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Articles

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Abstract

Migration ecology and habitat use of spring migrating birds using the Central Platte River is a well-explored topic, yet less is known about use of the North and South Platte rivers (NSPR) in western Nebraska. The efficiency and effectiveness of conservation efforts in the NSPR could be greatly improved with access to information about where and when birds roost and landscape prioritization tools. We used aerial surveys to determine population distribution and migration phenology of sandhill cranes *Antigone canadensis*, Canada geese *Branta canadensis*, and ducks using the NSPR for roosting during the mid-February to mid-April spring migration. We used these data and geospatial information to identify important river reaches for these species and habitat covariates that discriminate between those used at lower and higher densities. We found that sandhill cranes and waterfowl generally roosted in different segments of the NSPR and, subsequently, different factors were associated with high densities. Sandhill crane density was positively correlated with distance from obstructions greater than 1 m high and negatively correlated with area of unvegetated sandbar within 1 km. Density of Canada geese and ducks was high in segments positively associated with wetland and sand pit habitats. Human disturbance variables such as roads and bridges in this rural region had little effect on identification of roosting areas used by high densities of all groups. On the basis of our results, habitat conservation efforts that specifically target sandhill cranes will not have similar positive effects on waterfowl use and distribution in the NSPR. Our identification of the most important river segments should allow managers to better target land acquisition or management resources to areas that will have the greatest effect on either waterfowl or sandhill cranes during spring migration.

Keywords: migration; Nebraska; Platte River; roosting habitat; sandhill cranes; waterfowl

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Introduction

Midlatitude stopover and staging habitats play a critical role in the annual life cycle of migratory birds in North America (Kirby et al. 2008; Alerstam 2011; Sheehy et al. 2011; Klaassen et al. 2012). These sites provide adequate energetic resources that birds acquire and use to reach their northern breeding grounds, and also allow females of some species to accumulate nutrient reserves for egg laying and incubation (Drent et al. 2006, 2007; Newton 2006; Harrison et al. 2011). Multiple studies have confirmed the importance of cross-seasonal effects, where conditions or events in winter and spring influenced survival and reproductive success on the summer breeding grounds (summarized by Norris and Marra 2007). These effects may be especially apparent in wetland-dependent birds because of the high variability and relative scarcity of shallow-water aquatic habitats that most of these species require (Farmer and Parent 1997; Stralberg et al. 2011; Sedinger and Alisauskas 2014). Nutrient reserves gained during spring migration can be especially critical for larger-bodied birds, such as waterfowl and cranes (Krapu et al. 1985; Sedinger and Alisauskas 2014).

Nighttime roosting sites where wetland-dependent birds congregate in large flocks provide protection from ground predators and are typically located near high-quality foraging areas (Weller 1999). Throughout the Great Plains, riverine systems function as critical stopover and staging sites for migratory birds, providing key roosting and foraging resources (Iverson et al. 1987; Johnsgard 2012; Pearse et al. 2017a). The North and South Platte river (NSPR) systems in Nebraska are examples of both the invaluable and imperiled nature of these systems. These rivers, with a combined length traversing more than 460 total km in Nebraska, host hundreds of thousands of waterfowl, sandhill cranes *Antigone canadensis*, and other waterbirds during their annual spring migration (Currier et al. 1985; Krapu et al. 2014). State and federal agencies have prioritized sections of the NSPR as focus areas of conservation concern (Schnieder et al. 2011; USFWS 2017). Interchange between the NSPR and adjacent priority stopover and staging regions, such as the Central Platte River, may also occur in response to changes in habitat availability (Krapu et al. 2014). For example, Krapu et al. (2014) reported that $>$ 90% of sandhill cranes using the NSPR in spring breed in western Alaska and Russia. Although this indicates that NSPR is a selected staging area for the western Alaska–Russia subpopulation, it appears that habitat in the NSPR may be inadequate to support the entire subpopulation, as more than half use the Central Platte region instead. Therefore, Krapu et al. (2014) suggested habitat restoration on the NSPR to better accommodate the total subpopulation of sandhill cranes that historically used this region because the number of cranes using the NSPR has declined over time. Iverson et al. (1987) reported an average of 131,000 individuals in the NSPR and associated habitats during surveys conducted in 1979 and 1980 compared with an estimated 72,000 to 102,000 in 2016 (Dubovsky 2016). Many landscape stressors have also reduced riverine wetland habitats available to waterfowl migrating through in the spring (Williams 1978; Currier et al. 1985). Although the NSPR has been recognized as an important wintering area for waterfowl (Vrtiska and Lyman 2004), there have been limited efforts to quantify abundance and distribution of spring migrating waterfowl (Vrtiska 2004).

The NSPR is a substantially altered system with rapidly degrading habitats (Schneider et al. 2011; USFWS 2017). Habitat conditions have been affected by impoundments, diversions, altered hydrology, consumptive use, habitat conversion, and invasive vegetation species intrusion (Williams 1978; Johnson 1994; Strange et al. 1999; Kessler et al. 2011; Schneider et al. 2011; USFWS 2017). Multiple government and nongovernment entities are considering conservation strategies to restore these habitats for the benefit of cranes, waterfowl, and other priority species (Schneider et al. 2011; USFWS 2017). Current river management and conservation activities intended to benefit migrating sandhill cranes have been based on previously established habitat associations (Krapu et al. 1984; Iverson et al. 1987; Pearse et al. 2017b). Common restoration and management activities in the NSPR are similar to those used in the Central Platte region and include clearing invasive or undesirable woody plant species, mechanical removal of excessive sediment from the river channel or adjacent wetlands, and promotion of native wetland plant species with proven management techniques such as grazing and haying (Faanes and LeValley 1993; Pfeiffer and Currier 2005; Schneider et al. 2011; USFWS 2017). Much of the riverine habitat work in this region was intended to benefit sandhill cranes, but there is limited information on how habitat management efforts may affect distribution and abundance of other species that stopover in these areas, particularly waterfowl. Additionally, crucial information to guide habitat management or restoration and prioritize acquisitions or conservation is lacking, including species distribution and habitat attributes that drive distribution. Better information is required to shift management from the current opportunity-driven paradigm to one that is more strategic, targeting areas and actions that will give the greatest return on investment in terms of habitat quality and bird use.

Therefore, we conducted aerial surveys to determine the contemporary distribution of roosting sandhill cranes, Canada geese *Branta canadensis*, and ducks using the NSPR to initially identify areas where birds were concentrating use consistently through the spring migration and across years. Our objectives were to use these data to identify areas of consistently high use for roosting cranes and waterfowl, identify river and landscape characteristics associated with high use segments for roosting cranes and waterfowl, and determine whether similar river and landscape characteristics were selected for by roosting cranes and waterfowl. Results of this study could be used by conservation planners for more efficient and effective delivery of conservation, restoration, and management activities in the region.

Study site

The NSPR drain a large portion of the eastern Rocky Mountains in Colorado and Wyoming. The two rivers are primarily fueled by mountain snowmelt and other precipitation runoff and come together near the city of North Platte, Nebraska to form the Central Platte River (Eschner et al. 1983). The NSPR are characterized by numerous braided channels with sandbars interspersed and historically surrounded by grasslands, shallow wetlands, and wet meadow habitats (USFWS 2017). Natural flood cycles, fires, and trampling by native bison prevented tree and woody plant invasion. Disruption of these natural processes has allowed invasion of woody and nonnative species, whereas many areas of native habitat have been converted to agriculture and other uses (USFWS 2017). Currently, the most common land cover types within 1 km of the river center line are wet meadow, shortgrass prairie, riparian canopy cover, and agricultural row crop, mainly corn (Bishop et al. 2011).

Methods

Data collection

On the basis of recent known use patterns, we surveyed sandhill cranes in a reduced area split into two survey routes. One route covered the area from the confluence of the North and South Platte rivers west to the town of Sarben, Nebraska, and also included the 13-km section of Birdwood Creek, a total distance of approximately 73 km (Figure 1). The second route began at the western edge of Lake McConaughy and extended approximately 30 km to the Oshkosh, Nebraska bridge. We collected data using aerial waterfowl surveys on areas of the NSPR extending from their confluence near the city of North Platte, Nebraska west to the Wyoming and Colorado borders (Figure 1). We also surveyed a 13-km section of the Birdwood Creek tributary extending north from its confluence with the North Platte River. In total, we surveyed nearly 480 km of the NSPR study area for waterfowl. We limited habitat variable data to the area within 1 km of the U.S. Geological Survey National Hydrography Dataset center line because prior research has indicated this distance to be relevant to habitat selection by sandhill cranes (Sparling and Krapu 1994; Krapu et al. 2014; Pearse et al. 2017b).

We conducted aerial surveys using a Cessna 206 fixed-wing aircraft to collect data on crane and waterfowl distribution and abundance. We determined the seasonal survey periods on the basis of information about the timing of peak migrations in the adjacent Central Platte River region (Vrtiska and Sullivan 2009; Pearse et al. 2015) and NSPR (Krapu et al. 2014). In 2014, 2015, and 2016, we completed aerial surveys for cranes approximately once weekly from as early as 25 February to as late as 11 April. We divided crane surveys into two routes because of the time limitation due to cranes leaving the roost after the first hour of daylight and we flew them on two consecutive days when possible. We conducted aerial surveys for waterfowl weekly between 18 February and 20 March each year. For waterfowl surveys, we flew both the North and South Platte rivers in 1 d, reversing direction every week to limit time-of-day bias. We began all survey routes 30 min before daylight and completed them in 1 h or less to collect flock counts before birds departed the roosting sites.

The pilot flew at approximately 100 m above ground level at an airspeed of 110–120 knots. This allowed for sight distance of 400 m on either side of the aircraft for a total coverage width of 800 m. Where the valley bottom was too wide to allow full visual coverage, the pilot circled back to ensure full coverage of all habitat. Both the pilot and an observer counted waterfowl outside their respective sides of the aircraft. Where we encountered birds, we recorded flock count, flock type (Canada goose, duck, or sandhill crane), global positioning system (GPS) position, and habitat type (main channel, side channel, pond/wetland, or agricultural field; Data S1, *Supplemental Material*).

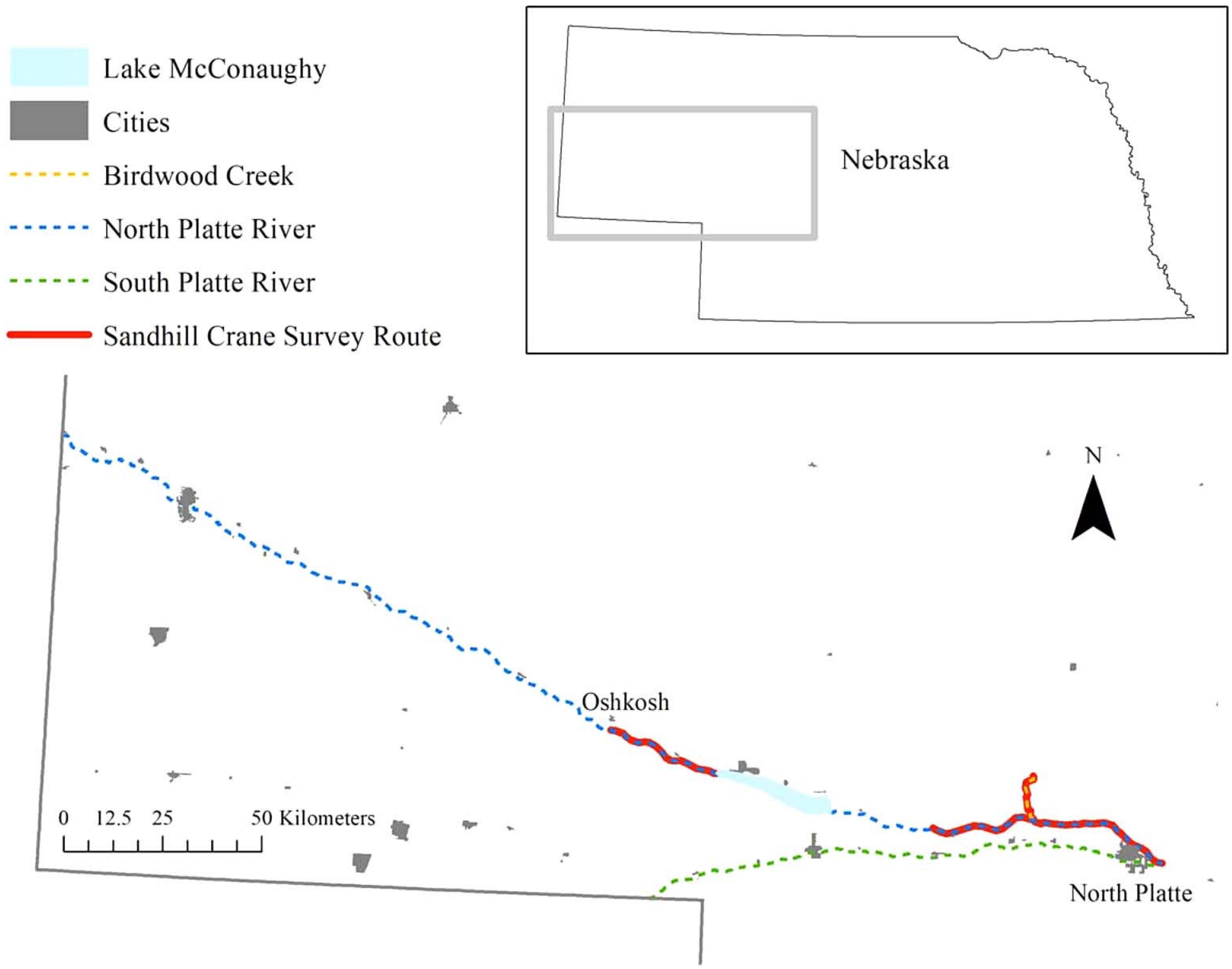

Figure 1. Sandhill crane *Antigone canadensis* and waterfowl survey flight areas on the North and South Platte rivers and Birdwood Creek, Nebraska during spring migration, 2014–2016.

Data analysis

To identify the most important roosting habitats, we divided the surveyed area into segments. Segment length for the sandhill crane analysis was 0.8 km, because cranes used a much smaller area of the North Platte River than waterfowl and this is a measure typically used in studies of cranes on the Platte River (Krapu et al. 1984; Davis 2001, 2003; Buckley 2011). For the waterfowl data analysis, we used 260 linear segments 2 km in length, which was consistent with the scale of conservation activities in the NSPR. Among public properties that intersect the center line of the NSPR, mean river length in conservation was approximately 2 km ($\mu = 2.28$, SE $= 0.55$, $n = 8$). Additionally, mean size of conservation projects implemented on the Platte River by Ducks Unlimited was 0.5 km^2 (J.C.D., Ducks Unlimited, unpublished data). Assuming we included the mean river channel width of 120 m (Williams 1978) and an equivalent buffer, mean river length encompassed by these projects was approximately 2 km. We assigned each flock counted to the nearest corresponding segment. For each survey flight, we estimated a utilization distribution for sandhill cranes, Canada geese, and ducks using segments identified along the river corridor (Worton 1989). We enumerated numbers of individuals observed by group within each segment and survey. We ranked river segments by density and determined the cumulative sum and proportion of individuals found within river segments (i.e., volume and cumulative proportion volume). Using methods described by Vander Wal and Rodgers (2012), we used volume metrics to identify areas of high density use by groups, where utilization distribution area and volume plotted. We fitted an exponential model to estimate the association between utilization distribution and volume and determined the volume at which the slope of the relationship equaled 1.0, which represented a transition point where we identified all segments with densities at or greater than the transition point as high-use areas and those below as nonhigh-use areas. Because we sought to identify roosting habitats that were consistently valuable over time, we designated segments as "conservation

Table 1. Potential predictor variables and expected direction of relationship for areas of high densities of sandhill cranes *Antigone canadensis* along the North Platte River and Birdwood Creek, Nebraska, during spring migration, 2014–2016.

Variable	Description	Predicted direction of relationship	Citation
Bridgemin	Minimum distance (km) to nearest bridge from segment edge	+	Krapu et al. 1984, Parrish et al. 2001, Pearse et al. 2017b
Conservmean	Mean distance (km) to nearest conservation lands from segment area	−	Iverson et al. 1987, Folk and Tacha 1990
Corn	Total area (ha) of corn in segment	+	Krapu et al. 1984, Iverson et al. 1987, Parrish et al 2001, Davis 2001, 2003, Pearse et al. 2017b
Grass	Total area (ha) of grassland in segment	+	Krapu et al. 1984, Parrish et al. 2001
Linesmin	Minimum distance (km) to nearest transmission lines or towers from segment edge	+	Krapu et al. 1984, Norling et al. 1992, Folk and Tacha 1990, Parrish et al. 2001
Pit	Total area (ha) of pits in segment	−	Parrish et al. 2001
RivChan	Total area (ha) of river channel in segment	+	Krapu et al. 1984
Roadmean	Mean distance (km) to nearest road from segment area	+	Krapu et al. 1984, Norling et al. 1992, Parrish et al. 2001, Pearse et al. 2017b
Trees	Total area (ha) of trees in segment	−	Norling et al. 1992, Folk and Tacha 1990, Buckley 2011
Unobswid	Mean unobstructed width (m) of the river channel and surrounding land	+	Krapu et al. 1984, Norling et al. 1992, Folk and Tacha 1990, Parrish et al. 2001, Davis 2001, 2003
Unvegsand	Total area (ha) of unvegetated sand in segment	−	Norling et al. 1992
Wetland	Total area (ha) of wetlands in segment	+	Iverson et al. 1987, Folk and Tacha 1990
WetMead	Total area (ha) of wet meadow in segment	+	Iverson et al. 1987, Folk and Tacha 1990, Parrish et al. 2001, Davis 2001, 2003

priority" segments if high-use status occurred during three or more separate surveys in $\geq$ 2 y.

On the basis of prior research, we identified several habitat variables that may affect use by sandhill cranes, including proximity to conservation lands (U.S. Geological Survey Protected Areas Database of the United States Version 1.4), bridges and roads (U.S. Census Bureau TIGER/Line database), and towers or transmission lines (Federal Aviation Administration Digital Obstacle File; Table 1). We derived unobstructed width, which we defined as the mean distance between the nearest obstructions $>$ 1 m in height on each river bank (Folk and Tacha 1990; Norling et al. 1992), from light detection and ranging data. We also identified several land cover types that may influence use (Bishop et al. 2011; Table 1). We also indicate the expected direction of the relationship for sandhill cranes on the basis of the cited research. We used a Spearman rank correlation analysis to test for collinear relationships between all habitat variables.

We used the same set of habitat variables for ducks and Canada geese to explore how management for the benefit of sandhill cranes might affect use of roost areas by waterfowl. We compared habitat traits between a binomial response variable, segments identified as conservation priority segments, and segments that were used but not identified as conservation priority. We excluded segments that were never used under the assumption that these locations may have some permanent feature that precludes use or, in the case of sandhill cranes, were located outside of their spring migration range. We modeled probability that a segment was identified as a high-use area three or more times in $\geq$ 2 y using the glm function in Program R 3.5.0 (https://www.r-project.org). Rather than identifying a best-fitting model, we instead made inferences for each species from a fully parameterized model that included an intercept and additive effects of all 13 predictor variables. This method is appropriate because we did not use model results to make predictions, we carefully selected relevant habitat variables on the basis of prior research, our sample size was adequate, and we did not detect collinearity between variables (Whittingham et al. 2006; Dahlgren 2010; Forstmeier and Schielzeth 2011; Fieberg and Johnson 2015).

Results

Peak crane migration numbers occurred during mid- to late March (Figure 2). Most sandhill cranes were counted in riverine (72%) or other aquatic (13%) roosting habitat, whereas 13% had already departed for agricultural foraging areas at the time of the survey. Canada goose counts peaked in late February, slightly earlier than for ducks (Figure 3). Most Canada geese were located on a riverine (39%) or other aquatic (47%) roosting area, whereas 14% had departed for agricultural foraging habitats at the time of the survey. Almost all ducks were counted in riverine (70%) or other aquatic (29%) roosting areas, with very few observations occurring in adjacent fields (1%).

Sandhill cranes used 82 of the 140 surveyed 0.8-km segments. We classified 44 segments (54%) as high use during at least one survey. We classified 20 conservation priority segments (24%) as high use during at least three surveys in at least 2 y for sandhill cranes (Figure 4). On average, we classified conservation priority segments as high use during 4.3 surveys. Canada geese used 214 of the 261 surveyed 2-km segments. Our analysis identified 147 segments as high use during at least one survey. We

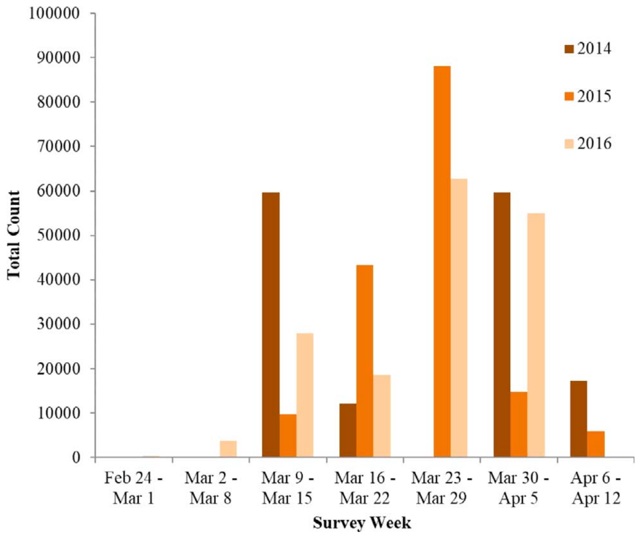

Figure 2. Total counts of sandhill cranes *Antigone canadensis* during spring migration each survey week on the North Platte River and Birdwood Creek, Nebraska, 2014–2016. We did not conduct surveys in weeks with zero counts.

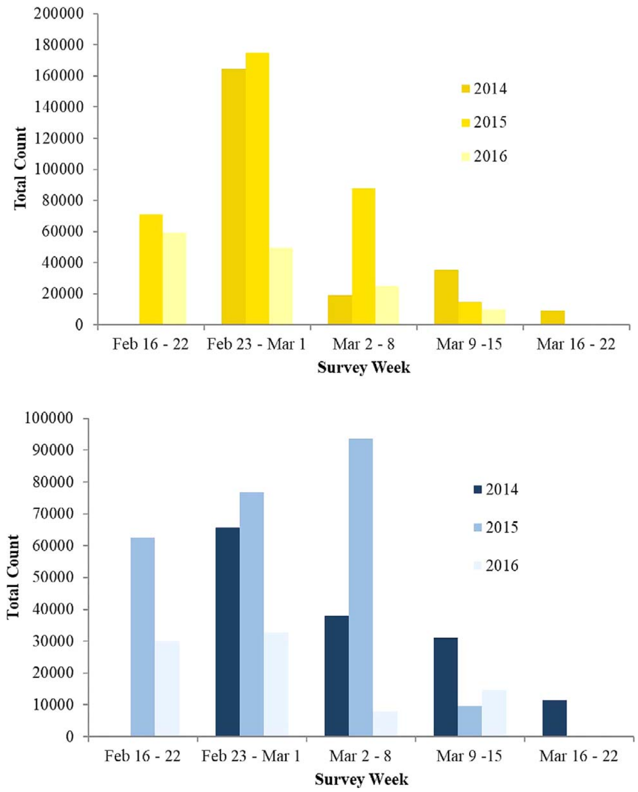

Figure 3. Total counts of Canada geese *Branta canadensis* (top) and ducks (bottom) during spring migration each survey week on the North and South Platte rivers and Birdwood Creek, Nebraska, 2014–2016. We did not conduct surveys in weeks with zero counts.

considered 50 segments (23%) high use during at least three separate surveys in at least 2 of the 3 study years and, thus, characterized as conservation priority segments (Figure 5). Conservation priority segments were high use on an average of 4.6 surveys for both ducks and Canada geese. Ducks used 218 of the surveyed segments. Of those, we classified 106 segments as high use during at least one survey and identified 40 segments (18%) as conservation priority segments for ducks (Figure 5). We classified 20 segments as conservation priority segments for both ducks and Canada geese (Figure 5). Three sandhill crane conservation priority segments overlapped with Canada goose conservation priority segments. No duck conservation priority segments overlapped with any sandhill crane conservation priority segments.

We did not identify any highly correlated ($r > 0.7$) habitat variables, so we included all variables in the models (Green 1979). The model indicated a negative relationship between conservation priority segments for sandhill cranes and total area of unvegetated sandbar habitats in each segment and a positive relationship with unobstructed width. For Canada geese, our model indicated a positive effect of total pit and wetland area, and a negative relationship with wet meadow area (Table 2). The habitat model for ducks indicated that conservation priority segments had greater total area of wetlands and lower mean distance to conservation lands than nonconservation priority segments (Table 2).

Discussion

Several studies have examined use of river habitats by sandhill cranes in Nebraska, primarily in the Central Platte River region. Many of these studies have found that spring-migrating sandhill cranes select wide channels away from human disturbance and visual obstructions for roosting (Krapu et al. 1984; Folk and Tacha 1990; Norling et al. 1992; Parrish et al. 2001; Davis 2003; Pearse et al. 2017b). Our model also indicated a positive association with areas free from obstructions taller than 1 m. Sandhill cranes may avoid visual obstructions because they primarily use eyesight to detect terrestrial predators (Armbruster and Farmer 1982; Norling et al. 1992). We did not, however, identify any significant relationships with human disturbance variables, roads, bridges, or power lines and towers. Human population densities near the NSPR were generally much lower when compared with the Central Platte River region (U.S. Census Bureau 2010), so effects of some forms of human disturbance may have been too low to be detectable considering our relatively small sample size. Additionally, we compared high-use areas with low-use areas in our analysis, so river segments that may be unavailable to cranes because of high levels of disturbance were not considered here. Wet meadows have been identified as important habitats for cranes and although we also detected a positive relationship, the effect was not significant (Iverson et al. 1987; Folk and Tacha 1990; Kessler et al. 2011). Prior research has generated mixed results regarding use of sandbars by sandhill cranes. Iverson et al. (1987) reported that sandhill cranes typically use sandbars and shallow water areas in the river channel as nocturnal roosting habitat, but Norling

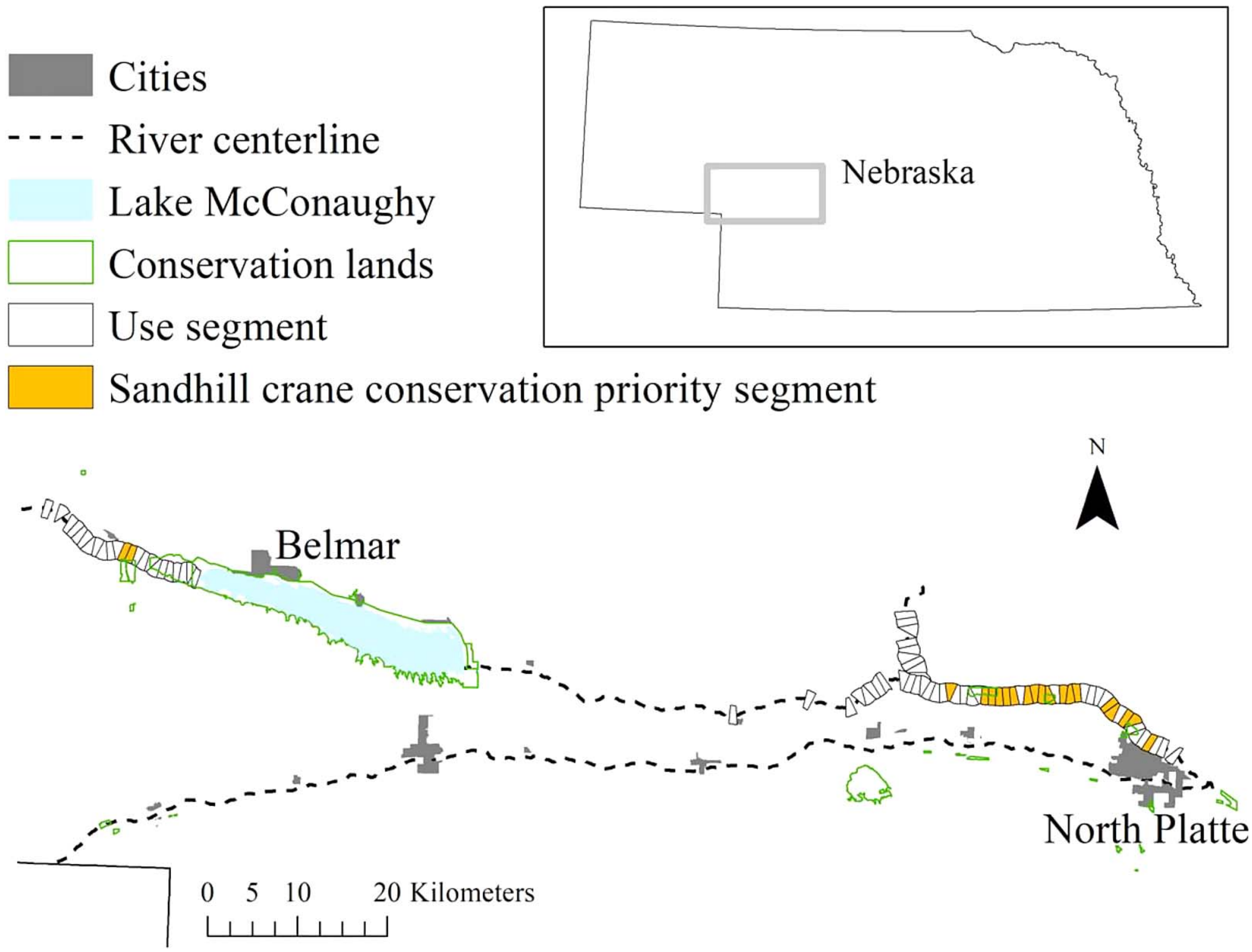

Figure 4. Conservation priority and use segments for sandhill cranes *Antigone canadensis* identified on the basis of spring aerial surveys on the North Platte River and Birdwood Creek, Nebraska, 2014–2016.

et al. (1992) found that exposed sand was avoided. We identified a negative relationship between unvegetated sand and priority segments; however, the constantly shifting nature of unvegetated sand in rivers made it challenging to characterize the distribution of this habitat.

We were able to identify several river reaches that likely contain important roosting habitats used by this migrating segment of the mid-continent sandhill crane population. Most of these areas were located in the region extending west of North Platte, Nebraska to the confluence with Birdwood Creek. Conservation efforts focused in this area are likely to have the greatest effect on sandhill cranes. Although we were able to pinpoint river segments that were consistently used by both ducks and Canada geese, these did not overlap with crane conservation priority areas. The geographic separation between crane and waterfowl priority regions suggests that there are many opportunities for targeted conservation actions that will benefit a large number and diversity of waterfowl while having no negative effect on cranes. Prioritizing specific sites that have characteristics that have been identified as important in this and prior research will result in more effective conservation planning efforts. For example, if a conservation organization is interested in activities that will benefit sandhill cranes, they may choose to remove trees and other woody obstructions near an existing conservation priority area. Because we identified unobstructed width as a habitat trait positively associated with high levels of sandhill crane use, this would likely be an efficient use of funds.

Although use of Nebraska's river habitats by spring-migrating cranes is a well-studied topic, very little data exist for waterfowl. Total waterfowl counts exceeded 200,000 during some surveys, although stopover times for this region are unknown. Behind the Rainwater Basin and adjacent Central Platte River, which host more than 400,000 Canada geese each spring, the NSPR may be one of the most important spring stopover habitats for this species in Nebraska (Bishop and Vrtiska 2008). The number of ducks using this area is comparatively small, considering that more than 7 million birds may stopover in the Rainwater Basin (Bishop and Vrtiska 2008). Although we did not identify ducks at the species level during this study, a prior survey found that the most

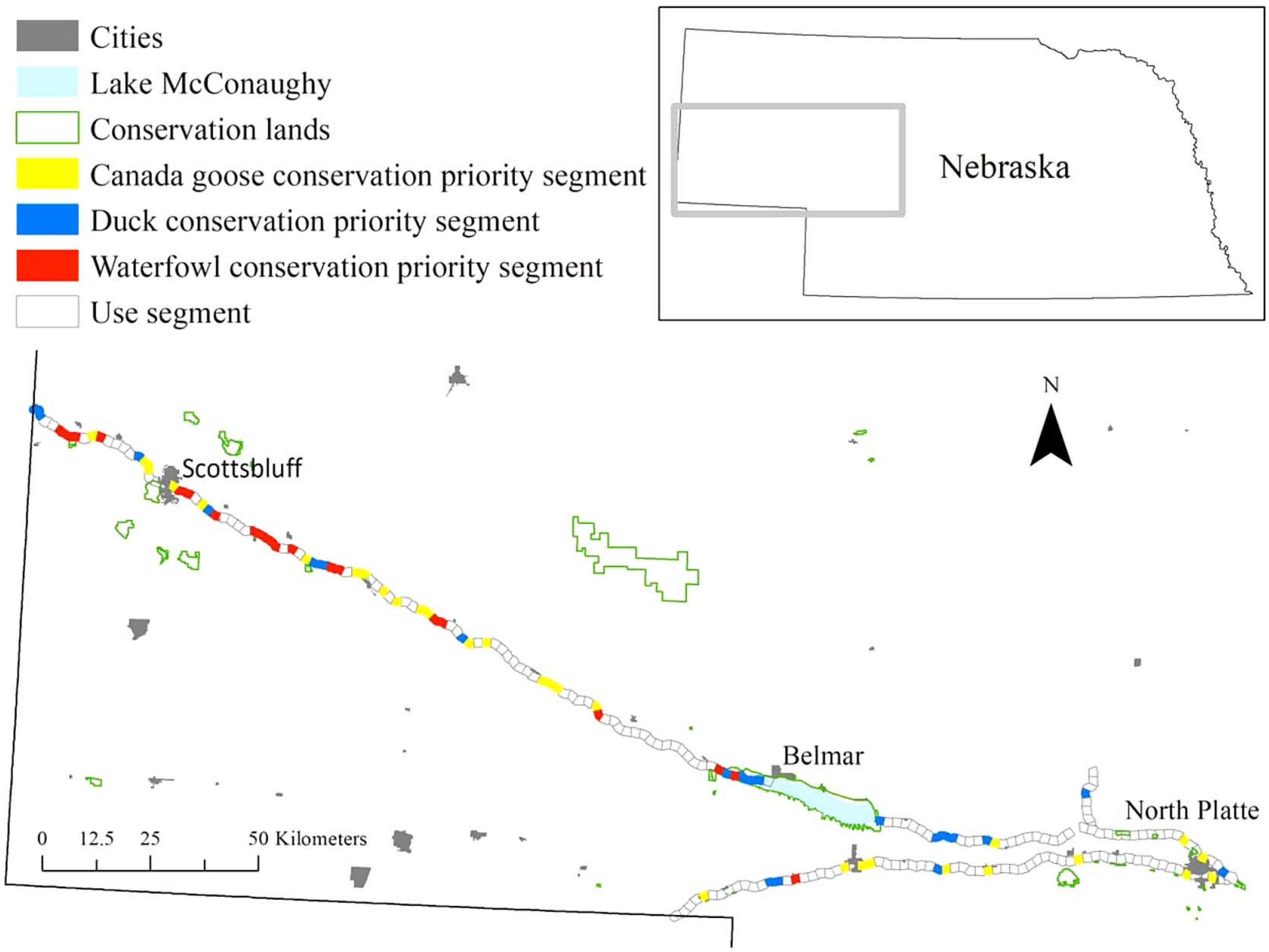

Figure 5. Conservation priority and use segments for ducks, Canada geese *Branta canadensis*, and both (waterfowl) identified on the basis of spring aerial surveys on the North and South Platte rivers and Birdwood Creek, Nebraska, 2014–2016.

frequently observed species in riverine habitats in the NSPR were mallards *Anas platyrhynchos*, gadwalls *Mareca strepera*, American wigeon *Mareca americana*, green-wing teal *Anas carolinensis*, northern pintail *Anas acuta*, and common mergansers *Mergus merganser* (Vrtiska 2004). Waterfowl used a much larger area of the NSPR than sandhill cranes. Only three crane conservation priority segments overlapped with Canada goose conservation priority areas and there was no overlap with duck conservation priority segments, highlighting the different roosting habitat requirements of these birds.

Most of the conservation priority segments for ducks and geese were located on the North Platte River west of Lake McConaughy in areas that sandhill cranes did not use. Both ducks and geese had greatest use in segments with larger areas of wetland habitat within 1 km of the river center line. Goose conservation priority segments were associated with lower amounts of wet meadow habitat, further evidence that geese have little in common with cranes in terms of habitat associations. Extensive use of segments containing sandpit habitats by waterfowl may indicate that certain natural wetland habitat types were lacking in the NSPR, particularly areas characterized by deeper, unvegetated water. Additionally, the presence of sandpits in a segment does not preclude use by waterfowl or cranes and thus, nearby areas can be considered for conservation activities.

Mean distance to nearest conservation lands was lower for duck conservation priority segments compared with use-only segments. Clustering conservation activities in a smaller area may have a greater positive effect for ducks than attempting to spread limited resources over a wider area. Because there was some overlap in the habitat needs of ducks and Canada geese, there may be efficiencies realized by obtaining or restoring roosting habitat that will be used by a variety of waterfowl species. Our analysis specifically identifies 20 segments that contained high densities and consistent use by ducks and Canada geese, the majority of which were located on the North Platte River west of Bridgeport, Nebraska.

In general, we found little overlap in river and landscape characteristics that explained consistent high-use roosting areas for cranes compared with ducks or Canada geese. Additionally, there was little overlap in locations of conservation priority areas for cranes and

Table 2. Results of three logistic regression models of habitat traits associated with high densities of sandhill cranes *Antigone canadensis*, Canada geese *Branta canadensis*, and ducks on the North and South Platte rivers and Birdwood Creek, Nebraska, during spring migration 2014–2016. Each model included an intercept and additive effects of 13 predictor variables. See Table 1 for definitions of abbreviations.

	Estimate	SE	*z*-value	*P*
Sandhill crane				
(Intercept)	−1.46	3.24	−0.45	0.65
Corn	3.01×10^{-6}	3.16×10^{-6}	0.95	0.34
Grass	-1.23×10^{-5}	7.01×10^{-6}	−1.75	0.08
Pit	1.36×10^{-5}	1.86×10^{-5}	0.73	0.47
RivChan	-8.13×10^{-6}	1.21×10^{-5}	−0.67	0.50
Trees	-3.52×10^{-6}	4.34×10^{-6}	−0.81	0.42
Unvegsand	$-1.89 \times$ E-10^{-4}	9.25×10^{-5}	−2.05	0.04*
Wetland	$-1.67 \times$ E-10^{-5}	1.87×10^{-5}	−0.89	0.37
WetMead	4.27×10^{-6}	2.85×10^{-6}	1.50	0.13
Bridgemin	2.94×10^{-5}	1.76×10^{-4}	0.17	0.87
Conservmean	-2.70×10^{-4}	4.90×10^{-4}	−0.55	0.58
Linesmin	-3.56×10^{-4}	3.51×10^{-4}	−1.02	0.31
Roadmean	7.12×10^{-3}	4.16×10^{-3}	1.71	0.09
Unobswid	1.39×10^{-2}	$6.21 \times$E-10^{-3}	2.24	0.03*
Canada goose				
(Intercept)	−2.35	1.0×8	−2.18	0.03*
Corn	7.05×10^{-7}	4.48×10^{-7}	1.57	0.12
Grass	2.10×10^{-7}	4.86×10^{-7}	0.43	0.67
Pit	8.30×10^{-6}	2.49×10^{-6}	3.33	< 0.01***
RivChan	1.43×10^{-6}	1.53×10^{-6}	0.94	0.35
Trees	-2.13×10^{-7}	5.80×10^{-7}	−0.37	0.71
Unvegsand	-3.17×10^{-6}	2.45×10^{-6}	−1.29	0.20
Wetland	1.65×10^{-6}	5.74×10^{-7}	2.88	< 0.01**
WetMead	-1.25×10^{-6}	6.25×10^{-7}	−2.00	0.04*
Bridgemin	-3.28×10^{-5}	7.57×10^{-5}	−0.43	0.66
Conservmean	7.02×10^{-5}	4.87×10^{-5}	1.44	0.15
Linesmin	-2.01×10^{-4}	1.34×10^{-4}	−1.50	0.13
Roadmean	-1.81×10^{-3}	1.79×10^{-3}	−1.01	0.31
Unobswid	-1.66×10^{-4}	5.28×10^{-4}	−0.31	0.75
Duck				
(Intercept)	−1.68	9.64×10^{-1}	−1.75	0.08
Corn	-1.50×10^{-7}	4.18×10^{-7}	−0.36	0.72
Grass	-1.05×10^{-7}	4.17×10^{-7}	−0.25	0.80
Pit	2.87×10^{-6}	1.71×10^{-6}	1.68	0.09
RivChan	5.67×10^{-7}	1.51×10^{-6}	0.38	0.71
Trees	-8.74×10^{-8}	5.20×10^{-7}	−0.17	0.87
Unvegsand	3.85×10^{-7}	2.25×10^{-6}	0.17	0.86
Wetland	1.26×10^{-6}	5.13×10^{-7}	2.46	0.01*
WetMead	-8.73×10^{-7}	6.09×10^{-7}	−1.43	0.15
Bridgemin	-1.05×10^{-4}	8.02×10^{-5}	−1.31	0.19
Conservmean	-2.08×10^{-4}	8.14×10^{-5}	−2.55	0.01*
Linesmin	1.73×10^{-4}	1.05×10^{-4}	1.66	0.09
Roadmean	-9.53×10^{-4}	1.34×10^{-3}	−0.71	0.48
Unobswid	3.39×10^{-4}	4.91×10^{-4}	0.69	0.49

* $P < 0.05$.
** $P < 0.01$.
*** $P < 0.001$.

waterfowl. Conservation efforts to create roosting habitat for sandhill cranes will, unfortunately, not benefit waterfowl as much and vice versa. In particular, the area upstream of Lake McConaughy was used by sandhill cranes, but not consistently. Much of this area was designated as conservation priority for ducks, so if habitat alterations were carried out in this area to benefit cranes, the area may not see any increase in waterfowl use because habitat associated with high levels of crane use may not affect waterfowl use. Our results indicate that habitat associations and current locations of high use of cranes differ greatly from waterfowl in the NSPR; thus, sandhill cranes are not an effective surrogate species for the larger community of waterbirds in this region. We recommend that conservation partners in the NSRP prioritize types and locations of management activities on the basis of whether they wish their actions to mostly benefit either sandhill cranes or waterfowl.

Supplemental Material

Please note: The *Journal of Fish and Wildlife Management* is not responsible for the content or functionality of any supplemental material. Queries should be directed to the corresponding author for the article.

Data S1. Aerial survey data of sandhill cranes *Antigone canadensis*, ducks, and Canada geese *Branta canadensis* collected during spring migration on the North and South Platte rivers, Nebraska, 2014–2016.

Found at DOI: https://doi.org/10.3996/042019-JFWM-030.S1 (952 KB XLS).

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