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Comparison of Microclimate at Grassland Bird Nests with Different Substrates

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ABSTRACT -- We compared the effects of two different nest placement strategies (shrubs vs. bunchgrasses) on microclimate conditions for grasshopper sparrow (*Ammodramus savannarum*) and lark sparrow (*Chondestes grammacus*) in Oklahoma. We predicted that the intensity and duration of extreme temperatures (greater than 39° C) and their variability would be reduced at shrub nests compared to bunchgrass nests. Average maximum temperatures were similar at nests of grasshopper sparrow and lark sparrow, but confidence intervals were more variable and included biologically detrimental temperatures at grasshopper sparrow nests compared to lark sparrow nests. The proportion of time greater than 39° C also was similar at nests of both species, but on average grasshopper sparrow nests exceeded 39° C for 1.2 hr compared to 2.6 hr per 29-hr sampling period for lark sparrow nests. Our results indicate shrub nesters (lark sparrow) might be able to moderate the intensity and duration of biologically detrimental temperatures at their nests more successfully than bunchgrass nesters (grasshopper sparrow).

Key words: *Ammodramus savannarum*, *Chondestes grammacus*, grasshopper sparrow, lark sparrow, nest placement strategies, microclimate.

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Nest-site selection is a process that affects reproductive outcomes and, ultimately, population dynamics in birds. Understanding nest placement strategies for grassland birds in light of continued population declines is needed (Herkert and Knopf 1998, Sauer et al. 2001). Throughout their respective ranges, grasshopper sparrow (*Ammodramus savannarum*) and lark sparrow (*Chondestes grammacus*) populations have been declining over the past three decades (Sauer et al. 2001). Although these declines have often been attributed to high rates of nest failure due to predation (Ricklefs 1969), other authors have suggested that microclimate conditions might be a major selective pressure (Wiebe and Martin 1998, Lusk et al. 2003).

With and Webb (1993) proposed the Microclimate Selection Hypothesis to account for patterns of nest-site selection in grassland birds. The Microclimate Selection Hypothesis states that females should select nest sites that minimize stress induced by extreme weather conditions. According to the Microclimate Selection Hypothesis, extreme temperatures should occur less often and last shorter durations at nests compared to random points. The authors evaluated their hypothesis by determining the effects of wind breaks and radiative cover on nest-site selection for three grassland bird species with different nest-placement strategies. Their results indicated that species that nested in shrubs or bunchgrasses like lark bunting (*Calamospiza melanocorys*) were shaded at least three times longer during the hottest portion of the day than species like McCown's longspur (*Calcarius mccownii*) that built exposed nests. In an extension of this hypothesis, we suggest shrub nesters will be more likely to minimize exposure to extreme temperatures than bunchgrass nesters because of the choice of nest sites. Although we were not able to detect differences in nest vegetation structure or composition on our site (Suedkamp 2000), grazing or other management practices on other sites might allow maintenance of optimal microclimate conditions by manipulating vegetation.

We investigated the effects of nest placement strategy on the resulting microclimate for two species of grassland birds. Although both species are ground nesters, grasshopper sparrow usually place their nests in clumps of grass, leaves, or litter (Patterson and Best 1998, Vickery 1996), whereas lark sparrow typically nest at the base of shrubs supported by branches (Baepler 1968). Both species are small passerines that are primarily monogamous and ground foragers, although lark sparrow tends to be more granivorous than the grasshopper sparrow (Ehrlich et al. 1998). We predicted that the intensity (maximum temperature) and duration (proportion of time greater than or equal to 39° C) of critical temperatures would be reduced and less variable at shrub nests (lark sparrow) compared to bunchgrass nests (grasshopper sparrow). We used 39° C as the critical threshold for biologically detrimental temperatures because it approximates the point at which heat gain exceeds heat dissipation, concordant with reported upper thermal tolerance limits for optimal survival in embryo and adult birds (Webb 1987).

METHODS

We conducted research at the Marvin Klemme Experimental Range Research Station (35°25'N, 99°05'W) located in Washita County, Oklahoma, during the breeding seasons of 1999 and 2000. The study site is classified as southern mixed-grass prairie (Coupland 1992) and included three experimental grazing treatments: no grazing (greater than 50 years), moderate grazing (0.2 animal units/ha), and heavy grazing (0.4 animal units/ha). However, previous analyses showed no effects of grazing on vegetation structure or composition at nests, so data were pooled across grazing treatments within a species (Suedkamp 2000).

We searched for nests from May through July in 1999 and 2000 by using systematic searches combined with walking haphazard paths. The majority of nests were found by walking close to a nest and force-flushing the incubating or brooding female. Nests were monitored every 3 to 4 days to determine a fate. We estimated the timing of nest initiation by assuming the nesting period was 20 days for grasshopper sparrow and 21 days for lark sparrow (Baicich and Harrison 1997).

Between May and July of 1999 and 2000, we recorded temperatures at a subset of recently inactive nests by using HOBO data loggers (Onset Computer Corporation, Pocasset, Massachusetts). Although nests might have become inactive up to two weeks prior to sampling, we elected to use inactive nests to minimize potential negative effects on nesting pairs. Sampling periods in 1999 were 20 to 21 May, 19 to 20 June, and 14 to 15 July. Sampling periods in 2000 were 19 to 20 May, 19 to 20 June, and 12 to 13 July. We constructed wooden shields that allowed air flow for each datalogger but prevented direct solar radiation as suggested by the manufacturer, and reduced equipment damage due to trampling by cattle (*Bos taurus*). As part of larger study on several other species, we had eight data loggers that we randomly allocated among nests of all species, including our two focal species, in the three grazing treatments. For nests, we placed the datalogger enclosed in a wooden shield at the nest entrance for comparison. Dataloggers were programmed to record temperature readings every 5 seconds over two consecutive days each month that began at 1100 hr on the first day and concluded at 1600 hr on the second day for a 29-hr sampling period. In 1999, we monitored two grasshopper sparrow nests in May and one nest in June. In 2000, we monitored three grasshopper sparrow nests and two lark sparrow nests in May, one grasshopper sparrow nest and three lark sparrow nests in June, and one grasshopper sparrow nest and two lark sparrow nests in July.

We used bootstrap analysis without replacement and 95% confidence intervals to test for significant differences between maximum temperatures (°C) and the proportion of time greater than 39°C at lark sparrow compared to grasshopper sparrow nests (Mooney and Duval 1993). We generated 1,000 bootstrap estimates for the mean of each variable at nests of both species by using SYSTAT ver. 8.0

(SPSS 1998). We used bootstrapping because we had small sample sizes and were unwilling to make stringent assumptions about the distribution of sample parameters, which are required by many of the more traditional statistical methods (Mooney and Duval 1993).

RESULTS

The majority of grasshopper sparrow nests located during the breeding season (68%, $n = 15$) were placed in bunchgrasses and the remaining nests (32%, $n = 7$) were placed in shrubs. With one exception, most lark sparrow nests ($n = 42$) were located at the base of broom snakeweed (*Gutierrezia sarothrae*) supported by branches. Peak times of estimated nest initiation were in late May for grasshopper sparrow and late May to early June for lark sparrow (Fig. 1). Raw nest success was 23% and 29%, respectively for grasshopper sparrow and lark sparrow. Average maximum temperatures at the subset of nests of lark sparrow ($37.8^{\circ}\text{C} \pm 0.03\text{ SE}$; 95% CI 36.0 - 39.8) monitored were similar to grasshopper sparrow ($40.3^{\circ}\text{C} \pm 0.04\text{ SE}$; 95% CI 38.0 - 42.6), but the confidence intervals were wider and included biologically detrimental temperatures (those greater than 39°C) at grasshopper sparrow nests. The average proportion of time greater than 39°C also was similar at the subset of monitored lark sparrow nests ($0.04 \pm 0.00\text{ SE}$; 95% CI 0.00 - 0.09)

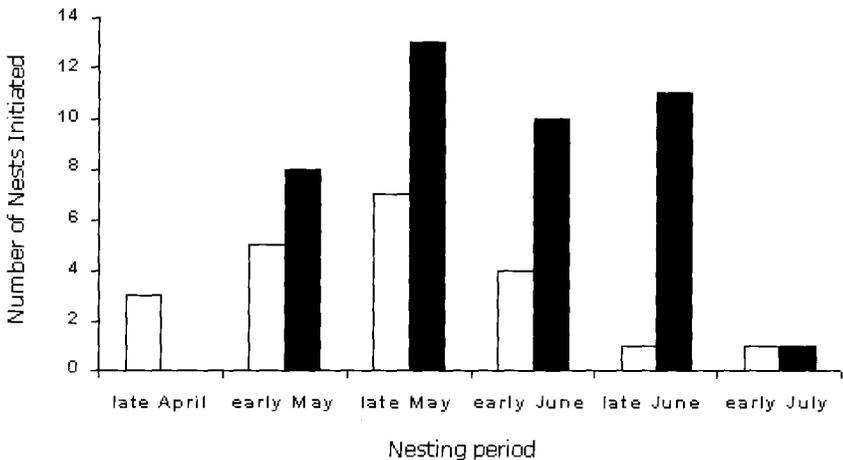


Figure 1. Nest initiation chronology of grasshopper sparrow (open bars; $n = 22$) and lark sparrow (solid bars; $n = 43$) by two-week period during the breeding seasons of 1999 and 2000 in Oklahoma.

and grasshopper sparrow nests (0.09 ± 0.00 SE; 95% CI 0.03 - 0.15), but on average lark sparrow exceeded 39°C for 1.2 hr per 29-hr sampling period compared to 2.6 hr at grasshopper sparrow nests. Greater variability in maximum temperatures and the proportion of time greater than 39°C , as indicated by the width of the confidence interval and sampling distribution (Fig. 2), showed that grasshopper sparrow might be less successful at moderating nest microclimate in bunchgrasses than lark sparrow that nest in shrubs.

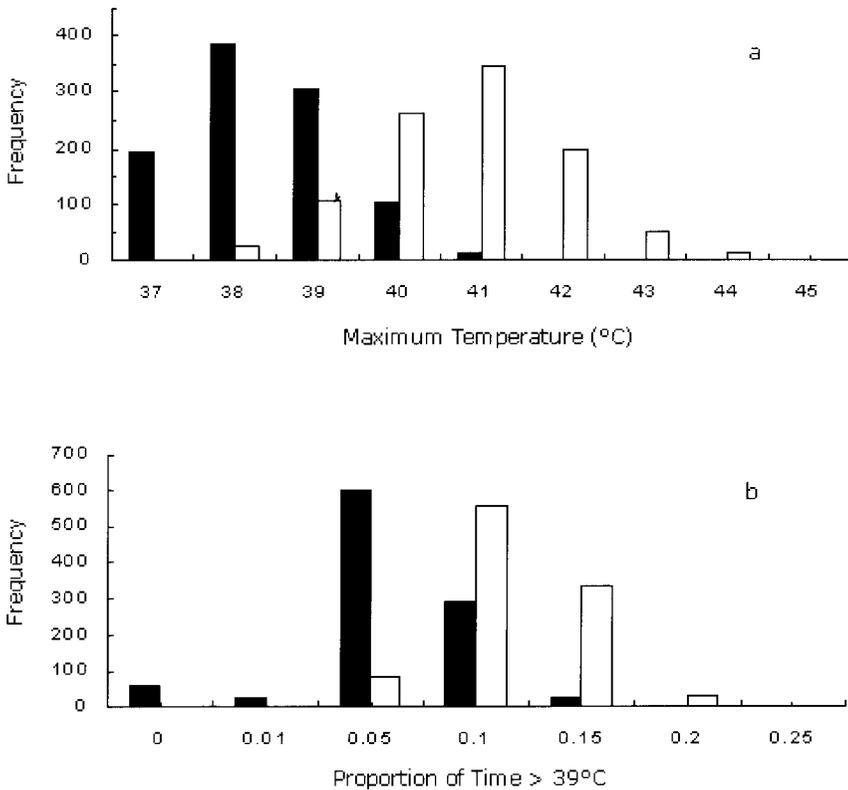


Figure 2. Distribution of 1,000 bootstrap means for (a) average maximum temperature ($^{\circ}\text{C}$) and (b) the proportion of time greater than 39°C for lark sparrow nests (solid bars; $n = 11$) and grasshopper sparrow nests (open bars; $n = 11$).

DISCUSSION

Although our results were not statistically significant, we suggest they might represent biological trends. Greater variation in maximum temperature and the proportion of time greater than 39° C at grasshopper sparrow nests compared to lark sparrow nests might have been a result of small sample sizes, but our bootstrap analysis provides evidence that sampling artifacts might not be the best explanation. Instead, we suggest our analysis shows that selection for nest sites that minimizes temperatures greater than 39° C might not have been necessary for grasshopper sparrow due to their nesting chronology. Our larger data set including all grasshopper sparrow nests found shows that peak nest initiation is in late May (Fig. 1) when ambient temperatures never exceeded 33° C during our sampling periods in either year (Suedkamp 2000). As a result, grasshopper sparrow actually might be selecting warmer nest sites to maintain optimal incubation temperatures (Webb 1987) early in the breeding season. Although mean trends in our data only provide circumstantial support for this theory, the selection of nest sites near bunchgrasses might be connected with selection for warmer nest sites early in the breeding season due to thermal benefits accruing from direct solar radiation.

Conversely, selecting nest sites near shrubs might be necessary for lark sparrow because peak nest initiation is later in the summer (Fig. 1) when ambient temperatures begin to exceed upper critical thresholds. For example, Lusk et al. (2003) identified woody cover as a key factor influencing nest-site selection in lark sparrow and attributed it to the potential for thermal protection. High selectivity of nesting sites near shrubs in this species might be reflective of the increased potential for thermal moderation in shrubs compared to bunchgrasses. For example, our data showed that the upper end of the confidence interval for maximum temperature at nests of lark sparrow is about 3° C lower than at grasshopper sparrow nests. Although it is possible that 3° C does not represent a biologically meaningful increase for short periods of time, the width of confidence intervals around the proportion of time greater than 39° C and the distribution of bootstrap means (Fig. 2) showed extreme temperatures persisted twice as long at grasshopper sparrow nests compared to lark sparrow nests. If this difference is sufficient to reduce potential effects on survival and reproduction, this would represent a biologically meaningful pattern in nest-site selection. Although we did not assess survivorship or cumulative reproductive efforts, evidence reviewed by Webb (1987) showed limited exposures (minutes to hours) within the ranges we observed have been associated with detrimental effects. Some of the documented effects include a reduction in breeding activity, shortening of the breeding season, (Guthery et al. 2001), cardiac and respiratory failure, and ultimately decreased survival in birds of all developmental stages (Webb 1987).

In conclusion, we suggest that we have observed biologically meaningful trends in nest-site selection for ground-nesting grassland birds that merit further evaluation. Our evidence indicated the choice of nest site might be related to nesting chronology. Further work investigating the potential of extreme temperatures to influence nest-site selection patterns is needed. Efforts to link survival and reproductive outcomes with nest sites and the resulting thermal profile at individual nests with larger sample sizes will be especially helpful.

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