	0.528	13.43-94.86
Gruiformes	Hazard rate ~ Region + Species	0.933	0.205	8.039	1.387	0.173	5.71-11.30
Passeriformes	Hazard rate ~ Wind + Region	0.479	0.173	438.210	78.529	0.179	308.78-621.93
Pelecaniformes	Hazard rate ~ Wind + Species	0.539	0.579	4.222	0.578	0.137	3.21-5.53
Podicipediformes	Half-normal ~ Region	0.725	0.327	13.658	2.704	0.198	9.18-20.31

Secretive Marsh Bird Density

Of 30 transect points we surveyed in the Blue Creek Wetland complex, we detected secretive marsh birds at 18 points, with 10 of those locations in the northern route which covered the extended wetland with emergent vegetation parallel to Idaho Highway 51. We had very few detections of focal species (n=13) at points along the main water body of the wetland complex over both years of surveys. Our best supported model for overall probability detection was hazard-rate key function and included species and region as covariates (Table 1.1). The overall density of the focal secretive marsh bird species was not significantly different from 2018 to 2019 but overall densities for both years did show a significant difference between the wetland complex and reservoir (Table 1.6) with higher estimated densities occurring at the reservoir even though the total area for the reservoir is less than the wetland complex. Since we recorded more Pied-billed Grebes in 2018 (n=46) and 2019 (n=64) than all other focal species collectively in 2018 (n=30) and 2019 (n=34), the overall higher densities for the reservoir are probably driven by these grebe detections. The estimates do not suggest an effect of year on density for overall detections or for individual estimates for Pied-billed Grebe, Sora, or Virginia Rail (Table 1.7). The density of Pied-billed Grebes was higher at Mountain View Reservoir in both years (Table 1.7). However, the results do not suggest differences in density of Virginia Rail or Sora between the wetland complex and the reservoir. We must note that our models for detection of secretive marsh birds predicted low probability of detection and coefficients of variation were variable with most being high which suggests these estimates are not very reliable.

Table 1.6 Overall density estimates for focal secretive marsh bird species in 2018 and 2019 reported as birds/km^2 and by site: Blue Creek Wetland complex (BCC) and Mountain View Reservoir (MVR)

	2018				2019			
	estimate	se	cv	95% CI	estimate	se	cv	95% CI
BCC	7.505	4.560	0.607	2.46-22.88	11.267	4.825	0.428	4.99-25.39
MVR	223.798	90.120	0.402	104.05-481.35	187.615	98.172	0.523	70.72-497.75

Table 1.7 Density estimates for three species of marsh birds: Pied-billed Grebe (PBGR), Sora (SORA), and Virginia Rail (VIRA) in 2018 and 2019 reported as birds/km^2 and by site: Blue Creek Wetland complex (BCC) and Mountain View Reservoir (MVR).

		2018				2019			
		estimate	se	cv	95% CI	estimate	se	cv	95% CI
PBGR	BCC	0.914	0.594	0.65	0.28 - 2.97	5.485	2.989	0.544	2.00 - 15.02
	MVR	144.301	55.867	0.387	68.91 - 302.14	132.601	52.594	0.396	62.21 - 282.61
SORA	BCC	2.233	1.265	0.566	0.78 - 6.39	4.095	2.009	0.49	1.63 - 10.28
	MVR	6.084	5.963	0.98	1.16 - 31.76	0.000	0.000	0.000	0
VIRA	BCC	4.356	3.683	0.845	1.01 - 18.67	1.633	1.37	0.839	0.38 - 6.93
	MVR	73.412	56.827	0.774	18.93 - 284.66	31.462	31.539	1.002	5.82 - 169.93

<u>Ibis Nest Survival</u>

Apparent nest survival for 2018 was 73.33% (n=15) and for 2019 was 60% (n=25), although 2019 survival was lower in the main colony area (46.67%, n=15) where high water levels and low vegetation growth persisted throughout the breeding season and we observed high wind and flooding events that destroyed unprotected nests. Apparent nest survival in the satellite colony site in 2019 was 80% (n=10). All nest failures in our sample in 2019 had a starting nest bowl height less than 20cm with varying heights of vegetation and water. The best supported logistic exposure model for 2019 ibis nest survival showed a positive effect of increasing nest bowl height above the surface of water on nest survival. The model predicts an average maximum effect of 25.8% increase in probability of nest success (95% CI 10.3-41.2%) when increasing nest height from 15cm to 18cm (Figure 1.4).

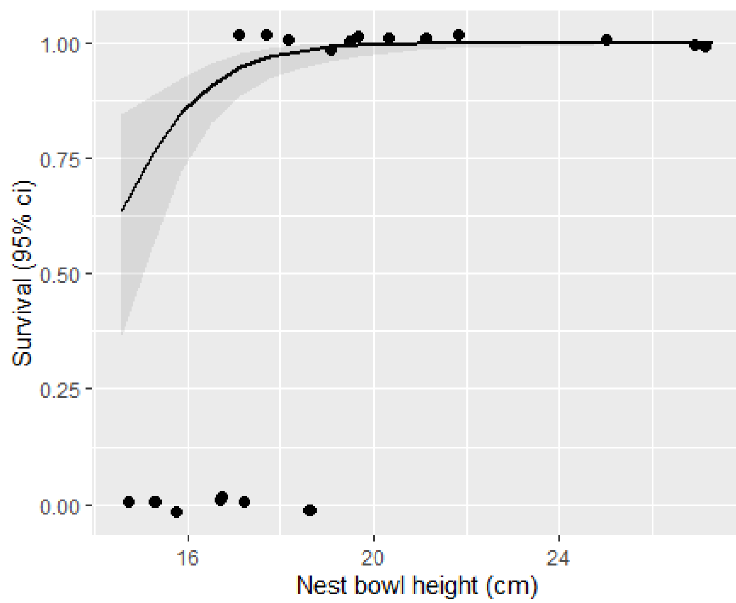

Figure 1.4 Predicted probability of ibis nest survival in 2019 in the Blue Creek wetland complex, Idaho modeled with the height of nest bowl above the surface water and shown with 95% confidence interval.

Discussion

Our results show the importance of the Duck Valley wetland complex to a variety of breeding birds, including White-faced Ibis, secretive marsh birds, and several other species of conservation concern in Idaho (IDFG 2017). In addition to the ibis, we documented evidence of breeding for numerous other species within the ibis colony, other habitats of the wetland complex, and in the emergent vegetation around Mountain View Reservoir. We also documented substantial habitat changes in the Blue Creek wetland between 2018 and 2019 that occurred due to naturally fluctuating water levels, and these water level changes contributed to changes in availability of emergent vegetation for colonial nesting birds like the ibis.

Our overall bird population estimates serve as a baseline for future bird monitoring and to document occurrences of species. Continued long term monitoring could increase understanding of occurrences as well as population trends at this site especially for species of concern. Breeding Bird Survey (BBS) population estimates for the western U.S. show that 26% of the species in the wetland breeding group have had a significant negative trend from 1966 to 2015 (Sauer et al. 2017). However, BBS estimates for waterbirds may have low credibility due to low sample size; as additionally, BBS routes do not cover wetland habitats and colonial waterbirds are better surveyed with separate monitoring protocols (Steinkamp et al. 2003). With a widespread lack of data on colonial nesting waterbirds throughout the western U.S., eight interior western states implemented the Western Colonial Waterbird Survey from 2009 to 2011 to provide data on size and location of waterbird colonies (Cavitt et al. 2014). The survey of the Blue Creek ibis colony in 2010 estimated 7,631 ibis nests resulting in an estimated

15,262 breeding adult ibis at the same colony location we observed in our study (Cavitt et al. 2014). Overall, our colony surveys showed similar abundance estimates for breeding adult ibis. From historical data in the same report, a survey in 1993 estimated just 2,320 breeding adult ibis at the site (Cavitt et al. 2014).

We saw little changes in secretive marsh bird density estimates between 2018 and 2019. Although density point estimates are different, with high coefficient of variations and large confidence intervals that overlap, the estimates do not suggest there are significant increases or decreases in overall secretive marsh bird density for both the wetland and reservoir. For Pied-billed Grebes, the estimates between sites were different in both 2018 and 2019, showing a higher density at the reservoir which historically has a deeper water level than the wetland complex. This is not surprising because Pied-billed grebes usually occupy wetland habitats with dense emergent vegetation but nearby open water, and they forage mostly by diving underwater in open water areas as well as among emergent vegetation (Muller and Storer 1999). While density estimates for Sora and Virginia Rail did not differ significantly between the wetland area and the reservoir, the northern part of the wetland area, around the ibis colony where we had the most detections for both species, usually offered more suitable habitat as both Sora and Virginia rail prefer wetland habitats with more shallow water depths (Johnson and Dinsmore 1986) which is more typical of the extended emergent vegetation area of the wetland than the reservoir. Although we did not calculate density estimates for American Bittern since we had only two detections in 2018 and one in 2019, this occurrence information is important to add to regional occurrence data for this species.

Overall, we observed similar ibis nesting timeframe characteristics in 2018 and 2019. Timing of ibis return, colony site establishment, nest building, and incubation was very similar even with the higher water levels in 2019. The second smaller colony site used by ibis in 2019 was not used by ibis in 2018. The establishment of the second colony site about a week after many nests had failed in the main colony site, along with our observations of ibis trying to nest in small bulrush patches around Mountain View Reservoir, support our observations that a high number of ibis were displaced from the main colony area in 2019. If a historically used nesting site experiences drought or flooding and thus is unable to support nesting ibis, ibis will move to new areas to nest both locally and regionally. After flooding at the Great Salt Lake in northern Utah from 1983-1989, ibis relocated to more favorable nesting sites and it is believed these ibis relocated as the population of breeding ibis in Oregon and Idaho increased (IWJV 2013). However, if habitat is limited and ibis do try to nest in less favorable habitats, colonial nesting birds are particularly more vulnerable to catastrophic environmental events. Thus, drastic changes in nesting habitat may result in population declines after several years of unsuccessful nesting.

Apparent nest success decreased from 2018 (73%) to 2019 (60%). For both years, this success rate was lower than estimated nest success in other studies of ibis colonies in the west which ranged from 80% (n=175, Kotter 1970) in Utah and 83% (n=42, Henry and Herron 1989) in Nevada and averaged 87% at sub-colonies at Lower Klamath National Wildlife Refuge (n=126, Taft et al. 2000). In 2019, we observed catastrophic weather events of severe afternoon rainstorms, high winds, and even hailstorms in May which, in combination with already higher water levels, resulted in obvious nest failures.

Our best supported model of nest success in 2019 included only one variable: nest bowl height above water as the predictor of a nest successfully hatching at least one egg. We observed height of nests ranging from 15.25-27.3cm above water. These measurements reflect the nest height at the start of incubation; with the natural wetland system allowed to drain, the water level throughout the breeding season lowered and nest height increased as a result. Other studies of ibis colonies located in bulrush showed slightly higher average nest heights of 20.2-99cm in Utah (Ryder and Manry 1994), but studies also recorded lower water levels varying from 28.7-60.8cm (Ryder and Manry 1994) than what we saw in 2019 with an average water depth of 150cm in the Blue Creek wetland. While the model supported nest bowl height as the best parameter to predict nest success, nest bowl height, vegetation height, water height, and colony site were all highly correlated. Water height and vegetation height may not directly predict nest success, but from our observations in 2019 compared to 2018, higher water levels flooded over the vegetation and the availability of nest material was then limited as older growth was flooded and new growth had not yet grown above the water surface. In some subsites of the colony, while vegetation may have been found and brought in from other areas, the ibis were unable to anchor and build their nest high enough above the water. Given more time, the ibis may have been able to build a taller nest and new bulrush growth may have increased protection, but we observed many nests destroyed during multiple spring rainstorms along with high winds. Additionally, there are many other variables we did not measure or account for in our model that could affect nest success such as predator density, ibis nest density within the colony, prevalence of harsh weather events, and diseases.

Conclusions and Management Implications

The use of the Blue Creek Wetland complex by White-faced Ibis and many other waterbirds as well as ibis nest success in 2018 and 2019 suggest natural weather events can limit ibis breeding but currently there is enough habitat that ibis can still build nests and be successful. Although we did not quantify other potential factors that might limit nest success, we suggest that management actions regarding water levels and emergent vegetation within the wetland complex can ensure habitat availability for ibis and other waterbirds. In wetland systems, hydrology is the main driver of wetland dynamics and so managing for certain water levels can help ensure favorable nesting habitat that can maintain or increase breeding success. At the historical colony site, water levels should be managed within a range to best mimic natural water cycles and optimize nesting habitat. Ideally, water levels will not be raised too high or suddenly especially during key times in nesting, to avoid catastrophic failures. Specifically, drastic water levels changes between late May, after eggs have been laid, and mid-July, when chicks are hatched and mobile, could cause widespread nest failures. During this time, nests with eggs or non-mobile chicks would not be able to escape rising water levels or, if water levels are lowered too far, predators (Ryder and Manry 1994). We recommend holding May through July water depth in the bulrush area between 0.6 to 1.2 meters as observed during 2018. Managing water levels will also ensure continued extensive patches of emergent vegetation needed for nesting success of all waterbirds occurring at this site (Nadeau and Conway 2015). Continued monitoring of the ibis nesting colony will ensure habitat goals are met and, in this way, ibis can also act as an ‘umbrella’ species as other colonial nesting waterbirds have similar habitat needs.

Since density estimates are often used to assess current population status and trends for management plans, we recommend continued long-term monitoring especially for ibis, other colonial nesting waterbirds like Black Terns, and secretive marsh birds which will help yield a better understanding of the bird community that the wetland complex supports each year. Long-term monitoring will also help in providing more detections and thus better population estimates. Based on our results and information from earlier studies of ibis and waterbirds in the West, habitat degradation and decline must be mitigated to ensure continued success for waterbird populations. Careful management of water resources both for wildlife and human activity can ensure habitat and population goals are met.

CHAPTER 2: IRRIGATION PRACTICES AND FORAGING HABITAT USE OF WHITE-FACED IBIS ON AND NEAR BLUE CREEK WETLAND, IDAHO

Abstract

Breeding bird populations can be limited by quality nesting habitat as well as food supply, which is driven by foraging habitat availability and quality. Waterbirds in western North America are limited by patches of wetland environments in an arid landscape which also have attracted agricultural operations seeking water resources. Waterbirds have been known to use flood-irrigated agricultural fields for additional foraging habitat but, with potential future decreases in water resources, more water efficient systems like sprinkler irrigation are being recommended to replace flood-irrigation practices. We investigated how wetland type (natural or agricultural) and irrigation type (flood or sprinkler) drives selection of foraging habitat by White-faced Ibis (*Plegadis chihi*) around a large breeding colony at a natural wetland system on Duck Valley Indian Reservation. We found ibis foraged most often in the natural wetland areas but frequently used flooded agricultural fields as additional foraging sites. We modeled habitat selection with generalized linear models and our results suggest the presence of water, resulting in saturation of a field with standing water, is the main predictor of selection while other environmental variables like vegetation type and height do not affect selection. We also investigated differences in macro-invertebrate abundance and diversity of agricultural fields with different irrigation practices which may also drive foraging habitat selection. Our results suggest no differences in diversity between fields, but abundance was higher

in flood-irrigated and naturally flooded fields. Our results offer important habitat selection information by breeding waterbirds which can help inform management decisions as the need for more water efficient systems increases in the face of decreasing water resources.

Introduction

Understanding factors limiting breeding success is a critical component of conservation plans for declining or vulnerable bird populations. Loss and degradation of habitat is a threat for declining bird species in almost every habitat type and with 20% of waterbirds still considered of high conservation concern (NABCI 2016), wetland habitats continue to be of high conservation value. Historically, the loss and degradation of wetland habitats has been attributed to human development including agriculture (Dahl 2000, 2006) but, for some waterbirds, certain agricultural practices have created usable artificial wetlands which may help supplement natural wetlands - or even act as surrogates - as landscapes continue to change.

The White-faced Ibis (*Plegadis chihi*) is a migratory waterbird species that breeds in freshwater wetlands throughout the Intermountain West (Ryder and Manry 1994). They nest colonially in shallow freshwater marshes by building nests out of emergent vegetation above the water surface. During breeding, they often forage in shallow pools, marshes, and edges of reservoirs within a few miles of the nesting colony (Bray and Klebenow 1988). They wade in shallow water and probe for a variety of aquatic and moist soil invertebrates including insects, earthworms, and snails (Bray and Klebenow 1988). Additionally, ibis frequently forage in agricultural fields near their breeding colony. Bray and Klebenow (1988) studied ibis foraging preferences in flood-irrigated agricultural fields at a site in the Lahontan Valley, Nevada and found that ibis most often preferred foraging in alfalfa fields with standing surface water and in fields 3-6 km from the breeding colony location. A study of ibis foraging habits near two breeding colony sites in eastern Idaho showed that 89% of ibis foraging observations occurred in fields without a center pivot system (i.e., flood-irrigated, drip-line, or movable sprinklers). The same study also observed a 6% conversion of non-pivot fields to center-pivot irrigated fields from 2011 to 2012 based on aerial imagery from 2011 and their field observations in 2012 (Moulton et al. 2013).

Ibis are recognized as a species of greatest conservation need in eight states (USGS SWAP 2017), including most states within their breeding range, due to threats to habitat and productivity. Conversely, regional population trend studies have shown an increase since 1984 (Earnst et al. 1998, Cavitt et al. 2014, IDFG 2017). Currently, Idaho supports up to 50% of the known ibis breeding population in the western U.S. (Cavitt et al. 2014), with the Blue Creek Wetland area on the Duck Valley Indian Reservation being one of six known breeding sites in Idaho. Like the ibis colonies in eastern Idaho, ibis have been known to forage in flood-irrigated fields and are known as “irrigation birds” by Tribal members (Gossett 2008). Most agricultural fields on the reservation are currently flood-irrigated but the Tribe is considering plans for future upgrades and modernization which might include switching from flood-irrigation to a more water efficient system of center-pivot (sprinkler) irrigation. Conserving flood-irrigated agriculture as “working lands” is included in many local and regional waterbird conservation plans (Kushlan et al. 2002, Ivey and Herziger 2006) but research quantifying use of agricultural lands by waterbirds is limited.

We surveyed for foraging ibis across the naturally flooded wet meadows, flood irrigated fields, and center-pivot irrigated fields surrounding a White-faced Ibis breeding colony on the Duck Valley Indian Reservation in southern Idaho throughout two summer breeding seasons to model foraging habitat selection. We also quantified and compared aquatic and moist soil invertebrate density and diversity between irrigation practices. With existing knowledge of ibis foraging habits, we predicted that flood irrigation would be chosen over sprinkler-irrigated fields because flood irrigation more closely mimics natural wetland habitats. Collecting data on habitat selection by ibis, especially environmental variables that drive selection, will help the Tribe and wildlife managers better understand habitat needs of ibis and help inform management decisions in the future.

Study Area

The Duck Valley Indian Reservation straddles the Idaho and Nevada border and is comprised of about 290,000 acres (Figure 2.1). Most of the reservation is characterized by high-elevation (5400-6800 ft.) shrub-steppe desert. The central valley of the reservation consists of the Blue Creek Wetland complex, three man-made reservoirs, and irrigated agricultural lands. The primary land use of Duck Valley is focused on cattle ranching with many irrigated fields used for growing alfalfa and hay while cattle are grazed in some irrigated fields but mostly in natural wet meadows and sagebrush rangeland.

The Blue Creek Wetland complex comprises about 4,400 acres and lies in a broad floodplain completely on the Idaho side of the reservation and stretches north to south running parallel to and west of Highway 51 (Gossett 2008, Figure 2.1). This palustrine system is characterized by persistent, emergent vegetation and extends into areas of wet meadows dominated by grasses (USFWS 2019). The primary open water areas are located just west of Mountain View Reservoir. The wetland seasonally floods and is fed by springs, most originating in plateaus on the eastern boundary, and the Owyhee River at the southern end of the wetland area which seasonally floods and feeds the wetland through culverts under Blue Creek Road. A White-faced Ibis colony, with approximately 5,000 nesting pairs, is historically established in the wetlands in a large Hardstem Bulrush (*Scirpus acutus*) stand about 10.5 miles north of the border town of Owyhee, Nevada (Gossett 2008). Ibis leave the colony area regularly every day to forage in the surrounding natural wetland areas as well as agricultural fields.

Most of the agricultural fields of Duck Valley are located along the Owyhee River in the central valley of the reservation (Figure 2.2). The Owyhee River is diverted to an irrigation ditch at China Diversion Dam where the river is then mostly channelized as it flows through the central valley agricultural fields along with the irrigation ditches. The river returns to a more natural state as it approaches the boundary with the southern edge of the Blue Creek Wetland where it then flows west and supplies water to Pleasant Valley agricultural fields. All agricultural fields on the reservation are flood-irrigated except for six center-pivot irrigated fields located adjacent to Mountain View Reservoir (Figure 2.2).

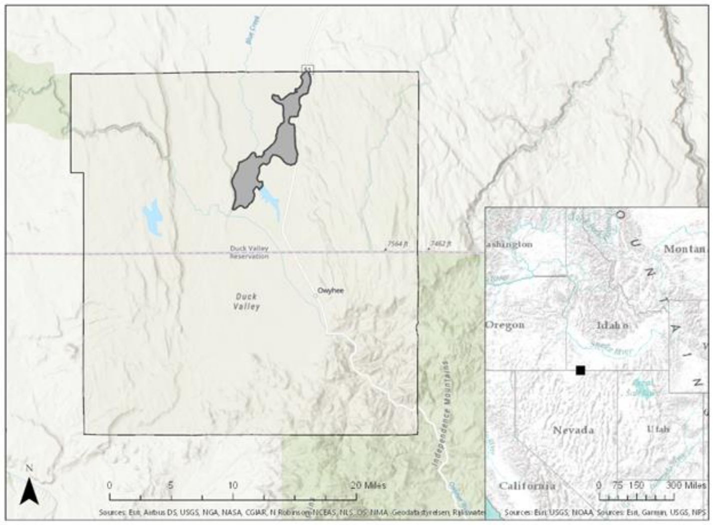

Figure 2.1 Blue Creek Wetland Complex study site on the Duck Valley Indian Reservation

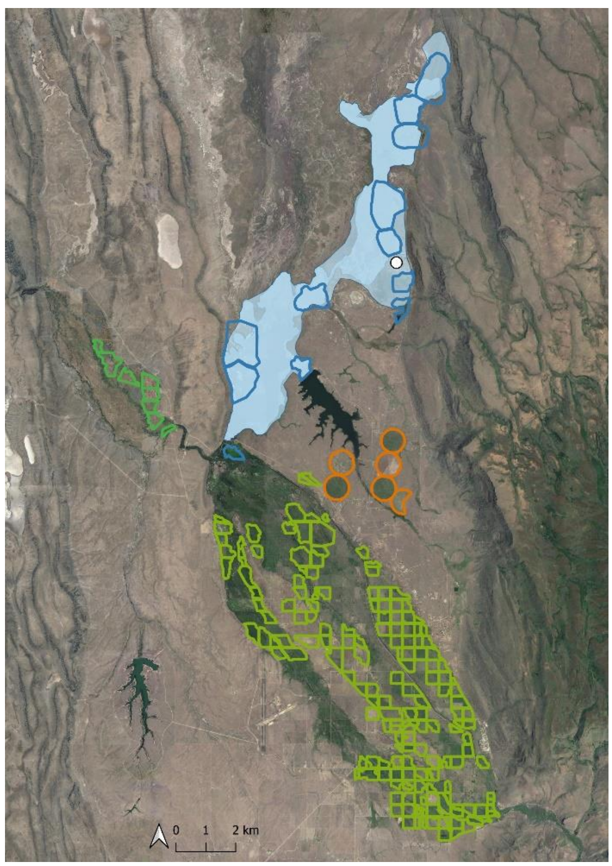

Figure 2.2 Blue Creek Wetland Complex, location of Ibis nesting colony (white circle), and surveyed agricultural fields including central valley flood irrigated fields (yellow-green polygons), Pleasant Valley flood irrigated fields (green), center-pivot fields (orange), and naturally flooded fields surrounding the wetland complex (blue).

Methods

Field Methods

Ibis Foraging Habitat Selection

Potential foraging habitat surrounding the Blue Creek Wetland complex includes the natural wetland areas and irrigated agricultural lands. We divided these areas into survey sites using Google Earth aerial imagery and based on our determination in the field that sites would be replicable by using natural barriers, fences, and roads to distinguish fields into distinct survey sites (Figure 2.2). In 2018, we surveyed all accessible agricultural fields and wet meadows in a random order throughout the summer, from May to August, to record foraging ibis. We surveyed approximately 30-40 fields per day, and in many cases the fields to be surveyed on a given day were widely scattered and required travel time between survey areas. A survey for one field consisted of a 5-minute scan using binoculars and a telescope to determine ibis presence or absence. In addition to recording ibis counts in a field, we measured environmental variables that we hypothesized would predict ibis use including vegetation type, vegetation height, water saturation level, and field use (i.e., pasture or natural but grazing). We surveyed all fields at least four times throughout the summer breeding season in 2018 and this roughly corresponded to sampling every field each in May, June, July, and August. With our random survey design in 2018, we failed to capture incidences of ibis foraging in agricultural fields on each day; thus, in 2019 we adjusted our approach to increase efficiency and ibis encounter rates. We conducted driving surveys in which we drove all accessible roads to scan all fields for foraging ibis each day of surveying. With this approach, we quickly scanned up to 200 fields per day including the natural wetland areas. When ibis were spotted, we recorded counts and environmental variables as in 2018. For comparison, we paired used fields with unused fields, including an unused field for each irrigation type, and recorded environmental variables.

Aquatic Invertebrate Sampling

We quantified wet soil and aquatic macro-invertebrate density and diversity of the ibis' foraging habitats using two common wetland aquatic invertebrate sampling methods (Meyer, Peterson, and Whiles 2011). We combined dipnet measured sweeps to collect surface water invertebrates and stovepipe sampler methods to collect benthic invertebrates. This ensured different water levels and vegetation cover were sampled since sites varied in their levels of water throughout the season. For the dipnet measured sweeps (when surface water present), we used 1-meter sweeps of the surface water and filtered contents through a screen for identification. We then used an 8-inch diameter stovepipe sampler to collect and filter saturated sediments. We conducted invertebrate sampling throughout the summer in 2019 in three main time frames - spring (May), early-summer (June), and mid-summer (July) - to quantify the invertebrate community and availability as the habitats changed in water level saturation. We randomly selected fields to sample for invertebrates but were restricted to sample only fields actively being irrigated and with some level of saturation. We sampled 5 fields in each irrigation type - natural, flood, and pivot - during each time frame and collected invertebrates at 5 sampling locations within each field that we then combined for one sample per field. Due to small differences in gradients in fields, an agricultural field was usually not entirely saturated with standing water. In this case, we sampled along the saturated zones with water levels ranging from 2-10cm. We randomly selected the first sampling location and sampled at locations every 50m following the saturated zone. We identified the collected invertebrates to order and recorded size and counts.

Analysis Methods

2018 Foraging Habitat Selection Modeling

We used a hurdle model consisting of generalized linear mixed models in a Bayesian framework to predict the effect of environmental variables on ibis foraging habitat selection. The hurdle model works by specifying two processes: the first model specifies the process by which either zero or positive counts occur, and the second model, once the 'hurdle' of a non-zero process is crossed, specifies the process for just the positive counts. We used the package 'rstanarm' (Goodrich, Gabry, Ali, and Brilleman 2020) in R (R Core Team 2019) to model both processes. First, presence or absence of ibis was modeled using a binomial response and, as fixed effects, we used predictor variables we hypothesized would influence ibis habitat selection for foraging: water depth, vegetation height, vegetation type, and field use. Second, counts of ibis foraging was modeled as a negative binomial response and, as fixed effects, we used predictor variables which we hypothesized influenced ibis use: water depth, vegetation height, percentage of surface water with little vegetation, vegetation type, and irrigation type. In our Bayesian framework, we were able to partially pool all field surveys while accounting for repeated surveys as a random effect variable included in both models. Visit number corresponded to repeat surveys for each field and roughly corresponds to possible temporal changes as all surveys for each visit took place within a two-week time frame during the summer. Irrigation type was either flood irrigation, center-pivot irrigation, and naturally flooded areas (i.e., naturally wet but no human influence), mostly including the saturated meadows of the wetland complex. The type of irrigation could influence the type of vegetation grown, the height of the vegetation, and level of water saturation with flood irrigated fields acting more like natural wetland areas than center-pivot irrigated fields (Donnelly et al. 2019). We also included an offset parameter to account for differences in field area (the size of each survey site) in the negative binomial response model of counts of ibis foraging. We obtained parameter estimates by running each model with 4 chains of 4000 iterations with 1000 iterations of warm-up. We checked model convergence and mixing of chains by visual inspection and that the 'R-hat' values were below the threshold of 1.1 (Gelman and Rubin 1992). To check for model fit, we performed posterior predictive checks to determine if the observed data deviated from the model-generated data.

2019 Foraging Habitat Selection Modeling

Because we paired used foraging sites with unused sites in 2019, we fit a Bayesian conditional logistic regression model with the 'rstanarm' package (Goodrich, Gabry, Ali, and Brilleman 2020) in R (R Core Team 2019). We included variables we hypothesized may predict foraging habitat selection: water depth, percentage of open water with low vegetation cover, vegetation height, and field use (either grazed or grown for hay). We obtained sampled from the posterior distribution and parameter estimates by running each model with 4 chains of 4000 iterations with 1000 iterations of warm-up. We checked model convergence and mixing of chains by visual inspection and that the 'R-hat' values were below the threshold of 1.1 (Gelman and Rubin 1992). To check for model fit, we performed posterior predictive checks to determine if the observed data deviated from the model-generated data.

Invertebrate Community Density and Diversity

We designated the number of detected invertebrate taxonomic orders within each field as order richness and used this order richness to calculate diversity using a Shannon-Wiener index with the 'vegan' package (Oksanen et al. 2019) in R (R Core Team 2019). We used a two-way ANOVA to test if diversity differed between irrigation type and month. We calculated invertebrate density as total counts per unit volume (L), as recommended by Kornijow and Pawlikowski (2016), to standardize samples when different heights of benthic cores are sampled. Calculating density as per unit volume also allowed us to account for different levels of surface water because for some fields, including all of the center-pivot irrigated fields, we could not get a dip net sweep sample since there was very little surface water to sample. We used the Shapiro-Wilk test to check for normal distribution and the Leven test to check for equal variances before using a two-way ANOVA to test for differences in invertebrate densities found in fields with different irrigation practices and between months. We used the 'car' package (Fox and Weisberg 2019) in R to perform all assumption and ANOVA tests.

Results

Ibis Foraging Habitat Selection

In 2018, we detected ibis foraging in 27 out of 763 total surveys of agricultural fields and natural wetland areas. We had only one observation of ibis foraging in a center-pivot irrigated field with the rest of the detections occurring in flood irrigated fields and natural fields around the wetland. No ibis were detected foraging in fields that were dry and most fields utilized by ibis had at least 1 inch of standing water covering most of the field. Our model suggests there is a 95% probability that the effect of saturation of fields with a standing water depth greater than zero increases the use of the field by ibis. The maximum average effect of an increase in water depth by 1 inch increases the probability of use by 20% (95% CI 15, 27.5, Figure 2.3). The model further suggests that vegetation height, vegetation type, and irrigation type do not predict the presence or absence of ibis using a field for foraging.

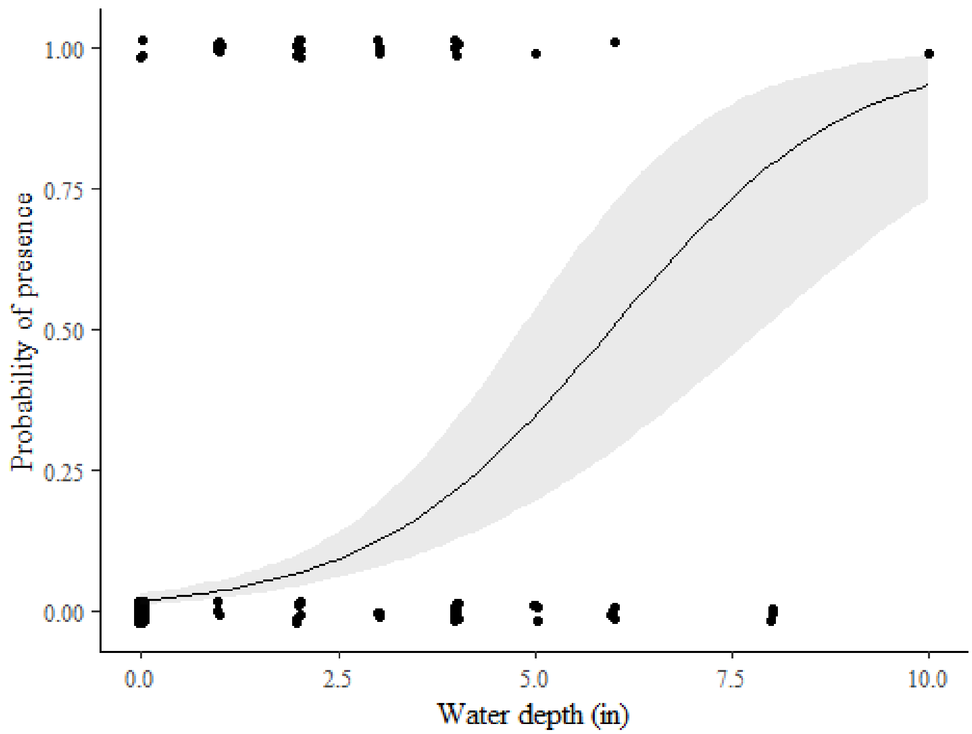

Figure 2.3 White-faced Ibis presence and absence dependent on water depth (inches) in a field surrounding the Blue Creek Wetland, of the Duck Valley Indian Reservation, Idaho in 2018. As water depth increases, the probability that birds use the field increases by an average maximum of 20%. Black line shows the average effect and blue shaded area shows 95% CI.

In 2018, we detected ibis foraging in fields for 27 surveys with the number of ibis in each field ranging from 3 to 365. Most of our observations of ibis foraging occurred in flood-irrigated fields and all observations of more than 40 ibis per field occurred in flood-irrigated fields. However, our model does not suggest the environmental variables of vegetation type, vegetation height, and irrigation type affect number of ibis using a field for foraging. Further, our model does not suggest water saturation height influences the number of ibis using a field. While most fields where ibis were observed had a measurable amount of standing water in the field ranging from 2 to 25cm, most fields also had similar environmental variables measurements - especially that the primary vegetation type was grass/hay.

In 2019, during our driving surveys of all agricultural fields and natural wetland areas, we recorded 112 detections of ibis foraging in fields away from the main colony area; thus, we were able to quadruple our number of observations by switching our approach from 2018 to 2019. We recorded ibis foraging in a center-pivot irrigated field just once and all 42 ibis foraging in the field at the time were in areas under the sprinklers which were actively irrigating the field. Of our total foraging observations, 64.3% (n=72) occurred in naturally flooded areas around the wetland complex, while 34.8% (n=39) occurred in flood irrigated fields. We recorded over 100 ibis in a single field just 13 times out of our total detections of ibis foraging, with most large groups foraging in flood-irrigated fields. Most detections of ibis foraging in the natural wetland areas away from the colony were in smaller groups of 10-30 birds. During our surveys, we noticed ibis seemed to find newly flooded agricultural fields soon after irrigation was initiated. Some fields were completely dry one day but as soon as the fields were flooded, we often observed the ibis foraging there within a day.

As with the 2018 analysis, our conditional logistic regression model comparing used foraging sites to unused sites in 2019 suggests that water depth is the best predictor of ibis use of a field for foraging. Increasing water depth has a significant effect on increasing the probability that a field will be used for foraging. The odds a field is used rather than unused is 15 (log odd 2.7, Figure 2.4) times more likely with water levels above 0 inches (95% CI: 3.41, 24.03), and the probability of use with a positive increase in water depth is 89% (95% CI: 0.805, 0.968). The parameter estimates for vegetation height, open water percentage, or field use all had credibility intervals overlapping zero, suggesting no evidence for an effect on selection for foraging (Figure 2.4).

We observed a few agricultural fields used for foraging both in 2018 and 2019 with many fields not used in either year. Overall, ibis used the natural wetlands for foraging more often than agricultural fields in both years and we only observed ibis foraging in a center-pivot irrigated fields once each year. For both years, the presence of water coverage in a field is the best predictor of foraging habitat selection according to our best supported models and similarly, environmental variables of vegetation height or type did not predict ibis foraging habitat selection in both years.

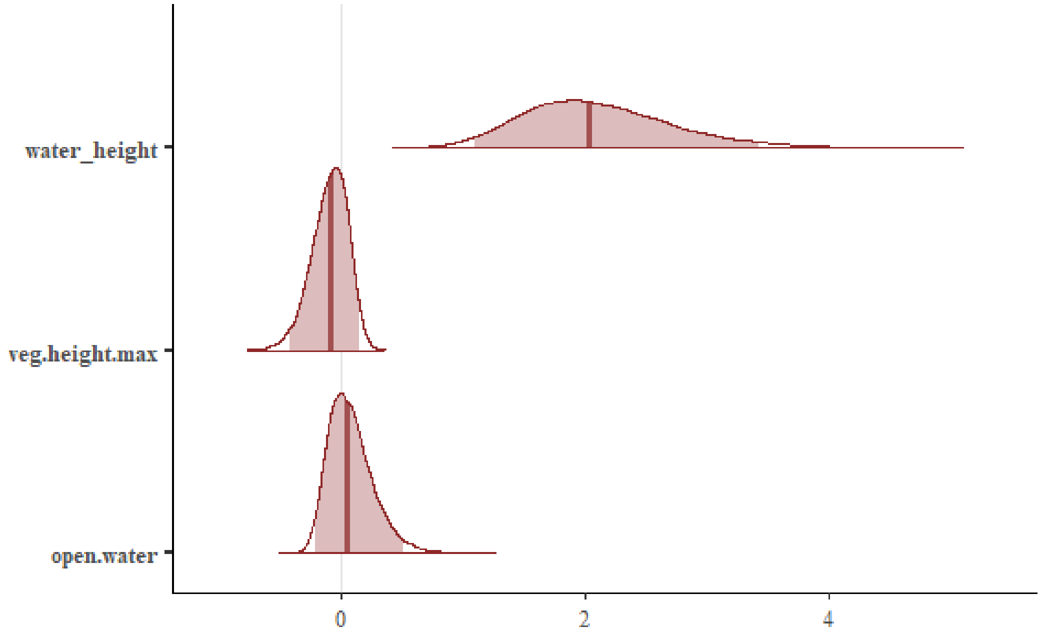

Figure 2.4 Posterior distributions of parameter estimates for conditional logistic regression model describing used versus unused fields for foraging by ibis during May-August 2019. Parameter estimates are shown in log odds to determine direction of effect and significance. Dark lines are medians, and light shaded area under the curves are 95% credible intervals.

<u>Invertebrate Community Diversity and Density</u>

We detected invertebrates from 11 different taxonomic classes or orders. Groups with the highest occurrences include class Gastropoda, order Diptera, order Haplotaxida, order Coleoptera, and order Hemiptera. We only recorded three different orders occurring in center-pivot irrigated fields with Haplotaxida (earthworms) being the most abundant. Diversity was low in May for flood and center-pivot irrigated fields because we mostly collected just a few earthworms in each field (Figure 2.5). Naturally flooded fields had a higher diversity in May and diversity did not increase or decrease over the summer. Overall, we did not detect a significant difference in diversity indices between irrigation type or month. However, for center-pivot irrigated fields, there was a significant difference in diversity between May and July only (t=2.22, p=0.03, Figure 2.5).

Overall, the samples from naturally flooded areas had higher average abundance for each field than the agricultural fields irrigated by flood or center-pivot and we found a significant difference in invertebrate density between fields with different irrigation practices (F= 7.03, df=2; p=0.0028). Across all months, average densities of flood-irrigated and naturally flooded fields were higher than center-pivot irrigated fields. Average invertebrate density decreased from May to July for center-pivot irrigated fields whereas density increased for flood and natural over the summer months, especially in July (Figure 2.6). We found a significant difference in average invertebrate densities between months across all irrigation types combined (F=6.856, df=2; p=0.0032).

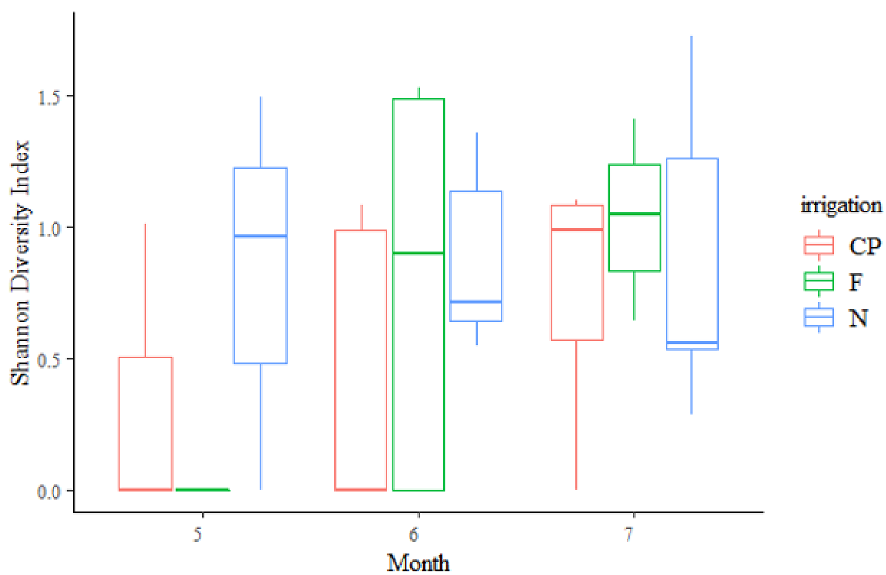

Figure 2.5 Shannon diversity index for invertebrate taxonomic order diversity by month and irrigation type (CP= center-pivot, F= flood, N= naturally flooded) from May to July 2019.

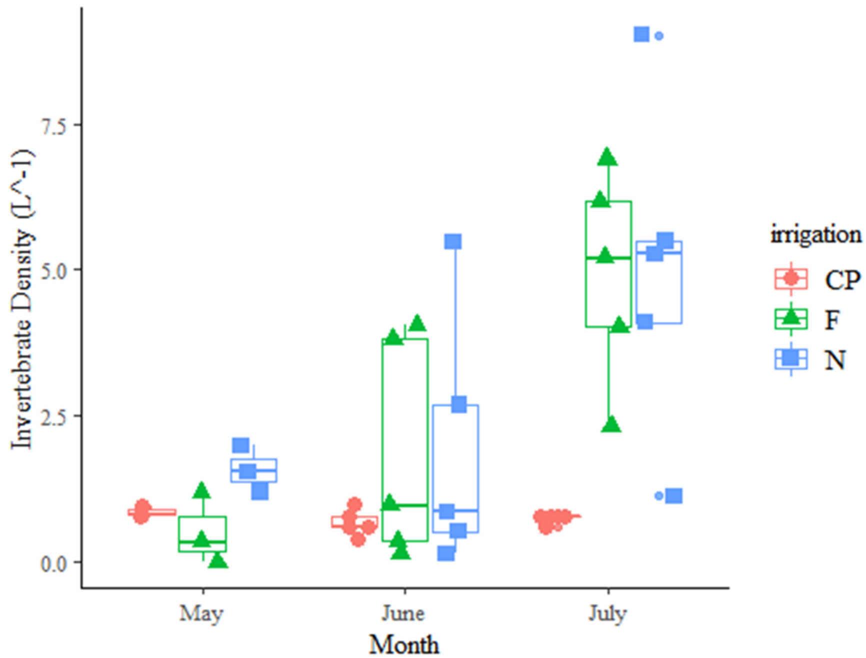

Figure 2.6 Average total density of invertebrate prey per volume unit (L^-1) by month and irrigation type (CP=center-pivot, F=flood, N= naturally flooded) for sampled available foraging habitats in 2019.

Discussion

Our results show that ibis' selection of foraging habitat around their breeding colony may be predicted by the presence or absence of water coverage, especially in agricultural fields, and this water presence may be indirectly determined by irrigation practice. We also found differences in the ibis' invertebrate prey density between fields with different irrigation practices and by month which may determine ibis foraging habitat selection as well. Other habitat variables like vegetation type, vegetation height and field use do not predict habitat selection for foraging although we saw little variation of these variables across the potential foraging habitats in our study area.

Our results suggest that the presence of water saturation in an agricultural field is the most important environmental variable that determines habitat selection for foraging. In Nevada, Bray and Klebenow (1988) also found that ibis foraged in irrigated fields with surface water present 99.9% of their observations. Similarly, in eastern Idaho, ibis were never observed foraging in dry fields (Moulton et al. 2013). The presence of water in a field is not surprising in its effect on ibis presence or absence considering the natural history of ibis and their foraging strategies of probing for prey suspended in water, moist soils, or in vegetation above water (Bray and Klebenow 1988). While the effect of water may determine presence of ibis, our models suggested water height does not affect abundance of ibis using a field to forage. Too much water would make an area unavailable for foraging in that the ibis would not be able to wade and reach the soil due to their morphological traits (Safran, Colwell, Isola, and Taft 2000). However, compared to shorebirds and waterbirds with shorter culmens and legs, ibis are able to use a larger range of water depths (Safran et al. 2000). The limit of presence and abundance in foraging habitat is most likely determined by the total area of habitat that has water coverage enough for foraging but is not too deep.

Since most agricultural fields in our study had similar vegetation height and type, it is not surprising that these variables did not show an effect on ibis' selection of foraging habitat in our models. However, we did expect vegetation height to affect ibis use as taller vegetation would make it more difficult for ibis to move around and forage in a field and ibis also tend to prefer open areas in natural wetland systems but within a few meters of the emergent vegetation (Safran et al. 2000). We did not record ibis foraging in fields with vegetation higher than 18 inches. However, throughout the summer, we noticed the vegetation height in the agricultural fields not growing higher than about 24 inches before the hay was harvested and cut back down to just a few inches, so we may not have had the opportunity to search for ibis in fields with a vegetation height in which ibis would stop using a habitat. Similarly, in eastern Idaho, ibis were recorded foraging in agricultural fields with vegetation higher than 12 inches just twice and, for both incidences, vegetation was not higher than 20 inches (Moulton et al. 2013). In Nevada, ibis were observed foraging in flood-irrigated fields with variety of vegetation heights ranging from less than 2 inches to 35 inches but were mostly found foraging in vegetation with heights ranging from 12 to 20 inches (Bray and Klebenow 1988). Interestingly, we found ibis foraging in naturally flooded fields around the wetland complex where grazing limited the vegetation height and, our observations of ibis foraging in hay fields often occurred in freshly cut fields in which flood irrigation started soon after cutting.

Similar to vegetation height, our models suggested vegetation type does not determine ibis' selection of habitat for foraging although vegetation type was mostly grass or a mix of herbaceous plants grown as hay, including alfalfa. Even in the naturally flooded grazed fields around the wetland complex, the vegetation type was mostly grass with small zones of emergent vegetation. In other studies of ibis foraging in agricultural fields, ibis were observed foraging in alfalfa fields from 58% (Moulton et al. 2013) to 86% of foraging observations (Bray and Klebenow 1988). Alfalfa was grown in 3 of the 6 center-pivot irrigated fields and a few flood-irrigated fields but our models do not show that ibis selected these fields for foraging because of the vegetation type.

We observed ibis foraging independently as well as flocked and, although our abundance model did not show an effect of water height, vegetation height, or vegetation type on abundance, we did observe that the ibis using the natural wetland areas exhibited less flocking and mostly solitary foraging behaviors even with more available area of surface water. In Nevada, ibis were observed foraging in large flocks of up to 1,000 but flock sizes were highly variable and averaged 25 birds in flood irrigated fields (Bray and Klebenow 1988). In eastern Idaho, ibis foraged in flooded agricultural fields in average group sizes of 122 birds (Moulton et al. 2013). Of our total foraging observations in 2019, more foraging events occurred in naturally flooded fields around the wetland complex, but with 35% of foraging events occurring in flood-irrigated fields and with higher flock sizes, these foraging events provide evidence of the importance of these additional foraging areas.

In addition to water coverage in a field, another variable that may be driving ibis' selection of foraging habitat is the density of the ibis' invertebrate prey. We did not directly measure invertebrate density in fields used by ibis for foraging, but we did find a difference in total density of invertebrates between sampled fields with different irrigation practices. We found lower densities of moist soil invertebrates in center-pivot irrigated fields than flood-irrigated and naturally flooded fields, especially in July when densities were significantly higher. Although there are few studies quantifying invertebrate density in relation to ibis foraging habitat selection, Safran, Isola, Colwell, and Williams (1997) found that during the nonbreeding season, ibis foraged in areas with greater densities of midge larvae and in areas with lower densities of oligochaetes than in random locations. The study also found water depth determined habitat selection, supporting our results that an interaction of water depth and density of invertebrates is driving foraging habitat selection.

Our results suggest ibis are using all available wetland areas and irrigated agricultural fields for foraging as long as there is standing water present in the field allowing the ibis to easily forage for invertebrates. Although there are 6 center-pivot irrigated fields adjacent to the wetland complex, we observed ibis foraging there just once each in 2018 and in 2019, and only when the irrigation was on creating mostly very moist soil with a limited amount of small pools of surface water. In eastern Idaho, ibis were observed foraging in center-pivot irrigated fields just 4 times but, similar to our observations, ibis were observed foraging in the areas of the fields where the water tended to pool which often occurred outside the center-pivot circle (Moulton et al. 2013). In our results, irrigation type did not directly affect ibis foraging habitat selection, but irrigation type may indirectly influence the selection of a field for foraging as ibis prefer standing water which is created with flood irrigation and more likely mimics historic wetland areas (Donnelly et al. 2019), and we found invertebrate density to be higher in flood-irrigated over center-pivot irrigated fields.

Conclusions and Management Implications

The Blue Creek Wetland complex possesses enough emergent wetland vegetation for ibis to establish a nesting colony each year for approximately 5,000 nesting pairs with the surrounding agricultural fields providing additional foraging habitat for ibis. Our results show working agricultural lands supplement and are compatible with ibis foraging strategies and that, broadly, water management can be used as a tool by wildlife managers to provide foraging habitat in partnership with agricultural needs and conservation planning.

Survival of ibis, as well as many other waterbirds, is dependent on conservation of wetland habitats and, for successful breeding, nesting habitat as well as foraging lands are needed. Because ibis selected habitats for foraging based on presence of water, management plans should include managing water levels within a range suitable for foraging for ibis and the many species of waterbirds that currently use the wetlands each year. Areas of low water levels tend to be used by many species of waterbirds and shorebirds, including ibis, while deeper water areas are used by fewer diving species (Colwell and Taft 2000) so managing the wetlands to ensure areas of shallow water depth are available could increase availability and use by ibis as well as other shorebird and waterbird species. Additionally, because water levels vary seasonally, dynamic water management and monitoring of available habitat is needed to ensure ibis habitat needs are met each year.

In recent years, pivot and sprinkler irrigation has been replacing flood irrigation practices to increase water use efficiency (Moulton et al. 2013). However, flood irrigation has historically provided wetland habitat for water birds and is important to the hydrology and functioning of remaining wetland systems, including aquifers (Peck and Lovvorn 2001, Donnelly et al. 2019). Irrigation methods used by ranchers are determined by many different factors, including the natural features of the land dictating the options for irrigation (Sketch, Dayer, and Metcalf 2020). Some ranchers even value wildlife conservation as a factor in their management decisions (Sketch et al. 2020) showing that ranchers and wildlife managers can work together towards a conservation goal.

Since not all available flood-irrigated fields we observed were used by ibis for foraging, some conversion to center-pivot or sprinkler irrigation may not decrease overall ibis foraging habitat at this site. However, if all the agricultural lands surrounding the ibis breeding colony were to be converted to sprinkler irrigation in the future, this would likely dramatically reduce the availability of one of their preferred foraging habitats. Thus, management for foraging habitat could include maintaining at least some proportion of flood irrigation to supplement wetland habitat. Since some fields we observed were never used or irrigated, if water resources are available, flooding these areas when other active agricultural fields cannot be flooded could provide additional foraging habitat especially when foraging habitat availability is low. Also, setting irrigation schedules to ensure fields are flooded on different days while also supporting the needs of ranchers will create consistent available foraging habitat. Our results highlight the potential benefits of continued flood irrigation practices in creating more available foraging habitat for ibis. The future for ibis will depend on continued monitoring and targeted management of water resources to best provide wetland habitat for the ibis and other bird life of the wetland complex as well as supporting working agricultural lands.

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APPENDIX A

Supplementary Tables: Chapter One

Table A.1 Bird species detected during June 2018 point counts of Blue Creek wetland complex and Mountain View Reservoir. Asterisk (*) denotes Idaho Species of Greatest Conservation Need.

Species	Scientific Name	# detections	relative abundance	# pts detected
American Avocet	*Recurvirostra americana*	9	0.00537	6
American Coot	*Fulica americana*	60	0.03578	34
American Robin	*Turdus migratorius*	10	0.00596	8
American Wigeon	*Mareca americana*	10	0.00596	10
American White Pelican *	*Pelecanus erythrorhynchos*	10	0.00596	9
Bank Swallow	*Riparia riparia*	1	0.00060	1
Barn Swallow	*Hirundo rustica*	14	0.00835	10
Black-billed Magpie	*Pica hudsonia*	13	0.00775	8
Black-crowned Night Heron	*Nycticorax nycticorax*	21	0.01252	15
Blue-gray Gnatcatcher	*Polioptila caerulea*	1	0.00060	1
Brown-headed Cowbird	*Molothrus ater*	37	0.02206	30
Black-headed Grosbeak	*Pheucticus melanocephalus*	4	0.00239	3
Black-necked Stilt	*Himantopus mexicanus*	4	0.00239	4
Bobolink *	*Dolichonyx oryzivorus*	5	0.00298	4
Brewer's Blackbird	*Euphagus cyanocephalus*	27	0.01610	15
Brewer's Sparrow	*Spizella breweri*	30	0.01789	18
Bullock's Oriole	*Icterus bullockii*	7	0.00417	5
Blue-winged Teal	*Spatula discors*	1	0.00060	1
Cassin's Finch	*Haemorhous cassinii*	1	0.00060	1
California Gull *	*Larus californicus*	6	0.00358	4
Canada Goose	*Branta canadensis*	34	0.02027	22
Canvasback	*Aythya valisineria*	1	0.00060	1
Canyon Wren	*Catherpes mexicanus*	3	0.00179	3
Caspian Tern	*Hydroprogne caspia*	15	0.00894	12
Cinnimon Teal	*Spatula cyanoptera*	23	0.01371	18
Clark's Grebe *	*Aechmophorus clarkii*	2	0.00119	2
Cliff Swallow	*Petrochelidon pyrrhonota*	26	0.01550	15
Common Nighthawk *	*Chordeiles minor*	3	0.00179	2
Common Raven	*Corvus corax*	39	0.02326	31
Common Yellowthroat	*Geothlypis trichas*	13	0.00775	8
Double-crested Cormorant	*Phalacrocorax auritus*	1	0.00060	1
Eared Grebe	*Podiceps nigricollis*	5	0.00298	4
Eastern Kingbird	*Tyrannus tyrannus*	3	0.00179	2
Eurasian Collared-Dove	*Streptopelia decaocto*	2	0.00119	2
European Starling	*Sturnus vulgaris*	7	0.00417	6
Forster's Tern	*Sterna forsteri*	50	0.02982	30
Gadwall	*Mareca strepera*	45	0.02683	29
Great Blue Heron	*Ardea herodias*	11	0.00656	8
Great Egret	*Ardea alba*	17	0.01014	12

Species	Scientific Name	# detections	relative abundance	# pts detected
Gray Flycatcher	*Empidonax wrightii*	27	0.01610	19
Grasshopper Sparrow *	*Ammodramus savannarum*	2	0.00119	2
Great-tailed Grackle	*Quiscalus mexicanus*	1	0.00060	1
Green-tailed Towhee	*Pipilo chlorurus*	2	0.00119	1
Green-winged Teal	*Anas crecca*	5	0.00298	5
House Finch	*Haemorhous mexicanus*	2	0.00119	2
Horned Lark	*Eremophila alpestris*	16	0.00954	9
House Sparrow	*Passer domesticus*	1	0.00060	1
Killdeer	*Charadrius vociferus*	26	0.01550	22
Lark Sparrow	*Chondestes grammacus*	3	0.00179	2
Lazuli Bunting	*Passerina amoena*	1	0.00060	1
Long-billed Curlew *	*Numenius americanus*	22	0.01312	16
Lesser Scaup	*Aythya affinis*	2	0.00119	2
Mallard	*Anas platyrhynchos*	20	0.01193	16
Marsh Wren	*Cistothorus palustris*	68	0.04055	22
Mourning Dove	*Zenaida macroura*	16	0.00954	15
Northern Harrier	*Circus hudsonius*	3	0.00179	3
Northern Pintail	*Anas acuta*	7	0.00417	6
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	1	0.00060	1
Northern Shoveler	*Spatula clypeata*	8	0.00477	8
Pied-billed Grebe	*Podilymbus podiceps*	30	0.01789	16
Ring-billed Gull *	*Larus delawarensis*	11	0.00656	10
Redhead	*Aythya americana*	7	0.00417	5
Rock Wren	*Salpinctes obsoletus*	28	0.01670	18
Red-shafted Flicker	*Colaptes auratus cafer*	1	0.00060	1
Red-tailed Hawk	*Buteo jamaicensis*	2	0.00119	2
Ruddy Duck	*Oxyura jamaicensis*	11	0.00656	8
Red-winged Blackbird	*Agelaius phoeniceus*	34	0.02027	16
Sandhill Crane *	*Grus canadensis*	17	0.01014	15
Say's Phoebe	Sayornis saya	1	0.00060	1
Sage Thrasher	*Oreoscoptes montanus*	12	0.00716	11
Savannah Sparrow	Passerculus sandwichensis	54	0.03220	24
Short-eared Owl *	*Asio flammeus*	2	0.00119	2
Sora	Porzana carolina	18	0.01073	13
Song Sparrow	*Melospiza melodia*	14	0.00835	12
Spotted Sandpiper	*Actitis macularius*	5	0.00298	4
Spotted Towhee	*Pipilo maculatus*	17	0.01014	11
Swainson's Hawk	*Buteo swainsoni*	2	0.00119	2
Tree Sparrow	*Spizella arborea*	12	0.00716	11
Turkey Vulture	*Cathartes aura*	1	0.00060	1
Vesper Sparrow	*Pooecetes gramineus*	35	0.02087	22
Virginia Rail	*Rallus limicola*	2	0.00119	2
Western Grebe *	*Aechmophorus occidentalis*	61	0.03637	27
Western Kingbird	*Tyrannus verticalis*	9	0.00537	8
Western Meadowlark	*Sturnella neglecta*	114	0.06798	55
Western Tanager	*Piranga ludoviciana*	2	0.00119	2
White-faced Ibis *	*Plegadis chihi*	129	0.07692	53
Willow Flycatcher	*Empidonax traillii*	4	0.00239	3
Willet	*Tringa semipalmata*	52	0.03101	34
Wilson's Phalarope	*Phalaropus tricolor*	22	0.01312	14
Wilson's Snipe	*Gallinago delicata*	16	0.00954	13
Yellow-breasted Chat	*Icteria virens*	2	0.00119	1
Yellow Warbler	*Setophaga petechia*	39	0.02326	25
Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*	107	0.06380	45

Table A.2 Diversity indices for overall bird point count surveys at Blue Creek Wetland and Mountain View Reservoir, Duck Valley Indian Reservation in June 2018

Shannon's diversity	Simpson's diversity	Pielou's evenness
3.927	0.971	0.849

Table A.3 Maximum nest counts for additional species nesting in the White-faced Ibis colony from perimeter surveys in 2018 and 2019.

Species	2018	2019
Black-crowned Night Heron	12	22
Black Tern	0	5
Forster's Tern	22	30
Great Egret	12	10
Sandhill Crane	4	5