Behavior of Migrant Shorebirds in Saline Lakes of the Southern Great Plains

ADRIAN E. ANDREI[1], LOREN M. SMITH[2], DAVID A. HAUKOS[3] AND WILLIAM P. JOHNSON[4]

[1]Department of Range, Wildlife, and Fisheries Management, Texas Tech University, Lubbock, TX 79409
Corresponding author; e-mail: andreia@lincolnu.edu

[2]Department of Zoology, Oklahoma State University, Stillwater, OK 74078

[3]U.S. Fish and Wildlife Service, Department of Range, Wildlife, and Fisheries Management, Texas Tech University, Lubbock, TX 79409

[4]Texas Parks and Wildlife Department, P.O. Box 659, Canyon, TX 79015

Abstract.—We recorded and compared diurnal and nocturnal time-activity budgets of American Avocet (*Recurvirostra americana*), Lesser Yellowlegs (*Tringa flavipes*), Least Sandpiper (*Calidris minutilla*), and Wilson's Phalarope (*Phalaropus tricolor*) on 21 saline lakes in the Southern Great Plains, USA, during spring and summer/fall 2002 and 2003 to examine importance of saline lakes as migratory stopover sites. All four species spent most of their time feeding (47-70%) and resting (7-37%) by day and at night during spring and fall migrations. Little time was spent in other behaviors. Time budgets differed among species and between seasons, likely due to different energy needs. Time spent foraging varied seasonally between saline lakes and freshwater playas for American Avocets and Least Sandpipers, likely due to differences in vegetation cover and availability of prey between these wetland types. For most species, time spent foraging and resting differed between day and night. Therefore, extrapolating diurnal activity budgets to the entire 24-hour period and from one type of habitat to another within the same region is not recommended. Saline lakes are used by migrant shorebirds as stopover sites where they replenish lipid stores. Conservation efforts should focus on preserving these unique wetlands and the freshwater springs that discharge in them. *Received 27 November 2006, accepted 15 March 2007.*

Key words.—American Avocet, Least Sandpiper, Lesser Yellowlegs, New Mexico, saline lakes, shorebirds, Southern Great Plains, Texas, Wilson's Phalarope.

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Time-activity budgets allow researchers to understand how birds use certain wetlands (Titman 1981; Davis *et al.* 1989). Previous studies suggest that shorebird behaviors differ between day and night (Dodd and Colwell 1998; Johnson *et al.* 2003) and location and type of wetland (Hötker 1999). However, few studies have provided detailed nocturnal activity budgets of migrating shorebirds (McNeil *et al.* 1992; Kostecke and Smith 2003). Additionally, time-activity budgets may vary among species and between seasons, because energy needs of migrant shorebirds depend on body size, migration patterns, and migration season (Pienkowski and Evans 1984; Battley *et al.* 2001; Morrison *et al.* 2005). Collecting nocturnal time-activity budgets, especially by focal individual sampling (Altmann 1974), requires considerable effort. Extrapolating data obtained from accessible wetlands or during daytime may allow researchers to save time and resources. However, because shorebird activity budgets likely vary among types of wetlands and between day and night, interpretations of life history or habitat importance could be biased.

During migrations through interior North America, shorebirds replenish energy reserves necessary for completion of migration at intermediate stopover sites that serve as "stepping stones" (Skagen and Knopf 1993). At freshwater playas (Smith 2003) in the Southern Great Plains (SGP), shorebirds spend most of their time feeding and resting (Davis and Smith 1998a; Kostecke and Smith 2003). In addition to playas, there are approximately 42 saline lakes in the SGP (Reeves and Reeves 1996). In contrast to playas (Smith 2003), saline lakes are large discharge wetlands in close contact with the saturated zone of the Ogallala aquifer (Holliday *et al.* 1996; Triplet 1998) and supplied freshwater by springs (Brüne 1981). Vegetation cover, if present, is less than 1% and water salinity varies from 1 ppt to >100 ppt (Andrei 2005). In contrast, freshwater playas

are filled by rainfall runoff, serve as recharge points for the Ogallala aquifer (Osterkamp and Wood 1987; Smith 2003), and are more vegetated than saline lakes (Haukos and Smith 1997). Ecological and hydrological differences between playas and saline lakes may cause migratory shorebirds to allocate time in different ways when using the two predominant types of wetlands in the SGP.

Information about the functional role of saline lakes for a range of shorebird species is important for understanding the needs of shorebirds migrating through the SGP and conservation planning. If saline lakes serve as stopover sites (Andrei *et al.* 2006), shorebirds should spend most of their time feeding and resting to restore and accumulate the energy reserves necessary to continue migration (Senner and Howe 1984; Skagen and Knopf 1993). However, if saline lakes are used mostly for roosting, shorebirds should spend most of their time resting.

We recorded diurnal and nocturnal time activity budgets of American Avocet (*Recurvirostra americana*), Lesser Yellowlegs (*Tringa flavipes*), Least Sandpiper (*Calidris minutilla*), and Wilson's Phalarope (*Phalaropus tricolor*) during spring and summer/fall migrations. These four species represent the range of body sizes and feeding guilds of shorebirds migrating through interior North America and the SGP (Skagen and Oman 1996; Davis and Smith 1998b). Our objectives were to (1) document time-activity budgets of representative species of shorebirds to examine the role of saline lakes as migratory stopover sites in both the spring and summer/fall, (2) compare diurnal and nocturnal time-activity budgets of the four representative species, and (3) examine differences among time-activity budgets of shorebirds using the saline lakes and those using freshwater playas in the SGP (Davis and Smith 1998a).

METHODS

Study Area

The study was conducted on 21 saline lakes in Deaf Smith, Parmer, Castro, Bailey, Lamb, Terry, Lynn, Gaines, Dawson, and Andrews counties in northwest Texas, and in Quay, Curry, Roosevelt, and Lea counties in northeast New Mexico. The saline lakes were located and identified following Reeves and Reeves (1996).

A detailed description of wetlands in the SGP is provided in Smith (2003). Behavior data were collected from all lakes that contained surface water, where shorebirds were present, and for which access permission was granted by landowners. The climate of the region, dry steppe with hot summers and mild winters, is characterized by average annual precipitation of 48 cm (Lubbock, Texas) occurring mostly between May and September (National Oceanic and Atmospheric Administration 2004). Preceding and during data collection, annual precipitation recorded in Lubbock, Texas, was below the 48 cm annual average (2001: 32.9 cm; 2002: 47.6 cm; 2003: 20.9 cm) (National Oceanic and Atmospheric Administration 2004).

Data Collection

Focal individual sampling (Altmann 1974) was used during spring (10 March-15 June 2002, 2 March-7 June 2003) and summer/fall (7 July-9 November 2002, 7 July-8 November 2003) to sample shorebird behavior. Behavior data were collected on randomly assigned lakes during three diurnal periods (Davis and Smith 1998a) and three nocturnal periods: early day (sunrise-11.00 h), midday (11.00-15.00 h), late day (15.00 h-sunset), early night (sunset-24.00 h), midnight (00.00-03.00 h), and late night (03.00 h-sunrise). For diurnal observations, we used 10×50 binoculars and a 20-50×80 spotting scope, whereas, for nocturnal observations, we used a night vision monocular (Noctron V, Aspect Technology and Equipment, Plano, Texas).

Individual birds were selected randomly by moving the optical instrument in a zigzag pattern across flocks of birds (Davis and Smith1998a) and choosing the bird nearest to the center of the field of view. For most small flocks (> ten birds), each individual bird in the flock was sampled. For larger flocks, birds from all portions of the flock were selected randomly by moving the optical instrument in a zigzag pattern and selecting the individuals in the center of the field of view. When multiple flocks were present, we sampled behaviors of birds in each flock. Each individual bird was observed for five minutes. Behaviors were dictated on a tape-recorder and a digital stopwatch was used to time duration of each behavior. Sampling periods were up to four hours in length, depending on abundance of shorebirds. Behavioral classifications were based upon descriptions by Baker (1971) and Metcalfe and Furness (1986). Duration of the following activities was recorded: locomotion (walk, swim, or flight), aggression (chasing, pecking, or threatening another individual), alertness (stationary birds visually scanning the surroundings), resting (loafing or sleeping), body maintenance (preening, bathing, neck or wing stretching), and feeding (Baker and Baker 1973; Hamilton 1975).

Data Analyses

Multivariate analyses of variance (MANOVA) were used to assess differences in behavior among the four species, because such data are not independent of each other (Davis and Smith 1998a; DeLeon and Smith 1999). Species, season, and year were independent factors. MANOVAs were also used to test for differences in percent time spent in each behavior between years, seasons, and diel periods (i.e., diurnal and nocturnal) with-

in each of the four species of shorebirds. Wilks' lambda (λ) was the test criterion. For significant ($P \leq 0.05$) overall MANOVAs, factorial analyses of variance (ANOVA) and Fishers' least significant difference tests were used to determine differences in individual behaviors among species, followed by 1-way ANOVAs to compare behaviors between day (sunrise to sunset) and night (sunset to sunrise) for each species (Zar 1999). Because overall behavior of Lesser Yellowlegs did not differ between seasons and diel periods, 1-way ANOVA and Fishers' least significant difference tests were used to determine differences in time spent among behaviors.

Differences Between Playas and Saline Lakes

Diurnal behaviors of American Avocets and Least Sandpipers were compared between freshwater playas and saline lakes. Diurnal activity budgets were available for these two species from both wetland types. Comparable data are lacking for other species. Diurnal data for American Avocets and Least Sandpipers in playas were collected in 1993 and 1994 (Davis and Smith 1998a), whereas, time activity data where collected in saline lakes in 2002 and 2003. For each wetland type, behavior data were pooled across years, and Z-tests (Zar 1999) were used to test whether feeding, resting, body maintenance and alert behaviors of American Avocet (playas: N = 1,421; saline lakes: N = 545) and Least Sandpiper (playas: N = 647; saline lakes: N = 583) were similar between saline lakes and playas during spring and fall migrations. The focal individual was the experimental unit and values presented are mean ± SE. All analyses were performed with SAS® software (SAS Institute 2000).

RESULTS

There was no 3-way interaction (i.e., year × season × species) in the initial analyses of shorebird behaviors (Wilks' $\lambda = 0.99$, n.s.). There was a 2-way season × species interaction (Wilks' $\lambda = 0.98$, $P < 0.001$). Therefore, subsequent analyses were conducted within season.

During spring, behaviors differed among species (Wilks' $\lambda = 0.77$, $P < 0.001$). Least Sandpipers fed more than the other species ($F_{3,1992} = 9.94$, $P < 0.001$; Fig. 1). Resting ($F_{3,1992} = 30.95$, $P < 0.001$), body maintenance ($F_{3,1992} = 4.38$, $P < 0.01$), alert ($F_{3,1992} = 47.79$, $P < 0.001$), locomotion ($F_{3,1992} = 120.27$, $P < 0.001$), aggressive ($F_{3,1992} = 3.22$, $P < 0.05$), and courtship and mating ($F_{3,1992} = 10.70$, $P < 0.001$) activities also differed among the four species (Fig. 1). Least Sandpipers spent the least time resting and the most alert and in locomotion. American Avocet spent the least time alert and were the only species observed in courtship (Fig. 1).

Feeding ($F_{3,2107} = 17.26$, $P < 0.001$), resting ($F_{3,2107} = 36.14$, $P < 0.001$), alert ($F_{3,2107} = 37.51$, $P < 0.001$), and locomotion ($F_{3,2107} = 110.90$, $P < 0.001$) activities differed among species (Wilks' $\lambda = 0.81$, $P < 0.001$) during summer/fall; whereas, aggression ($F_{3,2107} = 1.58$, n.s.) and body maintenance did not ($F_{3,2107} = 1.65$, n.s.) (Fig. 2). Least Sandpipers spent the most time feeding and the least time resting, whereas, American Avocets spent the most time resting and fed the least. Least Sandpipers were also the most alert among the four species, while American Avocets were the least alert (Fig. 2).

American Avocet. There were no year × season × diel period interaction (Wilks' $\lambda = 0.99$, n.s.) or year × diel interaction (Wilks' $\lambda = 0.99$, n.s.) in analyses of American Avocet behaviors. There was a 2-way season × diel interaction (Wilks' $\lambda = 0.98$, $P < 0.05$). Therefore, subsequent analyses were conducted within season.

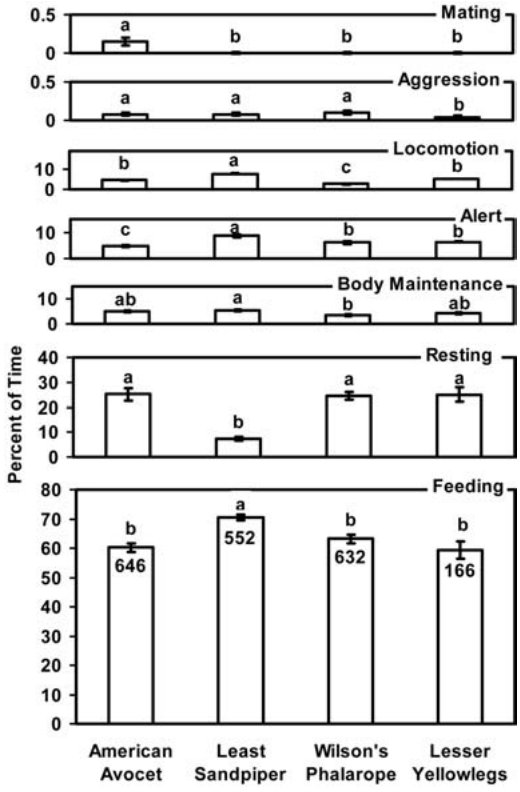

Figure 1. Activity budgets of four shorebird species during spring (2 Mar-15 Jun) migration in 18 saline lakes of the Southern Great Plains, 2002-2003. For each behavior, species with the same letter were not different (P > 0.05). Sample sizes are shown in the bottom graph.

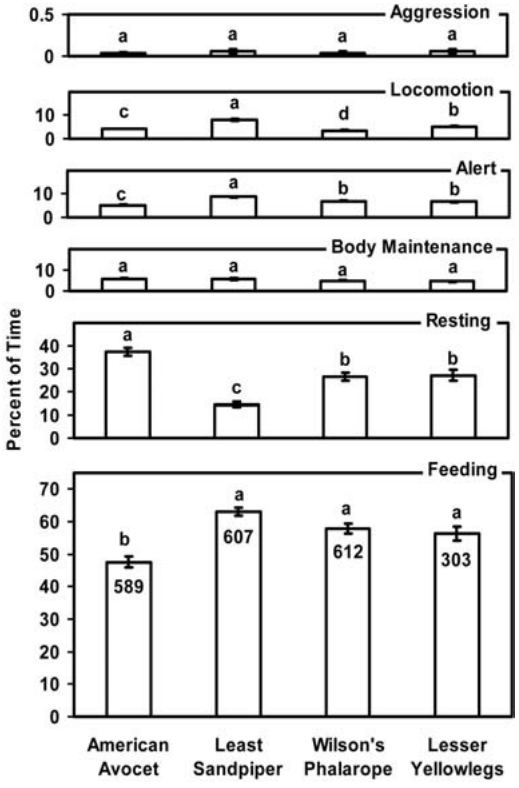

Figure 2. Activity budget of four shorebird species during summer/fall (2 Jul-9 Nov) migration in 17 saline lakes of the Southern Great Plains, 2002-2003. For each behavior, species with the same letter were not different (P > 0.05). Sample sizes are shown in the bottom graph.

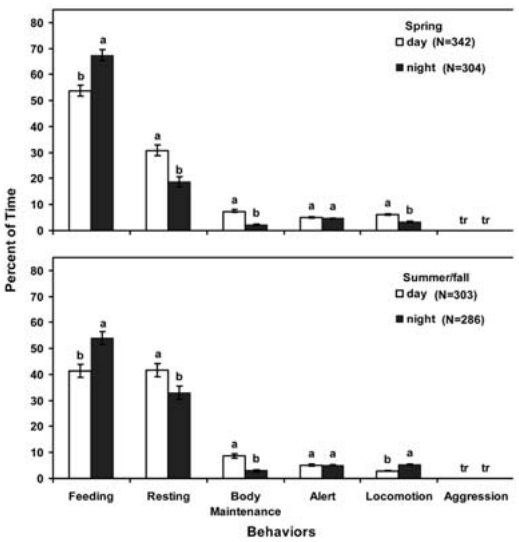

Figure 3. Diurnal and nocturnal activity budget of American Avocets during spring (2 Mar-15 Jun) and summer/fall (2 Jul-9 Nov) migration in 14 saline lakes of the Southern Great Plains, 2002-2003. For each behavior, periods with the same letter were not different (P > 0.05).

In spring, feeding ($F_{1,644}$ = 19.06, P < 0.001), resting ($F_{1,644}$ = 15.17, P < 0.001), body maintenance ($F_{1,644}$ = 32.47, P < 0.001), locomotion ($F_{1,644}$ = 45.91, P < 0.001), and mating ($F_{1,644}$ = 6.78, P < 0.01) differed between day and night (Wilks' λ = 0.86, P < 0.001), while time engaged in alert ($F_{1,644}$ = 0.20, n.s.) and aggressive ($F_{1,644}$ = 0.48, n.s.) behaviors did not. American Avocets fed more at night, whereas, time spent resting, in locomotion, and for body maintenance was greater during daytime (Fig. 3).

During summer/fall, American Avocet behavior differed between night and day (Wilks' λ = 0.85, P < 0.001). Time spent in feeding ($F_{1,587}$ = 12.11, P < 0.001), resting ($F_{1,587}$ = 6.10, P = 0.01), body maintenance ($F_{1,587}$ = 31.97, P < 0.001), locomotion ($F_{1,587}$ = 45.31, P < 0.001), and aggression ($F_{1,587}$ = 12.24, P < 0.001) differed between day and night, whereas, alert behavior did not ($F_{1,587}$ = 0.01; n.s.). Most feeding and locomotion occurred at night, whereas, resting and body maintenance occurred more during the day (Fig. 3).

Least Sandpiper. There were no year × season × diel period (Wilks' λ = 0.99, n.s.), season × diel period (Wilks' λ = 0.99, n.s.), or year × diel period interactions (Wilks' λ = 0.99, n.s.) in initial analyses of Least Sandpiper behavior. Sandpiper behavior differed between night and day (Wilks' λ = 0.87, P < 0.001). Time spent feeding ($F_{1,1157}$ = 8.06, P < 0.01), resting ($F_{1,1157}$ = 3.96, P < 0.05), body maintenance ($F_{1,1157}$ = 79.80, P < 0.001), alert ($F_{1,1157}$ = 10.78, P < 0.001), locomotion ($F_{1,1157}$ = 34.08, P < 0.001), and aggression ($F_{1,1157}$ = 53.22, P < 0.001) differed between day and night. Least Sandpipers spent more time feeding and resting at night, while body maintenance, alertness, and locomotion were greater during daytime (Fig. 4).

Wilson's Phalarope. There were no year × season × diel period (Wilks' λ = 0.98, n.s.), season × diel period (Wilks' λ = 0.98, n.s.), or year × diel period interactions (Wilks' λ = 0.97, n.s.) in analyses of overall Wilson's Phalarope behavior. Phalarope behavior only differed between night and day (Wilks'

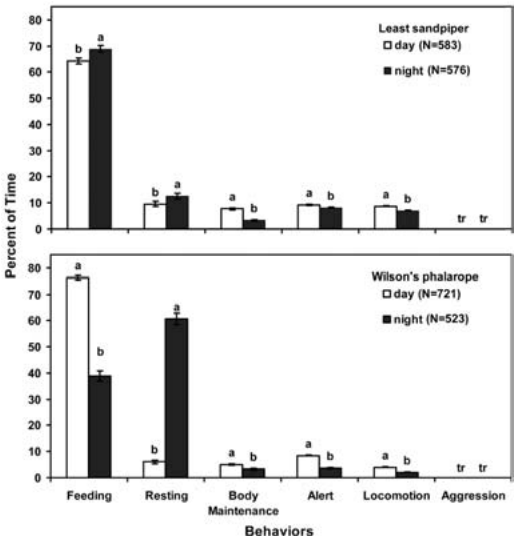

Figure 4. Diurnal and nocturnal activity budget of Least Sandpipers and Wilson's Phalaropes during spring (2 Mar-15 Jun) and summer/fall (2 Jul-9 Nov) migration in 15 saline lakes of the Southern Great Plains, 2002-2003. For each behavior, periods with the same letter were not different (P > 0.05).

$\lambda = 0.65$, $P < 0.001$). Time engaged in feeding ($F_{1,1242} = 392.56$, $P < 0.001$), body maintenance ($F_{1,1242} = 9.70$, $P = 0.001$), alert ($F_{1,1242} = 293.12$, $P < 0.001$), locomotion ($F_{1,1242} = 72.77$, $P < 0.001$), and aggression ($F_{1,1242} = 71.04$, $P < 0.001$) were highest during day; whereas, resting was highest at night ($F_{1,1242} = 508.40$, $P < 0.001$) (Fig. 4).

Lesser Yellowlegs. There were no year × season × diel period (Wilks' $\lambda = 0.98$, n.s.), season × diel (Wilks' $\lambda = 0.98$, n.s.), or year × diel interactions (Wilks' $\lambda = 0.98$, n.s.) in analyses of Lesser Yellowlegs behavior. Yellowlegs behavior also did not differ between night and day (Wilks' $\lambda = 0.98$, n.s.). Lesser Yellowlegs spent different ($F_{5,2808} = 460.05$, $P < 0.001$) amounts of time engaged in feeding (57.4 ± 1.8%), resting (26.4 ± 1.7%), maintenance (4.5 ± 0.2%), alert (6.5 ± 0.1%), locomotion (5.2 ± 0.1%), and aggression (<1%).

Differences Between Playas and Saline Lakes

During spring diurnal periods, American Avocets spent more time ($z = 3.91$, $P < 0.001$) feeding in saline lakes than in playas (playas: 47.0 ± 1.7; saline lakes: 53.7 ± 2.4). During summer/fall, American Avocets spent more time ($z = -4.11$, $P < 0.001$) feeding in playas (playas: 48.4 ± 0.5; saline lakes: 41.4 ± 2.6). Avocets rested more ($z = -3.45$, $P < 0.001$) in playas (playas: 36.9 ± 1.8; saline lakes: 30.7 ± 2.3) in spring, but during summer/fall they slept more ($z = 1.89$, $P < 0.05$) in the saline lakes (playas: 38.6 ± 1.7; saline lakes: 41.7 ± 2.5). Avocets spent more time (spring: $z = 5.02$, $P < 0.001$; fall: $z = 4.13$, $P < 0.001$) in body maintenance in saline lakes (spring: playas, 4.9 ± 0.5; saline lakes, 7.4 ± 0.8; fall: playas, 6.2 ± 0.6; saline lakes, 8.7 ± 0.9). Time spent alert (4.1-5.1%) did not differ (spring: $z = -0.42$, $P = 0.33$; fall: $z = 1.88$, $P = 0.30$) between playas and saline lakes.

Least Sandpipers spent more time feeding in playas than in saline lakes during spring (playas: 77.6 ± 1.6, saline lakes: 67.7 ± 1.3, $z = -6.12$, $P < 0.001$) and summer/fall migrations (playas: 71.2 ± 1.7, saline lakes: 61.5 ± 1.6, $z = -6.47$, $P < 0.001$). Alternatively, Least Sandpipers spent less time resting in playas than in saline lakes during spring (playas: 1.0 ± 0.6, saline lakes: 6.6 ± 1.0, $z = 9.21$, $P < 0.001$), and fall (playas: 1.3 ± 0.4, saline lakes: 12.4 ± 1.4, $z = 27.6$, $P < 0.001$). Time spent in body maintenance did not differ in spring (playas: 6.9 ± 1.3, saline lakes: 7.6 ± 1.0, $z = 0.53$, $P = 0.298$), but was greater in playas during fall migration (playas: 10.9 ± 1.2, saline lakes: 7.8 ± 0.6, $z = -2.68$, $P < 0.01$). Sandpipers spent more time alert (spring: $z = 4.81$, $P < 0.001$; fall: $z = 3.5$, $P < 0.001$) in the saline lakes during both seasons (spring: playas, 5.8 ± 0.7; saline lakes, 9.2 ± 0.3; fall: playas, 6.9 ± 0.7; saline lakes, 9.3 ± 0.3).

DISCUSSION

Ecological Correlates of Behavior

Shorebirds do not appear to accumulate fat deposits while wintering on the Gulf Coast (White and Mitchell 1990), but they do when stopping in the Great Plains (SGP) during migration (Davis *et al.* 2005). Migrant American Avocets, Least Sandpipers, Wilson's Phalaropes, and Lesser Yellowlegs spent most of their time in the saline lakes feeding and resting, likely accumulating lip-

id reserves to continue their migrations. Saline lakes, as well as playas (Davis and Smith 1998a), may be the first wetlands in the western Great Plains where shorebirds can stop to accumulate energy stores during spring migration between the Gulf Coast and the northern nesting grounds. However, annual variations in rainfall and availability of habitat and foraging resources in the freshwater playas of the SGP likely affect the ability of shorebirds to accumulate lipid reserves (Davis *et al.* 2005). Therefore, saline lakes which either have running springs or contain water may function as a "safety net" of stopover sites for shorebirds migrating through the SGP when playas are dry. Small areas with low salinity around the freshwater seeps are also important for nesting American Avocet, Snowy Plover (*Charadrius alexandrinus*), Killdeer (*C. vociferus*), and Black-necked Stilt (*Himantopus mexicanus*) (Conway *et al.* 2005). Shorebird chicks born in saline lakes may experience severe dehydration without freshwater (Hannam *et al.* 2003).

Time spent feeding and resting differed among species and between seasons, because long distance migrants and small bodied shorebirds have greater energy needs. Least Sandpipers spent the most time feeding and slept the least, whereas, American Avocets spent the most time resting and fed the least. Metabolic rates and migration distances differed among the four species in our study. To compensate for higher metabolic rates (Pienkowski and Evans 1984), the small bodied sandpipers needed to spend more time feeding than the large bodied American Avocets. Arctic nesting birds and long distance migrants, such as Least Sandpiper (Cooper 1994) and Lesser Yellowlegs (Tibbitts and Moskoff 1999) need to accumulate lipid reserves to continue migration and survive inclement weather and food shortages on the breeding grounds (Harrington *et al.* 1991; Butler and Kaiser 1995). In contrast, short distance migrants, such as American Avocets (Robinson *et al.* 1997) likely needed smaller lipid reserves and spent less time feeding and more time resting.

Shorebirds using saline lakes as stopovers fed more in spring than fall. Spring migrants need to compensate for increased metabolic rates due to heat loss (Wiersma and Piersma 1994). Lower spring temperatures also decrease availability of invertebrates (Pienkowski 1983; Zwarts and Wanink 1993; Davis and Smith 1998a) and shorebirds compensate by spending more time foraging to meet energy demands.

Time activity budgets of most species in our study differed between day and night. American Avocets and Least Sandpipers fed more at night than during the day, whereas, Wilson's Phalaropes fed more during the day. Variation in feeding between day and night among these species is likely in part due to their ability to detect invertebrate prey, or, that their preferred prey being active differently between night and day. Wilson's Phalaropes fed mostly by gleaning and sweeping at substrate surface, a foraging technique that requires visual location of prey. While visual abilities of Wilson's Phalaropes are unknown, they foraged more during the day than at night likely because they could not effectively locate prey on dark nights (Thomas *et al.* 2006). Tactile foragers such as American Avocets and Least Sandpipers were able to forage at night and supplement the energy reserves needed for migration and physiological transformations on the breeding grounds (McNeil *et al.* 1992; Dodd and Colwell 1996; Morrison *et al.* 2005). In contrast, Wilson's Phalaropes accumulate sufficient energy reserves by day, or need to reside longer at staging sites and migration stopovers to accumulate fat for their "jump" migrations (Piersma 1987; Jehl 1997).

Time spent feeding and resting did not differ between Wilson's Phalaropes and Lesser Yellowlegs, possibly because migration strategies, metabolic rates, and foraging efficiency had interactive effects resulting in similar energy needs. If wetlands along the migration routes used by shorebirds (i.e., the "stepping stones", Skagen and Knopf 1993: 539) do not offer favorable foraging conditions, shorebirds may arrive in the SGP with low energy stores and may need to spend more time feeding to be able to continue their migrations. Thus, shorebirds that encounter poor foraging conditions prior to

arriving in the SGP need to spend more time feeding, regardless of body size or migration distances.

Differences Between Saline Lakes and Playas

Diurnal activity budgets differed between saline lakes and the freshwater playas. In spring, American Avocets spent more time feeding and less time resting in saline lakes than in playas (Davis and Smith 1998a; Kostecke and Smith 2003), but they spent more time feeding in playas during summer/fall. Least Sandpipers spent more time foraging in playas than in saline lakes during both seasons. Biomass of invertebrates is lower in saline lakes compared to playas (playas: 0.92 g/m^2; saline lakes: 0.79 g/m^2), whereas, invertebrate density is higher in saline lakes (playas: 1,066/m^2, Davis and Smith 1998b; saline lakes: 2,616/m^2, Andrei 2005). Differences in availability of prey, energy needs, and foraging efficiency of migrant shorebirds likely resulted in different activity budgets between saline lakes and playas. However, data where collected in playas in 1993 and 1994 and in saline lakes in 2002 and 2003. Differences in precipitation and invertebrate communities between the two study periods may also account for time budgets differing between playas and saline lakes. During years with bellow average precipitation shorebirds may find poor foraging opportunities and may need to spend more time gathering energy reserves, regardless of type of wetland.

Vegetation cover also differs between playas and saline lakes, and may have influenced activity budgets. Shorebirds used playas with average cover of 9% (Davis and Smith 1998b), whereas, cover in saline lakes is ≤1% (Andrei 2005). In general, shorebirds prefer habitats with little vegetation (Rottenborn 1996; Colwell and Dodd 1997; Davis and Smith 1998b). In particular, the small bodied Least Sandpiper may have needed more time to forage in playas because vegetation inhibited their locomotion and prey extraction (Rottenborn 1996). In contrast, the large bodied American Avocets used a wider range of habitats (Davis and Smith 1998b) and were probably able to avoid the vegetated patches and to find more prey.

All four representative species in our study also spent between 3% and 9% of their time engaged in preening and body maintenance. In particular, American Avocets and Least Sandpipers spent slightly more time for body maintenance in saline lakes than in the freshwater playas (Davis and Smith 1998a; Kostecke and Smith 2003). Increased time for body maintenance may be needed in saline lakes to remove salt from feathers.

Management and Conservation Implications

Because activity budgets may differ among species, seasons, wetland types, and between day and night, researchers and conservation planners should exercise caution when extrapolating data from one type of habitat to another within the same region. Our findings, in addition to those of Kostecke and Smith (2003), show that nocturnal data should be included when examining shorebird energy needs and that diurnal activity data (Davis *et al.* 1989; Davis and Smith 1998a) should not be extrapolated to the entire 24-h period.

Conservation of shorebirds migrating through the Southern Great Plains (Davis and Smith 1998b; Andrei *et al.* 2006) should include preservation and restoration of saline lakes and the springs fed by the Ogallala aquifer. Decreasing water withdrawals from the aquifer in the vicinity of the lakes and throughout the region, easements and purchase of water rights by conservation organizations and government agencies, and restoration of aquifer recharge through the playa lakes (Osterkamp and Wood 1987; Wood and Osterkamp 1987; Wood 2000) are needed to protect these habitats.

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