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Preliminary Observations of Habitat Use and Movements of the Eastern Massasauga Rattlesnake (*Sistrurus c. catenatus*)

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ABSTRACT. - **We used radiotelemetry to monitor 12 eastern massasauga rattlesnakes, *Sistrurus c. catenatus*, within Bruce Peninsula National Park (Ontario) for 419 days. The snakes exhibited non-random use of habitat, strongly associating with wetlands and coniferous forest, and avoiding open areas (roads, trails), open water, and mixed forest. Hibernation sites also occurred in wetland and coniferous forest habitat. By contrast, snakes were disproportionately captured in open areas, presumably because they are much more easily detected there. Daily movements by transmitter-equipped snakes were frequent (60% of the time), averaging 56 m per episode (N = 11; SE = 12.35). Activity ranges averaged 0.25 km^2 (N = 11; SE = 0.06), with females covering significantly smaller areas than males. The habitat use and movement data are used to make preliminary management recommendations.**

An understanding of the habitat requirements, activity patterns, and spatial distribution of a species is critical to informed ecological management. Such background knowledge is especially important for preservation of endangered species and the protection of populations threatened with extirpation. The eastern massasauga rattlesnake (*Sistrurus c. catenatus*) is considered threatened with extinction throughout its range and in many regions persists as small, relict populations. The only published field studies addressing habitat use and movement patterns of the subspecies have been conducted in the middle (northeastern Illinois, Wright, 1941) and most easterly (Pennsylvania, Reinert and Kodrich, 1982; Missouri, Seigel, 1986) portions of its range.

In this paper we present the preliminary results of a radiotelemetry investigation of the movements and habitat use of the eastern massasauga rattlesnake near the northern edge of its distribution.

METHODS

We captured rattlesnakes in Bruce Peninsula National Park (BPNP) near Tobermory, Ontario, from July through September 1989 and from May through November 1990. These snakes are part of the disjunct population that occurs along the western side of Georgian Bay and represents the northernmost distribution of this subspecies. Snakes were captured (or collected as roadkills) either while driving along roads or while searching suitable habitat on foot. Capture locations were mapped and map locations were recorded as Universal Transmercator (UTM) grid coordinates. All snakes captured were weighed, measured, sexed, and given a unique identification brand on their caudal scutes.

In 1990 we implanted temperature-sensitive radio-transmitters (Holohil Systems Ltd.) in five snakes (one female and four males) on 29 June and seven snakes (three females and four males) on 3 August. Transmitters weighed 9.5 g, representing less than 5% of the body weight of individual snakes (body weights ranged from 193.3 to 456.7 g). We followed implantation procedures first developed by Weatherhead and Anderka (1984). The only major difference in our surgical method was the use of a mask-inducted halothane gas anesthetic as opposed to a Ketaset injection. All 12 transmitter-equipped snakes were held in a warm environment with food (dead mice) and water ad libitum for seven days following surgery.

Following the post-operative recovery period, snakes were released at their point of capture. Once the snakes had been released we attempted to locate them daily until the end of August. Following the summer, we were only able to track the snakes intermittently, until the snakes were hibernating. As with capture locations, radio-tracking locations were mapped and recorded by UTM grid coordinates. Habitat used by the snakes was quantified using the Spatial Analysis System (SPANS, Tydac Technologies Inc.), into which data on the habitat composition of the park had been previously entered. The park habitat composition was determined through a combination of satellite imagery and ground truthing.

SPANS was also used to analyze movements between locations and to calculate activity ranges. Snake #48 is not included in calculations of averages because she appeared unhealthy and therefore her behavior may have been atypical. Note that for all analyses movements are assumed to be straight lines between two successive points, and thus are minimum estimates of the distances moved. All mean values are reported with standard errors (SE).

RESULTS

Fifty-six rattlesnakes were examined within the boundaries of BPNP during 1989 and 1990. Nearly one third (17) of all snakes seen in 1990 were encountered as roadkills. No snakes captured and marked in 1989 (17) were recaptured in 1990.

Transmitter-equipped snakes were located each day during the summer following their release except where equipment failure prevented locating them (five occasions). Overall, the five snakes implanted in June were tracked for a maximum of 50 d during the summer and the seven snakes implanted in August were tracked for a maximum of 19 d during the summer. This produced a total of 367 snake-days (i.e., days on which a snake was located) for the summer. At the end of August snake #48 was captured and her transmitter was removed. This individual had moved very little since being released and appeared to be unhealthy. Snake #356 was not found after the end of August and snake #27 was not found during the fall until he was at his hibernation site. For the remaining 9 snakes we obtained between 2 and 10 locations during the fall. For these 9 individuals (plus #27) their final fall location was their hibernation site.

The 367 snake-days of tracking during the summer produced 294 distinct locations and the 52 snake-days of tracking in the fall produced 52 distinct locations. We considered tracking locations as distinct when they were at least 5 m apart.

Habitat Use. —We used SPANS to estimate the area of the park comprised of each of seven general habitat types (Table 1). We determined the patterns of habitat use by the snakes by calculating the habitat composition within a 10 m radius of all capture points or all radio-tracking points. For the summer radio-tracking data we also calculated a weighted habitat composition by weighting the habitat composition of each radio-tracking point by the number of days a snake remained at that point (i.e., habitat types occupied for extended periods were weighted most heavily). The weighted analysis clarified the relative importance of specific habitats to the snakes. No weighted analysis was possible for the fall or hibernation sites since no snake was found at the same site more than once and, by definition, each snake has a single hibernation site.

From these analyses several patterns are clear. First, comparing the habitat around capture locations with the park habitat, snakes were cap-

TABLE 1. Habitat composition (% area) within Bruce Peninsula National Park and the composition (% area) of habitats where snakes were captured (1989 and 1990) and where snakes were radio-tracked (1990). Weighted and unweighted estimates of habitat composition are provided for radio-tracking data where weighting is based on the number of days a snake spent at each location.

		Capture		Radio-tracking data			
Habitat	Park	1989	1990	Summer (unweighted)	Summer (weighted)	Fall	Hibernation
Deciduous forest	11.98	0.00	12.49	4.55	12.04	6.35	0.00
Mixed forest	41.61	30.94	29.36	36.14	4.01	34.98	30.00
Coniferous forest	29.69	15.77	20.66	30.77	47.78	19.32	36.67
Open water	4.75	6.25	0.91	4.80	0.25	5.92	0.00
Wetlands	8.50	15.42	6.88	19.67	34.62	16.64	20.00
Meadows	2.61	3.13	0.00	2.47	0.51	0.00	0.00
Open areas	0.86	28.50	29.70	1.60	0.65	0.00	0.00

tured significantly more than expected by chance in open habitat (i.e., roads and trails, $X^2 = 89.5$ and 292.9, df = 6, both *Ps* < 0.001, 1989 and 1990, respectively; Table 1). The capture locations for snakes differed substantially between 1989 and 1990, with forest habitat (deciduous, coniferous, and mixed) being almost 16% more common in 1990. Second, the habitat composition from both unweighted and weighted summer radio-tracking points also differed from the park habitat ($X^2 = 76.0$ and 323.1, df = 6, both *Ps* < 0.001, Table 1). The pattern in both cases was for the snakes to prefer wetland habitat and avoid mixed forest (dominant tree species include; sugar maple, *Acer saccharum*, whitespruce, *Picea glauca*, white cedar, *Thuja occidentalis*, and balsam fir, *Abies balsamea*). These patterns were more pronounced using the weighted data. Also, the results for snake capture locations were very different from the results from summer radio-tracking ($X^2 = 280.2$, df = 6, *P* < 0.001 for weighted values). During the summer, radio-tracked snakes avoided both open areas and meadows (dominated by grasses, Gramineae spp.) and showed an association with wetlands. The specific wetland types frequented by the snakes were shore marshes, shrubby swamps (both dominated by various willow species, *Salix* spp., speckled alder, *Alnus incana*, rushes, *Juncus* spp., reeds, *Sparganium* spp., and sedges, *Carex* spp.) and fens (dominated by white cedar, tamarack, *Larix lariciana*, shrubby cinquefoil, *Potentilla fruticosa*, and sedges).

The fall and hibernation site habitat analyses indicate that the snakes remain in the same habitat they preferred in the summer. There was no significant difference between summer (unweighted) and fall habitat selection ($X^2 = 2.19$, df = 6, *P* = 0.34, Table 1). During the fall the snakes continued to occupy wetlands and avoid deciduous forest (dominated by sugar maple) and open areas. Although the habitat at hibernation sites did not differ significantly from unweighted summer habitat ($X^2 = 3.51$, df = 6, *P* = 0.06, Table l), the reason the difference approached significance was an even stronger association of hibernation sites with coniferous forests (dominated by white cedar, balsam fir, white spruce, and, in some areas, jack pine, *Pinus banksiana*). Thus, hibernation sites were typically associated with wetlands and coniferous forests and were not found in open areas or either deciduous forest or mixed forests.

Movements and Activity Ranges.—During the summer, snakes changed locations between days on average 60% of the time and moved an average of 56 m (N = 11; SE = 12.35) per day (see Table 2). Movements ranged from as little as 5 m to as much as 1438 m. With data from only three females in our study, it was not possible to compare sex differences in movement with any reliability. However, the movements of the three females did not appear obviously different from the movements of the males.

In the fall, the snakes were not located daily. Therefore, it is not possible to determine the frequency of movement, so our analysis is limited to comparing distances between locations. These may or may not represent single moves. The average distance between successive locations in the fall was 132 m (N = 9; SE = 19.27) and ranged from 2 to 908 m. The movements of the two females tracked during the fall were not obviously different from the males.

Individual activity ranges were calculated as complex polygons. The distance between the two most distant points in the activity ranges (maximum range length) varied from 250 m to over 2 km. The mean maximum range length was 1030.36 m (N = 11; SE = 182.55). In addition, we found activity ranges averaged 0.25 km^2 (N = 11; SE = 0.06 km^2). The four females in our study had the four smallest activity ranges, a difference that is significant even if female

TABLE 2. Distance (m) travelled by snakes during the summer and activity ranges (km^2) for the complete tracking periods. Frequency of movements represents the proportion of observations in which a snake had changed location (note that snake 48 remained at the same location throughout the tracking period).

Snake Id.	Sex	Frequency of movements	Mean distance per day (m) (SE)	Number of moves	Maximum range length (m)	Activity range (km^2)	Total no. of days tracked
25	M	0.67	33 (7.50)	32	546	0.059	58
26	F	0.24	12 (3.25)	12	250	0.025	54
27	M	0.68	90 (39.77)	15	1819	0.429	18
28	M	0.82	70 (12.58)	40	2161	0.764	59
29	M	0.52	33 (5.00)	26	974	0.138	56
39	M	0.65	167 (102.58)	11	1750	0.595	24
46	M	0.69	50 (15.58)	33	1094	0.227	51
48	F	0.00	0 (0)	0	0	0.0	19
68	M	0.78	56 (35.35)	14	1001	0.323	24
69	M	0.71	44 (15.52)	12	881	0.128	22
79	F	0.56	17 (3.53)	10	497	0.037	20
356	F	0.86	46 (11.61)	13	355	0.053	15

#48 is excluded (Mann-Whitney U test, U = 0, $P = 0.006$). Thus, although females may be as active as males, they do not cover as much area. In all but one case the hibernation site was on the boundary of the activity range. This suggests that the snakes move out of their activity range to hibernate, albeit not very far.

DISCUSSION

Radio-tracked eastern massasauga rattlesnakes at BPNP showed a strong association with wetlands and coniferous forests. Typical wetlands used by the snakes included shore marshes, shrubby swamps, and fens. Previous studies have identified open marshes, swamps, and wet prairies as important habitats for this subspecies (Wright, 1941; Reinert and Kodrich, 1982; Seigel, 1986) but not coniferous forests.

The strong association of snakes with coniferous forest habitat in our study area may, in part, be the result of our use of SPANS for the habitat analysis. Snakes that we tracked in coniferous forest habitat occasionally frequented small openings (e.g., <5 m^2) in the forest interior. Several of these openings would have been too small to be distinguished from the surrounding forest by SPANS. Thus, our analysis may have somewhat over-emphasized the importance of coniferous forest. (Similarly, snakes located in peninsular, shore marsh habitat were occasionally misclassified as occupying the nearby open water.) Despite the likelihood of over-emphasis, extended occupation of extensive, relatively closed-canopy coniferous forest by a number of our transmitter-equipped snakes, suggests there was genuine use of that habitat.

Obviously, the gaps in the forest used by the snakes represent excellent basking sites in an otherwise shaded habitat. In addition, these gaps may provide foraging opportunities for rattlesnakes. At least two known prey species (Song sparrows, *Melospiza melodia*; snowshoe hares, *Lepus americanus*), whose young are known to be eaten by rattlesnakes in the study area (D. Sweiger, pers. comm.), were also often observed within the forest openings.

The association of the snakes with wetland and coniferous habitat (and the avoidance of open areas and other forest types) continued through both the fall and hibernation. The spatial analysis of fall and hibernation locations indicated that the snakes at BPNP appeared to use the same habitats year round. However, the tendency for hibernation sites to be located at the edge of the activity ranges of the snakes and the differences between hibernating and summer habitat suggest that the snakes may move short distances out of their regular activity range to hibernate. Other authors have documented seasonal patterns of habitat use by eastern massasauga rattlesnakes. Reinert and Kodrich (1982) found they preferred low, poorly-drained, heavily-vegetated habitats before and after hibernation, but preferred dry habitats with low, sparse vegetation during July and August. Seigel (1986) reported a preference for dry, open upland habitats in the summer and moist wetland sites in the fall. Such shifts may occur when habitats and associated resources change seasonally (Gregory et al., 1987).

There was a strong association of capture locations with open areas. The habitat where snakes were frequently captured was very different from where the snakes were tracked. This result again confirms the biased assessment of habitat use one obtains if relying only on opportunistic captures (Weatherhead and Charland, 1985; Burger and Zappalorti, 1988). Many of our snake captures come from snakes found either dead (most often) or alive on roads and trails, even though the tracking data indicate that snakes seldom use these habitats.

The analysis of snake movements indicated that the snakes were quite active during the summer and changed locations between days 60% of the time. Some movements were minimal, but overall snakes moved an average of 56 m per day and one individual (male #39) travelled almost 1.5 km in a single move. These values are much greater than those found for the species in more southern parts of its range. Eastern massasauga rattlesnakes in Pennsylvania (N = 25 snakes, 225 snake-days) averaged only 9.1 m per day (Reinert and Kodrich, 1982). Snakes in our study also exhibited both larger activity ranges (0.25 km^2 vs. 0.0098 km^2) and greater maximum lengths (1030.36 m vs. 89 m) than those reported by Reinert and Kodrich (1982). However, the snakes in Reinert and Kodrichs' study were force-fed their transmitters. The presence of a transmitter in the stomach may cause changes in foraging (Fitch and Shirer, 1971; Reinert and Cundall, 1982) and thermoregulatory (Lutterschmidt and Reinert, 1990) behavior and thus limit the normal movements of a snake. The snakes in our study remained active in the fall, although they were tracked too infrequently to know whether changes in locations that were detected were due to infrequent, long movements or many short movements.

Females had significantly smaller activity ranges than males. Reinert and Kodrich (1982) were unable to detect such a pattern, yet this type of intersexual difference is exhibited by several other species (e.g., timber rattlesnakes, *Crotalus horridus*, Reinert and Zappalorti, 1988; black rat snakes, *Elaphe o. obsoleta*, Weatherhead and Hoysak, 1989). More extensive movements by males may be related to the breeding system of the species. Larger activity ranges of males may increase their probability of encountering sexually receptive females (Reinert and Zappalorti, 1988). Gravid females often have reduced home ranges or activity centers in comparison to non-gravid females and males (e.g., copperhead, *Agkistrodon contortrix*, Fitch and Shirer, 1971; racer, *Coluber constrictor*, Brown and Parker, 1976; timber rattlesnake, Reinert and Zappalorti, 1988). We have evidence that one of the females in our study (#79) gave birth late in the summer of 1990 (D. Sweiger, pers. comm.).

In conclusion, geographic variation in habitat use and movement patterns of the eastern massasauga rattlesnake suggests that regional management of the subspecies should be based upon the characteristics of local populations, and not on published accounts from distant localities. Seigel (1986) made the same observation with respect to the reproductive ecology of this species. Our preliminary data provide the basis for some initial land use recommendations within BPNP. For example, in order to minimize human encounters with rattlesnakes, areas used by visitors should probably not be located near wetland areas, particularly those surrounded by coniferous forest. However, our data also illustrate and need to track many snakes from many locations to obtain a comprehensive picture of their habitat use.

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