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John P. McCarty

University of Nebraska at Omaha

Joel G. Jorgensen

Nebraska Game and Parks Commission, joel.jorgensen@nebraska.gov

Justin M. Michaud

University of Nebraska at Omaha

LaReesa Wolfenbarger

University of Nebraska at Omaha, lwolfenbarger@unomaha.edu

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Buff-breasted Sandpiper stopover duration in the Rainwater Basin, Nebraska, in relation to the temporal and spatial migration patterns in the Great Plains of North America

John P. McCarty¹, Joel G. Jorgensen², Justin M. Michaud¹ & L. LaReesa Wolfenbarger^{1,*}

¹Department of Biology, University of Nebraska Omaha, 6001 Dodge St., Omaha, NE 68182, USA

²Nongame Bird Program, Nebraska Game and Parks Commission, 2200 N. 33rd St., Lincoln, NE 68503, USA

*Corresponding author: lwolfenbarger@unomaha.edu

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Buff-breasted Sandpipers *Calidris subruficollis* are a species of significant conservation concern. Previous work shows densities are high during stopover in the Rainwater Basin of Nebraska, USA during the northward migration. However, one of the challenges for understanding the relationship between density at a given time and total numbers of birds using the area during a season is the lack of information about individual stopover duration. We used radio-telemetry to estimate stopover duration in the Rainwater Basin during 2006–2008. Based on information from 24 tagged individual birds, Buff-breasted Sandpiper stopover duration in the Rainwater Basin is *ca.* 24–48 hours for most individuals. To place our results in the spatial and temporal context of spring migration through the Great Plains of North America, we summarized information on Buff-breasted Sandpipers available from eBird and other online sources. This summary indicates that migration northward occurs rapidly after birds leave stopover sites in coastal Louisiana and Texas, and that there are several areas in a narrow band in the eastern Great Plains where concentrations of Buff-breasted Sandpipers occur. Overall, our results support two primary conclusions about the role of the Rainwater Basin during spring migration. First, we confirm earlier reports that this species occurs in exceptionally high densities in the Rainwater Basin, relative to other areas where the species stops on its way north. Second, individuals spend a short amount of time in the Rainwater Basin and appear to arrive in good physical condition. Their time in the Rainwater Basin is spent interacting with conspecifics and maintaining good migratory condition, but evidence suggests that pre-migratory and pre-breeding fattening may occur primarily at sites south of the Rainwater Basin. The short duration of stopover, relative to the amount of time the species is present in the Rainwater Basin, suggests the total number of individuals using the region is greater than previous estimates based on density at a given point of time.

Keywords

Buff-breasted Sandpiper
Calidris subruficollis
shorebird
migration
stopover
Rainwater Basin
radio-telemetry
Great Plains

INTRODUCTION

Buff-breasted Sandpipers *Calidris subruficollis* are a species of significant conservation concern because of low population size and possible long-term declines in numbers, and are classified as ‘highly imperiled’ by the U.S. Shorebird Conservation Plan (U.S. Shorebird Conservation Plan 2004, Lanctot *et al.* 2010). This species migrates from wintering areas in southern South America, through the North American Great Plains to its Arctic breeding range,

which extends from northern Alaska and Yukon, through the Northwest Territories, to Nunavut (Lanctot & Laredo 1994, Lanctot *et al.* 2002). Buff-breasted Sandpipers’ long migrations present an array of traditional risks throughout the annual cycle. Human alterations to the environment during recent decades have added a number of novel hazards, including recent and projected future climate change (Robinson *et al.* 2009, Galbraith *et al.* 2014, Urban 2015), development of both conventional and renewable

Fig. 1. Nebraska and the location of the eastern Rainwater Basin region. The central panel shows the outline of the Rainwater Basin study area, defined based on soil and topographic characteristics (Jorgensen 2007). The open circles represent the approximate location where radio-tagged Buff-breasted Sandpipers were captured and released; overlapping circles have been shifted for clarity. The upper inset shows the counties of Nebraska with the eastern Rainwater Basin shaded in. The area in the dashed rectangle is enlarged in the lower panel and shows the portion of the study area where Buff-breasted Sandpipers were captured. Letter codes correspond to the birds listed in Table 1. Gray lines indicate the 1 x 1 mile grid of paved and gravel roads that cover the majority of the Rainwater basin region.

energy resources (Wright & Wimberly 2013, Jones *et al.* 2015), and exposure to agricultural chemicals associated with the species' reliance on agricultural landscapes during migration and winter (Mineau & Whiteside 2006, Strum *et al.* 2010).

Developing conservation strategies depends on understanding patterns of habitat use on the breeding and wintering grounds, as well as at key stopover sites along the species' migratory route (Lancot *et al.* 2010). Buff-breasted Sandpiper concentrations during northward migration are consistently detected at several sites in central North America, including southern Texas, Louisiana, Oklahoma, Kansas, and Nebraska (Oring 1964, Lancot & Laredo 1994, Norling *et al.* 2012). The Rainwater Basin region of south-central Nebraska is known to be an important, traditional stopover site for Buff-breasted Sandpipers, as well as other shorebirds (Morris 1978,

1995, Sharpe *et al.* 2001, Jorgensen 2004). During their stopover in May, Buff-breasted Sandpipers rest, feed, and interact with one another in upland agricultural fields, while making relatively brief visits to drink and bathe in wetlands in the region (Jorgensen *et al.* 2007, McCarty *et al.* 2009). Buff-breasted Sandpiper density was first quantified in the Rainwater Basin during 2004–2005 spring migrations using a distance sampling approach (Jorgensen *et al.* 2008). Based on the densities of birds we found and the area surveyed, we conservatively estimated that between 14,000 and 43,000 individuals were present in the Rainwater Basin during migration, representing a significant percentage of this species' global population (Jorgensen *et al.* 2008). The global population estimate for Buff-breasted Sandpipers was increased from 15,000–20,000 individuals (Morrison *et al.* 2001) to 56,000 individuals (Andres *et al.* 2012) based, in part, on Jorgensen

et al. (2008), and the results were the basis for identifying the Rainwater Basin as a landscape of hemispheric importance for shorebird conservation (WHSRN 2009, Andres *et al.* 2012).

Uncertainty remains about the importance of the Rainwater Basin for the population of Buff-breasted Sandpipers. Previous work provided estimates of average density of Buff-breasted Sandpipers during a 15–20 day period in May (Jorgensen *et al.* 2008). One of the challenges for understanding the relationship between the density of birds measured at given time and the total number of birds passing through a region during migration is uncertainty regarding how long each individual is present at a site (Bishop *et al.* 2000, Frederiksen *et al.* 2001). We concluded that a large percentage of the population passes through the Rainwater Basin, but our estimates of population size implicitly assumed limited turnover of individuals during the approximately 15–20 day period when Buff-breasted Sandpipers were present. Some turnover of individuals undoubtedly occurs; however, our approach produced a low, conservative estimate consistent with our goals (Jorgensen *et al.* 2008). Determining length of stay will improve the understanding of whether the Rainwater Basin is an important site for birds to rest, forage, and accumulate or maintain the fat reserves needed to continue the northbound migration, and may also provide insights regarding risks associated with agriculture, energy development, and other human activities.

We used radio-telemetry to estimate Buff-breasted Sandpiper stopover duration in the Rainwater Basin. Our goal was to first estimate turnover rates in this region during migration. Second, we placed this information in a broader context of timing of spring migration throughout the Great Plains and central North America by using information gleaned from internet resources (e.g. eBird.org). Together, these approaches provide improved understanding of the species' northward migration and the relative importance of the Rainwater Basin as a stopover site.

METHODS

Our study area was the eastern portion of the Rainwater Basin, Nebraska, which is an important stopover area for Buff-breasted Sandpipers (Sharpe *et al.* 2001, Jorgensen 2004, Jorgensen *et al.* 2008). This area is bounded by the Platte River drainage to the north, the Little Blue River drainage to the south, and the Big Blue River drainage to the east, and covers eastern Adams, Clay, Fillmore, Hamilton, Polk, eastern Seward, eastern Butler, eastern Saline, northern Thayer, northern Nuckolls, and York Counties of Nebraska (Fig. 1; Jorgensen *et al.* 2007, 2008). Prior to settlement by Europeans in the late 1800s, the majority of land area in the Rainwater Basin was tallgrass prairie (Weaver & Bruner 1954, Kaul *et al.* 2012). Spread across this area were more than 11,000 shallow playa wetlands (Schildman & Hurt 1984, LaGrange 2005). Today, over 90% of all wetlands have been destroyed (Schildman & Hurt 1984) and remaining wetlands are degraded (LaGrange 2005). The region is now dominated by row crop agriculture,

primarily consisting of corn and soybean fields. Remaining functional wetlands are now interspersed within these fields (Jorgensen *et al.* 2007).

Capture and radio-telemetry in the Rainwater Basin

During spring migration in 2006–2008, we captured Buff-breasted Sandpipers in agricultural fields at night. Buff-breasted Sandpiper abundance and site use were variable during migratory stopover. We opportunistically searched for Buff-breasted Sandpipers in agricultural fields in late afternoons and evenings during early–mid May. Fields with birds were subsequently monitored until dusk to determine whether birds appeared to be settling down for the night and roosting in the field. Meanwhile, we identified and contacted the appropriate landowner or manager to obtain permission to access the field. We returned to the field a minimum of a half hour after sunset. We systematically searched fields for Buff-breasted Sandpipers and used spotlights and dip-nets to capture birds.

Captured Buff-breasted Sandpipers were marked with metal USGS bands and a unique combination of color bands. We recorded mass (in 2007 and 2008 only) and measured length of tarsus, exposed culmen, head plus bill, and flattened, straightened wing. With the exception of five birds released after banding in 2006, we then attached a radio-transmitter following the technique of Warnock & Takekawa (2003). This involved trimming a dorsal patch of feathers and affixing an ATS A2455 glue-on transmitter using cyanoacrylate glue (Advanced Telemetry Systems, Isanti, MN, USA). Transmitters weighed 1.2 g, representing 1.2–2.0 % of body mass. After testing to ensure the radio was transmitting, the bird was released back into the field where it was captured.

We tracked radio-tagged Buff-breasted Sandpipers using vehicle-mounted and hand-held antennas. Initial results in 2006 suggested some individuals left the area shortly after being tagged and released. Therefore, in 2007–2008, we recorded locations of radio-tagged birds immediately after release and attempted to relocate the signal in the hours post-release and before sunrise, to confirm the tagged individual had not moved. Location and transmitter information were then relayed to other team members who arrived before sunrise, and the radio-transmitter signal was again located before sunrise. After sunrise, birds became more active and radio-tagged bird often moved to nearby fields or continued migration and left the area altogether. When birds were relocated, the position was triangulated and we attempted to make a visual observation and confirm the leg band color combination.

We searched for missing signals from radio-tags using truck-mounted and airplane-mounted antennas and receivers. Our study area is covered by a 1 x 1 mile grid of roads laid out along the U.S. Public Land Survey System section lines (Fig. 1). Therefore, radio-tagged birds in our study site would be <1 km from a paved or graveled road, except in those few areas where the road grid is incomplete (Fig. 1). These roads were driven systematically

by up to three vehicles each day, starting at the location where tagged birds were last detected and scanning frequencies for all recently captured birds. The areas within *ca.* 10 km of the capture site were searched repeatedly using vehicles. The areas further away were also searched from the road, emphasizing the areas between where we captured birds and the Platte River to the north (Fig. 1). Since any birds present would be <1 km from a road, we should have been able to detect the transmitter signals from their transmitters. In 2007–2008, we also used an airplane with a radio receiver to improve tracking and increase our confidence that when a bird was not detected, it had left the area. Searches followed the road grid described above and concentrated on the northern half

of the Rainwater Basin up to the Platte River (Fig. 1).

During the study, we also attempted to capture Buff-breasted Sandpipers using mist nets as they visited wetlands. No Buff-breasted Sandpipers were captured at these wetlands, but other migrant shorebirds were captured. We banded and attached radio-transmitters to a subset of the White-rumped Sandpipers *Calidris fuscicollis*, Baird's Sandpipers *Calidris bairdii*, and Long-billed Dowitchers *Limnodromus scolopaceus* we captured, using ATS radio-tags appropriately sized for each species. While we initially intended to determine stopover duration for these species, the effort required to track Buff-breasted Sandpipers precluded devoting more than minimal effort

Table 1. Fates of radio-tagged Buff-breasted Sandpipers (BBSA).

Bird	Year	Capture date	Capture time	Observations	Hours tracked
A	2006	07 May	21:45	Not relocated.	0
B	2006	07 May	22:15	Located in capture field morning of 8 May. Signal disappeared with departing flock of BBSA evening of 8 May.	<i>ca.</i> 21
C	2006	09 May	22:15	Located in capture field 11:00–15:00 10 May.	16:45
D	2006	12 May	23:20	Not relocated.	0
E	2006	14 May	21:51	Not relocated.	0
F	2006	14 May	22:30	Not relocated.	0
G	2006	14 May	22:45	Not relocated.	0
H	2007	4 May	21:30	Not relocated.	0
I	2007	12 May	23:00	Moved <i>ca.</i> 1 km upon release. Last located 05:09 13 May.	6:09
J	2007	13 May	01:00	Located in capture field until 12:58 13 May. Relocated <i>ca.</i> 1.5 km away on 16 & 17 May. Departed between 05:26 and 07:13 on 17 May.	100:21
K	2007	13 May	01:00	Moved <i>ca.</i> 1.5 km upon release. Last located 05:37 13 May as flock of BBSA departed.	4:37
L	2007	16 May	23:16	Not relocated.	0
M	2007	16-May	01:00	Located in capture field until 06:15 16 May. Followed signal in departing flock of 50 BBSA for <i>ca.</i> 8 km to NW before signal was lost.	5:15
N	2007	17 May	23:30	Located in capture field until 05:39 18 May when bird moved to adjacent field. Moved to adjacent field 06:02. Departed 06:08 and relocated <i>ca.</i> 1.5 km north. Signal departed at 06:37 18 May.	7:07
O	2008	13 May	00:58	Located in capture field until 06:24 13 May. Relocated <i>ca.</i> 1.5 km north and remained through 13 May. Last located 05:34 14 May before departure.	28:36
P	2008	13 May	23:50	Not relocated.	0
Q	2008	14 May	23:26	Moved <i>ca.</i> 1.5 km north upon release. Last located 09:46 15 May as flock of 25 BBSA departed. Followed signal <i>ca.</i> 2 km N before signal was lost.	11:20
R	2008	15 May	00:28	Located in capture field until 14:20 16 May. Bird was reluctant to fly and may have been injured during capture or handling.	37:52
S	2008	15 May	23:09	Not relocated.	0
T	2008	15 May	23:45	Not relocated.	0
U	2008	16 May	01:13	Not relocated.	0
V	2008	16 May	23:01	Located in capture field until 05:40 17 May.	6:39
W	2008	16 May	23:45	Not relocated.	0
X	2008	17 May	00:30	Located in capture field until 05:05 17 May.	4:35

to following other species. When it was compatible with searching for Buff-breasted Sandpipers, we did search for signals from these other species to help confirm that we could locate transmitters that remained in the area. Finally, we also activated transmitters that were not deployed on birds and placed them near capture locations, to confirm that the airplane-based receiver was able to detect transmitter signals.

Compilation and review of migration reports

We compiled reported observations of Buff-breasted Sandpipers during spring migration from online sources. All Buff-breasted Sandpiper observations through summer 2014 from the eBird database were downloaded (eBird 2014). Observations from eBird were edited to eliminate observations outside March–June, outside the central flyway of North America, and before 1970. Sightings for which no number was associated, indicated with an ‘X’ in the eBird database, were changed to one.

These eBird observations were supplemented by observations submitted to state and provincial birding listservs. We used the search terms ‘buff-breasted’ and ‘bbsa’ to search available archives for Texas (Texbirds, 1997–May 2011, March 2012–2014), Louisiana (LABIRD-L, 1999–2014), Oklahoma (OKBIRDS, 2000–2014), Arkansas (ARBIRD-L, 1997–2014), Missouri (MOBIRDS-L, 2003–2014), Kansas (KSBIIRD-L, 1996–2014), Nebraska (NEBirds, 2001–2014), Minnesota (MOU-NET, 2009–2014), Iowa (www.iowabirds.org Species AdHoc Reporting, 2004–2012), South Dakota (sd-birds, 2004–2014), North Dakota (ND-Birds, 2000–2014), Saskatchewan (Saskbirds, 2001–2014), Alberta (ALBERTABIRD, 2000–2014), and Manitoba (manitobabirds, 2001–2014). Listserv records for March–June were examined and we manually extracted information about date, number of Buff-breasted Sandpipers observed, name(s) of observers, and locations. Where it was apparent that multiple postings were reporting the same birds, we selected the observation reporting the largest number of individuals and deleted duplicate records. If the report indicated the species was observed, but no numbers were

reported, we recorded one individual. In cases where exact numbers were not reported, but the report did contain an indication of numbers, we used these guidelines: ‘few’ = 3, ‘several/handful’ = 5, ‘many/lots’ = 10, ‘hundreds’ = 200. We then combined eBird and listserv observations into a single file, and sorted observations by date and location to identify and remove duplicate reports.

The eBird database includes the latitude and longitude of observations. Location descriptions for listserv reports were used to locate the site using online mapping services (i.e. Google Maps). We used ArcGIS 10.2 (ESRI, Redmond, CA, USA) to summarize observations by county or equivalent (i.e. parish in Louisiana and census division in Canada). A large portion of reports from Nebraska’s Rainwater Basin did not specify the county so we divided the total observations for this region equally among the four counties that account for the majority of the eastern Rainwater Basin. The date of each observation was converted to day of year, where day 1 = 1 January. Dates of observations were summarized for groups of states with each report weighted by the number of birds observed.

We summarized the mean and median number of Buff-breasted Sandpipers per report to eBird and listservs after removing the eBird reports that only indicated the species was present (‘X’). Four postings from coastal Texas and Louisiana and one report from the Rainwater Basin of Nebraska reported over 1,000 Buff-breasted Sandpipers. We excluded these reports from our calculations of mean and median birds per report.

RESULTS

Capture and radio-telemetry in the Rainwater Basin

We captured 29 Buff-breasted Sandpipers in 2006–2008; 12 in 2006, 7 in 2007, and 10 in 2008 (Table 1). All Buff-breasted Sandpipers were captured during 4–17 May. Morphological measurements for birds captured were variable. Mean ($\pm$ SE) for tarsus length = 29.4 ± 0.6 mm, wing length = 132.2 ± 0.9 mm, head + bill = 50.0 ± 0.5

Table 2. Mass of Buff-breasted Sandpipers (g).

Location	Season	$\bar{x}$	SD	Range	<i>n</i>
Argentina, Paraguay & Uruguay ¹	Winter	57.4	5.7	42.0–65.5	24
Brazil & Surinam ²	Migration	62.3	8.3	53.0–69.0	3
Texas & Kansas ¹	Migration	68.2	11.3	42.0–101.0	67
Nebraska ²	Migration	89.2	8.2	61.6–117.0	41
Nebraska ³	Migration	81.2	3.0	58.0–99.0	17
Alaska ²	Breeding	62.8	3.6	46.0–77.5	125

¹Strum et al. 2010. Summaries from pesticide and reference sites combined.

²Lancot & Laredo 1994. Summaries of males and females combined.

³This study.

Fig. 2. Observations of Buff-breasted Sandpipers during northward migration in North America, as reported on eBird and state and regional birding listservs. Each circle is centered on a county (or equivalent) and circle size indicates the total number of observations. The arrow indicates the location of the eastern Rainwater Basin in Nebraska.

mm, and exposed culmen = 19.5 ± 0.2 mm. Mean mass of the 17 birds weighed was 81.2 ± 3.0 g (range: 58–99 g; Table 2).

We attached radio-transmitters to 24 Buff-breasted Sandpipers (Table 1). Of the seven individuals radio-tagged in 2006, five were never relocated. Based on results from the modified tracking protocol used in 2007–2008, it is likely those five individuals either left the area immediately upon release or departed around sunrise that same morning. Radio-tags were placed on seven Buff-breasted Sandpipers in 2007 and on ten individuals in 2008. Although radio-tracking was initiated within minutes after birds were released in 2007 and 2008, we failed to relocate 7 of 17 individuals tagged. Three additional birds

left the field where they were captured immediately after release but were relocated in fields 1–2 km away. The remaining seven individuals remained in the field where they were captured after they were released. Overall, of the 12 birds relocated, seven were last located the morning after they were captured, two were located in the evening of day of capture, one was last located on the second morning, one was located the second evening, and one signal was detected over four days after capture (Table 1).

Despite searching for missing signals from the road grid and from the air, we never detected tagged Buff-breasted Sandpipers more than 2 km from where they had been captured. We were able to detect signals from test transmitters placed in the field from both ground and air. We

Fig. 3. Buff-breasted Sandpiper migration through the Great Plains of the United States. The total number of observations from each county is represented by the color. Observations reported from the Rainwater Basin region were divided equally among the four counties that cover the majority of the area; some observations may have occurred in adjoining counties. The arrow points to the counties that form the core of the eastern Rainwater Basin study area.

were also able to detect signals from other species of shorebirds captured at wetlands. In 2006 we attached radio-transmitters to three White-rumped Sandpipers, one Baird's Sandpiper, and six Long-billed Dowitchers. In 2007 we placed transmitters on 10 White-rumped Sandpipers, although because of the priority placed on

tracking Buff-breasted Sandpipers, we were only able to devote effort to relocating three of these individuals. Even with the minimal effort devoted to tracking these other species, all individuals were relocated after capture (7 individuals on the capture day, 5 on the following day, and 1 individual 4 days after capture).

Compilation and review of migration reports

We obtained 2,608 records of Buff-breasted Sandpiper observations during northward migration from eBird and extracted 611 observations from state and provincial listservs (Table 3). After combining these observations and deleting what we judged to be duplicate observations from the same location and date, 2,620 records remained (2,005 from eBird and 515 from listservs). The pattern of observations across years reflects the growth in the number of birders submitting reports online. The eBird database includes observations from before the start of the program in 2002 and we included reports after 1970. For the period of 1971–1995 we obtained an average of 10.2 ± 1.37 reports totaling 144.2 ± 48.8 birds per year. Starting in 1996 eBird observations were supplemented with observations reported in state listservs. For the 1996–2005 period we obtained an average of 51.2 ± 7.4 reports totaling an average of $1,119.1 \pm 409.1$ individual Buff-breasted Sandpipers per year. After 2005 the participation in eBird grew rapidly so that for the 2006–2014 period we obtained an average of 217.9 ± 35.7 observations totaling an average of $4,398.8 \pm 701.0$ individuals per year.

The locations of the vast majority of these observations were concentrated along a narrow geographic band stretching from coastal Texas and Louisiana north along the

eastern edge of the Great Plains (Fig. 2). The largest number of reports comes from the coastal counties and parishes of Texas and Louisiana (Table 3). Within the eastern Great Plains, large numbers of observations came from the counties at the core of Nebraska's Rainwater Basin, as well as from the area surrounding Tulsa, Oklahoma, and the Flint Hills of Kansas (Fig. 3). For most of the migratory route, the mean number of Buff-breasted Sandpipers per online report was 3–21 birds, with a median of 2–7 birds per report (Table 3). The exception to this were the reports from Nebraska, Iowa, and Illinois, primarily from the Rainwater Basin, where the mean number of birds was 86.6 and median was 22 birds per report (Table 3).

Reports of Buff-breasted Sandpipers early in the season were concentrated in coastal Texas and Louisiana (Table 3, Fig. 3). First observations in Texas and Louisiana (with extreme observations in January 2014 excluded) range from day 66 (7 March 2004) to day 107 (17 April 1995) for the 1995–2014 period, with a median date of first arrival at day 83 (24 March). The average date for observations in coastal Texas and Louisiana was day 117 (27 April; interquartile range = day 110–125 (20 April–5 May)). One observation from 25 June 2006 in Texas was excluded because it may have represented a southbound migrant.

Table 3. Observed numbers and dates for Buff-breasted Sandpipers during northward migration in the central flyway of North America. Observations were extracted from eBird and regional listservs for the years 1971–2014. Observations are arranged from south to north based on regions. *N* reports is the number of records summarized and *n* birds is the total number of birds reported. Mean and median birds give the average and median number of birds per report, after excluding reports that did not specify the number of individuals observed and after excluding five reports from Texas and Nebraska that included over 1,000 individuals over several days. Dates are reported as Julian Days. The 1st and 3rd quartiles, median, and mean day for reports, weighted by the number of birds observed, were calculated for each region.

Region	<i>n</i> reports	<i>n</i> birds	Mean birds	Median birds	First date	1 st quartile	Mean date	Median date	3 rd quartile	Last date
South/Central America & Caribbean	23	212	9.2	2	17	115	112.4	115	115	145
Coastal Texas & Louisiana	1,471	29,600	20.1	6	66	110	116.6	118	125	152
Inland Texas & Louisiana	213	1,705	8.3	2	86	118	125.1	129	133	155
Arkansas & Oklahoma	151	2,303	16.0	4	91	129	132.1	134	139	147
Kansas, Colorado & Missouri	113	1,318	13.4	3	105	127	130.9	131	135	160
Nebraska, Iowa & Illinois	126	13,083	86.6	22	115	130	134.2	134	138	168
Dakotas, Minnesota & Wisconsin	56	594	11.0	2	125	135	138.6	138	142	155
Alberta, Saskatchewan, Manitoba & British Columbia	72	1,365	20.9	7	129	141	141.9	141	144	157
Sub-Arctic	30	92	3.1	2	141	148	150.4	149	153	169
Arctic breeding	365	1,919	5.5	3	143	164	169.2	170	175	182

Fig. 4. Relationship between the latitude and date (day of year) of observations of Buff-breasted Sandpipers in North America. Each dot represents an observation. The solid line shows a smoothing spline curve. The approximate latitude of key locations during northward migration is indicated.

Significant movement north starts in late April and early May and the weighted average day for observations in different states indicates a rapid northward movement of the bulk of the population (Table 3). Reports from central and northern Texas and Louisiana (Fig. 3) typically peak around day 125.1 (5 May; interquartile range = day 118–133 (28 April–13 May); Table 3). The average day in the next tier of states, Arkansas and Oklahoma, occurs around day 132.1 (12 May; interquartile range = day 129–139 (9 May–19 May)). Further north in Kansas, Colorado, and Missouri, average date for observations is day 130.9 (11 May; interquartile range = day 127–135). In Nebraska and adjacent states, mean date for observations occurs on day 134.2 (14 May; interquartile range = day 130–138; Table 3).

Moving north from Nebraska, the average date of observations in the Dakotas and adjacent states is day 138.6 (19 May; interquartile range = day 135–142) and day 141.9 (22 May; interquartile range = day 141–144) in the provinces of Alberta, Saskatchewan, Manitoba, and British Columbia (Table 3). Observations between the southern provinces and breeding grounds are limited, but occur on average at day 150.4 (30 May; interquartile range = day 148–153). First observations in Arctic breeding areas during the 1995–2014 period ranged from day 146 (26 May 2010) to day 171 (24 June 1997) with a median date of first observation at day 156 (5 June); Table 3).

Once birds cross north of 30°N latitude (the northern edge of coastal Texas and Louisiana), there is a consistent relationship between latitude and day of observation (Fig. 4). The concentration of observations and spread of dates for the region of coastal Texas and Louisiana (25–30°N

latitude) suggests a more prolonged stopover in this region. The distribution of observations among days also shows that significant numbers of birds continue to occur in Texas and Louisiana after northward migration has begun and some individuals are approaching the breeding grounds (Fig. 4).

DISCUSSION

Long-distance migratory shorebirds have evolved variable migration strategies in response to spatially-isolated and discretely-distributed resources (Piersma 2007). These strategies incorporate locations where birds stop during migration to feed and rest, but the relative importance of specific locations differs among populations with differing migration patterns (Skagen 2006). Environmental changes at these stopover sites may have important consequences, both positive and negative, to individual birds and populations. Buff-breasted Sandpipers are known to migrate through the Great Plains and stopover in high densities in the Rainwater Basin region of Nebraska (Jorgensen *et al.* 2008). Both the location and timing of this stopover have shown a consistent pattern over the past several decades (Morris 1978, 1995, Jorgensen 2004), with significant numbers occurring in the Rainwater Basin for at least 10 days in early May. The pattern we observed in radio-tagged Buff-breasted Sandpipers suggests the stopover duration of individuals in Rainwater Basin is relatively short (on the order of 48 hours; Table 1), indicating a rapid turnover of individuals during the 15–20 days the species is present. If individual stopover duration is as short as our observations suggest, then the total number of birds using this area over the course of the season is

likely to be greater than the estimates derived from densities of individuals measured at a given point in time (Jorgensen *et al.* 2008).

The short stopover duration we report could result from a failure to detect radio-tagged birds that remained in the Rainwater Basin, rather than being a result of birds leaving the area. Similarly, if capture and handling induced Buff-breasted Sandpipers to depart sooner than they normally would, then the short durations we report might not be representative of the population as a whole. We cannot eliminate these alternatives but several lines of evidence suggest that these are not the primary drivers of the pattern we observed. The flat and open terrain of the Rainwater Basin, combined with its 1 x 1 mile road grid, should provide good conditions for detecting radio signals. Using identical tags and receivers we were able to detect activated tags both from the ground and from a small airplane. In addition, we were able to track other species of shorebirds for several days, despite devoting limited time and effort to finding their signals. Similar patterns have been found in previous studies of radio-tagged shorebirds, where individuals seldom moved more than a few hundred meters, and most individuals moving beyond that left the region entirely (Farmer & Parent, 1997). Likewise, similarly short duration of stopover has been observed in other shorebird species (Warnock & Bishop 1998).

The behavior of the birds we tracked was consistent with limited stopover duration. We often observed groups of Buff-breasted Sandpipers in flight during morning and evening hours and most groups were moving north. In addition, during opportunistic surveys of fields, we observed sudden increases in Buff-breasted Sandpiper abundance compared to previous days, suggesting an influx of new arrivals. We also observed decreases in abundance from day to day. Signals for eight of the tagged birds were lost during the hours after sunrise when flocks were observed moving north. In four of those cases, the loss of the signal occurred when groups of Buff-breasted Sandpipers were observed leaving the fields where the tagged birds were located (Individuals B, K, M, and Q in Table 1). In two of those cases, the signal was followed north for several kilometers before it was lost (Individuals M and Q). In two cases we did track birds for over 30 hours (Individuals J and R); however, our observations suggest these may have been anomalies related to stress caused by capture and handling, and the behavior of birds that departed the morning after capture was more typical.

Based on the behavior of Buff-breasted Sandpipers in the Rainwater Basin, it appears that they use the area to rest and congregate into flocks prior to continuing their northward migration. The level of social activity observed in Buff-breasted Sandpipers is high relative to what has been reported for other shorebirds during stopover (Davis & Smith 1998, DeLeon & Davis 1999, McCarty *et al.* 2009) and includes frequent single- and double-wing displays and chases associated with courtship and attracting

conspecifics (Oring 1964, Lanctot & Laredo 1994). In the Rainwater Basin, Buff-breasted Sandpipers spend 25–30% of daylight hours resting or performing maintenance activities such as preening or bathing, and almost half of their time actively foraging in agricultural fields (McCarty *et al.* 2009). Based on the body masses of birds we captured, as well as previous reports of birds from the Rainwater Basin, it appears that Buff-breasted Sandpipers are at or near their peak mass when they arrive (Table 2). Individuals captured both further south during spring migration and on the breeding grounds had lower masses (Lanctot & Laredo 1994, Strum *et al.* 2010). This, combined with the short duration of stopover, suggests that individuals have already undergone pre-migratory fattening upon arrival and the foraging observed in our study area serves to maintain fat reserves, helping ensure that birds arrive on the breeding grounds in good condition.

Our summary of observations reported on eBird and other online outlets supports the suggestion that migrating Buff-breasted Sandpipers pass quickly through the Great Plains without prolonged stopovers. The pattern we found suggests Buff-breasted Sandpipers do spend several weeks in coastal Texas and Louisiana during late March and April (*ca.* days 85–120; Fig. 3 and Table 3). Once migration recommences in late April and early May, the population rapidly moves north (Table 3). Reports from central and northern Texas and Louisiana typically peak around day 125.1 (5 May), followed by peak observations in the Rainwater Basin of Nebraska and in adjacent states on day 134.2 (14 May; Table 3). This represents a 9-day window between peak observations in northern Texas and Louisiana and the peak observations in Nebraska, approximately 1,000 km to the north (Fig. 3).

First observations in Arctic breeding areas during the 1995–2014 period ranged from day 146 (26 May 2010) to day 171 (24 June 1997) with a median date of first observation at day 156 (5 June), consistent with the reports from the breeding grounds summarized by Lanctot & Laredo (1994) indicating that birds arrive on the breeding grounds 'late May through the first week of June'. This represents a distance of *ca.* 5,000 km between departure from the stopover sites in southern Texas and Louisiana at the end of April, to arrival at the breeding grounds approximately a month later (Table 3).

The number and time span of observations in coastal Texas and Louisiana highlights the need for better understanding of the function of this region for migrating Buff-breasted Sandpipers (Norling *et al.* 2012). Based on available mass data, it is also likely that Buff-breasted Sandpipers accumulate considerable fat reserves during this time (Table 2). The observations further inland, especially in the arc stretching from Austin to Dallas, TX, to Shreveport, LA occur at the start of the northward migration in late April–early May (Fig. 3).

North of Texas and Louisiana, observations of Buff-breasted Sandpipers are concentrated along the eastern edge of the Great Plains (Fig. 3). Based on these observations, the majority of migrants continue north through

the area around Tulsa, OK, through the Flint Hills of Kansas between Wichita, Manhattan, and Topeka, and on the Rainwater Basin in southern Nebraska (Fig. 3). Observations in South Dakota continue to be concentrated in the eastern half of the state, but the pattern suggests that the migration pathway widens to the west starting in North Dakota and through the Prairie Provinces to the breeding grounds (Figs. 1 and 3). The relatively small number of reports after they move north from the Rainwater Basin may result from relatively low density of birders in the northern Great Plains of USA and Canada, combined with birds becoming more dispersed as they approach the breeding grounds.

The indication that Buff-breasted Sandpipers pass quickly through the Great Plains region using multiple stopover sites is consistent with the 'hop' migration strategy (*sensu* Piersma 1987, described in Colwell 2010). Further, the relatively short stopover duration and high capture masses in the Rainwater Basin suggest the area does not meet the definition of a staging area (Skagen & Knopf 1994, Warnock 2010), although coastal Texas and Louisiana may fit this definition. This pattern of northward migration has several possible implications for conservation. The stopover duration we report means that each bird spends only a limited amount of time in the Rainwater Basin. However, the high turnover of individuals also means that the total number of birds using the site is likely greater than previous estimates based on the density of birds at a given point in time (Jorgensen *et al.* 2008). This spatial concentration of the population during migration magnifies any risks associated with the habitats they use, while the short stopover limits exposure to hazards. Buff-breasted Sandpipers use agricultural fields during stopover and that habitat may not be limiting. However, agricultural habitats themselves present potent, potential risks in the form of agricultural chemicals (Mineau & Whiteside 2006), reduced food availability (Thorbeck & Bilde 2004), and rapid land use change (Wright & Wimberly 2013) including shifts from preferred crop types such as soybean to other, less suitable crops (Jorgensen *et al.* 2007). The temporal concentration of migration north through the Great Plains also raises concerns about possible catastrophic threats such as severe storms (Newton 2006). Taken together, the timing and location of migration present significant conservation challenges and emphasize the need to refine our understanding of the relative importance of habitats and resource needs of Buff-breasted Sandpipers, both spatially and temporally, during this critical life history stage.

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