

## Habitat Use and Activity of Prairie Kingsnakes (*Lampropeltis calligaster calligaster*) in Illinois

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**ABSTRACT.**—The natural history of Prairie Kingsnakes (*Lampropeltis calligaster calligaster*) is largely unknown because of their secretive nature. We radio-tracked 10 adult Prairie Kingsnakes (six males, four females) for one complete active season to determine activity patterns and habitat use in an area in Illinois that included forest, grassland, agricultural fields, and roads. The active season extended from approximately April to mid-October. Home ranges of males averaged over four times larger than those of females and usually included the individual's hibernation site. Males and females had similar activity levels throughout the season, with no differences in frequency of movement or distance traveled per move. Snakes were underground at least 73% of the 574 times they were relocated, suggesting most activity is nocturnal. Collectively, kingsnakes completely avoided agricultural fields and showed a preference for grasslands, but females were strongly associated with grassland edges along roads. This association with roadside edges, and failure of Prairie Kingsnakes to cross roads, suggests that roads may be barriers to movement—an observation consistent with recent evidence that roads can be barriers to movement, negatively affecting snakes in ways other than via direct mortality.

Many North American snake populations are declining because of habitat loss (Dodd, 1987; Greene, 1997). In the Midwestern United States, natural habitat has largely been replaced by agriculture, which is generally unsuitable for snakes (Durner and Gates, 1993; Keller and Heske, 2000). Knowledge of habitat associations are crucial for conservation and to identify the role of snakes in interspecific interactions, such as nest predation (e.g., Thompson et al., 1999; Thompson and Burhans, 2003; Weatherhead and Blouin-Demers, 2004). For many snake species, however, even their basic natural history, including habitat selection, is unknown because of snakes' secretive behavior (Seigel et al., 1987; Seigel and Collins, 1993). Here we present results of a study on activity patterns and habitat use by Prairie Kingsnakes (*Lampropeltis calligaster calligaster*), a species that is poorly studied despite occurring throughout the Midwest (Ernst and Ernst, 2003) and being large enough that it should be easily observed.

Fitch (1978) provided a preliminary ecological description of Prairie Kingsnakes from analysis of 255 captures and recaptures over 30 yr in Kansas. Prairie Kingsnakes are considered to be a grassland species and males reportedly range more widely than females, although Fitch (1978)

recaptured too few individuals to calculate home ranges. We used radio telemetry to study kingsnakes intensively. Our first goal was to quantify habitat use by Prairie Kingsnakes relative to available habitat. Our second goal was to add to conclusions regarding Prairie Kingsnake natural history reached by Fitch (1978) from capture data. We evaluated habitat selection at both macro- (e.g., grassland, edge, forest) and micro- (i.e., structural features) scales. We paid particular attention to two anthropogenic landscape features—edges and roads. Edges between forest and open habitats are apparently preferred by some snakes because of superior thermal properties of edges (e.g., Blouin-Demers and Weatherhead, 2001), whereas roads are detrimental to snakes, either because snakes are killed when crossing roads (e.g., Rosen and Lowe, 1994; Ashley and Robinson, 1996) or because roads are barriers to movement (Shine et al., 2004).

### MATERIALS AND METHODS

**Study Area.**—We conducted the study from April 2004 to May 2005 at the 6698-ha Jim Edgar Panther Creek (JEPC) State Fish and Wildlife Area, in Cass County, Illinois. Forests, grasslands, and croplands account for approximately 36, 37, and 25% of the area, respectively. Grasslands at JEPC are divided into 41 units that undergo prescribed burns on a four-year rotation. Forests at JEPC are burned more

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sporadically. Roads fragment JEPC and often separate burn units.

**Radiotelemetry.**—We captured Prairie Kingsnakes opportunistically and under cover sheets from April to July 2004. Cover sheets were metal sheets of varying sizes (mean =  $2.73 \times 0.759$  m) or  $3.05 \times 1.58$  m or  $2.44 \times 1.98$  m plastic sheets anchored by ground staples (Kjoss and Litvaitis, 2001). Upon capture, snakes were sexed by presence of hemipenes and marked by subcutaneous injection of a PIT tag. Individuals large enough to carry a transmitter (a transmitter was  $< 4\%$  of a snake's mass) were retained for telemetry. Transmitters (Holohil Systems Ltd., Carp, Ontario, Canada) weighed 5 g (Model SB-2T; battery life of 10 months at  $25^\circ\text{C}$ ) or 9 g (Model SI-2T; battery life of 12 months at  $25^\circ\text{C}$ ). Transmitters were surgically implanted by veterinarians, using methods of Reinert and Cundall (1982) and Blouin-Demers and Weatherhead (2001), into six males and four females. Snakes were released at their point of capture one to four days following surgery.

We tracked snakes for periods ranging from 14–193 days (avg = 120 days) from 10 May to 16 October 2004 and 29 March to 3 May 2005 to complete one annual cycle. We located each snake every 48 h until it moved to the hibernaculum area and ceased most activity. We resumed tracking when snakes emerged from hibernation. Tracking occurred between 0550 and 2022 h to incorporate variation in activity and habitat use that may have occurred throughout the day. Upon locating a snake, we recorded its location, position (i.e., belowground or aboveground microhabitat), and behavior (i.e., concealed, basking, traveling, or underground). We considered that an individual had changed locations if it was  $> 2$  m from its previous location. We recorded a snake as being underground when the snake could not be seen from any angle and the transmitter signal was noticeably weaker at the lowest gain setting than for snakes that were aboveground. When snakes were not seen, but signal strength was ambiguous, we recorded the position (above or belowground) as unknown. All snake locations were flagged and mapped using GPS.

We calculated home ranges as 100% minimum convex polygons (MCP; Jennrich and Turner, 1969) and 95% fixed kernels (Worton, 1987) in ArcView GIS 3.3. MCP is the most commonly used method for calculating home ranges (Tinkle et al., 1962; Schoener, 1981; Macartney et al., 1988), whereas the kernel estimator shows areas of concentrated activity (Worton, 1987). For both estimators, we included all positions observed except those at the hibernaculum immediately before fall entry, after spring emergence, or recorded when

snakes were commuting to or from hibernacula. We calculated home ranges only for the eight snakes that we tracked for  $> 90$  days.

**Characterization of Habitat Associations.**—At each snake location, excluding locations where snakes were traveling ( $\sim 1\%$  of all locations), we classified macrohabitat as forest, grassland, agricultural field, natural edge, or artificial edge. Natural edges were 15 m on either side of the interface between grassland and forest (73%), grassland and open areas (water or bare ground; 19%), or forest and water (8%), whereas artificial edges were interfaces between natural and anthropogenic habitat, primarily ( $> 97\%$ ) edges between grassland and roads. We quantified available habitat by selecting a random location at every other snake location by walking a randomly determined distance between 10 and 100 paces in a randomly selected direction. We then used compositional analysis (Aebischer et al., 1993) to assess macrohabitat preferences and to determine whether snakes used macrohabitat nonrandomly. Where proportions of "used" habitats were zero, we substituted a value of 0.01 (Aebischer et al., 1993).

We quantified microhabitat (i.e., vegetation structure) at each snake and random location. Snake sites were characterized about one week after they were located. Microhabitats used more than once (assumed to be the same if  $< 5$  m apart) were included only once in analyses. We initially measured 28 structural variables within circular plots, using methods and variables from Blouin-Demers and Weatherhead (2001). Because 23 variables occurred at fewer than 50% of snake and random locations, we used only the five remaining variables for analysis (distance to nearest sapling, distance to nearest edge, percent of grass cover, percent of herbaceous cover, mean vegetation height). We used linear discriminant function analysis (DFA) to identify differences in microhabitat for male and female snakes and random locations. Proportional data were arcsine-transformed and other data were log-transformed when necessary to achieve normality. Means throughout are given  $\pm 1$  SD.

## RESULTS

**Natural History.**—Several snakes hibernated in the same general area, such as a 30-m length of creek bank, but none shared hibernacula. One hibernaculum was in a forest-grassland edge and seven were in grasslands, three of which were within 2 m of a creek bank. Although Prairie Kingsnakes reportedly use road embankments and rock ledges for their hibernacula (Smith, 1961; Fitch, 1978), at JEPC they used

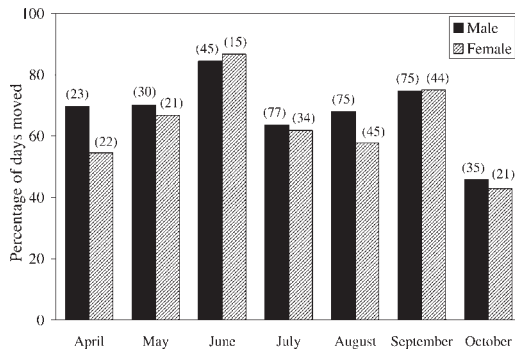


FIG. 1. Percentage of times each month that radio-tracked male and female Prairie Kingsnakes moved more than 2 m from their previous location. Sample sizes are given in parentheses.

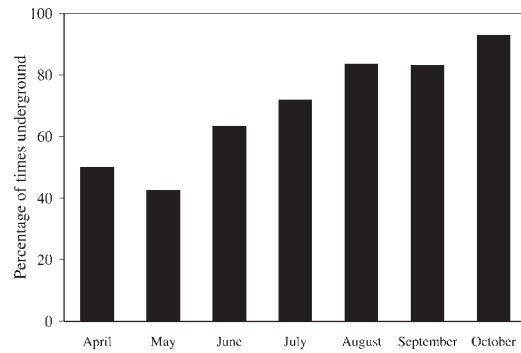


FIG. 2. Percentage of times each month that Prairie Kingsnakes were underground when located.

mammal burrows indistinguishable above-ground from burrows used during active months. Movements toward hibernacula occurred between mid-September and mid-October, with most activity stopping in mid-October. Exact dates that snakes permanently entered hibernacula were not determined, but all occurred after mid-October. Five of eight individuals hibernated within their home ranges. The other three snakes, a male and two females, moved distances of 68, 505, and 962 m, respectively, from their MCP home ranges to hibernate.

Three transmitters failed over winter. Two of the remaining five snakes emerged from hibernation before tracking resumed on 29 March. The other three snakes emerged between 31 March and 7 April. All snakes returned to their home ranges from the previous year. Male home ranges averaged 3–4 times larger than female home ranges (MCP: male =  $8.3 \pm 6.5$ , female =  $2.4 \pm 1.1$  ha; 95% kernels: male =  $11.1 \pm 8.6$ , female =  $2.5 \pm 1.2$  ha), but variance between the sexes was not significant (MCP and 95% kernels: Mann-Whitney *U*-test,  $U = 3.0$ ,  $P = 0.18$ ). Home-range size was not affected by how long snakes were tracked ( $N = 8$ ,  $r^2 = 0.02$ ,  $P = 0.77$ ).

A creek intersected home ranges of two snakes but was not a barrier to movement because snakes were frequently located on opposite sides of the creek. In contrast, roads may have affected movement. A portion of the home range of every snake, for which home ranges were mapped, was bounded by a road (within 15 m for six snakes and 30 m for two snakes). We documented only a single instance of a snake crossing a paved road, which occurred when the snake moved to its hibernaculum. Only one snake had a road bisect its range. Because we located the snake 22 times

under the bridge where the road crossed a creek, however, we suspect the snake crossed under the road rather than over it.

Overall, males were slightly more active than females across much of the season (Fig. 1), changing locations on 248 of the 360 (68.9%) snake-days of monitoring compared with 137 of 202 (63.4%) snake-days for females, but this difference in activity was not significant (Mann-Whitney *U*-test,  $U = 18.0$ ,  $P = 0.41$ ). Males and females also did not differ in distances traveled per move (males =  $61.5 \text{ m} \pm 60.8$ ,  $N = 268$ ; females =  $62.8 \text{ m} \pm 88.9$ ,  $N = 139$ ;  $F_{1,405} = 0.03$ ,  $P = 0.86$ ).

**Habitat Associations.**—Snakes were underground at least 73% of the 574 times they were relocated, suggesting they moved at night. Use of underground locations increased through the season from about 44% of locations in April and May to > 90% in October (Fig. 2).

Macrohabitat was determined for 146 random, 359 male, and 207 female locations. Results from compositional analysis show the use of macrohabitats did not differ significantly from random for males ( $\Lambda = 0.134$ ,  $F_{3,3} = 6.48$ ,  $P = 0.08$ ), females ( $\Lambda = 0.015$ ,  $F_{3,1} = 22.2$ ,  $P = 0.15$ ) or both sexes combined ( $\Lambda = 0.403$ ,  $F_{3,7} = 3.45$ ,  $P = 0.08$ ). Rank order of habitat use for males was grasslands > natural edges > artificial edges > forests. Rank order for females was artificial edges > grasslands > natural edges > forests. The rank order for males and females combined was grasslands > natural edges > artificial edges > forests, with grasslands used significantly more than forests ( $t = -2.83$ ,  $df = 9$ ,  $P = 0.02$ ). Repeating these analyses with the two edge types combined, male habitat use remains qualitatively the same. Female habitat use, however, becomes significantly nonrandom ( $\Lambda = 0.014$ ,  $F_{2,2} = 71.1$ ,  $P = 0.01$ ) with edges used more than forest ( $t = -10.0$ ,  $df = 3$ ,  $P = 0.002$ ) and grasslands intermediate. Also, males and females com-

bined used habitat nonrandomly ( $\Lambda = 0.477$ ,  $F_{2,8} = 4.39$ ,  $P = 0.05$ ), with grasslands used significantly more than forest ( $t = -2.57$ ,  $df = 9$ ,  $P = 0.03$ ) and edges intermediate.

We characterized microhabitat at 146 random locations, 208 locations of males, and 102 locations of females. DFA produced three functions that separated males, females, and random locations. The first function explained 87.3% of the variation among groups and based on factor loadings, can be interpreted as a gradient of distance from edge ( $-0.88$ ). Distances between group centroids indicated that males and females used microhabitat differently ( $F_{5,499} = 5.71$ ,  $P < 0.001$ ), with males found further from edges. Male use of microhabitat did not differ from random ( $F_{5,499} = 0.88$ ,  $P = 0.49$ ), whereas female use was significantly different from random ( $F_{5,499} = 4.67$ ,  $P < 0.001$ ). Consistent with the macrohabitat analysis, roads appeared to affect males and females differently. Roads were the nearest edge for males for 28.8% of locations compared to 45.1% for females. Mean distance to the nearest road was  $32.2 \pm 29.3$  m for males and  $12.3 \pm 11.3$  m for females.

#### DISCUSSION

Despite tracking a small number of snakes for only one annual cycle, several general patterns emerged and other patterns warranting further investigation were detected. Prairie Kingsnakes appear to hibernate individually. This finding could reflect an abundance of good hibernation sites but may also be related to diet. Because Prairie Kingsnakes prey on other snakes (Klimstra, 1959; Fitch, 1978), they may actively avoid each other and be avoided by other species.

Fitch (1978) concluded that Prairie Kingsnakes were scarce throughout their range, although he conceded that the snakes' secretive nature probably meant his estimates of abundance were low. Our observations confirm that Prairie Kingsnakes will be difficult to sample with conventional methods such as funnel traps and cover boards (Fitch 1978). Snakes were normally underground when relocated, sometimes remaining in the same location below ground for more than two weeks. Given a reasonable level of activity, changing locations 42–87% of the time between relocations, but few sightings, it seems likely that Prairie Kingsnakes were primarily active at night. Also consistent with this interpretation was the pattern of increased use of underground refuges as the season progressed. Aboveground temperatures become more favorable for nocturnal activity, and thermal profiles of subterranean refuges presumably improve over the season. If diurnal

activity is largely restricted to spring and fall (Ernst and Ernst, 2003), opportunities for direct sightings will be rare.

Croplands accounted for 25% of total land area at JEPC but were completely avoided by kingsnakes, consistent with the view that agricultural land is unsuitable for many snake species (Durner and Gates, 1993; Keller and Heske, 2000). Prairie Kingsnakes generally preferred grasslands, but edges affected how snakes used grasslands, particularly edges created by roads bisecting grasslands. Males appeared to avoid road edges, whereas females showed an affinity for these edges. That affinity, however, might be best interpreted as roads being a barrier to movement (e.g., Shine et al., 2004), causing females to stop moving when they encountered a road edge. This interpretation is consistent with Prairie Kingsnake home ranges butting up to, but not crossing, roads.

If further work confirms that roads restrict movement by Prairie Kingsnakes, the challenge will be to design research to quantify costs (e.g., finding food, mates, etc.) resulting from restricted movement. For some snake species, direct costs of roads (i.e., road kills) might be mitigated in part by roads creating artificial edges useful for thermoregulation (e.g., Blouin-Demers and Weatherhead, 2001). Because Prairie Kingsnakes live in grasslands where access to preferred temperatures should be easier than for forest species, however, there seems likely only to be costs associated with roads bisecting their habitat. Because natural habitat in the midwestern United States is replaced by agriculture and urbanization, large tracts of road-free grassland habitat is needed for conservation of Prairie Kingsnakes.

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