Landscape and habitat variables affecting Buff-breasted Sandpiper *Tryngites subruficollis* distribution during migratory stopover in the Rainwater Basin, Nebraska, USA

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The Rainwater Basin, Nebraska, appears to be an important stopover site for Buff-breasted Sandpipers *Tryngites subruficollis* during their northward spring migration. Buff-breasted Sandpipers have been observed using agricultural field and wetland habitats within the Rainwater Basin. This study is the first to examine specific habitat use during spring migration in the Rainwater Basin. Our results show that Buff-breasted Sandpipers were five times more likely to occur in fields that were planted to soybeans the previous growing season than in those planted previously to corn. In addition, birds were more likely to occur in fields in open areas free from human obstructions and in areas with higher densities of historic wetlands. These results indicate that shorebird conservation should include terrestrial habitats when developing conservation plans for the Buff-breasted Sandpiper and other similar shorebird species.

INTRODUCTION

Habitat loss and degradation at migratory stopover sites is an important contributor to shorebird population declines (Brown *et al.* 2001, Schekkerman *et al.* 2003, Skagen 2006, Thomas *et al.* 2006). The Buff-breasted Sandpiper *Tryngites subruficollis* is a long-distance migrant shorebird of high conservation concern, the species is considered "highly-imperiled" by the United States Shorebird Conservation Plan (Brown *et al.* 2001, USSCP 2004). Buff-breasted Sandpipers winter in southern South America and breed in high Arctic areas of western Canada, Alaska and eastern Siberia (Lanctot & Laredo 1994). The primary northward migratory route passes through the middle of North America, with birds arriving in Louisiana and Texas in late April (Lanctot & Laredo 1994). Buff-breasted Sandpipers continue through the Great Plains in May (Lanctot & Laredo 1994). The specifics of habitat use and the ecology of stopover sites along this route is not well understood for Buff-breasted Sandpipers (Lanctot & Laredo 1994).

Large concentrations of Buff-breasted Sandpipers have only rarely been observed during spring in the Great Plains (Lanctot & Laredo 1994, Skagen *et al.* 1999). Unlike many shorebird species that congregate in large numbers at wetlands during migratory stopover in the Great Plains, Buff-breasted Sandpipers prefer more terrestrial habitats such as agricultural fields, sod farms, mowed hayfields, and pastures (Jorgensen 2004, Lanctot & Laredo 1994, Oring & Davis 1966). Past work on shorebird migration in the Great Plains has focused on important wetland complexes (Davis & Smith 1998, Skagen 2006) and the tendency of Buff-breasted Sandpipers to use terrestrial habitats likely contributes to the lack of information about its migratory habits.

There is evidence that the Rainwater Basin of Nebraska is an important and regularly used stopover site for large numbers of Buff-breasted Sandpipers during spring migration (Jorgensen 2004, Morris 1978). The majority of observations in the Rainwater Basin from the 1970s to the present have been in agricultural fields, with regular observations of groups of over 100 birds (Jorgensen 2004, 2007, L. Morris, pers. comm.). The apparent dependence of large concentrations of Buff-breasted Sandpipers on agricultural fields raises concerns about how changing land use and agricultural practices might impact the population. Here, we identify landscape and habitat variables that affect Buff-breasted Sandpiper occurrence and abundance in the Rainwater Basin. Understanding habitat use during this time is important both to identify emerging threats and as a starting point for improving environmental conditions for this species during migration.

METHODS

We studied Buff-breasted Sandpipers in the Rainwater Basin during May of 2004 and 2005. The Rainwater Basin is a relatively flat to gently rolling loess plain encompassing approximately 10,000 km^2 in south-central Nebraska (Kuzila 1994; Fig. 1). Prior to European settlement, the Rainwater Basin

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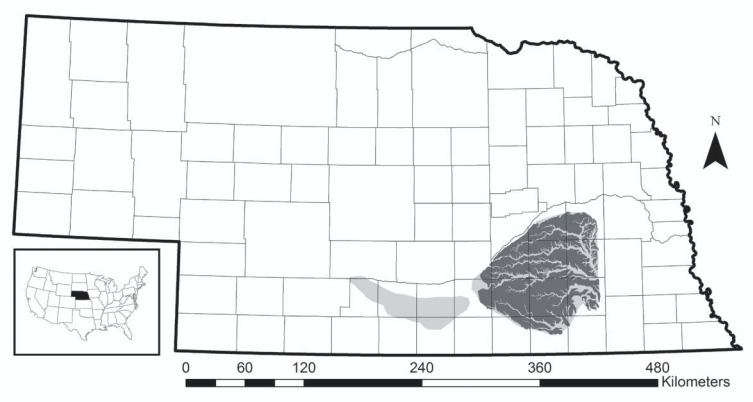

Fig. 1. Location and extent of the Rainwater Basin, Nebraska, (light gray) and the delineation of the loess uplands study area in the eastern Rainwater Basin (dark gray).

region was a tall- and mid-grass prairie plain that contained a network of between 4,000 and 10,000 playa wetlands (LaGrange 2005). Today the land cover is dominated by human use; over 90% of all wetlands have been destroyed and those that remain are degraded (LaGrange 2005, Schildman & Hurt 1984).

Surveys by Jorgensen (2004) showed that during spring migration, Buff-breasted Sandpipers occur almost exclusively in the distinct, eastern portion of the Rainwater Basin (Fig. 1). This prior work also showed that Buff-breasted Sandpipers were confined to areas of "loess uplands" and did not occur in areas associated with the drainage of larger waterways (Jorgensen 2004). Based on this information, we focused exclusively on the eastern Rainwater Basin and used U.S. Department of Agriculture Soil Survey data (SSURGO; USDA 1995) in a geographic information system (ArcGIS 8.3, Environmental Systems Research Institute, Inc, Redlands, CA) to define a precise study area of 8,490 km^2 (Jorgensen 2007).

Distribution and abundance of Buff-breasted Sandpipers were measured using distance sampling at point transects (Buckland *et al*. 2001, 2004). Point transects were located at 4.83 km (3 mile) intervals throughout the loess uplands region and along county roads that followed Public Land Survey System section boundaries. Groups of 14–20 points that were in close proximity to each other were grouped together to form routes. Each route was run four to five times during 1–26 May at intervals of three to six days. We used multiple covariate distance sampling (Buckland *et al*. 2004) in Program DISTANCE (Thomas *et al.* 2004) to determine whether the ability to detect sandpipers was a function of the habitat they were in.

Land use was measured around each sample point. Using the Public Land Survey System, four quadrants around each sample point were defined explicitly when points were located at intersections of town or county roads. When points were not located at intersections, we delineated the quadrant by using a line perpendicular from the section line. Most agricultural fields in the Rainwater Basin are a minimum 65 ha and because all detections were less than 800 m and most were less than 500 m during the two years, land use measurements were generally focused on one field in each quadrant. Land use within each quadrant and stage of the row-crop agricultural fields were classified for each visit because field conditions changed during the study period due to seasonal farming activities and weather. Land use categories (Table 1) reflected the fact that the region is dominated by human activities, primarily agriculture (USDA 2002). Even

Table 1. Number and proportion of quadrants by habitat recorded in eastern Rainwater Basin during 2004 and 2005.

Field type	Description	2004 proportion of quadrants (n = 2,776)	2005 proportion of quadrants (n = 3,162)
Row crop agricultural field	Corn or soybean fields	0.859	0.807
Alfalfa hayfield	Alfalfa hayfield	0.023	0.027
Wheat field	Winter wheat field planted previous fall and actively growing.	0.017	0.007
Warm-season grass	Native, warm season grass, usually within state or federal conservation properties	0.007	0.008
Cool-season grass	Cool-season, non-native grass (i.e. *Bromus inermis, Poa Pratensis*) planted as pasture and grazed by livestock	0.023	0.027
Permanent or semi-permanent wetland	Palustrine Rainwater Basin wetland	0.013	0.005
Sheetwater wetland	Temporary or seasonal wetland occurring within an agricultural field	0.001	0.005
Farmstead	Rural human dwelling and out-buildings	0.045	0.075
Cemetery	Rural cemetery	<0.001	0.003
Cattle yard	Commercial cattle feed lot	0.006	0.006
Hedgerow	Multiple rows of planted woody vegetation, often adjacent to road and obstructing view	0.007	0.006
Other and/or not viewable	Area not viewable due to a visual obstruction	0.010	0.027

remnants of native land cover (e.g. wetlands, warm season grass) are actively managed by humans.

Habitat data analysis

All sandpiper observations at point transects were in agricultural fields. We tested whether either of the two primary land uses – corn or soybeans – were used more often than expected based on their availability. We also tested whether associations differed between years. Habitat associations were determined using a multifactorial logistic regression model with habitat (e.g. crop type) and year as predictor variables and presence/absence as the response variable. Because most Buff-breasted Sandpipers passed through this region just before or during the time fields were planted, habitat in crop fields was influenced both by the crop grown in the previous growing season and by preparations for current year's crop. Habitat categories of agricultural fields were changing during the time we conducted bird surveys and we considered each visit as an independent observation. A given location might occur twice in the analysis, but the predictor variables for that site are not repeated.

We also tested whether structures or other landscape obstructions, such as farms, cities, hedgerows, or any other form of human development, affected the occurrence of Buff-breasted Sandpiper distribution using multifactorial logistic regression. We characterized a point as having an obstruction if a human structure or landscape obstruction was present within 300 m of the point. Points were classified as having birds present if sandpipers were detected in any of the four quadrants around the point. Presence or absence of obstructions did not change across visits within a year so each point is included as a single observation.

Landscape data analysis

The Rainwater Basin is a region defined by wetlands, thus of particular interest was whether relationships existed between sandpiper distribution and historic and/or modern wetland coverage. Using a geographic information system, we calculated four landscape variables: 1) area of historic wetland coverage, 2) numbers of individual historic wetlands, 3) area of modern wetland coverage, and 4) minimum distance to a wetland footprint (hydric soils) >150 ha. We determined the number and area of wetlands within a 1, 2 and 4 km radius surrounding each point. Historic wetlands were identified using a dataset representing hydric soils provided by the Rainwater Basin Joint Venture (A. Bishop, United States Fish & Wildlife Service, Grand Island, Nebraska). The area of modern wetlands was determined using U.S. Fish and Wildlife Service's National Wetlands Inventory (NWI) data for the 12 counties located in the Eastern Rainwater Basin.

Variables for each point were measured using ArcGIS 8.3 (Environmental Systems Research Institute, Inc, Redlands, CA). A *t*-test was used to determine whether landscape variables differed between points where birds were recorded (presence points) and those where no birds were found (absence points).

RESULTS

Row-crop agricultural fields accounted for 86% of surveyed quadrants in 2004 (n = 2,776 observations of 716 unique quadrants) and 81% of surveyed quadrants (n = 3,165 observations of 884 unique quadrants) in 2005 (Table 1). At the time of the bird surveys, 50% of the row-crop quadrants were categorized as having had corn the previous year and 27.1% were categorized as having had soybeans harvested the previous year (Table 2). In 2005, >50% of all fields sampled had corn and 37% had soybeans harvested the previous year (Table 2).

All Buff-breasted Sandpipers encountered on the surveys were in row crop agricultural fields. Buff-breasted Sandpipers were recorded at 31 points and 35 quadrants in 2004, and, 42 points and 44 quadrants in 2005 (Table 2). Agricultural fields with standing corn stubble >10 cm high were not included in the analysis because Buff-breasted Sandpipers were not found in any fields of this type. In 2004, 388 Buff-breasted Sandpipers were found in 25 fields where soybeans were harvested the previous year and 82 Buff-breasted Sandpipers were found in 10 fields where corn was harvested the previous year. In 2005, 302 Buff-breasted Sandpipers were found in 35 fields where soybeans were harvested the previous year and 19 Buff-breasted Sandpipers were found in seven fields

Table 2. Number of row-crop agricultural fields by crop harvested the previous year and number of quadrants occupied by Buff-breasted Sandpipers (BBSA) in the eastern Rainwater Basin during 2004 and 2005. Number in parenthesis is overall number of sandpipers observed.

Field type	Description	2004		2005	
		Proportion of quadrants (n = 2,387)	No. of quadrants with BBSA	Proportion of quadrants (n = 2,552)	No. of quadrants with BBSA
Agricultural field	Default designation when further distinction about status was not determined.	0.195	0	–	–
Corn stubble	Field where corn was harvested the previous growing season. Litter no longer erect due to discing or mowing at base.	0.424	10 (82)	0.493	7 (19)
Standing corn stubble >10 cm	Field where corn was harvested the previous growing season. Base of corn stalks remains erect.	0.080	0	0.110	0
Soybean stubble	Field where soybeans were harvested the previous growing season.	0.271	25 (388)	0.369	35 (302)
Wheat stubble	Field where wheat was harvested the previous growing season.	0.011	0	0.011	1 (8)
Wheat >10 cm	Winter wheat field planted previous fall and actively growing.	0.019	0	0.009	0
Bare	Very little crop residue present and litter undeterminable.	–	–	0.009	1 (5)
Total			**35**		**44**

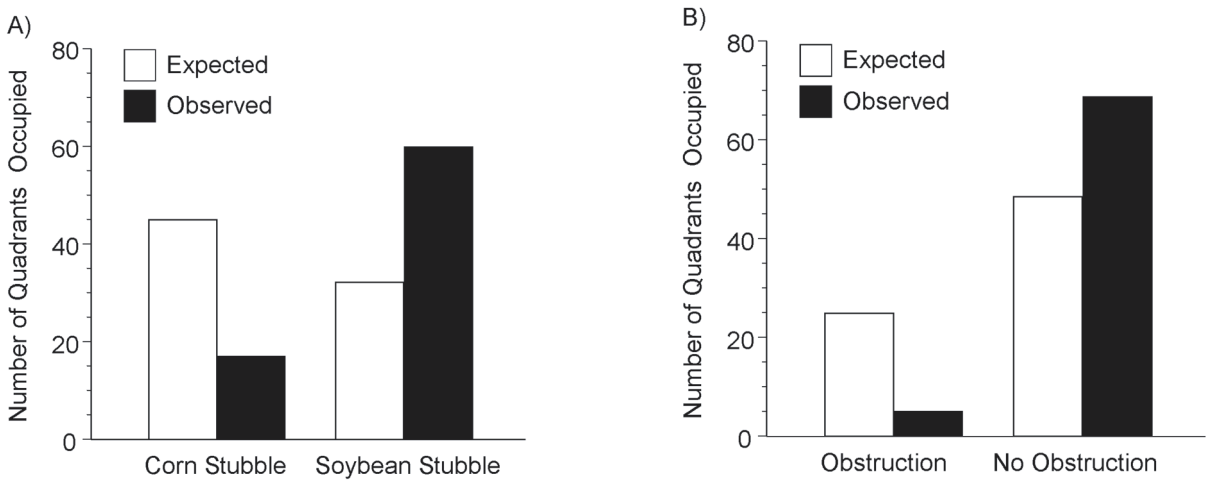

Fig. 2. Buff-breasted Sandpiper habitat use in the eastern Rainwater Basin compared to expected use based on habitat available. The expected number of quadrants occupied by Buff-breasted Sandpipers (white bars) and observed number of quadrants occupied (black bars) in 2004 and 2005 are pooled. Sandpipers use soybean fields significantly more often and corn fields significantly less often than expected based on availability (Fig. 2A. multifactorial logistic regression, $p < 0.0001$). Fields with obstructions are used significantly less often and those without obstructions are used significantly more often than expected (Fig. 2B. multifactorial logistic regression, $p < 0.0001$).

where corn was harvested the previous year. Buff-breasted Sandpipers were five times more likely to occur in fields with soybean stubble than fields with corn stubble (likelihood ratio $\chi^2 = 43.6$, df = 1, $p < 0.0001$; Fig. 2A). The number of occupied quadrants did not differ between years (likelihood ratio $\chi^2 = 1.20$, df = 1, $p = 0.27$) and there was no significant interaction between year and habitat (likelihood ratio $\chi^2 = 0.90$, df = 1, $p = 0.34$). All Buff-breasted Sandpipers recorded in corn stubble were in fields where litter had no vertical structure but where the stalks were cut at the base or disked. Since fields with standing corn stubble >10 cm high had been removed from the analysis, visibility was similar in the two habitat types. Results of the multiple covariate distance sampling showed that models with and without habitat included as a covariate were similar based on a Δ AICc = 0.41, indicating that the ability to detect birds was similar in corn and soybean fields.

Buff-breasted Sandpipers were eleven times more likely to occur in fields without obstructions than in fields with obstructions (likelihood ratio $\chi^2 = 20.5$, df = 1, $p < 0.0001$; Fig. 2B). The number of occupied points did not differ between years (likelihood ratio $\chi^2 = 0.07$, df = 1, $p = 0.77$) and there was no significant interaction between year and obstructions (likelihood ratio $\chi^2 = 0.03$, df = 1, $p = 0.87$). In 2004, 56 points had at least one obstruction within 300 m of the point and 123 points had no obstructions. Buff-breasted Sandpipers were recorded at two points with an obstruction and at 29 points without obstructions. In 2005, 79 points had at least one obstruction within 300 m of the point and 140 points had no obstructions. Buff-breasted Sandpipers were recorded at three points with an obstruction and at 39 points without obstructions.

In both years, the presence of Buff breasted Sandpipers was associated with greater numbers of historic wetlands within a 2 km radius of survey points (2004: $t_{177} = -2.12$, $p = 0.03$, 2005: $t_{219} = -2.05$, $p = 0.04$; Tables 3 and 4). In 2004, presence was also associated with greater historic wetland numbers within the 4 km radius ($t_{177} = -2.41$, $p = 0.02$), and also greater wetland area within the 2 ($t_{177} = -1.13$, $p = 0.05$) and 4 km radius ($t_{177} = -2.40$, $p = 0.02$; Table 3). In 2005, presence was also associated with greater wetland area within the 1 km radius ($t_{219} = -4.5$, $p < 0.01$; Table 4).

DISCUSSION

During their spring migratory stopover in the Rainwater Basin, Buff-breasted Sandpipers make extensive use of agricultural fields. Although agricultural habitats are recognized as being important to some breeding species of shorebirds such as Northern Lapwings *Vanellus vanellus* (Milsom *et al.* 1985), Upland Sandpipers *Bartramia longicauda* (Houston & Bowen 2001), and Mountain Plovers *Charadrius montanus* (Shackford *et al.* 1999), use of agricultural habitats by wintering and migrant shorebirds has been viewed as being of secondary importance relative to use of wetlands (Colwell & Dodd 1997, Rottenborn 1996). However, the Buff-breasted Sandpiper's use of agricultural fields during migratory stopover is not unique. Large concentration of American Golden-Plovers *Pluvialis dominica* have been observed in soybean fields in the Midwest United States (Braile 1999, Johnson 2003, Johnson & Connors 1996), and alfalfa and winter wheat fields in Kansas may be an important spring migratory stopover site for Long-billed Curlews *Numenius americanus* (Shane 2005). Our observations in the eastern Rainwater Basin have recorded 16 species of shorebirds in dry, upland agricultural fields, often foraging in association with Buff-breasted Sandpipers (unpublished data), including large numbers of species of conservation concern such as American Golden-Plover, Baird's Sandpiper *Calidris bairdii*, and Pectoral Sandpiper *Calidris melanotos*.

Differential use of agricultural fields was largely based on the crop cover from the previous year. Sandpipers were more likely to occur in fields with soybean stubble from the previous year's harvest than fields with corn stubble or other agricultural crops (Table 2, Fig. 2A). American Golden-Plovers may also make extensive use of soybean fields (Johnson 2003). It is unclear why shorebirds seem to prefer to use fields that have previously held soybeans. Agricultural practices during the previous growing season and preparation for the upcoming growing season differ among field types so

Table 3. Comparison of amount of past and current wetland in the vicinity of point transects where Buff-breasted Sandpipers (BBSA) were present or absent in 2004.

Radius from point transect	BBSA present Mean ± SD	BBSA absent Mean ± SD	P-value (two-tailed t-test)
Area (ha) of historic wetland			
1 km	86.1±17.8	67.8±5.8	0.26 (t_{177} = –1.10)
2 km	169.7±25.1	127.2±7.8	0.05 (t_{177} = –1.13)
4 km	652.0±72.1	503.7±21.9	0.02 (t_{177} = –2.40)
Number of historic wetlands			
1 km	4.5±0.5	3.8±0.2	0.27 (t_{177} = –1.10)
2 km	19.6±1.7	15.6±0.7	0.03 (t_{177} = –2.12)
4 km	71.2±4.8	58.0±2.0	0.02 (t_{177} = –2.41)
Area (ha) of modern wetland based on National Wetlands Inventory			
1 km	7.0±3.0	8.5±2.0	0.80 (t_{177} = –0.26)
2 km	36.5±11.0	33.4±4.5	0.81 (t_{177} = –0.25)
4 km	119.8±22.7	112.5±9.3	0.79 (t_{177} = –0.27)
Distance (km) to nearest large wetland, historic or modern			
Distance	4.7±0.53	5.9±0.41	0.18 (t_{177} = –1.37)

Table 4. Comparison of amount of past and current wetland in the vicinity of point transects where Buff-breasted Sandpipers (BBSA) were present or absent in 2005.

Radius from point transect	BBSA present Mean ± SD	BBSA absent Mean ± SD	P-value (two-tailed t-test)
Area (ha) of historic wetland			
1 km	87.1±11.1	66.9±5.8	0.14 (t_{219} = –1.45)
2 km	139.4±16.3	124.9±7.3	0.42 (t_{219} = –0.81)
4 km	1269.0±103.9	1235.4±53.2	0.79 (t_{219} = –0.26)
Number of historic wetlands			
1 km	5.8±0.1	3.6±0.5	<0.01 (t_{219} = –4.52)
2 km	18.7±1.7	15.4±0.6	0.04 (t_{219} = –2.05)
4 km	59.0±5.0	64.4±1.9	0.26 (t_{219} = –1.16)
Area (ha) of modern wetland based on National Wetlands Inventory			
1 km	12.9±6.0	6.7±1.5	0.16 (t_{219} = –1.40)
2 km	37.6±10.2	28.0±3.6	0.31 (t_{219} = –1.02)
4 km	107.9±9.5	112.1±19.6	0.85 (t_{219} = 0.18)
Distance (km) to nearest large wetland, historic or modern			
Distance	4.4±0.5	5.2±0.3	0.21 (t_{219} = –1.25)

factors such as available food or prior insecticide use could influence this habitat selection.

Although Buff-breasted Sandpipers occurred primarily in agricultural fields (Table 2), there remains an uncertain level of association with wetlands during migratory stopover. Indeed, even though Buff-breasted Sandpipers are found in dry, upland, row-crop fields, in south-central Nebraska they are found in significant numbers only in the Rainwater Basin area: an area distinguished from the surrounding landscape by relatively flat terrain and the presence of large numbers of wetlands. Our results suggest that a relationship between Buff-breasted Sandpiper distribution and wetlands may also exist at a finer scale within the Rainwater Basin. However, while we found that the likelihood of Buff-breasted Sandpiper presence in fields was associated with landscape features, the feature that emerged as important was the historical wetland numbers within 2 km, rather than existing wetlands (Tables 3 & 4). Although this relationship was weak and some of the relationships would be non-significant if controlling for multiple comparisons, the pattern occurred in both years of the study. A relationship between the distribution of Buff-breasted Sandpipers and a landscape feature that no longer exists could occur either because of continued use of a traditional stopover site or because of a relationship between locations of historic wetlands and existing environmental conditions. While there is evidence that Buff-breasted Sandpipers have stopped in the Rainwater Basin for at least the past several decades (Jorgensen 2007), it is likely that birds are responding to landscape features associated with historic wetlands. For example, areas with greater numbers of historic wetlands are typically more level and sandpipers may be responding to the terrain. Alternatively, soils associated with historic wetlands might continue to provide greater resource availability even after wetlands have been drained. While these and other plausible explanations remain to be tested, understanding the role wetlands play in the stopover ecology of Buff-breasted Sandpipers is important because significant conservation efforts in the region are devoted to restoring and protecting remaining wetlands.

One of the significant changes to the landscape of the Rainwater Basin is the addition of vertical structures (i.e. trees, buildings) to what had been essentially a two-dimensional grassland habitat. The result that obstructions, such as rural farmsteads or hedgerows, negatively affected the occurrence of Buff-breasted Sandpipers being present in a field conformed to our expectations based on the open habitat used by this species on its breeding and wintering range. Obstructions typically include trees that potentially serve as vantage points for avian predators. Shorebird site use and behavior has been documented to be directly affected by the presence of raptors (Cresswell 1994, Cresswell & Whitfield 1994, Ydenberg *et al.* 2004) and thus it is plausible that predator avoidance plays a role in this aspect of habitat selection.

Even though the Buff-breasted Sandpiper is a bird of considerable conservation concern (Brown *et al.* 2001, USSCP 2004), the primary focus of shorebird conservation has been on slowing the loss and reversing the degradation of wetland habitats, both internationally (Barter 2003, Harrington 2003, Long & Watkins 2005) and regionally in the Great Plains (Colwell & Oring 1988, Davis & Smith 1998, De Leon & Smith 1999, Dinsmore *et al.* 1999, Hands *et al.* 1991, Skagen 2006, Skagen & Knopf 1994). The large concentrations of shorebirds that occur at wetlands, including those of the Rainwater Basin (Brennan 2006, Jorgensen 2004), makes wetlands conservation a necessary component of shorebird conservation. But our observations indicate that an exclusive focus on wetland habitats it is not sufficient for all shorebird species and in particular the Buff-breasted Sandpiper. This suggests that conservation efforts that focus on wetlands for stopover habitat overlook the needs of this species of high conservation concern.

Today, Buff-breasted Sandpipers use a human-created agricultural habitat that did not exist in the region prior to European settlement. An important unanswered question is whether sandpipers are using row-crop fields because they provide resources needed during stopover, or whether this habitat is used simply because it is the dominant habitat remaining within a traditional stopover region. Limited information from early settlers suggests that the eastern Rainwater Basin was an important stopover site for this species before

conversion to row-crop agriculture (Jorgensen 2007). The likely habitat used by Buff-breasted Sandpipers and other upland shorebirds consisted of prairie that had been recently burned or heavily grazed by bison *Bison bison* or prairie dogs *Cynomys* spp. However, large native prairie tracts no longer exist in the eastern Rainwater Basin. While attempts are being made to restore native grasslands in this region, we have not observed Buff-breasted Sandpipers using these grasslands, perhaps because of patterns of grazing and fire management. Few of these restored grasslands are heavily grazed and only small parcels are burned. If areas of restored grassland increase, and management mimics historical disturbance levels, then future studies could evaluate whether native habitats provide higher quality stopover habitat.

Given the concentration of Buff-breasted Sandpipers in soybean fields, predicting and monitoring the effects of changes in agricultural practices, especially shifts from soybeans to other crops, on sandpiper distribution is a high priority for conservation of this species. It is equally important to understand and monitor the effects of changing agricultural practices on the physical condition of sandpipers in the context of their overall annual cycle. These information and monitoring priorities will help ensure a rapid identification of positive or negative impacts and minimize declines in the population due to changes in stopover habitat.

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REFERENCES

Barter, M. 2003. The Yellow Sea: a race against time. *Wader Study Group Bull.* 100: 111–113.

Braile, T.M. 1999. *Migration studies of shorebirds in west-central Indiana*. M.Sc. thesis, Purdue University, Lafayette, Indiana.

Brennan, E.K. 2006. *Local and landscape level variables influencing migratory bird abundance, diversity, behavior, and community structure in Rainwater Basin wetland.* Ph.D. Dissertation, Texas Tech University, Lubbock, Texas.

Brown, S., C. Hickey, B. Harrington & R. Gill (eds). 2001. *The United States Shorebird Conservation Plan, 2nd ed*. Manomet Center for Conservation Sciences, Manoment, MA.

Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers & L. Thomas. 2001. *Distance Sampling: Estimating Abundance of Biological Populations*. Oxford University Press, Oxford and New York.

Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers & L. Thomas. 2004. *Advanced Distance Sampling: Estimating Abundance of Biological Populations*. Oxford University Press, Oxford & New York.

Colwell, M.A. & S.L. Dodd. 1997. Environmental and habitat correlates of pasture use by non-breeding shorebirds. *Condor* 99: 337–344.

Colwell, M.A. & L.W. Oring. 1988. Habitat use by breeding and migrating shorebirds in southcentral Saskatchewan. *Wilson Bull.* 100: 554–566.

Cresswell, W. 1993. Age-dependent choice of redshank (*Tringa tontanus*) feeding location: profitability or risk? *J. of Anim. Ecol.* 63: 589–600.

Cresswell, W. & D.P. Whitfield. 1994. The effect of raptor predation on wintering wader populations at the Tyninghame Estuary, southeast Scotland. *Ibis* 136: 223–232.

Davis, C.A. & L.M. Smith. 1998. Ecology and management of migrant shorebirds in the playa lakes region of Texas. *Wildlife Monographs* No. 140.

De Leon, M.T. & L.M. Smith. 1999. Behavior of migrating shorebirds at North Dakota prairie potholes. *Condor* 101: 645–654.

Dinsmore, S.J., S.K. Skagen & D.L. Helmers. 1999. Shorebirds: an overview for the Prairie Pothole Joint Venture. Prairie Pothole Joint Venture, Denver, CO.

Hands, H.M., M.R. Ryan & J.W. Smith. 1991. Migrant shorebird use of marsh, moist-soil, and flooded agricultural habitats. *Wildlife Society Bull.* 19: 457–464.

Harrington, B.A. 2003. Shorebird management during the non-breeding season – an overview of needs, opportunities, and management concepts. *Wader Study Group Bull.* 100: 59–66.

Houston, C.S. & D.E. Bowen, Jr. 2001. Upland Sandpiper (*Bartramia longicauda*). In *The Birds of North America*, No. 580 (A. Poole & F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union, Washington, D.C.

Johnson, O.W. 2003. Pacific and American Golden-Plovers: reflections on conservations needs. *Wader Study Group Bull.* 100: 10–13.

Johnson, O.W. & P.G. Connors. 1996. American Golden-Plover (*Pluvialis dominica*), Pacific Golden-Plover (*Pluvialis fulva*). In: *The Birds of North America*, No. 201–202 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union, Washington, D.C.

Jorgensen, J.G. 2007. *Buff-breasted Sandpiper (*Tryngites subruficollis*) abundance, habitat use, and distribution during migratory stopover in the Rainwater Basin, Nebraska*. M. Sc. thesis, University of Nebraska at Omaha, Omaha, Nebraska.

Jorgensen, J.G. 2004. *An overview of shorebird migration in the Eastern Rainwater Basin, Nebraska*. Nebraska Ornithologists' Union Occasional Paper Number 8.

Kuzila, M.S. 1994. Inherited morphologies of two large basins in Clay County, Nebraska. *Great Plains Research* 4: 51–63.

LaGrange, T. 2005. *Guide to Nebraska's wetlands and their conservation needs*. Nebraska Game and Parks Commission, Lincoln, Nebraska.

Lanctot, R.B., D.E. Blanco, R.A. Dias, J.P. Isacch, V.A. Gill, J.B. Almeida, K. Delhey, P.F. Petracci, G.A. Bencke & R.A. Balbueno. 2002. Conservation status of the Buff-breasted Sandpiper: historic and contemporary distribution and abundance in South America. *Wilson Bull.* 114: 44–72.

Lanctot, R.B. & C.D. Laredo. 1994. Buff-breasted Sandpiper. In *The Birds of North America*, No. 91 (A. Poole & F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union, Washington, D.C.

Long, W.L. & D. Watkins. 2005. Shorebird action plan for the east Asian–Australasian flyway – lessons learned. In *Status and conservation of shorebirds in the east Asian–Australasian flyway* (P. Straw, ed.). International Wader Studies 17: 190–194.

Milsom, T.P., R.S. Holditch & J.B.A. Rochard. 1985. Diurnal use of an airfield and adjacent agricultural habitats by Lapwings (*Vanellus vanellus*). *J. of App. Ecol.* 22: 313–326.

Morris, L. 1978. Buff-breasted Sandpipers. *Nebraska Bird Review* 46: 77–79.

Morrison, R.I.G., R.E. Gill, Jr., B.A. Harrington, S. Skagen, G.W. Page, C.L. Gratto-Trevor & S.M. Haig. 2001. *Estimates of shorebird populations in North America. Occasional Paper No. 104*, Canadian Wildlife Service, Ottawa, Ontario, 64 pgs.

Oring, L., B. Harrington, S. Brown & C. Hickey (eds). 2000. *National shorebird research needs: a proposal for a national research programs and example high priority research topics.* Manomet Center for Conservation Sciences, Manomet, Massachusetts. *http://www.manomet.org/USSCP/file.htm*

Oring, L.W. & W.M. Davis. 1966. Shorebird migration at Norman, Oklahoma: 1961–63. *Wilson Bull.* 78: 166–174.

Rottenborn, S.C. 1996. The use of coastal agricultural fields in Virginia as foraging habitat by shorebirds. *Wilson Bull.* 108: 783–793.

Schekkerman, H., I. Tulp & B. Ens. 2003. Conservation of long-distance migratory wader populations: reproductive consequences of events occurring in distant staging areas. *Wader Study Group Bull.* 100: 151–156.

Schildman, G. & J. Hurt. 1984. Update of Rainwater Basin wetland survey. Survey of habitat work plan K-83. W-15-R-40. Nebraska Game and Park Commission, Lincoln, Nebraska.

Shackford, J.S., D.M. Leslie & W.D. Warren. Range-wide use of cultivated fields by Mountain Plovers during the breeding season. *J. of Field Ornithology* 70: 114–120.

Shane, T.G. 2005. A significant midcontinental stopover site for the Long-billed Curlew. *Kansas Ornithological Society Bull.* 56 (4): 33–37.

Skagen, S.K. 2006. Migration stopovers and the conservation of Arctic-breeding calidridine sandpipers. *Auk* 123: 313–322.

Skagen, S.K. & F.L. Knopf. 1994. Migrating shorebirds and habitat dynamics at a prairie wetland complex. *Wilson Bull.* 106: 91–105.

Skagen, S.K., P.B Sharpe, R.G. Waltermire & M.B. Dillon. 1999. Biogeographical profiles of shorebird migration in midcontinental North America. Biological Science Report USGS/BRD/BSR-2000-0003. U.S. Government Printing Office, Denver, CO.

Thomas, G.H., R.B. Lanctot & T. Székely. 2006. Can intrinsic factors explain population declines in North American breeding shorebirds? A comparative analysis. *Animal Conservation* 9: 252–258.

Thomas, L., J.L. Laake, S. Strindberg, F.F.C. Marques, S.T. Buckland, D.L. Borchers, D.R. Anderson, K.P. Burnham, S.L. Hedley, J.H. Pollard & J.R.B. Bishop. 2004. Distance 4.1. Release 2. Research Unit for Wildlife Population Assessment, University of St Andrews, UK. *http://www.ruwpa.st-and.ac.uk/distance/*

Thompson, M.C. & C. Ely. 1989. *Birds in Kansas*. Volume 1. University of Kansas Museum of Natural History, Lawrence, Kansas.

United States Department of Agriculture (USDA). 1995. Soil survey geographic (SSURGO) data base: data base information. Miscellaneous Publication 1527, Washington, DC, USA.

United States Department of Agriculture (USDA). 2002. National Agricultural Statistical Service 2002 Census of Agriculture. Nebraska county level data.
http://www.nass.usda.gov/census/census02/volume1/ne/index2.htm

United States Shorebird Conservation Plan (USSCP). 2004. High priority shorebirds – 2004. Unpubl. report, U.S. Fish and Wildlife Service, 4401 N. Fairfax Dr., MBSP 4107, Arlington, VA 22203 U.S.A.

Ydenberg, R.C., R.W. Butler, D.B. Lank, B.D. Smith & J. Ireland. 2004. Western Sandpipers have altered migration tactics as Peregrine Falcon populations have recovered. *Proc. of the Royal Society B: Biological Sciences* 271: 1263–1269.