HABITAT USE AND MOVEMENT PATTERNS OF THE EASTERN MASSASAUGA RATTLESNAKE IN WISCONSIN

by

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ABSTRACT

The eastern massasauga rattlesnake (*Sistrurus catenatus catenatus*) has been listed as endangered in Wisconsin since 1975. The current status of the massasauga in Wisconsin is uncertain. A recent statewide survey located only 9 specimens throughout the state. Little is known about its life history or habits, other than its preference for lowland habitats.

Radio-telemetry was used to determine habitat use and movement patterns of monitored massasauga rattlesnakes (n=10) in Juneau Co., and Monroe Co., WI. Data were collected on the habitat types where the massasaugas were located. Proportional observed use values were compared to the expected values. A correlation coefficient indicated there was low correlation(0.402) between available habitat and use. A chi-square analysis was used to determine if there was a significant (critical value = 9.49, df=4) difference between the observed use of habitats, and the available habitat. The Z-statistic was used to determine if certain habitats were selected or avoided. Neonatal snakes (n=32) also were monitored. Proportional use of habitat was compared to adults by using the chi-square test and the Z-statistic.

Results showed that adult snakes (n=10) avoided upland forest habitats, and selectively used upland meadows and roadbeds(X^2 = 77.48). Male snakes (n=3), avoided upland forest (X^2=25.69). Female snakes (n=7) avoided upland and lowland forests, and selected upland meadows and roadbeds(X^2=124.92). Neonates used upland and lowland meadows more often than adults (X^2=47.72). Movement patterns suggest that the snake is a relatively sedentary species.

The results suggest that behavior of massasaugas is similar to that of other high latitude *Crotalid* snake species. Females use upland meadows as basking sites and breed every other year; males and non-gravid females forage in more closed canopy areas. Each snake hibernates individually in the root systems of trees in lowland areas.

Increased enforcement of current laws, public education and continued commitment to the protection of wetland habitats are probably crucial to maintaining the massasauga in Wisconsin.

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The eastern massasauga rattlesnake (*Sistrurus catenatus catenatus*) was placed on the Wisconsin endangered species list in 1975. Vogt (1981) attributed the population decline of the massasauga in Wisconsin to habitat destruction, killing for bounties, and a lack of suitable hibernation sites. The current status of massasauga rattlesnake populations in Wisconsin is uncertain. A recent status survey (Hay et al. 1993) located only 9 specimens throughout Wisconsin in areas previously known to harbor them. Until this study was undertaken, no massasauga rattlesnakes had been located regularly in Wisconsin in recent years.

The massasauga rattlesnake is a medium sized, stout bodied snake, generally 50-75 cm long (Vogt 1981). It is gray or brown, patterned with dorsal and lateral dark brown, saddle-shaped patches, with the characteristic rattle on the distal portion of its tail.

The eastern massasauga occurs from central New York, western Pennsylvania, and southern Ontario, to eastern Minnesota and central Missouri (Conant 1975). In Wisconsin, the eastern Massasauga was distributed widely in the southern half of the state, bounded by a line running from St. Croix Co. in the northwest to Ozaukee Co. in the southeast. Massasaugas were typically associated with lowland areas along rivers, lakes, and marshes (Maple 1968, Vogt 1981, Reinert and Kodrich 1982). They also are found in uplands associated with wetland areas. Their preference for these habitat types has resulted in the common names for the species, "swamp rattler" and the Ojibwa word massasauga, which translates as "great river mouth" (Vogt 1981). The massasauga is a somewhat atypical rattlesnake; it does not hibernate communally as do most of the other rattlesnake species. Instead it hibernates individually in low-lying areas, in the root systems of trees, or in crayfish burrows (Maple 1968). This makes locating large numbers of snakes difficult. Massasaugas have small home ranges close to their hibernacula (Reinert and Kodrich 1982).

The spatial ecology of snakes has been poorly understood until recently. Data from mark and recapture studies with snakes can be ambiguous due to their secretive nature (Madsen 1984). Duvall et al. (1985) thought that snakes migrated from hibernacula randomly until detecting the presence of prey species and settling in to ambush them.

The objective of this study was to determine the activity patterns of the eastern massasauga rattlesnake in Wisconsin, relative to habitat use.

STUDY AREA

Eastern massasauga rattlesnakes were captured and monitored at 2 separate study areas, 1 located in central Juneau Co., WI, the other in northern Monroe Co., WI.

Juneau County

The Juneau Co. study area was located 10 km north of the village of Necedah, WI, along the river bottoms and adjacent uplands of the Yellow River. The area once was the bed of glacial Lake Wisconsin, as evidenced by the level topography and poorly drained sandy soils (Grenbach et al. 1991). The area is a mix of bottomland forests, wet meadows, and adjacent upland fields and forests. The bottom land forests are composed mainly of silver maple (*Acer saccharinum*), river birch (*Betula nigra*), black ash (*Fraxinus nigra*), and swamp white oak

(*Quercus bicolor*). The herbaceous layer is highly variable due to seasonal flooding, composed of large stands of nettle (*Urtica* spp.), jewelweed (*Impatiens capensis*), and sedges (*Carex* spp.). Other typical species include bugleweed (*Lycopus uniflorus*), skullcaps (*Scutellaria* spp.), and various mints (*Labiatae* spp.) . Wet meadows have moist or saturated soils which flood often; typically open areas along stream bottoms consist mainly of sedges, reed canary grass (*Phalaris arundinacea*), scattered iris (*Iris versicolor*), and scattered shrubs such as speckled alder (*Alnus rugosa*), and buttonbush (*Cephalanthus occidentalis*).

The upland portion of the Yellow River study area is typified by dry sandy soils. Before European settlement, much of the area was predominantly pine barrens (Curtis 1959). Though degraded by the absence of fire, remnant barrens remain in the study area. Jack pine (*Pinus banksiana*) and Hill's oak (*Quercus ellipsoidalis*) are interspersed in the upland fields with a dominant herbaceous layer of grasses, such as little bluestem (*Andropogon scoparius*) and witch grass (*Leptoloma cognatum*). Sweetfern (*Comptonia peregrina*) also is characteristic of the barrens. The forested portions of the uplands are dominated by jack pine, oaks, and quaking aspen (*Populus tremuloides*). Scattered white pine (*Pinus strobus*) and red pine (*P. resinosa*) also occur there.

Human impacts in the Juneau Co. study area are mixed. Some drainage and diking have occurred near the river bottoms, as well as development for cranberry cultivation on the east side of the river. Some year-round, seasonal, and abandoned home sites and an abandoned sawmill also occur within the study area. Fallow and cultivated agricultural fields are present. The biggest impacts on the area probably have been the suppression of fire and the drainage of wetlands for agriculture. The river bottoms are the least heavily impacted portion of the study area.

Monroe County

The Monroe Co. study area is located in the northern part of the county, 12 km west of Warrens, WI, on the eastern edge of the driftless area, with its uneven topography (Bart and Langton 1984). Before European settlement, this area was composed predominantly of pine barrens (Curtis 1959). This site is characterized by ridges and sandstone outcroppings encircling a low-lying depression.

The surrounding uplands are composed mainly of contiguous jack pine and oak forests, with scattered small openings. Soils are sandy and excessively drained. The herbaceous vegetation is sparse, with scattered bracken fern (*Pteridium aquilinium*), little bluestem, raspberries (*Rubus* spp.), and blueberries (*Vaccinium* spp.) in the open areas.

The soil in the lowlands is composed of a deep layer of peat and organic matter over sand. A small creek drains into and flows through the depression, from the southeast to the northwest where it empties into a cranberry bog reservoir. The depression slopes gently with transition from a dry oak and pine forest into a lowland mesic forest, dominated by red maple (*Acer rubrum*), silver maple, white pine, and white birch (*Betula papyrifera*). The ground and shrub layers are dominated by large tracts of cinnamon ferns (*Osmunda claytonia*), shield ferns (*Athyrium* spp.), oak ferns (*Dryopteris* spp.), and various sedges and shrubs, especially juneberry (*Amelanchier* spp.). Numerous white pine saplings are also present. The northwestern portion of the lowland transitions into a tamarack bog, composed mainly of open canopy tamarack (*Larix laricina*) and white pine, with a ground layer mainly of moss, various ferns, sedges, scattered patches of blueberries, scattered *Rubus*, and other species typical of bog communities in Wisconsin. The site is bisected by an active rail line, with a grade at 3-5 m higher than the rest of the site. It is also next to Interstate Highway 94. The site has remained relatively pristine because it serves as part of the watershed of a cranberry bog.

METHODS

Telemetry

Adult snakes were captured by conducting intensive searches (Fitch 1987) throughout the study areas in locations where rattlesnakes had been located recently. Snakes were anesthetized by placing them in an inhalation chamber, and administering isofluorane gas (Reinert and Cundall 1982). Transmitter packages (Holohil Systems Ltd., Woodlawn, Ontario) were surgically implanted abdominally or subcutaneously, while the external whip antenna was placed subcutaneously in accordance with standard techniques (Reinert and Cundall 1982, Weatherhead and Anderka 1984). Subcutaneous packages (1g, 1cm x 1cm x 0.5cm) had a reported battery life of about 90 days; abdominal packages (12g, 7cm x 2cm x 2cm) had a reported battery life of about 450 days. Snakes were measured, weighed, and permanently marked by clipping ventral scales (Brown and Parker 1976).

Neonatal snakes were captured in association with monitored females upon parturition. The antennas were removed from the transmitters which were implanted subcutaneously in the neonates. Removal of the antennas was necessitated by the small size of the neonates; transmitter range was not impaired greatly. Snakes were returned to the point of capture and released the day after surgery. No known mortality occurred before or immediately after implantation surgery.

Ten adults were monitored during the 1994 and 1995 field seasons (May-November). Three of the adult snakes were monitored at the Juneau Co. study site and 7 at the Monroe Co. study site. During the 1994 field season, 32 neonatal rattlesnakes were captured and monitored. Adult snakes were monitored during their active period (May-November) for periods of 1-12 months (2 field seasons). Neonatal snakes were monitored for periods ranging from 2 days to 2 months, into hibernation.

Snakes were located at randomized intervals around the clock every 48-72 hours (Durner and Gates 1993, Reinert 1993). A handheld Yagi antenna and radio receiver (Advanced Telemetry Systems, Isanti, MN) were used to pick up the signals from the transmitter. All snakes were located visually. An effort was made to avoid disturbing the snakes. Each time a snake was located, date, time, location, vegetation, structure of habitat, and behavior of snake were recorded. Structural features of the habitat appear to be more important than specific plant species for habitat use (Reinert 1993, Morrison et al. 1992).

Data Analysis

Lowland wet meadows and tamarack bogs, though different in plant composition between sites, were structurally similar in the ground layer. Both had little canopy cover and a herbaceous layer that provided cover while permitting sunlight to reach the ground. Reinert

(1993) noted that Crotalid snakes appeared to use different habitats based on the plant community, but that the communities proved to be structurally similar. Therefore the tamarack bogs and lowland wet meadows were considered functionally equivalent when categorized.

Each location was placed into 1 of the 5 habitat categories (Curtis 1959) available to the snakes (Table 1). Snake locations were plotted on air photos and topographic maps of the study areas. These locations were used with convex polygons to determine the home ranges of the snakes (White and Garrot 1990, Rose 1982, Jennrich and Turner 1969). A 500-m buffer was then placed around the home ranges on air photos. This distance was selected because it represented the greatest distance between any 2 points in all of the snakes' home ranges. All habitat within this buffer area was considered available to the snakes (Aebischer et al. 1993). The habitat within this area was quantified, and a percent value for each type of habitat was determined. This value was then compared to the values of actual snake locations to determine possible habitat preferences. A correlation coefficient test was performed to determine whether habitat use by the snakes was correlated to its availability. A chi-square test was performed to determine if the differences in frequencies between actual and expected locations were due to chance or non-random occurrence. The Z-statistic was then used to calculate 95% confidence intervals to determine if each habitat type was selected or avoided (Neu et al. 1974, Byers et al. 1984). Snakes also were compared between study sites.

Neonatal snakes were relocated via radio telemetry throughout their active period until hibernation or until the snake was lost due to predation or other factors. Locations were categorized by

Table 1. Habitat categories for the massasauga rattlesnakes in the Juneau Co., WI, study area, 1994 and 1995.

Habitat[a]	Description
Upland dry meadow	Xeric soil, grasses, open canopy, low shrubs, scattered trees mostly jack pine and oaks
Lowland wet meadow/Tamarack bog	Moist or saturated soil prone to flooding; open canopy, dominated by sedges, rushes (*Scirpus* spp.), reed canary grass; shrubs present at times/thick layer of peat over sand, tamarack, white pine and spruce (*Picea* spp.)
Upland hardwood forest	Dry sandy soil, closed canopy, dominated mostly by oak, jack pine, quaking aspen, scattered white pine and maples; varied understory, can be dense or relatively open
Riparian hardwood forest/Lowland mesic forest	Sandy soil, flood plain, closed canopy of silver maple, red maple, river birch; understory dense in places, composed of nettles/Saturated soil, thick layer of peat over sand; closed canopy predominantly red maple, white pine; herbaceous layer predominantly ferns (*Osmunda* and *Athyrium* spp.), moss common
Road or railroad bed	Active or abandoned roads, rail lines and associated ditches and/or slopes

[a]Curtis 1959.habitat type.

Frequencies for the types of habitat were determined. Locations for the neonates were compared to those of the adults by using a chi-square test. A *Z*-test was used to see if any significant differences could be detected between adult and neonate habitat use.

RESULTS

Adult Habitat Selection

Three adult males, and 7 adult females were monitored from 24 May to 1 November 1994 and from 10 May to 20 October 1995, resulting in 282 locations categorized into 1 of the 5 habitat types available to the snakes in the study areas. A correlation coefficient of 0.402 correlation, Indicated low correlation between available habitat and use. Confidence intervals of 95%, calculated for each habitat type, showed that adult snakes were selecting upland dry meadows, and railroad and road beds (X^2=77.4, df=4). Snakes avoided upland forest types. Lowland wet meadows and lowland forests were neither selected nor avoided (Table 2).

Males avoided upland forest, with none of the other habitat types being selected or avoided (X^2=25.7, df=4). Females selected upland meadows, and railroad and road beds (X^2=124.9, df=4). They avoided upland and lowland forest types, and neither selected nor avoided wet meadows.

Seven snakes were followed until hibernation in October 1994 and 1995. Snakes at both study sites apparently used the root systems oftrees in lowland areas in which to hibernate individually. Hibernation extended from 1 November to 10 May.

Table 2. Chi-square and *Z*-statistic test results of proportional habitat utilization-availability data for adult male and female eastern massasauga rattlesnakes, Juneau Co. and Monroe Co., WI, study areas (*n*=10), 1994 and 1995. Utilization is based on 282 locations.

	Upland meadow	Lowland meadow/ tamarack bog	Upland forest	Riparian/ Lowland forest	Rail/road bed
		Adults (*n*=10)			
Observed %	22	20	1	36	21
Expected %	7	16	23	46	8
95% CI (*Z*-test)	selected		avoided		selected
X^2= 77.48		df = 4		$P \leq 0.05$= 9.49	
		Adult males (*n*=3)			
Observed %	8	27	0	62	3
Expected %	6	19	17	51	7
95% CI (*Z*-test)			avoided		
X^2 = 25.69		df=4		$P \leq 0.05$ = 9.49	
		Adult females (*n*=7)			
Observed %	25.5	18	1.5	28	27
Expected %	8	15	26	44	7
95% CI (*Z*-test)	selected		avoided	avoided	selected
X^2 = 124.92		df=4		$P \leq 0.05$ = 9.49	

Neonate Habitat Selection

During summer and fall 1994, 32 neonates were monitored, resulting in 211 locations classed into 1 of the 5 habitat categories. Chi-square comparisons between adult habitat use and neonate habitat use (Table 3) revealed differences in the use of the lowland forest component (X^2=47.72, df=4). Adult snakes used the lowland forest habitat more often than the neonates did. Neonates used upland and lowland meadows/tamarack bogs more often than adults did. No differences were found between adults and neonates in the use of upland forest and road or rail beds.

Chi-square comparisons at the Juneau Co. study site revealed that neonates used upland meadows more often than adults did; adults used lowland meadows and lowland forests more often than did neonates (Table 3). No differences in the use of upland forest and road beds were detected (X^2=84.22, df=4).

Monroe Co. adults used lowland forests more often than did neonates (Table 5). Neonates used tamarack bogs more often than did adults. No differences were found in the use of the other 3 habitat types (X^2=132.83, df=4).

Table 3. Chi-square and *Z*-statistic test results of proportional utilization of available habitats, neonates (*n*=32) versus adults[a] (N=10), Juneau Co. and Monroe Co., WI, 1994 and 1995. Utilization is based on 493 locations.

	Upland meadow	Lowland meadow	Upland forest	Riparian/ lowland forest	Rail/road bed
		Juneau Co. neonates(*n*=17)			
Observed %	79	1	5	11	4
		Juneau Co. adults(*n*=3)			
Observed %	41	21	2	35	1
95% CI (*Z*-test)	neonate use greater	adult use greater		adult use greater	
X^2 = 84.22		df = 4		$P \leq 0.05$ = 9.49	
		Monroe Co. neonates(*n*=15)			
Observed %	1	62	1	1	35
		Monroe Co. adults(*n*=7)			
Observed %	1	19	1	36	43
95% CI (*Z*-test)		neonate greater		adult greater	
X^2 = 132.838		df = 4		$P \leq 0.05$ = 9.49	

Table 3. (Continued)

	Upland meadow	Lowland meadow	Upland forest	Riparian/ lowland forest	Rail/road bed
		Total neonates (*n*=32)			
Observed %	37	34	3	5	21
		Total adults (*n*=10)			
Observed %	22	20	1	36	21
95% CI (*Z*-test)	neonate use greater	neonate use greater		adult use greater	
X^2 = 50.72		df = 4		$P \leq 0.05 = 9.49$	

[a] Chi-square analysis in this table is a direct comparison between the utilization of available habitats between adults and neonates. Adult habitat use is utilized to represent expected habitat use by the neonates.

Movement Patterns

Gravid females moved an average of 8.3 m (range=0-200 m, SE=26.2) between locations during the period of time they were monitored. While gravid they showed an average home range of 113 m^2 (range=25-300 m^2, SE=102.82). Within 10 days of parturition, they moved into lowland habitats such as the tamarack bogs, lowland meadows, or lowland forest that had more canopy cover and moist soil.

Female snakes (n=5) in Monroe Co. spent June, July, and August 1994 in or within 25 m of a ~2 x 3 m pile of discarded railroad ties. During 9-24 August 1994, these snakes gave birth. From 9 days before to 9 days after giving birth, the females dispersed into the surrounding lowlands. Female snakes (n=2) in Juneau Co. also spent June, July, and August 1994 in open, upland areas, then moved into lowlands 10 days after parturition.

A month by month analysis from June to September 1994 and 1995 found that August and September were periods of heightened movement by female snakes (n=7) in both study areas. Average distance between movements increased from 5.3 m in June and July to 15.7 m in August and September. This likely represents the movement of females away from basking sites into adjacent lowlands following parturition.

Males (n=3) did not display any obvious temporal shifts in movement patterns throughout the periods they were monitored. Average distances moved were longer for males than gravid females (x=20.4 m, range 0-500 m, SE=35.4). Most (89%) locations were in lowland areas. Monthly male movement patterns, June-September 1994 and 1995, did not differ, probably due to continuous hunting and/or mate searching activity.

At least 8 neonates remained within 10 m of their birth site. Seven neonates moved 50-200 m (x =63.63, SE=85.52) from the birth site.

DISCUSSION

The behavior of the eastern massasauga rattlesnakes in this study probably is similar to that of related species. Seigel (1986) found massasaugas in Missouri moving from lowland hibernation areas in the spring and into outlying upland areas as the summer progressed. They then moved back into the lowland areas in the fall. Tiebout and Cary (1987) found that female northern watersnakes (*Nerodia sipedon*) tended to shift from 1 localized area of intense activity to another. King and Duvall (1990) found that male prairie rattlesnakes (*Crotalus viridis viridis*) spend their activity period foraging and seeking mates. Female snakes did not seek out the males; instead they allowed the males to come to them. Larger home ranges relative to females, are not uncommon for male snakes, possibly reflecting mate searching strategies (Durner and Gates 1993, King and Duvall 1990). Another factor influencing activity patterns is the trailing of envenomated prey (Duvall et al. 1980). Rattlesnakes will follow the trail of an animal from the ambush site after it has been bitten. The prey item is consumed after it has been located, the snake then conceals itself to digest the meal, and then locates a new ambush nearby (Reinert et al. 1984).

Female timber rattlesnakes (*Crotalus horridus*) spend more time in open habitats than do males (Reinert 1993). Gravid females need to bask in the sun to incubate their young. Males and non-gravid females spent their time foraging in more closed canopy areas. Massasauga rattlesnakes probably exhibit a similar pattern, as my results suggest.

The apparent differences in habitat use between study sites are explained by the relative absence of upland meadows at the Monroe Co. site. The railroad bed probably acts as the functional equivalent of an upland meadow; the soil is dry, tall grass and shrubs are present, cover is provided by debris such as railroad ties, and plenty of sun is available. At the Juneau Co. site, enough upland meadows exist that road beds are not selected to serve as basking sites.

Pregnant female snakes probably select these sunny upland open sites for use as incubators. The females can bask in the sun while remaining concealed in the grass or under structures such as logs, scrap metal, or railroad ties. This probably assists the development of their internally held young (Reinert and Zappalorti 1988). These areas were not used by non-gravid females. Two females in my study spent most of the year after parturition apparently foraging in lowland habitats. Males were located in the uplands at this site only in association with post-parturition females (probable mating behavior). Male snakes avoided upland areas. They showed more of a propensity to use closed canopy lowland forest and lowland wet meadows than did the females. Males and non-gravid females do not need to maintain as high a body temperature as gravid females, and are more concerned with foraging and searching for mates (King and Duvall 1990, Reinert 1993).

The massasauga is a relatively sedentary animal. The greatest distance between any 2 known locations from a single individual, was about 500 m. Factors that probably influence the habitat use and movement patterns of the snakes include the gravid state of the female, foraging behavior, and active searching for mates. Males and non-gravid females spend their active months foraging in lowland habitats, sometimes within 50 m of the previous winter's hibernation site (Reinert 1984, Reinert et al. 1984).

Like some other high latitude rattlesnake species, female massasauga rattlesnakes might give birth every other year (Macartney and Gregory 1988, Martin 1993). They probably do not feed while basking during the summer that they give birth (Keenlyne and Beer 1973). Then they must spend the summer after parturition foraging in lowland habitats to replenish fat reserves. After emerging from hibernacula the next year they return to the open upland basking sites to incubate their internally held young and begin the cycle again.

The use of root systems as hibernacula in lowland areas is consistent with previous research (Maple 1968, Vogt 1981, Reinert and Kodrich 1982, Weatherhead and Prior 1992). Lowland areas appear to be the preferred hibernation sites of the massasauga (Maple 1968, Conant 1975). Snakes might be hibernating just below the water table at both sites. Moisture levels in hibernacula are an important feature in allowing snakes at higher latitudes to survive through the long winters (Costanzo 1989).

Neonate movement patterns varied from 10 to 200 m from the birth site. The factors influencing their dispersal from the birth site are unclear.

MANAGEMENT IMPLICATIONS

The eastern massasauga is currently a category 2 species, which means that it is a candidate for listing as a federally threatened or endangered species. It is important that managers survey for them. This project suggests that surveys for them will be difficult. Because it is a sedentary species, methods such as drift fence trapping are unlikely to be effective in surveying for this species. The best method for detecting the snakes is to search actively areas that appear to be suitable habitats. This approach is labor intensive. The searches can be narrowed by focusing on areas where the snakes have been located previously. Landowner surveys can be useful in narrowing search areas. Railroad bed and roadbed surveys also can be a more effective way to conduct surveys, particularly if these areas represent the only important upland habitat, in an area composed mainly of lowlands.

Protection of existing populations of snakes also presents difficulties. The affinity of the snakes for lowland habitats suggests that the protection of wetland habitats is critical to maintain suitable areas. Protecting wetlands is already an important issue for most state and federal wildlife agencies. A more important issue is that remaining populations of snakes might be isolated genetically due to fragmentation of habitat. These isolated populations are more prone to extinction from stochastic events.

A separate issue is protection of the snake populations themselves. The propensity for gravid females to spend most of their time in open upland habitats makes them the most vulnerable part of the population. During the bounty period, snakes were captured opportunistically, and the snakes most easily located were basking females. The removal of these reproductively active females from the population exaggerated the effects of the bounty system on the snakes and represents, in my opinion, the greatest current challenge facing managers. These snakes are considerably more vulnerable to predation, killing by misguided members of the public, and collection by reptile collectors. Stronger law enforcement and a public awareness campaign are probably critical to maintaining the eastern massasauga in its remaining strongholds in the state and throughout its current range.

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Appendix I. Identification number, number of locations, capture date, sex, weight, and length of adult eastern massasauga rattlesnakes monitored at the Juneau Co. and Monroe Co., WI study areas, 1994 and 1995.

Individual snake ID#[a]	# of Locations	Capture date	Sex	Weight (g)	Length (cm)	Snout-vent length (cm)
YF01	41	5/24/94	F	240.5	60.0	53.4
YF02	62	5/24/94	F	386.5	72.5	67.5
WF03	20	7/14/94	F	252.5	63.3	56.7
WF04	13	7/14/94	F	249.1	62.2	55.2
WF05	48	7/14/94	F	284.0	67.3	59.3
WF06	08	7/14/94	F	335.6	62.9	55.3
WM07	13	8/12/94	M	278.0	71.4	62.5
WM08	13	8/12/94	M	345.0	74.6	64.2
WF09	24	6/13/95	F	n/a	n/a	n/a
YM10	40	6/16/95	M	n/a	n/a	n/a

[a] YF=Juneau County female, YM=Juneau County male, WF=Monroe County female, WM=Monroe County male.

Appendix II. Identification number, weight, length, date of birth, and capture date of neonatal eastern massasauga rattlesnakes at the Juneau Co. and Monroe Co., WI, study areas, 1994.

Individual Snake ID#[a]	Weight (g)	Total length (cm)	Date of birth	Date of capture
YN03	10.6	22.0	8/24/94	8/24/94
YN04	10.3	21.8	8/24/94	8/24/94
YN05	7.4	20.2	8/23/94	8/24/94
YN06	10.2	21.3	8/24/94	8/24/94
YN07	10.9	22.3	8/24/94	8/24/94
YN08	10.8	21.4	8/24/94	8/24/94
YN09	10.1	22.0	8/24/94	8/24/94
YN10	9.6	21.4	8/24/94	8/24/94
YN11	9.8	21.3	8/24/94	8/24/94
YN12	10.6	23.0	8/24/94	8/24/94
YN13	10.4	21.5	8/24/94	8/24/94
YN14	9.6	21.2	8/24/94	8/24/94
YN15	9.6	20.8	8/24/94	8/24/94
YN16	9.2	20.8	n/a	8/25/94
YN17	9.5	21.2	n/a	8/25/94
YN18	n/a	n/a	n/a	9/12/94
YN19	n/a	n/a	n/a	9/12/94
WN09	10.0	21.0	8/13/94	8/15/94
WN10	10.0	22.0	8/13/94	8/15/94
WN11	10.0	n/a	8/13/94	8/15/94
WN12	7.5	22.0	8/9/94	8/9/94
WN13	6.6	20.5	8/9/94	8/9/94
WN14	7.6	21.5	8/9/94	8/9/94
WN15	7.5	22.0	8/9/94	8/9/94
WN16	7.4	22.0	8/9/94	8/9/94
WN17	7.9	21.3	8/9/94	8/9/94
WN18	8.0	22.0	8/9/94	8/9/94
WN19	8.8	18.5	8/9/94	8/9/94
WN20	6.9	21.5	8/9/94	8/9/94
WN21	10.4	22.0	n/a	8/24/94
WN22	8.3	19.0	n/a	8/24/94
WN23	6.0	18.0	n/a	8/24/94

[a] YN=Juneau County neonate, WN=Monroe County neonate.

Appendix III. Food habits of the eastern massasauga rattlesnake in Wisconsin.

I observed a massasauga feeding on 26 June 1995, at 1040 hours. Snake WF05 was feeding on a deer mouse (*Peromyscus leucopus*) at the Monroe Co. study area, in the lowland forest habitat. A neonate at the Juneau Co. study area was located on 16 September 1994 near a dead blue spotted salamander (*Ambystoma laterale*), lying out in the relative open. The snake was located the following day in the same location. The salamander was not present and the neonate appeared distended as if by a meal. It probably envenomated and then fed on the salamander.

Keenlyne and Beer (1973) collected 323 massasaugas during 1967 in Buffalo Co., WI, along the Chippewa River. Over 85% of the diet was found to consist of field voles (*Microtus pennsylvanicus*), 4.4% was deer mice and 4.4% was garter snakes (*Thamnophis sirtalis*). They found that gravid females contained fewer food items, lower in the digestive tract, than males did, especially later in the summer. This suggests that gravid females feed little if at all while incubating young. The only food item found in young-of-the-year massasaugas were young-of-the-year garter snakes. Keenlyne and Beer (1973) believed that massasaugas probably take small mammals in proportion to their occurrence. They suggested that young-of-the-year massasaugas would have difficulty locating suitable small mammals, and therefore feed on amphibians and reptiles their first year. Schuett et al. (1984) also found that young massasaugas used their tails to lure small frogs into striking distance, which were killed and eventually consumed.

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Appendix IV. Predation and survival of adult and neonatal eastern massasauga rattlesnakes.

Little information is available concerning the predation rates on eastern massasauga rattlesnakes. It is likely that they are preyed upon by a wide variety of species such as raptors, raccoons, foxes, coyotes and other predators. Predators took 30% (3) of the adult snakes monitored during the 2 field seasons. Two adults at the Monroe Co. site were taken in 1994. Snakes WF06 and WF04 were predated on or about 15 August 1994, and 9 September 1994 respectively. It is not clear what species of animal is responsible for the predation. Snake WF05 was taken the following summer on or about 25 August 1995, at the Monroe Co. study site by an unknown predator.

Young-of-the-year of most animals are generally considered more vulnerable to predation than are adults. At the Juneau Co. study site 8 neonates were killed by an unknown person. This accounted for 25% of the total number of neonates being monitored. Only 5 neonates were confirmed as predated (16%). Three transmitters from neonates (Snakes WN09, WN14, WN16) were recovered in an owl pellet at the Monroe Co. study site on 10 September 1994. The rattle of an adult snake was also recovered in the same pellet. The fate of 9 of the neonates (28%) is unknown. They either dispersed out of transmitter range, experienced transmitter failure, or were preyed upon. Ten neonates (31%) were tracked until 1 November, when all snakes were believed in hibernation.

Overwinter survival also proved to be important. Three adult snakes (WF03, WM07, WM08) at the Monroe Co. study site apparently experienced mortality while hibernating during winter 1994-95. The reasons for this are unclear. The winter of 1994-95 experienced little snowfall, a period of extremely cold weather occurred in late January to February 1995. The extreme cold weather might be responsible for the winter mortality, exacerbated by the absence of a thick layer of insulating snow cover.

A single adult snake (WF09) died of unknown causes at the Monroe Co. study site around 22 August 1995. Facilities for a necropsy were not available to determine the cause of death. During summer 1995 heavy herbicide application occurred along the railroad tracks within 2 m of where the snake spent the summer. Such herbicide application to kill brush along the railroad tracks also might kill these relatively sedentary snakes that seem to prefer such habitat.

Predation upon eastern massasauga rattlesnakes appears to be a factor at the Monroe Co. site. Human induced mortality appears to be a factor at the Juneau Co. study area. In addition to the killing of the neonates, 2 adult snakes not part of the study were found road killed in the spring and summer of 1994. The owl predation suggests that raptors are probably an important predator of massasaugas. Humans probably remain an important source of mortality for the snakes in areas contacted.

Appendix V. ID number, final status, and last date monitored of adult eastern massasauga rattlesnakes (N=10), Juneau Co. and Monroe Co., WI, study areas 1994 and 1995.

Snake[a]	Status	Last date monitored
YF01	hibernation 1994/unknown	11/1/94
YF02	hibernation 1994/hibernation 1995	10/27/94
WF03	hibernation 1994/winter mortality	10/11/94
WF04	predated 1994	9/9/94
WF05	hibernation 1994/predated 1995	8/25/95
WF06	predated 1994	8/15/94
WM07	hibernation 1994/winter mortality	10/11/94
WM08	hibernation 1994/winter mortality	10/11/94
WF09	unknown mortality 1995	8/21/95
YM10	hibernation 1995	10/20/95

[a] YF=Juneau County female, WF=Monroe County female, WM=Monroe County female, YM=Juneau County male.

Appendix VI. ID number and final status, and last date monitored of neonatal eastern massasauga rattlesnakes (N=32) at the Juneau Co. and Monroe Co., WI, study areas, 1994.

Snake[a]	Status	Last date monitored
YN03	human mortality	9/1/94
YN04	human mortality	9/1/94
YN05	hibernation	11/1/94
YN06	human mortality	9/1/94
YN07	human mortality	9/1/94
YN08	human mortality	9/1/94
YN09	human mortality	9/1/94
YN10	human mortality	9/1/94
YN11	predated	9/12/94
YN12	unknown	9/28/94
YN13	predated	9/12/94
YN14	hibernation	11/1/94
YN15	human mortality	9/1/94
YN16	hibernation	11/1/94
YN17	hibernation	11/1/94
YN18	unknown	9/27/94
YN19	hibernation	11/1/94
WN09	predated*	8/31/94
WN10	unknown	9/1/94
WN11	unknown	8/24/94
WN12	unknown	8/24/94
WN13	hibernation	10/03/94
WN14	predated*	8/31/94
WN15	unknown	9/8/94
WN16	predated*	8/31/95
WN17	hibernation	11/1/94
WN18	unknown	8/26/94
WN19	unknown	8/24/94
WN20	hibernation	11/1/94
WN21	hibernation	10/27/94
WN22	hibernation	11/1/94
WN23	unknown	9/29/94

[a] YN=Juneau County neonate, WN=Monroe County Neonate.

[b] Transmitters recovered in an owl pellet.