HABITAT USE BY NESTING GRASSLAND BIRDS AND THEIR SNAKE PREDATORS IN THE TALLGRASS PRAIRIE

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ABSTRACT

Grassland bird populations have seen greater declines than any other group of birds in North America. Although snake predation is considered the primary reason for nest failure, little is known about how management practices in the Flint Hills region of Kansas impact movement and habitat use of snakes, and the predator-prey interaction between snakes and nests of grassland birds. Radio telemetry was used to study habitat use, considering 11 habitat variables, of 6 Eastern Racers (*Coluber constrictor*) and 9 Great Plains Rat Snakes (*Elaphe emoryi*). Grassland bird nests were monitored, including 84 nests that were eventually predated and 37 nests that fledged. After nesting was complete, a similar habitat analysis was conducted. Nest monitoring results showed snakes accounting for up to 72% of all nest failures; however, the rate of snake predation depended on land management techniques. The average daily nest survival rate was 90.03%, or a total survival rate of 12.98%. Several habitat characteristics including percent coverage by shrubs and grass were important in distinguishing among the habitats of the four groups. Fledged nests were found in habitats with sparser vegetation and more rocks than predated nests. Predated nests and both snake species shared habitats, but fledged nests were located in significantly different habitats from the other three groups. Thus, land management practices that manipulate habitat structure may directly influence grassland bird nest success by altering snake predation risk.

INTRODUCTION

The tallgrass prairie ecosystem of the North American Great Plains once encompassed over 631,700 km^2. Currently, only about 25,700 km^2 of this unique landscape persists, and it is widely considered to be the single most endangered ecosystem in the United States (Steinauer and Collins, 1996). Long term survival of tallgrass prairie communities depends upon a regime of frequent burning and moderate bison or cattle grazing (Anderson, 1990; Knapp et al., 1999). The Kansas Flint Hills, the largest surviving region of tallgrass prairie, provides vital habitat for grassland fauna (Axelrod, 1985). However cattle ranching, a major industry in the Flint Hills region, has transformed the landscape with such traditional practices as annual spring burns to maximize grass productivity (Robbins et al., 2002; Wilgers and Horne, 2006). Although degradation of this rare habitat has affected many species, grassland birds have suffered most, declining more than any other bird groups in North America (Peterjohn and Sauer, 1993; Knopf, 2004).

Long term stability of grassland bird populations depends on reproductive success. Predation and brood parasitism both cause nest failure (Johnson, 1990). Fragmentation consistently affects rates of nest predation but does not consistently influence brood parasitism. This suggests that the decline in grassland bird populations observed with continued habitat degradation may result from increased predation threats (Best, 1978; Herkert et al., 2003; Klug, 2005). Studies that have videotaped predation events or evaluated the condition of the nest bowl afterwards show that much predation is caused by snakes (Best, 1978; Klug, 2005).

Land management practices may simultaneously attract birds and snakes to the same areas, thus creating habitats for predators and their unwitting prey. Studies have shown that Dickcissels (*Spiza americana*) nest in lower densities near woodland edges than in cropland or shrub edges even though the three habitats experience similar predation rates (Jensen and Flick, 2004). Nest predation rates of Dickcissels and other grassland-nesting species are density-independent (Zimmerman, 1984; Winter and Faaborg, 1999). Moreover, studies show that the rate of nest predation was related to the fate of nearby nests and the level of nest concealment regardless of nesting density, which suggests the ability of predators to exploit habitat differentially (Mankin and Warner, 1992). Snake predation on nesting birds may be coincidental. Indeed, snakes may use habitat regions for reasons other than foraging but opportunistically encounter and exploit prey (Blouin-Demers and Weatherhead, 2001). The Eastern Racer (*Coluber constrictor*), a common snake of prairie ecosystems, is thought to be an indiscriminate feeder with birds making up 16.5% of its diet in a study by Klimstra (1959).

Despite the role of snake predation in nest failure, little is known about how land management practices, such as grazing and burning, affect snake movement and habitat use. Evaluating the habitat used by common snake species that eat grassland birds helps explain how snake predation varies as a function of land management. The goal of the current study was to determine the vegetation characteristics that influence nest survival, and whether survival variation can be explained by a nest's proximity to predator habitat. The effects of different management regimes on habitat use by snakes and grassland birds have important implications for the conservation of grassland bird populations in the tallgrass prairie.

METHODS

Study Area

Konza Prairie Biological Station (KPBS) is a mosaic of watershed-sized grassland areas exposed to various land management practices in the Flint Hills region of Kansas. The habitats we studied were either burned annually or quadrenially. We chose these fire frequencies because annual burns are traditional in cattle ranching, while the tallgrass prairie naturally burns once every three to five years (Wright and Bailey, 1982). The grassland bird portion of the study was restricted to ten different one-year and four-year burned watersheds either nongrazed or grazed within a 1100 ha bison enclosure with a stocking rate of approximately 6 ha per animal unit. The snake portion of the study included other areas through which snakes traveled, such as two-year and twenty-year burned watersheds and private land surrounding the station.

Study Animals

The study targeted grassland snake species that are potential bird nest predators. Snakes were hand captured opportunistically or by using coverboards, drift fences, and funnel traps (Fitch, 1987). Two sets of ten coverboards (60 x 180 cm plywood sheets) were spaced a minimum of 50 m apart within each study site. Each snake captured was identified by species and given a unique scale clipping (Blanchard and Finster, 1933) for mark-recapture studies evaluating the number of reptiles in different watersheds. Various morphological measurements including snout-vent length (SVL) and weight were also recorded. All potential grassland bird-eating snakes larger than 100g were implanted with thermal sensitive radio-transmitters, either model SI-2T from Holohil Systems Inc., Carp, Ontario, Canada, or model G3-1V Temp B from AVM Instrument Company, Ltd., Colfax, California. Each transmitter weighing 3.8 to 5.0 g and having a 6 to12 month battery life at 20 ºC, was implanted following the surgical procedures of Reinert and Cundall (1982), modified by Hardy and Greene (1999).

A total of 6 Racers and 9 Great Plains Rat snakes was monitored up to 61 days. Each snake was released at the site of capture and radio-tracked once every 48 hours. A radio-telemetry receiver indicated locations and recorded daily body temperatures of each snake from 0600 to 2200 hours. Snake locations were marked using a GPS device and flagging. Activity of the snake, habitat descriptions, weather conditions, and ambient temperatures were also recorded.

We spent equal time searching each habitat type for grassland bird nests by rope dragging and behavioral observation (Rodewald, 2004). Artificial nests have yielded substantially different results from natural nests and thus were not used (Davison and Bollinger, 2000; Robel et al., 2003). Nest locations were marked using a GPS device and flagged one meter from the nest, then monitored every third day. To minimize disturbances that encourage predation, we took alternate routes to nests and did not handle their contents (Lloyd et al., 2000). Nests were not monitored during inhospitable weather to minimize stress. Only nesting failures possibly caused by snake predation, indicated by reduced nest composition but no nest bowl damage, were included in the analyses. Predation attributed to brood parasites, indicated by replacement of host young by brown-headed cowbird young, or to small mammals, predominantly thirteen-line ground squirrels, indicated by a torn nest bowl and egg shell fragment remains, was ignored when comparing habitat of nest and snake locations (Thompson et al., 1999; Pietz and Granfors, 2000; Williams and Wood, 2002). We grouped predations from 2006 and 2007 into three categories by predator after examining nest bowl contents after each event. Besides the two main categories of snakes and mammals, the third category included failures caused by brood parasitism of brown-headed cowbirds, ant infestation, skunks, and crows.

Habitat Analysis

We completed a full habitat evaluation at each snake location within five days of the snake relocating and at each bird nest within five days of predation or immediately after parents discontinued alarm calls when we approached a fledged nest. For each snake and nest location, we evaluate the eleven vegetation and structural variables listed in Table 1 at the flagged location and three randomly selected points 3, 15, and 30 meters away, totaling ten plots for each full analysis. Horizontal vegetation structure was evaluated using a Daubenmire (1959) frame (0.5 m x 0.5 m) to quantify percent cover including rock or litter and dead/live grass, forb, or shrub. We also recorded maximum vegetation height and mean litter depth. A Robel pole was used to quantify vertical habitat structure by measuring vertical obstruction from four positions equidistant around a circle 3 m from the plot (Robel et al., 1970). In addition to using the 11 directly measured variables, we calculated the coefficient of variation (Sokal and Rohlf, 1995) for mean litter depth, biomass, and vegetation height to determine habitat heterogeneity.

Table 1. Habitat variables used in analysis.

Abbreviation	Variable	Sampling Method
ROCK	Percent rock cover	Percent coverage on ground visible within Daubenmire frame (0.5m x 0.5m)
LITTER	Percent litter cover	Same as ROCK
DGRS	Percent dead grass cover	Percent coverage on ground within Daubenmire frame (0.5m x 0.5m)
LGRS	Percent live grass cover	Same as DGRS
DFORB	Percent dead forb cover	Same as DGRS
LFORB	Percent live forb cover	Same as DGRS
DWOOD	Percent dead shrub cover	Same as DGRS
LWOOD	Percent live shrub cover	Same as DGRS
LTD	Mean litter depth	Mean of 4 measurements taken with ruler (cm) in each corner of Daubenmire frame
VGHGT	Vegetation height	Maximum vegetation height (cm) in plot
BIOMAS	Vertical obstruction	Mean value of four Robel Pole readings

Statistics

Daily nest survival rates were determined using program MARK (Dinsmore et al., 2002). The daily nest survival rate was extrapolated over the twenty-day nesting cycle to obtain a total nest survival rate. Although four snake species were used in the radio telemetry study, only two, the Eastern Racer and Great Plains Rat Snake, were studied in sufficient number for statistical analysis. We grouped the habitat data into four categories: Eastern Racers, Great Plains Rat Snakes, grassland bird nests that fledged at least one offspring, and grassland bird nests that were predated. Then, we used a discriminant function analysis (Sokal and Rohlf, 1995) to determine which habitat variables were most significant in distinguishing between the fledged and predated nest groups. Next, discriminant scores were calculated for the raw habitat data obtained for the two snake species and placed into the discriminant space defined by nesting habitat. Kruskal-Wallis (Sokal and Rohlf, 1995) and pairwise sign tests (Zar, 1998) were used to compare mean discriminant scores because of heterosedastic variances among groups. Prior to analysis, we removed outliers comprising no more than 10% of the total group data set.

Snakes frequently returned to the same location. In these instances, the vegetation data collected for the repeatedly used location were incorporated into the analysis each time the snake was located. To increase sample sizes for analysis, we combined the data collected during the 2007 field season with unpublished data collected by P. Klug in 2006.

RESULTS

During 2006 and 2007, vegetation characteristics were sampled for 37 fledged bird nest locations, 84 predated bird nest locations, 170 Great Plains Rat Snake locations from 9 snakes, and 119 Eastern Racer locations from 6 snakes. Snakes were probably responsible for 72.2% of all nest failures. The rate of snake predation was not constant. Snakes accounted for 80% of predation in four-year burn sites and 64% of predation in annual burn sites. Small mammals showed the reverse trend with 24% of predation occurring in the annual burn sites and 11% in four-year burn sites. Program MARK calculated a daily nest survival rate of 90.03%. Extrapolated over the 20-day nesting cycle, this equated to a total survival rate per nest of 12.98%.

Using a two-group discriminant function analysis, we partitioned habitat variation into fledged nests and predated nests. One can compare habitat use among the four groups by considering each variable independently (Table 2). However, it is more realistic to use a multivariate approach (i.e., discriminant function analysis) which yields new composite variables while maintaining the correlations among the original variables. The discriminant function significantly separating predated and fledged nest sites was most strongly correlated with the

Table 2. Means (± SE) of each habitat variable for the four study groups.

Variable	Fledged Nest N = 37	Great Plains Rat Snake n = 170	Predated Nest n = 84	Eastern Racer n = 119
ROCK (%)	15.9 ± 2.98	15.3 ± 1.00	11.7 ± 1.48	9.4 ± 0.81
LITTER (%)	43.7 ± 6.23	55.1 ± 2.27	43.2 ± 4.23	57.5 ± 2.42
DGRS (%)	15.0 ± 4.34	7.9 ± 0.43	15.2 ± 2.51	14.3 ± 1.08
LGRS (%)	36.7 ± 2.19	45.9 ± 1.11	41.3 ± 2.46	35.1 ± 1.19
DFORB (%)	3.5 ± 1.33	3.1 ± 0.18	3.1 ± 0.61	4.3 ± 0.32
LFORB (%)	31.5 ± 1.76	37.8 ± 0.81	32.8 ± 1.58	33.7 ± 1.32
DWOOD (%)	0.3 ± 0.11	1.9 ± 0.21	1.1 ± 0.26	3.5 ± 0.41
LWOOD (%)	4.6 ± 1.12	14.8 ± 1.22	8.8 ± 1.40	22.1 ± 1.42
LTD (cm)	1.4 ± 0.31	1.9 ± 0.14	1.3 ± 0.23	1.9 ± 0.19
VGHGT (cm)	67.5 ± 2.81	86.8 ± 1.64	65.5 ± 1.94	76.5 ± 1.24
BIOMAS	27.9 ± 2.37	43.5 ± 0.95	27.8 ± 1.49	40.5 ± 1.24
CVLTD (cm)	0.9 ± 0.16	1.0 ± 0.04	0.8 ± 0.09	0.9 ± 0.05
CVVGHGT (cm)	0.2 ± 0.02	0.4 ± 0.02	0.3 ± 0.02	0.4 ± 0.02
CVBIOMAS	0.5 ± 0.05	0.5 ± 0.02	0.5 ± 0.03	0.6 ± 0.02

percent coverage of live and dead shrubs and live grass (Table 3). A Kruskal-Wallis test indicated a significant difference among means, despite a high degree of similarity in habitat use by the four groups ($P < 0.001$). Predated and fledged nests had significantly different mean discriminant scores according to pairwise Sign tests ($P < 0.001$). Predated nests did not differ from either Great Plains Rat Snakes ($P = 0.445$) or Eastern Racers ($P = 1.00$) while fledged nests differed from both snake groups ($P = 0.001$ and $P = 0.003$, respectively). In comparison to successfully fledged nests, predated nests and snakes were found in habitat areas with more dense vegetation, primarily live and dead shrubs and live grass and forbs, as well as fewer rocks (Figure 1).

DISCUSSION

As other studies have shown, snakes may be important predators of bird nests in the tallgrass prairie (Klug, 2005). The results from this study concluded that nest predation was nonrandom and support an earlier study on KPBS that found the daily probability of a nest being taken by a predator was 104 times greater for old-field nests than for prairie nests (Zimmerman, 1984). Moreover, daily nest predation rates increase with decreasing prairie fragment size (Herkert et al., 2003). The results from this study were more telling: the risk of nest predation was higher in habitats with an increase in vegetation cover and decrease in rock cover. The function generated in this study may describe an easily observable habitat gradient in the Flint Hills from dense shrubby draws at low elevation to sparse rocky outcrops at higher elevation. The function may also be a gradient of succession from frequently burned prairie to fire-suppressed regions dominated by shrub islands. Further, the results from this study emphasized that the differential nesting success observed in numerous other studies of prairie ecosystems strongly correlates with the degree of habitat similarity between grassland bird nests and two common snake species. Because mammals were responsible for a relatively small percentage of predation events, benefits to grassland bird populations resulting from a reduction in snake predation should outweigh any increases in mammal predation in annually burned sites.

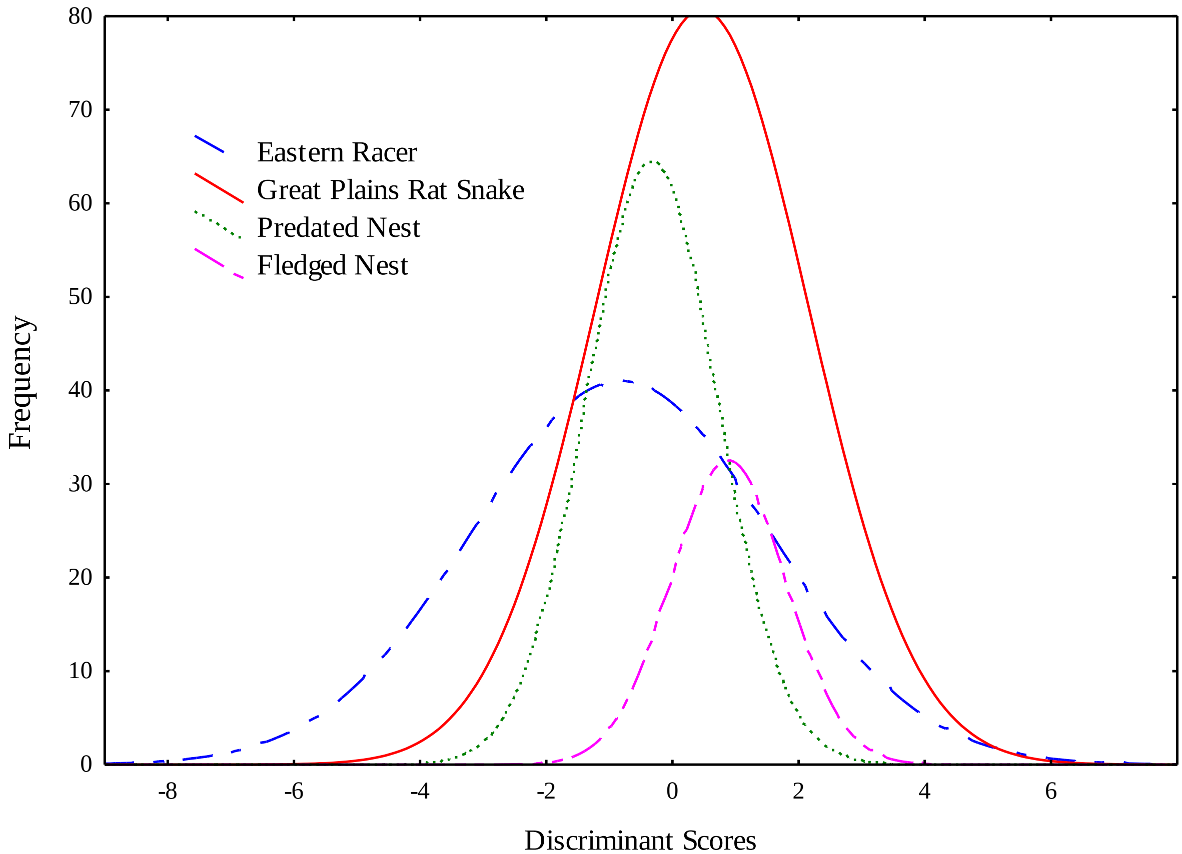
Table 3. Summary statistics for a discriminant function analysis and the linear correlations between measured variables and the discriminant function. Significance level indicated $P < 0.01$.

Statistic	Discriminant function
Eigenvalue	0.312
Chi-square test	30.27*
Degrees of freedom	15
Linear correlation (*r*) with:	
DWOOD	-0.335
LGRS	-0.294
LWOOD	-0.286
ROCK	0.192
LFORB	-0.167
CVVGHGT	-0.125
VGHGT	0.096
CVBIOMAS	0.094
CVLITTER	0.069
LTD	0.056
DFORB	0.047
DGRS	0.041
BIOMAS	-0.036
LITTER	0.007

An important limitation of this study was that only two snake species were studied in significant number to be included in the statistical analysis. Researchers at KPBS have observed Common Kingsnakes (*Lampropelitis getula*) actively predating Dickcissel nests. Because only one Common Kingsnake was captured for the radio telemetry study, no conclusions on habitat use could be made for this potentially important predator (P. Klug and J. Rivers, pers. com.).

Many studies have found predation rate to be independent of nesting density (von Haartman, 1971; Gottfried, 1978; Zimmerman, 1984). Consequently, scientists believe that snakes find nests by random encounters rather than actively selecting habitat with higher nesting density (Best, 1978). Strategic management practices that remove habitat types frequently used by snakes may therefore reduce the potential for random encounters between nests and snake predators. The results of this study suggest that management techniques that minimize invasion of shrubs and dense vegetation reduce the habitat for Eastern Racers and Great Plains Rat Snakes, thereby decreasing nest predation and promoting grassland bird population recovery. However, efforts first should be made to determine how snakes rely on these habitats. Otherwise, attempts to promote grassland bird recovery may unintentionally remove a habitat type vital to the well being of these snakes, which are equally valuable members of this endangered ecosystem.

Previous studies have suggested that annually burned, moderately cattle-grazed pastures support a greater abundance of grassland birds than annually burned nongrazed habitats (Klute et al., 1997). A study by Lueders et al. (2006) suggested that grassland bird abundance was greater in habitats managed with moderate cattle grazing without fire than habitats under a regime of low bison grazing combined with fire. However, the study did not evaluate nesting



High shrub, grass, and forb cover
Low rock cover

Low shrub, grass, and forb cover
High rock cover

Eastern Racer	Predated nest	Great Plains Rat Snake	Fledged nest
-0.44	-0.34	0.38	0.84
-8.35 – 2.84	-3.23 – 1.91	-7.70 – 4.72	-0.70 – 3.17

Figure 1. Normal curves of discriminant scores from an analysis of predated and fledged nests with snake groups added relative to nest space. Median and range of discriminant scores of groups that share common underlines are not significantly different according to pairwise Sign tests ($P < 0.01$)

success of grassland birds in these habitats. Ultimately, recovery of these grassland bird species will not rely largely on preservation of pristine tallgrass prairie. Instead, the reproductive value to grassland birds of altered landscapes will determine the long-term stability of these populations. For these reasons, unraveling the complex interactions of grassland birds and nest predators is vital to devising alternative ranching techniques that support grassland bird population recovery in the Flint Hills.

ACKNOWLEDGMENTS

I would like to thank my mentors Page Klug and Professor Kimberley With, Professor Howard Reinert for guidance in statistical analysis and editing of this paper, and Professors Jeffery Erickson and Amanda Norvell for advice in completing this work. Funding for this research was provided by the National Science Foundation and the Kansas State University Division of Biology.

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