Stopover dynamics of fall migrant Pectoral Sandpipers in Iowa

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Many species of shorebirds (order Charadriiformes) undergo bi-annual long-distance migrations between temperate and tropical wintering areas to extreme northern latitudes for breeding purposes. We examined stopover dynamics of Pectoral Sandpipers *Calidris melanotos* at a stopover site in Iowa during fall 2012. We radio-marked and tracked 52 individuals to determine their departure date. We also modeled daily probability of local survival within the stopover site with the nest survival model in program MARK and utilized daily local survival to estimate minimum stopover durations. The most competitive model included both a negative linear day-of-season effect and negative effect of body condition index on daily survival rates, with mean minimum stopover duration calculations of 7.4 days (95% confidence interval 4.3 to 13.6 days). Our work provides important baseline information on stopover site use by a common migrant shorebird in mid-continental North America and further documents the benefits of water level management to waterbirds.

INTRODUCTION

Migration is a widespread life history strategy undertaken by a great diversity of organisms that generally functions to maximize availability of resources such as food items, shelter, or breeding and oviposition sites across an array of spatial and temporal scales (Dingle 1996, Weber *et al.* 1998). Shorebirds are certainly an example of the prevalence of migratory life history strategies, as over 60% of the 215 shorebird species globally are known to be migratory (Warnock *et al.* 2001). Shorebirds are often renowned for bi-annual long distance migrations as many species move between temperate or tropical wintering sites and extreme northern latitudes for breeding purposes. Some species, such as Red Knot *Calidris canutus*, are known for extensive stopover periods at crucial or historical sites that culminate in large continuous migratory bouts (Piersma *et al.* 2005). Conversely, there are many shorebird species that utilize a strategy of more frequent stopover events along a network of less predictable stopover sites along migratory routes through mid-continental North America as well as coastal routes in Africa and Europe (Alerstam & Hedenstrom 1998, Alerstam & Lindstrom 1990, Haig *et al.* 1998, Piersma 1987, Skagen 2006, Skagen & Knopf 1993, Skagen *et al.* 1999). There is generally less knowledge about shorebird non-breeding ecology and migratory ecology through the mid-continent region of North America as most previous studies have focused on coastal areas or coastal ecosystems (Skagen *et al.* 1999). In addition to being remarkable for migratory feats, shorebirds are also closely tied to very specific wetland habitat types across the globe (Colwell 2010). Substantial wetland losses have been documented globally. In North America such losses account for roughly 50% of historical wetlands in the coterminous United States (Dahl 1990, Dahl 2000). Because of this there is a great interest in research and management of this vital shorebird habitat type (Helmers 1992, Myers *et al.* 1987).

Iowa's Prairie Pothole Region (PPR) often hosts many shorebird species during migration; 34 species of shorebirds are regularly observed in Iowa (Kent & Dinsmore 1996). Shorebirds represent a diverse yet highly specialized group heavily tied to shallow aquatic and moist soil habitats (Helmers 1992). Eight species of shorebirds in the PPR and 21 species nationally are listed as species of conservation concern (Brown *et al.* 2001, U.S. Fish and Wildlife Service 2008). Many factors, such as concentration of populations into limited areas during migration/winter, high energy requirements for migration, exact timing requirements for migration, and anthropogenic influence, raise conservation issues for migratory shorebirds (Myers *et al.* 1987). In light of these and other increasing threats to shorebirds and potentially crucial shorebird stopover habitat in the form of ongoing land-use changes throughout North America, increased study of poorly understood or documented life history stages becomes more crucial.

Pectoral Sandpipers *Calidris melanotos* are Holarctic-breeding sandpipers and common spring and fall migrants through the PPR that exhibit the above-mentioned 'frequent stopover' migratory strategy at more dynamic sites in lieu of extended stopover periods at large sites (Farmer & Wiens 1999). Previous studies on the migratory ecology of Pectoral Sandpipers or related species have been done primarily during spring and in areas outside of the PPR such as the Lower Mississippi River Alluvial Valley (Lehnen & Krementz 2005) and in central Kansas and Missouri (Skagen & Knopf 1994). Because of their abundance, scarcity of knowledge on their fall migratory ecology, and adequate body size to accommodate radio-marking, Pectoral Sandpipers were a good candidate for this study. The primary objective for this study was to estimate minimum stopover duration of Pectoral

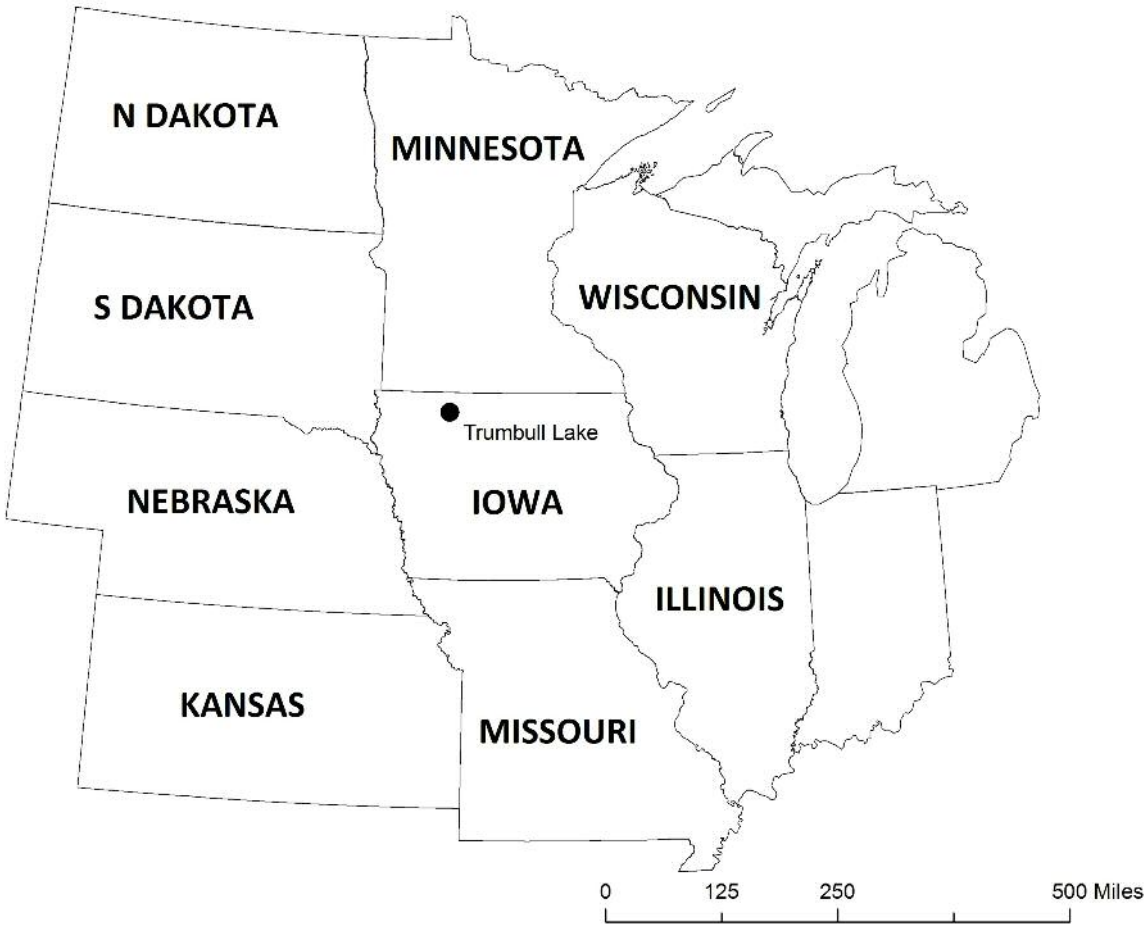

Fig. 1. Map illustrating the study site location in relation to surrounding states in North America's mid-continent region.

Sandpipers using capture-mark-recapture techniques and test for effects of sex, body condition, and seasonality on daily local survival. Because this was a study of individuals during fall migration, we hypothesized that sex would not affect stopover duration as it does during spring migration (Iverson *et al.* 1996, Warnock & Bishop 1998, Warnock *et al.* 2004). We also hypothesized that body condition and seasonality would be negatively correlated with estimates of minimum stopover duration because increased body condition represents higher fuel loads that require shorter stopover duration (Goymann *et al.* 2010).

METHODS

Study area

This study was conducted at Trumbull Lake, Clay County, Iowa, USA (Fig. 1). Trumbull Lake has a mean depth of 0.9 m (maximum depth is 1.2 m) and is predominantly ringed by trees and sparse emergent vegetation with extensive riprap in the southeast portion of the lake. This 485-ha shallow lake underwent a temporary water drawdown in spring 2012 to encourage aquatic vegetation growth, but a severe drought that affected much of the North American mid-continent greatly increased the planned drawdown of 56 cm (Iowa Department of Natural Resources 2012) and left extensive mudflats and shallow water habitat favored by foraging shorebirds (Helmers 1992).

Capture and handling

Beginning in late July, Trumbull Lake was hosting concentrations of >1,000 shorebirds and we initiated trapping on 5 August 2012. Trapping continued until 5 September 2012 at which time overall shorebird numbers had declined and very few individuals of the target species remained in the area. There were a total of 12 capture occasions during the course of this study with a mean interval of 2.8 days between capture occasions (minimum interval 1 day, maximum interval 5 days). Surveys for radio-marked birds were conducted on the same days as capture occasions. Individuals were captured with 60-mm model mesh mist-nests (Avinet, Inc., Dryden, NY) placed at the edge of standing water perpendicular to the shoreline in areas where Pectoral Sandpipers were observed actively feeding. Two pairs of nets were set in conjunction approximately 100 m apart and constantly monitored for trapped birds. Nets were deployed during daylight hours unless weather made continued trapping unsafe for either birds or researchers.

After capture birds were immediately removed from mist- nets and placed into mesh holding bags for processing and measurement. Morphometric data were recorded for all captured birds, including flattened wing chord, tarsus length, and body mass. Birds were sexed by wing chord length with wing lengths >133 mm being the determinant for males and wing lengths <133 mm indicating a female (Pitelka 1959, Pyle 2008). Plumage was used to distinguish adults and juveniles (Holmes & Pitelka 1998); we captured

only two juveniles during this study. In addition to determining sex, morphometric data can be utilized to calculate an index of body condition or energy stores as an alternative to destructive methods (Peig & Green 2009). A body condition index that scaled overall body mass by a morphometric measurement was calculated for each individual by dividing overall body mass by wing chord length. Many methods are available for calculating an index of body condition, including ratio-based methods like ours (Brinkhof 1997, Chastel *et al.* 1995, Whitfield *et al.* 1999), ordinary least squares regression methods (Schulte-Hostedde *et al.* 2005), non-parametric methods such as principle components analysis (Chastel *et al.* 1995, Schulte-Hostedde *et al.* 2005), and others. Ongoing discussion has identified the limitations and appropriateness of some methodologies (Green 2001, Jakob *et al.* 1996). Given that there is no single best approach, we assumed wing chord length was broadly representative of overall structural body size when choosing our ratio method to estimate a body condition index.

Birds were radio-marked using 1.1 g VHF transmitters (Sirtrack Limited 2012) that were fixed to feather roots with cyanoacrylate glue (Loctite®) on the interscapular region with the transmitter antenna facing posterior in a manner similar to that described by Warnock & Warnock (1993). To minimize the chance of poor adhesion a 1-cm square of feathers in the scapular region was trimmed to leave only feather roots exposed. Transmitters were held in place until the adhesive had hardened and then examined to ensure that proper adhesion had occurred and that there was no outward appearance of inhibited motion of the wings or surrounding feathers. Birds were then released near the shoreline where they were captured within 20 minutes. Most were observed preening the feathers around the transmitter immediately after release; within five minutes all of them flew to rejoin conspecifics or resumed foraging.

Maximum detection range of the radio transmitters was found to be approximately 1 km at ground level without major obstructions (pers. obs.). Because of this, multiple points around the study site, including nearby suitable habitat, were used to check for the presence of radio-marked individuals and ensure complete coverage of the study site. We assumed that all radio-marked individuals still present were detected on a given day and that non-detection indicated a departure from the study site. Upon detection we attempted to locate the individual marked bird to confirm that the radio had not detached. In <5% of the bird days, birds were not detected but still present, indicated by later observations in the study site. This was largely driven by two days of difficult detectability of deployed radios due to high wind speeds (18 and 23 August 2012). On both of these days wind speeds remained high until after sunset and an additional check for present radio-marked birds was done at sunrise the following morning when wind conditions made for better detection conditions. The end of the survey period was determined by the day after the last capture occasion when no deployed radios were detected.

Statistical analyses

Data were analyzed using the nest survival model (Dinsmore *et al.* 2002) in program MARK (White & Burnham, 1999) to model daily local survival and estimate minimum stopover duration at the study site by transforming survival estimates with the formula [minimum stopover duration = -1/ln (survival probability)] (Kaiser 1995) . This model is appropriate for use with ragged telemetry data and makes more efficient use of losses that occur during broad time intervals than does the more familiar known fate model (Dinsmore *et al.* 2002). Models were compared and selected by AIC_c criteria (Akaike 1973), with models having ΔAIC_c <2 being considered as well supported or competitive (Burnham & Anderson 2002). Model effects tested included an effect of sex (Sex), body mass (Mass), body condition index (BCI), a linear seasonal effect (T), a quadratic seasonal effect (TT), and no effect (.).

For this study 'daily local survival' is the probability that an individual will remain ('survive') at this particular study site and not continue on its migratory journey. This does not reflect actual survival or mortality of individuals within the site, and actual mortality was assumed to be zero for marked individuals within the study site. Fat scores were not recorded but rather a scaled body condition index was calculated as body mass standardized using wing chord length (Peig & Green 2009) and used as a covariate when finding competitive models. This method of estimating condition has been used frequently (Iverson & Vohs 1982, Owen & Cook 1977, Odum *et al.* 1964) in studies of passerine birds, some waterfowl, and in cranes and is shown to substantially improve estimates of condition compared to using only body mass to assess condition (Johnson *et al.* 1985).

Table 1. Mean body mass (g), wing chord length (mm), tarsus length (mm), and the results of a two-sample t-test of morphometric measurements of male and female individuals assuming unequal variances for Pectoral Sandpipers radio-marked at Trumbull Lake, Clay County, Iowa, during fall 2012. The test for a difference in the means was a paired t-test with subscripted degrees of freedom, the test statistic, and significance (P-value).

	Males (n=19) x ± SD	Females (n=33) x ± SD	Test for difference of means
Mass (g)	93.2 ± 20.5	79.3 ± 12.5	t_{24} = -2.50, P = 0.02
Wing (mm)	137.1 ± 3.7	129.6 ± 1.8	t_{22} = -7.80, P <0.001
Tarsus (mm)	31.8 ± 1.36	30.8 ± 0.8	t_{26} = -2.56, P = 0.02
Condition Index (body mass/wing chord)	0.68 ± 0.13	0.61 ± 0.09	t_{26} = -1.77, P = 0.09

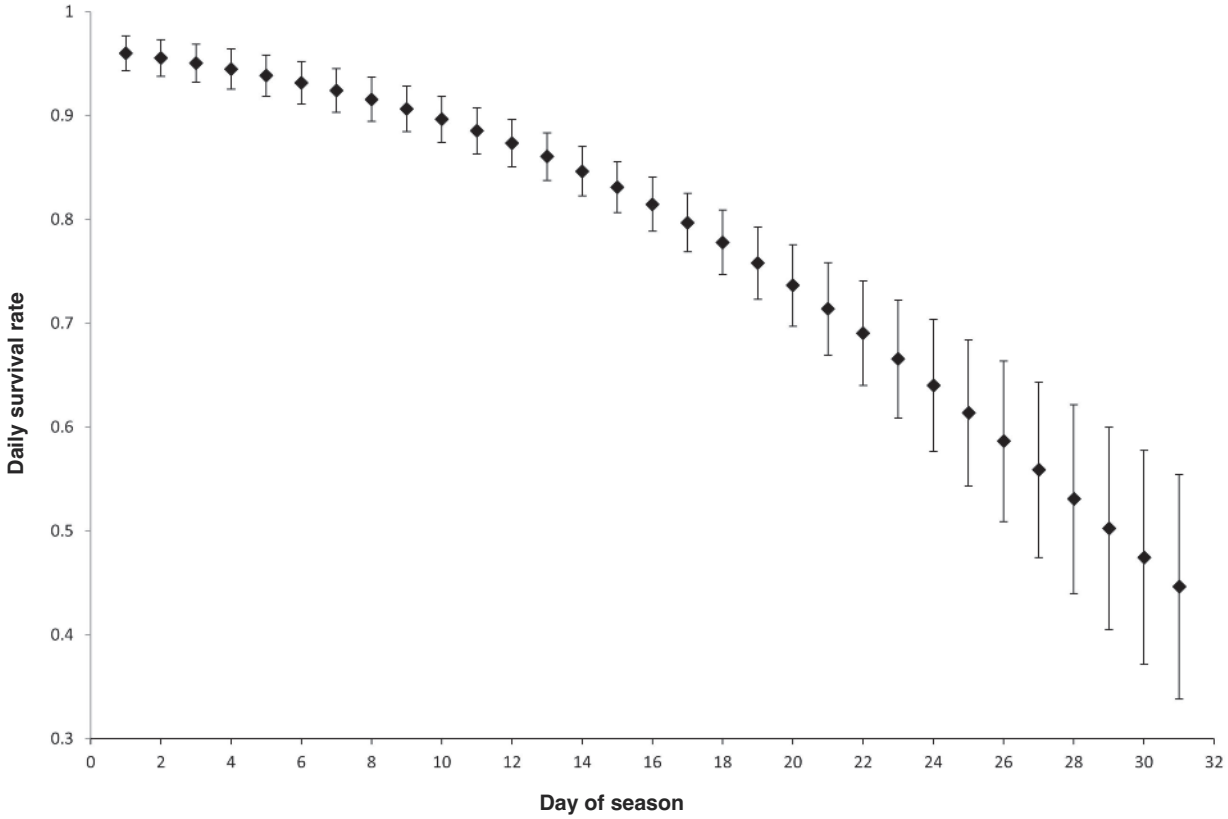

Fig. 1. Daily survival rate of marked Pectoral Sandpipers at Trumbull Lake, Clay County, Iowa from 5 August 2012 (day 1) to 5 September 2012 (day 31). Points represent the estimate and standard error of daily survival probability of marked individuals at the stopover site over the course of the study season.

RESULTS

Fifty-two Pectoral Sandpipers were captured and radio-marked between 5 August and 5 September 2012. Nineteen (37%) were males and 33 (63%) females, but the proportions were not quite significantly different from equality (χ^2 = 3.77, d.f. = 1, p = 0.052). Two of 52 radio-marked individuals were juveniles. Males were on average larger for all recorded body measurements (Table 1). All birds were assumed to have departed the study area with their radio; no known mortality events were documented.

The model set for these analyses consisted of ten models examining patterns of local survival for marked Pectoral Sandpipers, three of which were competitive (ΔAICc < 2) (Table 2). The most competitive model included both a negative linear day of season effect (β = -0.11, SE = 0.03, 95% confidence interval -0.17 to -0.06) and body condition index effect (β = -5.94, SE = 1.64, 95% confidence interval -9.15 to -2.73) on daily survival rate. The estimates for the time effect and condition index effect are both negative and indicate that as body condition improves (higher condition index score) or the season progresses, local survival declines and individuals with a higher condition index (assumed to indicate better body condition) or individuals that remain at the study site later in the season are more likely to depart. Other competitive models included a linear time effect and mass effect model (ΔAIC_c = 0.83) and a non-linear time effect and condition index effect (ΔAIC_c = 1.78). Similar negative relationships between parameter estimates for mass and non-linear time effect and daily survival were observed in these two models. Models containing only sex, mass, or condition index or models with only a time effect were among the least competitive models considered.

Mean minimum stopover duration was 7.4 days (95% confidence interval 4.3–13.6 days) but ranged from 24.4 days (95% confidence interval 10.6–57.2 days) at the beginning of the study to 1.2 days (95% confidence interval 0.7 to 2.4 days) at the end of the study.

DISCUSSION

This study adds to a growing body of information on the stopover ecology of shorebirds in the interior US. Our estimate of the mean minimum stopover duration for Pectoral Sandpipers at a fall stopover site (7.4 days) is similar to findings from other studies that found mean minimum stopover durations of 8.5 days and 6.8 days for spring migratory White-rumped Sandpipers *C. fuscicollis* (Skagen & Knopf 1994) and 10.0 days for fall migratory Pectoral Sandpipers (Lehnen & Krementz 2005). We were not able to detect a difference between male and female stopover duration in an apparent contrast to findings by Farmer & Wiens (1999), but it is not surprising that shorebirds could utilize different migratory strategies for fall and spring migrations due to seasonal changes in habitat suitability or exhibit different strategies in fall migration when there is no pressure to arrive and establish nesting territories (Tottrup *et al.* 2012). The most competitive model also contained a scaled body mass condition index as an individual covariate. A major assumption of the condition index is that birds with lower body mass metrics relative to structural measurements are in poorer overall condition relative

to individuals with higher condition indices. Higher values indicate larger nutrient and fat reserves that have been related to increased reproduction (Jones & Ward 1976) and survivorship (Johnson *et al.* 1985, Lack 1966).

The observed negative relationship between condition index and minimum stopover duration suggests that birds in worse condition are remaining at this stopover site longer and theoretically increasing their condition index by building nutrient stores (body mass) before reaching some satisfactory or required condition and departing for the next stopover site. Similar relationships were found in spring migrant White-rumped Sandpipers (Skagen & Knopf 1994) and fall migrant Semipalmated Sandpipers *C. pusilla* (Dunn *et al.* 1988) while most other studies have failed to elucidate any concrete relationships between lipid scores or body condition and minimum stopover duration (Farmer & Wiens 1999, Lank 1983, Lyons & Haig 1995, Page & Middleton 1972). The negative relationship between body condition and minimum stopover duration found here is interesting but it is unknown whether this relationship would hold true in other stopover sites, other species, other seasons, or other years. The seasonal time effect (negative relationship between season day and minimum stopover duration; Fig. 2) was an expected result because this relationship was already documented in Pectoral Sandpipers (Farmer & Wiens 1999) and other calidridine sandpipers (Dunn *et al.* 1988). It would be of potential value in future studies to also sample invertebrate resources at stopover sites to investigate if resource abundance provides additional information for estimating stopover duration.

Certain assumptions were made about both our models and the processes used to collect data during the course of the study. We operated under the assumption that both males and females as well as adult and juvenile individuals were equally vulnerable to capture with the methods used. While there were 74% more females than males radio-marked, the sample size was small enough (n = 52) that this could be a sampling effect rather than a true difference in capture vulnerability; alternatively, greater numbers of females than males might use this site in fall or our trapping period (which started on 5 August) missed early migrating males. The latter would seem to be quite likely because of evidence males depart from the breeding grounds earlier than females (Holmes & Pitelka 1998). We were unable to test for differences between adult and juvenile birds as only two juveniles were captured and radio-marked.

A potential bias in estimates of stopover duration may have resulted because initial capture likely did not correspond to an individual's arrival in the study area. In nest-success studies it is possible to back-calculate nesting initiation via egg flotation (Liebezeit *et al.* 2007, Westerkov 1950) or candling (Lokemoen & Koford 1996). Currently there are some modeling methodologies available to determine overall stopover duration by modeling an individual's arrival at a stopover site prior to its capture and observation (Schaub *et al.* 2000). However, we assumed that capture and radio-marking corresponded with an individual's arrival. In reality this creates estimates of stopover duration that are essentially minimum stopover durations, and actual stopover durations could be greater than those estimated. We also assumed that capture and tagging had no effect on stopover duration. There is evidence that radio-marking can increase minimum stopover duration in some shorebird species (Western Sandpiper *C. mauri*; Warnock & Bishop 1998). Given the larger body size of Pectoral Sandpipers compared to Western Sandpipers we assumed them to be more stress tolerant and would be less affected by handling stress than Western Sandpipers. Handling times were also minimized to reduce any effect capture may have had on stopover duration, and we assumed no effect for our analyses. After radio-marking we assumed 100% detectability of marked individuals given that they were present within the study site. There was a single potential alternate habitat patch that shorebirds could have utilized in the form of another drying lakebed approximately 1.5 km to the east of our study site location. This site was also checked during every survey for radio-marked individuals and only on one occasion was an individual found at this site instead of the main Trumbull Lake site. Because of

Table 2. Model selection results for daily local survival rates of radio-marked Pectoral Sandpipers at Trumbull Lake, Clay County, Iowa, during fall 2012. Model effects tested included an effect of sex (Sex), body mass (Mass), body condition index (BCI), a linear seasonal effect (T), a quadratic seasonal effect (TT), and no effect (.). Models are ranked by ascending AICC values (AICC = 139.25 for the best model) and we also report the model weights (wi), number of parameters (K), and model deviance.

Model	ΔAIC_c	W_i	K	Deviance
T+BCI	0	0.44	3	133.17
T+Mass	0.83	0.28	3	134
TT+BCI	1.78	0.18	4	132.89
TT+Mass	2.69	0.1	4	133.79
T	12.82	0	2	148.03
TT	14.46	0	3	147.62
BCI	19.59	0	2	154.8
Mass	20.95	0	2	156.16
No effect	26.48	0	1	163.72
Sex	28.46	0	2	163.67

drought conditions, we were convinced there was no other suitable Pectoral Sandpiper habitat within 10 km of Trumbull Lake and that non-detections of radio-marked birds indicated departure from the study area.

Management implications

Knowledge of migration and stopover ecology is important when considering management plans or actions designed to benefit migratory shorebirds. Shallow-lake management actions (such as seasonal lowering of water levels to promote aquatic vegetation growth and improve water quality via invasive fish removal) have the potential to create highly productive and attractive foraging sites for migratory shorebirds (Helmers 1992). The Iowa Department of Natural Resources currently operates a lake restoration program ('Lake Restoration' 2012) that has identified 35 lakes in Iowa as a priority for restoration to improve water quality and habitat via drawdowns, rough fish removal, water control structures, and other management actions. Here, we demonstrated that shorebirds will respond favorably to a fall drawdown and that a common species, the Pectoral Sandpiper, was able to refuel at a single stopover site and depart south. We assume Pectoral Sandpipers were able to increase their body condition because of abundant invertebrate resources that were concentrated in shallow water. A drawdown can provide extensive shorebird habitat (Helmers 1992) in addition to increased macrophytic vegetation and seed production that are valuable to other waterbirds. Drawdown actions would have the most benefit to shorebirds in Iowa during peak migratory periods, generally during April–May and July–September (Kent & Dinsmore 1996). Ideally a drawdown would be gradual (Helmers 1992) and constantly expose new and productive shallow water and moist soil areas throughout the peak of shorebird migrations.

There has been an increased focus on conservation of species that utilize mid-continent migratory routes and stopover habitat (Skagen *et al.* 2005, Skagen 1997, Haig *et al.* 1998, Warnock *et al.* 1998) to supplement already identified traditionally important stopover areas. Because mid-continent stopover sites are ephemeral in nature and are increasingly isolated with land-use changes, a more complete understanding of all life stages of migratory shorebirds is necessary to formulate comprehensive conservation plans for these species. Our work provides important baseline information on stopover site use by a common migrant shorebird in the mid-continent region and further documents the benefits of water level management to waterbirds.

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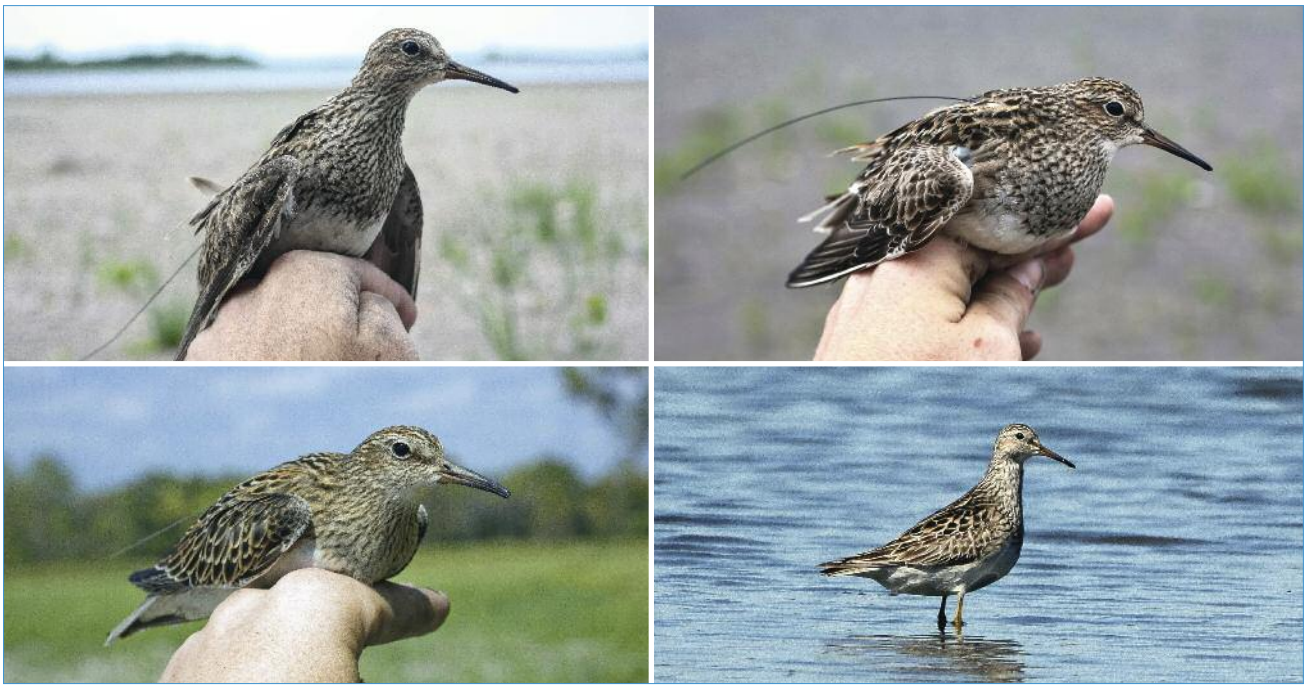

Pectoral Sandpipers (photos: Kevin Murphy).