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DIURNAL TIME BUDGET OF BURROWING OWLS IN A RESIDENT POPULATION DURING THE NON-BREEDING SEASON

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ABSTRACT—We present the first non-breeding-season time budget of adult burrowing owls (*Athene cunicularia*). We evaluated the hypothesis that during the non-breeding season the gender-specific allocation of time and effort observed diurnally in the breeding season changes, with males and females exhibiting more similar time budgets. Owls spent most of their time alert (58.4 ± 7.2% and 42.6 ± 8.3%) and in the burrow (19.3 ± 5.3% and 46.2 ± 7.2% for males and females, respectively). Females tended to spend more time in the burrow, and males spent more time alert. Although we found little evidence for temporal variation of these patterns for males, females were found more often in the burrow during early afternoon. Our results support a hypothesis that time-allocation differences between males and females during the breeding season are at least partially retained into the non-breeding season. The major finding of the study was the high percentage of time owls spent within the nest burrow during the non-breeding season, contrary to previous understanding of the ecology of this species from which management guidelines are based. Our findings indicate that considerable care should be taken when modifying areas that contain burrows within areas occupied by burrowing owls during the non-breeding season.

RESUMEN—Presentamos el primer presupuesto de tiempo de adultos de la lechuza llanera (*Athene cunicularia*) fuera de su época reproductiva. Evaluamos la hipótesis de que la distribución de tiempo y esfuerzo de los sexos en las actividades diurnas durante la época reproductiva cambia en la época no reproductiva, con machos y hembras exhibiendo presupuestos de tiempo con mayor similitud. Los búhos pasaron el mayor tiempo alertas (58.4 ± 7.2% y 42.6 ± 8.3% para machos y hembras, respectivamente) y en la madriguera (19.3 ± 5.3% y 46.2 ± 7.2% para machos y hembras, respectivamente). Las hembras tendieron a pasar más tiempo en las madrigueras y los machos más tiempo alertas. Aunque las hembras fueron encontradas frecuentemente en las madrigueras temprano en la tarde, encontramos poca evidencia en la variación temporal de esos patrones para los machos. Nuestros resultados apoyan la hipótesis de que las diferencias de distribución de tiempo entre machos y hembras durante la época reproductiva son al menos parcialmente mantenidas fuera de la época reproductiva. El resultado principal del estudio fue el elevado porcentaje de tiempo que las lechuzas pasaron en la madriguera de nido fuera de la época reproductiva, al contrario del conocimiento previo de la ecología de estas lechuzas, en el cual están basadas las pautas de manejo de la especie. Nuestros resultados indican que se debe practicar mucha precaución cuando se modifican áreas con madrigueras de lechuzas llaneras fuera de la época reproductiva.

Analysis of time budgets allows evaluation of temporal relationships of behaviors in relation to ecological, behavioral, physiological, and anthropogenic variables (Verner, 1965; Afton, 1979; Altrichter et al., 2002). To understand optimal use of time by an individual, allocation of time

among behavioral categories must be known. Orians (1961) argued that even subtle differences in time budgeting can influence reproductive success and survival of an individual and thus have evolutionary and management implications. Time budgets also have been used to assess management and land-use practices that may impact target species, such as wintering waterfowl (Quinlan and Baldassarre, 1984; Bergan et al., 1989) and nesting burrowing owls (*Athene cunicularia*; Plumpton and Lutz, 1993). The burrowing owl is an excellent example of the management relevancy of time budgets because of its habit of nesting and roosting underground, where it is not seen and assumptions made on the timing of minimal direct impact of disturbance activities are critical (California Department of Fish and Game, in litt.).

The burrowing owl is a conspicuous inhabitant of grasslands, deserts, agroecosystems, and other arid areas throughout western North America, Florida, and Central and South America (Haug et al., 1993). It is unique among North American owls in that it nests and roosts underground in burrows or other crevices in the ground, typically in burrows made by fossorial mammals (Haug et al., 1993). Most research has focused on the breeding season (reviewed in Haug et al., 1993). Moreover, the only published time budget of burrowing owls (Plumpton and Lutz, 1993) was conducted during the breeding season. During the breeding season, males spend more time alert at the burrow entrance, whereas females spend more time in the burrow (Plumpton and Lutz, 1993). During the post-hatch period, males and females adopt the more similar roles of providing food to young (Haley, 2001), and inter-gender differences are less apparent in their time budgets (Plumpton and Lutz, 1993).

In this study, we investigated allocation of time for paired and non-paired burrowing owls during the non-breeding season. We hypothesized that during the non-breeding season the gender-specific allocation of time and effort observed in the breeding season changes, with both genders adopting similar time-allocation patterns. This is not only important for understanding the winter ecology of burrowing owls, but also in guiding management during the non-breeding season.

Materials and Methods—*Study Area*—We studied burrowing owls in the Imperial Valley located at the southern end of the Salton Sea in southern California. The 1,175-ha study area consisted of agriculture fields located within a system of concrete water-delivery ditches and canals, and earthen drains (Rosenberg and Haley, 2004), and included privately owned lands and portions of the Sonny Bono Salton Sea National Wildlife Refuge. The breeding-season population of burrowing owls in the Imperial Valley is considered non-migratory and nests primarily along canals and ditches that line the agricultural fields (Coulombe, 1971; Rosenberg and Haley, 2004). Little is known about composition of the population outside of the breeding season, but presumably it includes migrants from owls nesting in the northern portion of its breeding range; burrowing owls are known to winter in coastal California (Conway et al., 2006).

Time Budget—Nest burrows were selected for observation that had at least one radiotagged individual occupying the burrow. Radiotagging occurred as part of a separate investigation on the breeding dispersal of burrowing owls (Catlin, 2004). Adult owls were captured using bow-nets and two-way burrow traps (Rosenberg and Haley, 2004) and were fitted with a harness mounted radiotransmitter (total assembly weight 5.08 $\pm$ 0.02 g, $\mu \pm 1SE$; Catlin, 2004). Each owl also was fitted with metal, colored, alphanumeric leg bands during the breeding season. Gender was determined from inspection of the brood patch during banding and subsequent observations during the breeding season (Catlin et al., 2005).

An instantaneous, focal-animal, sampling scheme was used for observation (Altmann, 1974). We collected behavioral observations for the focal individual every 15 s during a 15-minute observation period. Observations were made using a window-mounted spotting scope from a vehicle parked 20–60 m from the burrow.

Owls at the same burrow were sampled consecutively, and burrows were grouped by proximity for ease of travel between nest burrows. The sampling order of burrows in each group was randomized prior to each sampling period. Starting from sunrise and ending at sunset, we divided the daylight hours into four observation quarters of equal duration. We attempted to sample each group during one observation quarter per day. Behaviors observed were classified as agonistic, alert, comfort movements (i.e., preening, yawning, or defecating), feeding, locomotion (e.g., flying or running), out-of-sight, and resting. We determined location of out-of-sight owls with radiotransmitters using a hand-held receiver and H-antenna. Out-of-sight locations were classified as either (1) in burrow, or (2) away from burrow. Away from burrow indicated owls were not within the range of the radiosignal, indicating owls were $\geq$500 m from the burrow (Catlin, 2004) or within a different burrow than the observer checked and thus not detectable. If an owl without a radiotransmitter was out-of-sight for the duration of the observation period, we used an infrared probe (Sandpiper Technologies, Manteca, California) to determine if the bird was in the burrow. If so, the bird was recorded as in burrow. Otherwise, out-of-sight was recorded and the observation period was not included in analyses. Thus, our estimates for behavior are given that the owl was observed at the observation burrow (owls without radiotransmitters) or $<$500 m from the burrow (owls with radiotransmitters). As such, our estimates of away

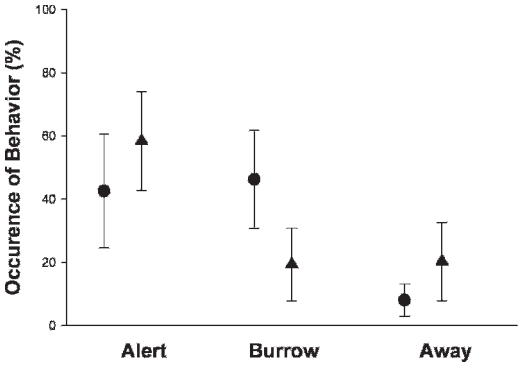

FIG. 1—Mean percentage occurrence of observations of alert, in burrow, and away from burrow by female and male burrowing owls (*Athene cunicularia*) in Imperial Co., California, autumn 2002. Error bars represent 95% confidence intervals. Mated pairs and single owls were pooled and the percentage occurrence for each owl was pooled over all observations.

from the observed burrow are underestimates of the actual percentage of time owls were not at or adjacent to the observed burrow. Observations took place from 30 October to 17 November 2002. Weather conditions did not vary during the study sufficiently to affect our observations.

Analysis—We calculated percentage occurrence by dividing number of instantaneous recordings for each behavior by total number of behavioral observations (Quinlan and Baldassarre, 1984) during each 15-min observation period for which owls were seen near the nest. Because number of observation periods varied among owls, we used the mean of all observations for a given owl in the comparison of behaviors, and used the mean of observations of an individual within a time period (quarter) for comparison of specific behaviors across quarters.

We used a descriptive rather than a hypothesis-testing approach because for a non-experimental study of behavior, we expect a priori that there were differences among groups of individuals observed. This follows the recent argument for emphasizing estimation rather than statistical significance of null hypotheses that are trivial and presumably false (Yoccov, 1991; Johnson, 1999). Our primary interest was in estimating time budgets and comparing relative differences between genders and among time periods. We present the mean ± 1*SE* and 95% confidence intervals for all comparisons. We treated members of mated pairs as independent samples, and hence our estimates of precision are approximate.

RESULTS—We observed 28 individual owls, including 23 owls that were from mated pairs (known from the previous breeding season) and 5 single adults. Our sample included an equal number of males and females ($n = 14$ for each gender). Our study consisted of 215 15-min observations, including 99 observations of females and 116 of males. Average number of 15-min observation sessions/individual owl was 7 ($SD = 3.4$), equivalent to 105 min of observation, ranging from one observation session/individual to 12. The variability was due to difficulty in consistently locating individuals. The majority of activity of males consisted of being alert (58.4 ± 7.2%), whereas females spent most of their time alert (42.6 ± 8.3%) and in the burrow (46.2 ± 7.2%; Fig. 1). Based on when owls were observed in the vicinity of the observed burrow, males and females spent considerable time away from the burrow (Fig. 1). All other behaviors occurred <4% of the time.

Behavior of females varied temporally, whereas behavior of males remained fairly constant throughout the day. There was some evidence that alert behavior varied throughout the day; however, the large variation and small sample sizes resulted in imprecise estimates of this relationship (Fig. 2A). Estimates suggest that male owls were alert a high proportion of the time, remaining alert throughout the day. In contrast, females were observed more often in the burrow throughout the day, but particularly during early afternoon (Fig. 2B).

DISCUSSION—Although previous studies of activity patterns of burrowing owls report temporal variation in behaviors, we expected similar allocation of time throughout the day during the non-breeding season based on the finding that inter-gender differences in time budgets were minimized later in the breeding season (Plumpton and Lutz, 1993). Our findings demonstrate that at least some inter-gender differences in time budgets remain into the non-breeding season. Males tended to be observed more frequently alert than females, and despite small sample sizes, it was clear that females were more frequently in the burrow. We suggest two possible explanations for this. First, females may need to conserve energy during the non-breeding season in order to have an optimum body condition for the breeding season, which usually begins in April at our study site (Rosenberg and Haley, 2004). Second, the male may be protecting his mate from predation and from unmated males by being vigilant at the entrance. When approached, owls at the burrow entrance often will fly a short distance away and exhibit a call-head-bobbing display, which is

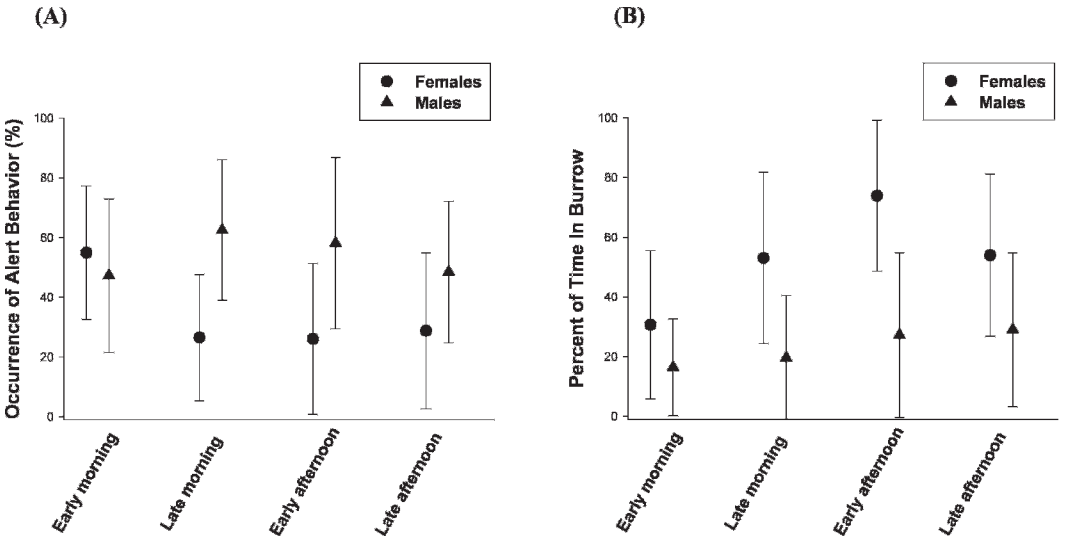

FIG. 2—Mean percentage occurrence of (A) alert and (B) in-burrow behavior for male and female burrowing owls (*Athene cunicularia*) during four time periods of the day, Imperial Co., California, autumn 2002. Error bars represent 95% confidence intervals. Mated pairs and single owls were pooled and the percentage occurrence for each owl was pooled over all observations within each time period in which they were observed. Sample size was 11–13 among time periods and gender.

believed to be an alarm response (Haug et al., 1993), even during the non-breeding season (D. LaFever, pers. observ.).

We observed diurnal time patterns of behaviors for females but not for males. Females tended to be more frequently in the burrow in the early afternoon. The amount of time an individual devotes to different activities influences energy allocation and ultimately may influence survival and reproductive rates (Orians, 1961; Maxson and Bernstein, 1984). Time spent in a burrow may reduce energy use (Finlayson et al., 2005), act as a thermoregulatory mechanism (Coulombe, 1971), and lower predation rates (Karels and Boonstra, 1999), or conversely, the time above ground should facilitate the capture of prey. The imprecise estimates for time allocated to each behavior during each time period limited our ability to detect less-pronounced differences than what was apparent with the amount of time females spent in burrows.

Our most important finding was the high frequency with which owls occupied burrows during the non-breeding season, contrary to our expectations and that which is used to guide management decisions. We found there to be extensive time spent within burrows, particularly by females, in the non-breeding season. This is important because construction activities in areas occupied by burrowing owls, and maintenance activities associated with roads and irrigation structures in agricultural areas (Catlin and Rosenberg, 2006), may directly harm burrowing owls by damaging occupied burrows. Because management guidelines assume owls do not regularly roost in burrows during the non-breeding season, our results suggest that avoidance measures for disturbing burrows during the breeding season apply to the non-breeding season as well.

Current management guidelines outline methods for minimizing disturbance to burrowing owls during both the breeding and non-breeding seasons (California Department of Fish and Game, in litt.). Mitigation measures include not disturbing occupied burrows during the nesting season, protection of foraging and burrow habitat, passive relocation of owls, and enhancement of unsuitable burrows when destruction of occupied burrows is unavoidable. The California Burrowing Owl Mitigation Guidelines (California Department of Fish and Game, in litt.) recommend that these mitigation measures be carried out 1 September–31 January, which is prior to the nesting season. In light of our

findings that burrowing owls frequently use burrows during the non-breeding season, and given that auxiliary burrows often are used (Desmond and Savidge, 1999), we emphasize the need for careful evaluation of burrow use during the non-breeding season before disturbance of burrows that could be occupied. This should include an evaluation of nest burrows that were used during the breeding season as well as potential auxiliary burrows.

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