BODY CONDITION OF THE UPLAND SANDPIPER (*BARTRAMIA LONGICAUDA*) EN ROUTE THROUGH CENTRAL MEXICO

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Abstract · There is little information on the body condition of the Upland Sandpiper (*Bartramia longicauda*) during migration. We measured biometric traits and body condition parameters of *B. longicauda* in central Mexico in 2016 and 2017. Mean morphometric values were 170.4 ± 4.3 mm (wing length), 28.9 ± 1.7 mm (bill length), 61.5 ± 2.2 mm (head length), and 55.3 ± 2.6 mm (tarsus length). Mean body condition parameters were 169.7 ± 24.1 g (body weight), and 4.6 ± 1.8 (fat score). Body condition values were higher during 2017 than 2016 ($P < 0.05$) but similar between sexes and sites. Fluctuating asymmetry (FA) was low compared to other studies, but was present in rectrices, tarsus, and wings. We found a negative correlation between wing FA and fat score, and a positive correlation between body weight and fat score, suggesting that birds with higher fat scores were in better condition during molt, leading to lower asymmetry. Our Data showed a 1:1.6 male:female ratio, similar across years and sites. Contrary to other studies, we found no significant sexual size dimorphism. Birds in our sample had higher body weight, tarsus, and wing length but were similar in head length to birds wintering in South America, but smaller than birds from Minnesota. We recommend carrying out further studies on stop-over sites to contribute to a better understanding of patterns on the functional ecology of the species.

Resumen · Condición corporal del Zarapito Ganga o Batitú (*Bartramia longicauda*) en ruta a través del centro de México
Existe poca información sobre la condición corporal del Zarapito Ganga o Batitú (*Bartramia longicauda*) durante la migración. Medimos parámetros de condición corporal de *B. longicauda* en el centro de México en 2016 y 2017. Los valores morfométricos promedio fueron 170.4 ± 4.3 mm (ala), 28.9 ± 1.7 mm (culmen), 61.5 ± 2.2 mm (cabeza) y 55.3 ± 2.6 mm (tarso). Los parámetros promedio de condición corporal fueron 169.7 ± 24.1 g (peso corporal) y 4.6 ± 1.8 (grasa). Los valores de condición corporal fueron mayores durante 2017 que durante 2016 ($P < 0.05$), aunque similares entre sexos y sitios. La asimetría fluctuante (AF) fue baja comparada a otros estudios, aunque estuvo presente en rectrices, tarsos y alas. Encontramos una correlación negativa entre AF en alas y grasa, y una correlación positiva entre peso corporal y grasa, lo cual sugiere que las aves con mayores valores de grasa se encontraban en mejor condición durante la muda de plumaje, conduciendo a menor asimetría. Nuestros datos mostraron una tasa macho:hembra de 1:1.6, similar entre años y sitios. Contrario a otros estudios, no encontramos dimorfismo sexual significativo. Las aves en nuestra muestra tuvieron mayor peso corporal, tarso y longitud de ala, pero fueron similar en longitud de cabeza a aves de Sudamérica, pero menores a aves de Minnesota. Recomendamos llevar a cabo más estudios en sitios de escala para contribuir a un mejor entendimiento de los patrones en la ecología funcional de la especie.

Key words: *Bartramia longicauda* · Fat score · Fluctuating asymmetry · Morphometry · Sexual dimorphism

INTRODUCTION

The Upland Sandpiper (*Bartramia longicauda*) is an obligate grassland member of the family Scolopacidae protected under the U.S. Shorebird Conservation Plan (USFWS 2004). Listed as endangered or threatened in the U.S. (10 states and six states, respectively), and considered one of the most significant breeding shorebird species in Canada (Houston et al. 2011), it is a priority species for conservation in the Americas. It breeds mainly in the U.S. Great Plains, with smaller breeding populations dispersed in Canada and Alaska, migrating south throughout Mexico east of the Sierra Madre Occidental and Central America, to its wintering grounds in South America from northern Chile and Suriname to Uruguay and Argentina (Haverschmidt 1966, Di Giacomo & Krapovickas 2005, Vickery et al. 2010, Houston et al. 2011, Medrano et al. 2018). Pulich (1988), and Houston et al. (2011), report current southernmost breeding sites from Oklahoma and formerly (before the 20th century) from north-central Texas; there are no reproductive populations in Mexico (Howell & Webb 1995).

The Upland Sandpiper starts fall migration from mid-July to late August (Vickery et al. 2010), after a short 4-month breeding season and concludes with a long, 6–8-month wintering period (Houston et al. 2011). Most information regarding its

biology has been acquired from breeding and wintering grounds (Haverschmidt 1966, Vickery et al. 2003, Blanco & López-Lanús 2008, Vickery et al. 2010, Azpiroz et al. 2012; Alfaro et al. 2015, 2018), while little information exists from stop-over sites. Data from Mexico are practically nonexistent, with only a few specific mentions from the southern states of Oaxaca (Winker 1995, McAndrews & Montejo 2010, Alcántara-Salinas et al. 2011) and Tabasco (Córdova-Avalos et al. 2009), revealing a knowledge gap in the life cycle of this migratory species.

Being an intermediate-distance migrant (6000–12,000 km, Skagen et al. 1999), determining its body condition throughout its migration route is important, as rest and energy intake on stop-over sites can impact upon survival during migration and posterior breeding (Newton 2010, Tan et al. 2018). However, only scarce data exists on its physical state, even from breeding grounds (Houston et al. 2011). Fat reserves before the start of fall migration range from no fat in adult Alaska birds to abundant fat in Wisconsin adults (Buss 1951, Roselaar et al. 1983 in Houston et al. 2011); body weight reports suggest depletion from the start of fall migration, ranging from 135–170 g (males) and 127–226 g (females) on breeding areas, to 97–166 g (males) and 98–166 g (females) on wintering sites (Table 3 in Houston et al. 2011, Alfaro et al. 2018). According to Alfaro et al. (2018), body condition exhibits a U-shaped trend during the non-breeding season, showing declines after arrival at wintering grounds and a progressive recovery until departure on spring migration, but no further data exists on body condition elsewhere. Information on fluctuating asymmetry (FA) is also lacking for the species. FA reflects an animal's ability to cope with the sum of challenges that affect it during the growth period and can signal physical responses of individuals to environmental stress, as it results from physiological stress (Møller & Pomiankowski 1993, Meissner et al. 2019). If available, such data as morphometric measurements, body condition, and FA can be interpreted to better describe the life stages of the species during migration and used to construct tools for future management (see Cimprich & Moore 2006, Morrison et al. 2007). Addressing this concern, we determined body condition and several morphometry parameters of the Upland Sandpiper from stop-over sites in Mexico.

METHODS

In our study, we received bird specimens donated by hunters from the state of Guanajuato, Mexico. Birds were not sacrificed for this study, but they were killed for consumption. We received birds on 26 August 2016, 31 August 2016, 4 September 2016, 5 September 2016, 28 August 2017, 5 September 2017, and 18 September 2017. Hunting of Upland Sandpipers is allowed in Mexico in 16 states from early August to early October (SEMARNAT 2018). Donating hunters held hunting licenses 8080, 3825, 0842, 0841, 3822, and 3820 issued by SEMARNAT, the wildlife authority in Mexico. Birds were hunted in Valle de Santiago (20°26'60"N, 101° 21'36"W, 1700 m a.s.l.) and Dolores Hidalgo (21°12'36"N, 101°01'48"W, 2027 m a.s.l.). Valle de Santiago had alfalfa and corn crops interspersed with non-cultivated plots of land (for rotation of crops) covered with gramineous and other annual plants; the landscape in Dolores Hidalgo was mostly comprised of open shrublands dominated by < 2 m tall Aca-

cia spp. (Fabaceae) and Opuntia spp. (Cactaceae) with sparse corn plots.

We received carcasses the same day the birds were hunted and maintained them overnight on ice, conducting the analyses the following day at the Facultad de Biología at UMSNH. We determined sex by gonad inspection. We returned bird remains to hunters after analyses, except for 30 skins deposited at the Bird Collection of the Ornithology Lab (Facultad de Biología at UMSNH). We measured all carcasses (left and right-wing length, left and right longest rectrix feather, accuracy ± 1.0 mm; bill length, head length [including bill], and left and right tarsus, accuracy ± 0.1 mm). We then calculated mean wing length, mean longest rectrix feather length, and mean tarsus length. We considered body weight (± 0.2 g), and a qualitative subcutaneous fat score (FS) as indicators of body condition (O'Reilly & Wingfield 2003). Fat scores ranged from 0 to 7, determined through inspection of axillary and furcular fat depots (Meissner 2009). To determine possible sexual dimorphism in size, we made calculations separating individuals by sexes (Masero et al. 2017). To determine whether sexual size dimorphism was present in our sample, we used the formula: male mean/ female mean x 100 (Wagner 1999, Liu & Sun 2016) applied to the variables wing length, bill length, head length, tarsus length, body weight, and fat score, considered as significant at $P < 0.05$ through analysis of variance to test for differences between sexes. Values above 100 show male-biased sexual dimorphism (larger males), while values below 100 show female-biased sexual dimorphism (larger females). Because of the naturally large differences in the mean values of the measurements, we calculated coefficients of variation (C.V.) for each sex and measurement (SD/mean x 100; Fletcher & Hamer 2003, Liu & Sun 2016), to more clearly compare variability among body measures, and to have a better understanding of variability of each measurement (Sokal & Rohlf 1995).

We calculated fluctuating asymmetry (FA) as the absolute difference in right- and left-wing length, the right and left longest rectrix feather, and the right and left tarsus measurements (Balmford et al. 1993). To determine significance of FA (defined as a departure from 0 at $P < 0.05$), we conducted one-sample t-tests; if data departed from normality, we removed outliers for further testing (Balmford et al. 1993, Palmer 1994). If we detected a significant FA effect, we conducted further analyses (one-way ANOVAs) on the respective measurement to determine if overall FA differed between the sexes. We also used one-way ANOVAs to compare body measurements between sexes, sites and years, and measurements between our results and other published data. If data did not meet assumptions regarding the homogeneity of variances or normal distribution, we used instead Mann-Whitney U-tests. We analyzed data using statistical software IBM SPSS Statistics v23 for Mac (IBM Corporation 2015). We used significance level ($P < 0.05$) for all statistical tests, stating statistics as mean ± SD.

RESULTS & DISCUSSION

Sampling comprised 72 individual Upland Sandpiper carcasses. Upon gonad inspection, we observed an overall male:female ratio of 1:1.6 (N = 72; 28 males, 44 females), which was similar ($F = 0.26$, $P = 0.872$) between 2016 (N = 42;

Table 1. Morphometry and body condition of the Upland Sandpiper (*Bartramia longicauda*) in central Mexico (sites and years pooled); females (N = 44), males (N = 28). Mean measurements did not differ significantly between sexes (one-way ANOVAs, $P > 0.05$).

Body measurements	Dimorphism index	Sex	Mean ± SD	Range	CV (%)
Wing length (mm)	99.4	Female	171.8 ± 4.3	162.5–180.0	2.5
		Male	170.8 ± 4.5	161.5–181.0	2.6
Bill length (mm)	100.7	Female	29.0 ± 2.1	25.0–32.5	7.2
		Male	29.2 ± 1.5	26.2–32.3	5.1
Head length (mm)	99.3	Female	61.8 ± 3.0	55.2–67.0	4.9
		Male	61.4 ± 1.7	58.5–63.9	2.8
Tarsus length (mm)	99.6	Female	55.3 ± 2.5	46.2–61.4	4.5
		Male	55.1 ± 2.3	47.7–59.9	4.2
Body weight (g)	101.5	Female	161.2 ± 22.5	117.6–227.8	14.0
		Male	163.7 ± 23.6	125.2–201.6	14.4
Fat score	108.9	Female	4.5 ± 1.9	0–7	42.2
		Male	4.9 ± 1.7	1–7	34.7

16 males, 26 females) and 2017 (N = 30; 12 males, 12 females). Sex ratios were also similar between sites (Valle de Santiago, N = 60, Dolores Hidalgo, N = 12, $F = 0.735$, $P = 0.394$). We detected no sexual dimorphism in morphometrics, as body measurements were similar ($P > 0.05$) in males and females (Table 1). Overall measurements including both sexes were: 170.4 ± 4.3 mm wing length, 28.9 ± 1.7 mm bill length, 61.5 ± 2.2 mm head length, 55.3 ± 2.6 mm tarsus length, 169.7 ± 24.1 g body weight, and 4.6 ± 1.8 fat score. We found no significant differences in length measurements between sampling sites or years ($P > 0.05$, Table 2). Body weight differed between sampling years, as birds were 6.9% heavier during 2017 compared to 2016 ($F = 4.44$, $P = 0.039$, Table 2) but were similar between sexes and sites ($P > 0.05$; Tables 1, 2). Fat scores exhibited a similar pattern, as values were similar between sexes and sites (Tables 1, 2) but were 32% larger during 2017 compared to 2016 ($F = 20.11$, $P < 0.001$, Table 2). Both sexes exhibited a large variation (C.V.) in body weight (14.0–14.4%) and fat scores (34.7–42.2%), in contrast to other body measurements (Table 1).

Spearman rank-order correlations performed for 2016 and 2017 showed no significant association between date of sampling and fat scores or body weight ($P > 0.05$, Table 3). The significant positive association between fat score and body weight was clear ($r_S = 0.755$, d.f. = 56, $P < 0.01$). We found significant FA in wing length (1.9 ± 1.8 mm, $t = 7.34$, $P < 0.001$), rectrix length (3.4 ± 2.7 mm, $t = 7.30$, $P < 0.001$), and tarsus length (0.8 ± 1.0 mm, $t = 5.81$, $P < 0.001$). FA in wing length was significantly higher ($U = 133$, $P = 0.016$) in females (2.35 ± 1.95 mm) than males (1.00 ± 0.89 mm), but similar in rectrix and tarsus length ($P > 0.05$). We found evidence of a significant negative association between fat scores and FA in wing length ($r_S = -0.338$, d.f. = 46, $P = 0.028$), but did not so for rectrix length or tarsus length ($P > 0.05$), or between any FA measurements and body weight ($P > 0.05$).

Alfaro et al. (2018) found more even sex ratios (1:1.2, N = 62) in an Upland Sandpiper population wintering in Uruguay. The extent to which sex ratios differ between non-breeding sites is unknown, as there are no further data for comparison. Contrary to our results, Hooper (1997) and Houston et al. (2011) suggest a male-biased (although non-specified)

ratio in breeding sites in Alberta, based on observations by Rowan (1926) that trios were more common than pairs, and that single adults and the third member of a trio were males. The determination of sex ratio on shorebirds is central to understanding behavioral strategies and for conservation management, as factors affecting life history can alter sex ratios at different age stages and sites (Dos Remedios et al. 2010). Upland Sandpiper males depart later from breeding sites, as they perform parental care duties (Casey et al. 2011, Houston et al. 2011), which may be reflected by larger numbers of females in stop-over sites closer to reproductive areas during early summer migration. A female-biased sex ratio could also be due to differences in spatial use (territorial size) and behavior (dominance) that make males easier to detect (Ancona et al. 2017) and may increase their human-induced mortality because of hunting (Donald 2007).

In our sample population, sexual size dimorphism was non-significant. However, available information from other non-breeding areas is mixed. We calculated dimorphism indices (DI) from source data in Alfaro et al. (2018) (N = 62); results showed significant reversed size dimorphism on wing length (DI = 96.1, $F = 8.563$, $P = 0.005$), tarsus length (DI = 96.5, $F = 6.369$, $P = 0.014$), and body weight (DI = 93.3, $F = 9.142$, $P = 0.004$), but non-significant reversed size dimorphism on head length ($P > 0.05$). Conversely, Haverschmidt (1966) reports body weight data from Suriname that shows a non-significant normal sexual size dimorphism on body weight (DI = 101.1, $F = 0.811$, $P = 0.383$). Although there are not enough source data to perform dimorphism calculations, Wells & Lawrence (1887) in Grenada and Salvador (1990) in Argentina report larger measurements for male wing lengths and body weight, respectively.

Birds in our sample were heavier (body weight) and larger (tarsus length, wing length) but similar in head length to other sites in South America. Female individuals from our sample were similar to those reported from Uruguay (N = 34, calculated from data in Appendix 1, Table A1 *in* Alfaro et al. 2018) in head length ($F = 1.327$, $P = 0.253$), but were 10% larger in tarsus length ($F = 81.969$, $P < 0.001$), 2.5% larger in wing length ($U = 470.5$, $P = 0.007$), and had 13.1% heavier body weight ($U = 260.5$, $P < 0.001$). Males exhibited a similar pattern, with similar measurements to the Uruguay male

Table 2. Morphometry and body condition (mean ± SD) of the Upland Sandpiper (*Bartramia longicauda*) in central Mexico (sexes pooled). *Significantly higher values ($P < 0.05$, one-way ANOVAs comparing means between collecting sites and between years).

	N	Wing length (mm)	Bill length (mm)	Head length (mm)	Tarsus length (mm)	Body weight (g)	Fat score
Valle de Santiago	60	170.1 ± 4.0	28.9 ± 1.8	61.4 ± 2.3	55.2 ± 2.5	168.0 ± 25.4	4.6 ± 2.0
Dolores Hidalgo	12	171.8 ± 5.5	29.0 ± 1.4	62.0 ± 1.7	55.9 ± 2.8	178.1 ± 13.0	4.8 ± 1.0
2016	42	170.7 ± 4.1	29.2 ± 1.7	61.6 ± 2.3	55.2 ± 2.4	164.7 ± 23.2	3.8 ± 1.6
2017	30	169.9 ± 4.6	28.5 ± 1.7	61.3 ± 2.2	55.6 ± 2.7	176.9* ± 24.0	5.6* ± 1.5

Table 3. Fat scores and body weight of the Upland Sandpiper (*Bartramia longicauda*) in central Mexico according to sampling date (consecutive day of the year starting on 1 January in parentheses).

	26 Aug 2016 (239)	31 Aug 2016 (244)	4 Sep 2016 (248)	5 Sep 2016 (249)	28 Aug 2017 (240)	5 Sep 2017 (248)	18 Sep 2017 (261)
Fat score		2.8	4.8	3.6	4.5	6.3	5.5
Body weight (g)	171.1	147.4	178.2	163.3	160.0	182.54	186.27
N	11	12	12	7	8	16	6

sample (N = 28) in head length ($F = 1.911$, $P = 0.173$), but 13.3% larger for tarsus length ($F = 114.688$, $P < 0.001$), 9.6% larger for wing length ($F = 7.397$, $P = 0.009$), and 20.2% heavier for body weight ($U = 60.5$, $P < 0.001$). Birds in our sample also had significantly heavier body weight than Suriname birds (calculated from data in Haverschmidt 1966), with 21% heavier males (N = 5, $F = 10.192$, $P = 0.003$) and 17% heavier females (N = 11, $F = 12.151$, $P = 0.001$). Houston et al. (2011), summarizing data from Dorio (1977) and Roselaar et al. (1983), report mean measurements for eastern (N = 26, breeding, U.S. from Wisconsin eastward; wintering, Suriname and NE Brazil), western North America (N = 16, breeding), and Minnesota (N = 16, breeding) populations. When compared to these data, birds from our sample (both males and females) had similar measurements (within 4%) of bill length and wing length, while tarsus length was larger (9–11%) than birds from both eastern and western populations. However, individuals from the Minnesota population were larger overall than our sample birds, with a larger bill length (4% in males, 8% in females), and slightly larger wing length (1%) and tarsus length (0.4% in males, 3% in females). Differences in body weight between birds from our sample and studies from southern latitudes seem to reflect weight loss through stored lipid depletion as fuel during long flights (Jenni-Eiermann et al. 2002).

Asymmetry values are usually lower in primaries of migratory birds (Meissner et al. 2019), which have more symmetrical wings than more sedentary species (Balmford et al. 1993). Food scarcity seems to affect feather keratin synthesis and therefore levels of asymmetry in feathers (Swaddle and Witter 1994, Møller 1996, Freed & Cann 2012). High levels of asymmetry can show poor body condition or nutritional stress during molt (Meissner et al. 2019), as feather length and asymmetry are determined during molt. We found that asymmetry levels in our study showed a negative relationship with fat scores, which suggests that individuals with higher fat scores during migration were probably less stressed and in better condition during molt, leading to lower levels of asymmetry. Low asymmetry can be crucial during migration, as wing asymmetry affects flight efficiency (Thomas 1993, Swaddle 1997, Swaddle & Witter 1998).

Feather FA values on our sample (wing 1.1%, rectrix 4.3%) are low compared to other shorebirds, which can reach in certain individuals over 20% (e.g., Meissner et al. 2019), showing no signs of flight-related (aerodynamics) stress. There are no data on FA for Upland Sandpipers elsewhere. However, it is easily measured and can assess the nutritional constraints that occur during molt (Meillère et al. 2017); we therefore recommend that it is taken in account for future studies of Upland Sandpipers along their migration route. To our knowledge, this constitutes the first report on body condition for the species in Mexico. It is important to continue generating information on the species on stop-over sites, to get a better understanding of its complete life cycle.

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