HABITAT USE AND SEASONAL ACTIVITY PATTERNS OF THE GREAT PLAINS RATSNAKE (*ELAPHE GUTTATA EMORYI*) IN CENTRAL TEXAS

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ABSTRACT—The Great Plains ratsnake (*Elaphe guttata emoryi*) is a poorly known species of the central and southern United States. We captured 24 Great Plains ratsnakes over 3 years at Fort Hood, Texas, and used radiotelemetry to determine habitat use and seasonal activity patterns of five adult male snakes. Great Plains ratsnakes showed an affinity for human-made structures with the majority of locations in rock structures used to control erosion. When compared to random sites, snake-selected sites were in areas of increased structure with more trees and ground cover and closer to habitat edges. Despite Great Plains ratsnakes having been documented preying on nests of arboreal birds, tracked snakes were found almost exclusively at or below ground level. Snakes were active year round and did not exhibit distinct hibernation times or sites. Snakes exhibited a bimodal pattern of activity with peaks in late spring and autumn, most likely due to temperature constraints.

RESUMEN—La serpiente (*Elaphe guttata emoryi*) es una especie muy poco conocida de la parte central y sur de los Estados Unidos. Capturamos 24 *E. g. emoryi* en Fort Hood, Texas, durante 3 años y usamos radiotelemetría en cinco serpientes macho adultas para determinar su uso de hábitat y su actividad estacional. Las *E. g. emoryi* mostraron afinidad hacia estructuras hechas por humanos con la mayoría de las ubicaciones en estructuras de rocas hechas para el control de erosión. Al comparar con lugares al azar, los lugares elegidos por las serpientes estuvieron en áreas con mayor estructura, más árboles, más cobertura y las más cercanas a los bordes de hábitat. A pesar de que *E. g. emoryi* ha sido documentada acechando a los nidos de pájaros arbóreos, las serpientes rastreadas fueron encontradas casi exclusivamente a nivel del suelo o a nivel subterráneo. Las serpientes estuvieron activas todo el año y no exhibieron lugares o tiempos específicos para invernar. Las serpientes mostraron un tipo de actividad dual con picos al final de la primavera y otoño, lo más probable debido a restricciones de temperatura.

Many species of snakes are declining in abundance, and habitat loss is believed to be a major contributing factor (Gibbons et al., 2000). Conservation efforts often are hindered by a paucity of information regarding habitat requirements of species. Habitat selection affects many aspects of ecology of snakes including thermoregulation (Blouin-Demers and Weatherhead, 2002), selection of nest site (Blouin-Demers et al., 2004; Cunnington and Cebek, 2005), predator avoidance (Duvall et al., 1985; Shine et al., 2000), food availability (Heard et al., 2004), and predator-prey interactions (Weatherhead and Blouin-Demers, 2004). Our goal was to conduct a pilot study of habitat use and seasonal activity of the Great Plains ratsnake (*Elaphe guttata emoryi*), a poorly known species of the central and southern United States. We focused particularly on how the snakes use habitat in a human-modified landscape and the implications of habitat use for importance of Great Plains ratsnakes as avian nest predators.

Great Plains ratsnakes range from southwestern Illinois to southeastern Colorado and from eastern New Mexico to northern Mexico. They are in a wide variety of habitats although often associated with rocky structures and caves (Tennant, 1985; Werler and Dixon, 2000). Currently, Great Plains ratsnakes are considered a subspecies of corn snakes (*Elaphe guttata*), although recent phylogenetic analyses suggests they should be classified as a separate species (Burbrink, 2002).

Although little is known about natural history of corn snakes generally, or Great Plains ratsnakes in particular, corn snakes (*Elaphe guttata*

guttata) are known to prey on a variety of species of birds (Phillips and Gault, 1997; Miller, 2002). Great Plains ratsnakes have been documented taking the eggs and incubating female of the golden-cheeked warbler (*Dendroica chrysoparia*), a federally listed endangered species (Stake, 2001). Here we attempt to acquire information on natural history of a poorly studied species of snake and provide data that potentially could be important in efforts to conserve an endangered species of bird.

Materials and Methods—We conducted this study July 2004–October 2006 while conducting a more extensive study of Texas ratsnakes (*Elaphe obsoleta lindheimeri*) on Fort Hood, an 88,500-ha military base in Bell and Coryell counties, Texas. Topography of Fort Hood is characterized by flat-top mesas and bottomlands. Most of our work was conducted in bottomlands, in habitat comprised of grasslands and oak savannahs (*Quercus*). Our study area was on the west side of Fort Hood in an intensive military training area. Numerous human-made structures were present on the landscape including rock gully plugs and juniper (*Juniperus*) brush piles. Gully plugs are crushed-rock barriers placed in drainages to control erosion and to allow maneuvering by heavy machinery. On our study site, most gully plugs were 7–8 m wide and were 20–80 m in length. Rocks used to construct gully plug were fairly uniform in size and averaged ca. 25 cm in diameter. Brush piles varied from a few meters to several hundred meters in length and were created when junipers were cleared by bulldozers from savannah areas to improve laser targeting of military equipment or to improve habitat for endangered species of birds.

Great Plains ratsnakes were caught opportunistically by hand throughout the year while we were searching for Texas ratsnakes. We weighed, measured snout–vent length, and determined sex of each snake by gently probing for hemipenes. Snakes were considered to be juveniles if they were too small to determine sex with an adult size probe (ca. 1.5 mm diameter). All snakes were marked by subcutaneous injection of a passive-integrated transponder (PIT) tag. Great Plains ratsnakes were chosen for the radiotransmitter portion of the study if the transmitter weighed $<2.5\%$ of body mass. Mass of transmitter was 9 and 13 g with batteries lasting 12 and 24 months, respectively (Model SI-2T, Holohil Systems, Inc., Carp, Ontario, Canada).

Transmitters were implanted using the surgical technique described by Reinert and Cundall (1982) as modified by Blouin-Demers and Weatherhead (2001). Snakes were transported to a veterinary clinic, anesthetized using isoflurane gas, and a transmitter was inserted into the body cavity and sutured to a rib to prevent migration. The flexible antenna was inserted subdermally, extending toward the head of the snake. After surgery, snakes were injected with sterile fluids (0.9% lactated Ringer's solution at a dosage of 50 mL/kg) and gentacimin sulfate (2.5 mg/kg) to prevent infection. Snakes were held in captivity and monitored for 3 days following surgery, given another dose of antibiotic, and then released at location of capture. Data collection on habitat use and activity did not begin until 7 days post-surgery to allow a transmitter-acclimation period. We relocated snakes about every 48 h during March–November and every 7 days during December–February. Date, time, UTM coordinates, type of substrate, and behavior of snake were recorded at each location.

Habitat measurements were taken at every other new location. At every other location at which habitat was quantified (i.e., every fourth location overall), we also quantified availability of habitat at a random location. Random locations were chosen by determining a UTM coordinate from a random distance (10–200 m) at a random bearing from the original location of the snake. We used methods and variables similar to those used by Blouin-Demers and Weatherhead (2001:Table 1) that characterized distance to cover (rocks and logs), cover density, distance to trees, and tree density. Canopy height was estimated using a clinometer. Ground cover and canopy cover were estimated using a sighting tube with crosshairs at one end (Winkworth and Goodall, 1962). For ground cover we aimed the sighting tube at 50 random locations within 2 m of the snake/random location and recorded type of substrate located at the crosshairs. These values were doubled to estimate percent cover of each substrate type. Canopy cover also was estimated using a sighting tube in which number of canopy hits were recorded out of 20 random sightings. Distance to edge was calculated as distance to the nearest canopy break >3 m in diameter. Locations used more than once by a snake were only included once in microhabitat analysis. We did not include sites in which we found snakes actively traveling to avoid instances where snakes were retreating in response to our presence, and also to remain consistent with previous studies (Reinert, 1984; Blouin-Demers and Weatherhead, 2001).

We calculated size of home range using minimum-convex polygons with Hawth's Analysis Tools (http://www.spatialecology.com/htools) in ArcMap 9.2. We compared microhabitat characteristics between snake-selected and random sites using two-sample *t*-tests and MANOVA in NCSS (Number Cruncher Statistical Systems, Kaysville, Utah). Our primary analysis used pooled habitat locations from all snakes. Wilk's lambda was used to determine if snake-selected sites differed from random sites. Individual snakes represented 12–28% of total locations. In addition, we ran separate ANOVAs with mean values for individual snakes for each microhabitat variable to control for pseudoreplication and to assure that one snake was not unduly biasing the group mean. We ran correlation tests on pairs of variables and found that none of the variables were highly correlated (all $r \leq 0.47$). Means are presented ± 1 *SE*.

Results—We captured 5 adult female, 15 adult male, and 4 juvenile Great Plains ratsnakes. Mean snout–vent length (cm) was 85.7 ± 3.39 for males, 78.8 ± 7.25 for females, and 40.7 ± 3.91 for juveniles. Mean length of tail (cm) was 16.6 ± 0.66 for males, 12.1 ± 1.02 for females,

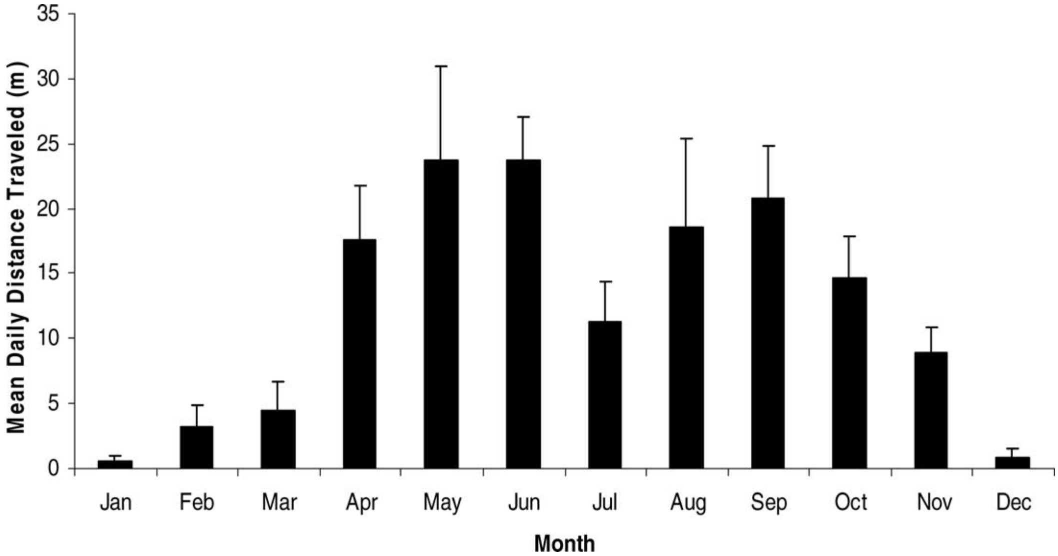

FIG. 1—Mean daily distance traveled per Great Plains ratsnake (*Elaphe guttata emoryi*; $n = 5$) averaged by month at Fort Hood, Texas, 2004–2006. Error bars denote standard error.

and 7.4 ± 0.55 for juveniles. Mean mass (g) was 252.1 ± 29.88 for males, 212.0 ± 76.30 for females, and 30.5 ± 8.63 for juveniles.

We implanted five males and two females with radiotransmitters. The signal of the first female was lost after 13 days of tracking and the transmitter of the second female was found with no associated carcass after 16 days of tracking. Loss of the signal could have been due either to mechanical failure of the transmitter or predation, although the second female was most likely preyed upon. Both females were lost after <10 relocations and so were not included in the analysis. The five males were tracked an average of 401 days/snake (range for individuals = 112–821), which yielded a total of 748 telemetry relocations (range for individuals = 55–298). Mean distance moved by snakes for data pooled across years varied among months, with peaks in May–June and September–October ($F = 2.04$, $P = 0.02$; Fig. 1). All snakes had reduced activity during colder months, but did not exhibit a prolonged period of hibernation nor did they enter distinct hibernacula. Size of home ranges determined by minimum convex polygon were 3.98–26.95 ha with a mean of 10.17 ha. There was no overlap in home range among the five individual snakes.

Thirty-six locations were removed from habitat analysis because the snakes were traveling. Of the remaining 712 locations, 505 (70.9%) were in human-made structures; gully plugs (56.7%), brush piles (13.1%), and mulch piles (0.6%). Other sites used included underground (13.9%), in grass or litter (6.2%), under logs (4.6%), under rocks (3.6%), and in brush (1.1%). Percentage of use of gully plugs by individuals was 14.8–69.4% of total locations with a mean of 44.8% (±10.7). In contrast, only 7.1% (5 of 70) of randomly selected habitat sites were located in gully plugs. With the exception of one snake found once 1 m high in a shrub, all other locations were on or below ground. Of all sites, two-thirds were used more than once and snakes stayed an average of 4.5 (±0.5) days at a site during the active season (April–November) and 29.6 (±2.1) days during winter (December–March). Retreat sites in winter were similar to those in summer, including use of brush piles and gully plugs.

Including only novel locations, microhabitat analysis was conducted on 129 snake-selected sites and 70 random sites. MANOVA indicated that the microhabitat of snake-selected sites differed significantly from that of random sites (Wilk's $\Lambda = 0.59$, $F = 6.30$, $P = <0.001$; Table 1), with snakes using sites with more structure (e.g., more trees, cover, litter) and closer to habitat edges. Similarly, most microhabitat variables differed between snake-selected and random

TABLE 1—Habitat characteristics at selected sites and random sites in a study of the Great Plains snake (*Elaphe guttata emoryi*) at Fort Hood, Texas, 2004–2006. Test statistic and *P*-value from MANOVA includes all locations of snakes. P_{IND} indicates *P*-value from analysis with mean values for individual snakes.

Variable	Use by snakes		Random				
	Mean	*SE*	Mean	*SE*	*F*	*P*	P_{IND}
Canopy height (m)	3.48	0.36	0.91	0.32	22.92	<0.01	<0.01
Canopy closure	2.95	0.39	1.07	0.41	15.71	<0.01	0.03
Distance to cover (m)	7.15	0.98	18.12	1.47	67.89	<0.01	<0.01
Distance to tree (m)	8.35	0.90	15.95	1.41	38.79	<0.01	0.01
Number of large trees	2.54	0.40	1.07	0.40	8.86	<0.01	0.04
Number of small trees	4.91	0.63	1.63	0.52	18.85	<0.01	0.01
Rocks (% ground cover)	16.79	2.48	7.23	2.62	4.04	0.05	0.25
Litter (% ground cover)	8.70	1.45	3.94	1.62	6.90	0.01	0.43
Logs (% ground cover)	3.89	0.75	0.69	0.33	12.36	<0.01	<0.01
Grass (% ground cover)	28.73	2.37	42.54	3.37	14.56	<0.01	0.07
Shrubs (% ground cover)	5.37	1.12	0.71	0.44	10.99	<0.01	0.05
Bare ground (%)	11.70	1.19	22.16	2.79	12.93	<0.01	0.02
Herbs (% ground cover)	14.41	1.35	20.80	1.83	15.56	<0.01	0.05
Woody ground cover (%)	10.30	1.59	1.86	0.79	19.62	<0.01	0.04
Number of woody stems	10.20	1.59	3.36	1.40	10.15	<0.01	0.18
Distance to edge (m)	13.88	2.25	33.02	4.65	30.11	<0.01	0.01

sites when we used mean values from individual snakes (Table 1).

To determine if habitat preferences reflected the location of structures such as gully plugs, or whether snakes preferentially used structures that were located in habitats with more structure, we ran a separate MANOVA with locations in human-made structures removed. Again, snake-selected sites differed significantly from random sites (Wilk's $\Lambda = 0.74$, $F = 2.92$, $P = <0.001$, $n_{[snake]} = 74$, $n_{[random]} = 70$) with snake-selected sites in areas with more trees and cover.

DISCUSSION—Our results are based primarily on five male Great Plains ratsnakes, and although those individuals were studied intensively, insights we obtained must be interpreted cautiously. Nonetheless, several patterns emerged that warrant further study. Most apparent was the affinity of Great Plains ratsnakes for using human-made cover, particularly rock gully plugs. Use of similar rocky structures associated with road construction or to control erosion has been documented for a variety of species of snakes (Shine et al., 2004; G. D. Wylie et al., in litt.; P. Weatherhead, pers. observ.). Use of gully plugs by Great Plains ratsnakes was not simply a consequence of lack of other cover because Texas ratsnakes that we tracked in the same study area used gully plugs <2% of the time (J. Sperry, unpublished data).

Human-made structures such as gully plugs might improve habitat quality for Great Plains ratsnakes by providing the type of cover they prefer but that is otherwise limited in availability. Alternatively, these structures could create ecological traps by attracting snakes closer to roads (where most gully plugs were located), thereby increasing road mortality. An intensive survey of snakes on Fort Hood, completed prior to installation of gully plugs, captured only four Great Plains ratsnakes in 4 years (K. W. Johnson, in litt.). Using similar methods, we captured 24 Great Plains ratsnakes in 3 years. This change in number of captures could indicate the snake population has increased because gully plugs have improved the habitat. Alternatively, snakes might have been attracted to roads and, thus, are encountered more often, or factors unrelated to human alteration of the habitat could be involved. Further research is needed to examine effects of human-made structures on abundance and distribution of Great Plains ratsnakes as well as other species of snakes.

Identification of natural habitat used by Great Plains ratsnakes will require studying the snakes in areas without human-altered habitat. However, the microhabitat analysis indicated that snakes used the natural aspects of their habitat non-randomly. Habitat in the study area consisted of clumps of wooded vegetation in a matrix of grassland. Snakes preferred locations close to the edge of these clumps, whether they were in a clump or not. Preference for edge has been shown in black ratsnakes (*Elaphe obsoleta*) in Canada and Illinois, where the thermal heterogeneity in edges provides snakes the most flexibility for regulating their body temperatures behaviorally (Blouin-Demers and Weatherhead, 2001, 2002; Carfagno and Weatherhead, 2006).

Great Plains ratsnakes were active most of the year and did not hibernate. They exhibited a bimodal pattern of seasonal activity, with peaks of activity in early summer and again in autumn. This pattern is likely due to activity being constrained by the extremely hot temperatures in central Texas in July and August and cool temperatures in winter. In future studies, efforts to capture Great Plains ratsnakes are likely to be most productive if conducted in the spring and autumn.

Video monitoring of nests of two endangered, arboreal-nesting, species of birds on Fort Hood (Stake and Cimprich, 2003; Stake et al., 2004) documented only one instance of predation by Great Plains ratsnakes compared to 28 by Texas ratsnakes. We observed Great Plains ratsnakes in a tree in only one of 712 relocations. In contrast, in the same study area, Texas ratsnakes were in trees 33% of the time (J. Sperry, unpublished data). Our results suggest that the one video recording of predation by a Great Plains ratsnake on an arboreal nest was truly a rare event and that this species does not appear to be an important predator for the golden-cheeked warbler.

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