Management and Conservation Article

Massasauga Home Range Patterns in the Midwest

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ABSTRACT The massasauga (*Sistrurus catenatus*) has drastically declined throughout its range mainly due to habitat loss and human persecution. Populations of the massasauga that occur north and east of the Missouri River, USA, are currently candidates for listing under the United States Endangered Species Act. In areas where land managers wish to improve habitat for existing populations or create habitat for repatriation efforts, an understanding of massasauga spatial ecology is necessary to ensure that adequate sized blocks of habitat are created and properly managed. We studied spatial ecology of massasaugas at 2 sites in Wisconsin and 3 sites in Missouri over an 11-year period. Our results indicated that male massasaugas had larger spatial requirements than all other cohorts. Our study sites supporting viable populations indicated that managers interested in restoring or enhancing massasauga habitat should use 100 ha as a minimum restoration or management target. (JOURNAL OF WILDLIFE MANAGEMENT 72(3):754–759; 2008)

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Knowledge of animal movement patterns and home range size and juxtaposition is critical for making effective wildlife management decisions regarding the management of threatened or endangered species and their habitats. The spatial ecology of snakes can be influenced by several factors including gender, age, reproductive status, size, and resource distribution (Gregory et al. 1987, Macartney et al. 1988, Weatherhead and Prior 1992, Johnson et al. 2000). Additionally, the spatial ecology of a species may vary among populations (Shine 1987, Macartney et al. 1988). Sources of variation in spatial ecology need to be identified so they may be incorporated into the habitat management process.

The massasauga (*Sistrurus catenatus*) is a small rattlesnake species that occurs from Texas to New York, USA (Schmidt and Davis 1941, Conant and Collins 1991, Szymanski 1998). Populations of the massasauga that occur north and east of the Missouri River are candidates for listing under the United States Endangered Species Act (Code of Federal Regulations 64 FR 57534; Szymanski 1998). The general decline of this species throughout its range can be attributed to habitat loss and fragmentation; overutilization for commercial, recreational, scientific, or educational purposes; predation due to habitat fragmentation; inadequacy of existing regulatory mechanisms; and indiscriminant or accidental killing (Szymanski 1988). Johnson et al. (2000) summarized the general life history of massasauga populations occurring in this area and research on adult massasauga spatial ecology and long-term changes in movement patterns has been conducted in limited portions of its range (Reinert and Kodrich 1982, Weatherhead and Prior 1992, Johnson 2000, Seigel and Pilgrim 2002, Marshall et al. 2006). However, no large-scale, comprehensive home range studies have been initiated in this geographic area and several important aspects of massasauga ecology still need to be investigated. Additionally, the spatial ecology of neonate massasaugas has never been examined.

Various researchers have demonstrated the massasauga's need for early successional, open habitats but recommendations incorporating spatial ecology information including minimum area requirements and habitat juxtapositions needed to support massasauga populations are lacking (Maple 1968, Reinert and Kodrich 1982, Seigel 1986, Weatherhead and Prior 1992, Johnson and Leopold 1998). This information void complicates massasauga recovery. Even as massasauga habitat is being managed and repatriation techniques are being developed, habitat managers still do not know the spatial requirements of massasauga populations (King et al. 2005). Our primary objective was to determine the spatial requirements of massasauga populations in the Midwest. Our secondary goal was to determine if we could identify consistent spatial ecology trends that managers could use to direct management and restoration activities.

STUDY AREA

We studied snakes from 2 sites in southern Wisconsin and 3 sites in north-central and northwestern Missouri (Fig. 1). Due to potential illegal collecting of massasaugas on unprotected study sites in Wisconsin, we refer to them only by county. Wisconsin study sites consisted of a 669-ha bottomland hardwood community located in Juneau County (JC) and a 69-ha peat bog community located in Monroe County (MC; Fig. 1). The JC study site was typical of southern Wisconsin bottomland hardwoods with a history of logging in the late 1800s followed by failed agriculture (Curtis 1959). Following initiation of wildfire suppression and control activities in the 1930s, most of the bottomland hardwood study site succeeded to closed-canopy forest. The

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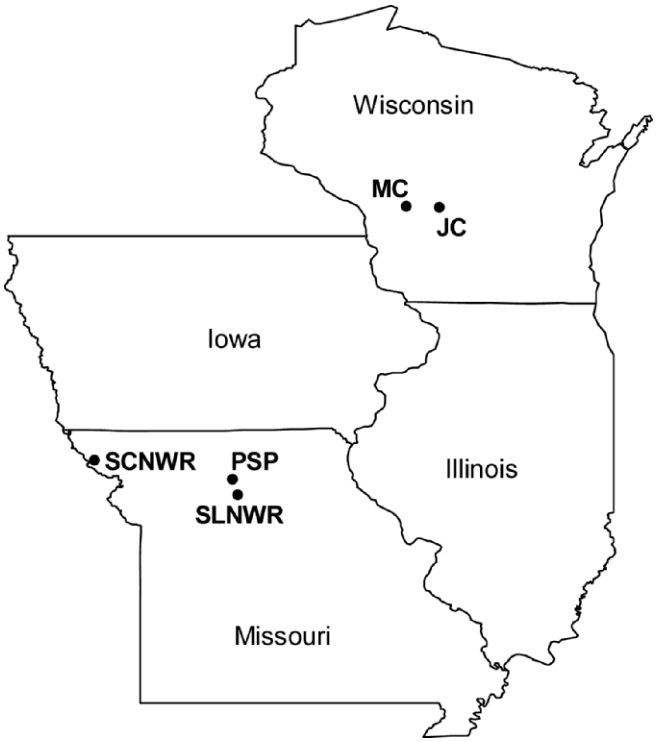

Figure 1. Location of massasauga rattlesnake study sites in Missouri and Wisconsin, USA, including Squaw Creek Wildlife Refuge (SCNWR), Swan Lake National Wildlife Refuge (SLNWR), Pershing State Park (PSP), Juneau County (JC), and Monroe County (MC), 1994–2004.

JC site had little open, early successional habitat and what little remained was widely dispersed. The MC study site was within an area of central Wisconsin that had a long history of both wild and prescribed fires (Grange 1948). The history of the MC study site also included logging followed by farming. Fire control on the bog study site also resulted in its degradation to closed-canopy forests. Open-canopy habitat on the MC study site was limited to a railroad grade that ran through the northern portion of the site.

Massasaugas used open, xeric areas at both Wisconsin study sites that were dominated by little bluestem (*Schizachyrium scoparium*) and mesic sites that were dominated by reed canary grass (*Phalaris arundinacea*) and sedges (*Carex* spp.). Although massasauga use was greater in open areas, they comprised only 15% to 17% of available habitat at the Wisconsin study sites. There was no active habitat management at either Wisconsin study site. Because the Wisconsin study sites were not publicly managed properties, we used the area utilized by radiomarked snakes to determine size of the MC and JC study sites. Both Wisconsin populations were considered to be declining, based on reported encounters, due to habitat loss and indiscriminant killing (Szymanski 1998).

The Missouri study sites included 3 bottomland wet prairie sites with associated upland xeric prairie habitat located on 3 different publicly owned lands including Squaw Creek National Wildlife Refuge (SCNWR; 3,012 ha) in northwestern Missouri, Swan Lake National Wildlife Refuge (SLNWR; 4,400 ha) in north-central Missouri, and Pershing State Park (PSP; 1,443 ha) in north-central Missouri (Fig. 1). The SCNWR contained ≥478 ha of occupied massasauga habitat, and massasaugas occupied approximately 200 ha and 100 ha on SLNWR and PSP, respectively. Vegetation and management on the 3 Missouri study sites was similar, with Indian grass (*Sorghastrum nutans*), switch grass (*Panicum virgatum*), big bluestem (*Andropogon gerardi*), eastern gamma grass (*Tripsacum dactyloides*), and sedges (*Carex* spp.) dominating. Several invasive species including reed canary grass (*Phalaris arundinacea*), dogwood (*Cornus* sp.) and honey locust (*Gleditsia triacanthos*) were encroaching on portions of these sites. Prescribed fire, chemical control, and mechanical control were commonly used to retard invasive species and maintain early successional prairie habitat on all 3 study sites. The population on SCNWR was considered secure, whereas the populations on SLNWR and PSP were considered vulnerable (Szymanski 1998).

METHODS

We captured massasaugas on the JC, MC, and SLNWR study sites by visually searching under railroad ties, other cover objects, and burned areas. We used drift fences, similar to those used by Fitch (1960), and visual searches to capture massasaugas on the SCNWR and PSP study sites.

We surgically implanted radiotransmitters (Holohil Systems, Ltd., Carp, ON, Canada) in individual snakes following techniques similar to Reinert and Cundall (1982), Reinert (1992), and Hardy and Greene (1999). Transmitter weights never exceeded 5% of adult body mass or 7.6% of neonate body mass and depending on the mass of individuals we used either Model SI-2T transmitters (9–14 g) or Model BD-2 transmitters (2–5 g). Our study conformed to all rules and regulations under Missouri Department of Conservation and Wisconsin Department of Natural Resources Wildlife Collection Permits.

We used radiotelemetry to monitor movement and obtain snake locations. We relocated each snake a minimum of twice weekly on nonconsecutive days to prevent possible avoidance behavior. We recorded snake locations using handheld Global Positioning Systems (GPS) with accuracies from 1 m to 5 m. We transferred all GPS locations to a microcomputer for subsequent analysis with a Geographic Information System.

We calculated home ranges for adult snakes with ≥30 locations and for each population using all individual locations combined as 95% and 50% fixed kernel home range utilization distributions (UD home ranges) and minimum convex polygon home ranges (MCP home ranges; Worton 1989, Seaman and Powell 1996, Seaman et al. 1999). Additionally, we calculated MCP home ranges for neonates with ≥3 positions. In all cases, we calculated MCP home ranges to facilitate comparison with previous studies. We used least squares cross validation to calculate smoothing parameters for all 95% and 50% UD home ranges (Silverman 1986, Seaman and Powell 1996, Seaman et al. 1999). We calculated both UD and MCP home ranges with

Table 1. Mean range length (m) and home range calculations (ha) for adult massasauga rattlesnake populations in Missouri and Wisconsin, USA, 1994–2004.

				Home range estimator[b]					
Population[a]	*n*	Range length	SE	MCP	MCP SE	95% FK	95% FK SE	50% FK	50% FK SE
MC	10	272.1	74.1	2.4	1.6	5.5	3.1	1.0	0.5
JC	4	1,378.6	1,102.1	135.8	134.2	25.8	24.5	5.2	5.0
PSP	10	643.2	147.3	11.9	3.8	18.8	8.0	3.8	1.9
SCNWR	27	669.9	83.7	17.1	4.3	18.8	4.3	3.4	0.9
SLNWR	8	475.6	72.9	7.4	1.5	6.5	1.0	1.1	0.2

[a] MC = Monroe County, WI; JC = Juneau County, WI; PSP = Pershing State Park, MO; SCNWR = Squaw Creek National Wildlife Refuge, MO; SLNWR = Swan Lake National Wildlife Refuge, MO.
[b] MCP = min. complex polygon; FK = fixed kernel.

the Animal Movement Extension for ArcView 3.2 (Hooge and Eichenlaub 1997). Additionally, we also calculated range length for each population and among cohorts, which we define as the measurement between the 2 most distant locations within an individual home range.

We tested all home range data for cohort and population differences using Kruskal–Wallis tests (Seigel and Castellan 1988, Durner and Gates 1993, Brito 2003, Wunderle et al. 2004). Population comparisons were limited to adult massasaugas because we radiomarked no Missouri neonates. Cohort categories included adult male, nongravid adult female, gravid adult female, and neonate. We used 2 years of monitoring for 3 individuals from Wisconsin. We pooled location data for one of the snakes (M) by year to calculate home range statistics. We analyzed locations for the 2 remaining snakes (F) separately for each year as both individuals were gravid during the first year of monitoring and nongravid during the second year. Separate analysis of each year was necessary as nongravid and gravid eastern massasaugas are known to exhibit significantly different movement patterns (Parent 1997, Johnson 2000). Additionally, a dramatic increase in postparturition movements has been demonstrated for rattlesnakes (Prival et al. 2002).

RESULTS

We radiomarked 87 massasaugas, including 28 neonates from Wisconsin, during our study. For individual home range data analysis we used 69 massasaugas that met the minimum location criteria, including 10 adults and 6 neonates from MC, 4 adults and 6 neonates from JC, 10 adults from PSP, 25 adults from SCNWR, and 8 adults from SLNWR. Telemetry resulted in 2,718 locations with an average interval of 3.3 days.

Among populations the 50% UD home ranges ($\chi^2_4 = 8.060$, $P = 0.089$) were comparable and ranged from a minimum of 1.0 ha on the MC site to a high of 5.2 ha on the JC site (Table 1). However, we found differences among populations for MCP home range estimates ($\chi^2_4 = 15.820$, $P = 0.003$) and 95% UDs ($\chi^2_4 = 11.070$, $P = 0.026$), with the JC population having the highest values for both of these home range estimators followed in order by the SCNWR, PSP, SLNWR, and MC populations (Table 1). The MCP home range for the JC population (135.8 ha) was approximately 8 times larger than the MCP home range for the SCNWR population (17.1 ha), the next largest, and 25 times larger than the MC population, which had the smallest MCP home range (2.4 ha). Similarly, the JC population 95% UD home range (25.8 ha) was approximately 1.5 times larger than the 95% UD home ranges for the PSP (18.8 ha) and SCNWR (18.8 ha) populations and 5 times larger than the MC population (5.5 ha).

Among cohorts the MCP home range estimates ($\chi^2_3 = 29.72$, $P \leq 0.001$), 95% UD home ranges ($\chi^2_2 = 13.64$, $P \leq 0.001$), and 50% UD home ranges ($\chi^2_2 = 18.40$, $P \leq 0.001$) were all different (Table 2). In all cases males had the highest values followed by gravid females, nongravid females, and neonates (Table 2). Male MCP home range values (38.3 ha) were approximately 8 and 12 times larger than gravid females (5.1 ha) and nongravid females (3.1 ha), respectively. A similar trend was also demonstrated for the UD home ranges with males having a 95% UD home range (25.3 ha) approximately 4 and 5 times larger than gravid (6.8 ha) and nongravid females (4.7 ha), respectively, and a 50% UD home range (5.0 ha) approximately 5 and 10 times larger than gravid (1.1 ha) and nongravid females (0.5 ha), respectively.

Table 2. Mean range length (m) and home range calculations (ha) for female, gravid female, male, and neonate massasauga rattlesnakes in Missouri and Wisconsin, USA, 1994–2004.

				Home range estimator[a]					
Cohort	*n*	Range length	SE	MCP	MCP SE	95% FK	95% FK SE	50% FK	50% FK SE
F	8	366.5	50.7	3.6	0.9	4.7	1.5	0.5	0.1
Gravid F	22	423.2	63.8	5.1	1.1	6.8	1.8	1.1	0.3
M	29	845.5	165.8	38.3	19.7	25.3	5.4	5.0	1.2
Neonates	28	64.3	20.5	0.6	0.2				

[a] MCP = min. complex polygon; FK = fixed kernel.

Table 3. Population level home range calculations (ha) for massasauga rattlesnake populations in Missouri and Wisconsin, USA, 1994–2004.

Population[a]	Min. convex polygon	95% fixed kernel	50% fixed kernel
MC	30.7	18.8	1.6
JC	538.5	58.3	10.4
PSP	104.3	59.6	5.2
SCNWR	133.4	68.1	9.7
SLNWR	100.8	66.9	6.6

[a] MC = Monroe County, WI; JC = Juneau County, WI; PSP = Pershing State Park, MO; SCNWR = Squaw Creek National Wildlife Refuge, MO; SLNWR = Swan Lake National Wildlife Refuge, MO.

Populations level home range calculations resulted in a wide range of values for both MCP and UD home range calculations with the MC population having the smallest values for all 3 home range estimators (Table 3). The MCP home range values ranged from 30.7 ha for the MC population up to 538.5 ha for the JC population. The JC population also had the largest value for the 50% UD home range estimate (10.4 ha), and the SCNWR population had the largest value (68.1 ha) for the 95% UD home range estimate. In both cases the MC population had the smallest 50% UD home range (1.6 ha) and 95% UD home range (18.8 ha).

Range length ($\chi^2_4 = 8.500$, $P = 0.075$) was found to be similar among populations, ranging from a low value of 272.1 m for the MC population up to 1,378.6 m for the JC population (Table 1). However, we found differences among cohorts for range length estimates ($\chi^2_3 = 48.24$, $P \leq 0.001$) with males having values (845.5 m) approximately 2 times higher than nongravid females (366.5 m) and gravid females (423.2 m) and 13 times higher than neonates (64.3 m; Table 2).

DISCUSSION

All of our MCP home range estimates fell below those reported by Weatherhead and Prior (1992) and Johnson (2000) with the exception of the JC population (135.8 ± 134.2 ha), which is the largest eastern massasauga home range ever reported. These differences can be explained by varying habitat quality and availability among the sites, which directly effects home range size. However, all of our MCP home range estimates are greater than those reported by Reinert and Kodrich (1982) but direct comparisons are problematic because that study involved force-fed transmitters that may have impacted movements.

Among the populations we studied, individuals from the MC population used the smallest home range area for all 3 estimators (Table 1), which we believe was a function of the railroad corridor being the only open canopy habitat within that study site. In fact, most of the radiomarked massasaugas did not leave the railroad corridor until just prior to migrating to hibernacula, which were located in wooded, peat-dominated wetlands. As predicted, the concentration of individuals in the only available open-canopy habitat made massasaugas susceptible to predation; we found the radiotransmitters from 3 neonates and the rattle from an adult (unknown to the researchers) in one owl pellet. For these reasons, we contend that the MC site may represent a population sink and therefore did not use data from this site when making habitat management recommendations.

Individuals from the JC site had the largest home ranges among the studied populations (Table 1), which we postulate was related to open-canopy habitat being limited and widely dispersed at that study site. While navigating among these habitat patches, we observed a male from this population crossing closed canopy forests, pastures, and residential areas. The use of roads at the JC study site may have been caused by limited open-canopy habitat necessary for dispersal. Regardless, we found as many road-killed massasaugas during this study as we did live individuals. The JC study site also may represent a population sink due to the limited availability of open-canopy habitat and the juxtaposition of those habitats. Therefore we also excluded data from the JC study site when making habitat recommendations.

Many authors reported studying massasaugas at small study sites across their range including Illinois (1.5 ha, Anton 1993; 9.1 ha, Wilson and Mauger 1998), Ohio (20 ha, Jaworski 1993), New York (37 ha, Johnson 2000), and Pennsylvania (36 ha, Reinert and Kodrich 1982). Like our Wisconsin study sites, we contend that previous research based on small study sites should not be used to model the spatial ecology of massasauga populations, because sustainability of all these populations is in doubt, and modeling habitat requirements based on potential population sinks is not desirable (Szymanski 1998).

Among cohorts, we found that regardless of calculation method, males had the largest home range estimates, followed by gravid females, nongravid females, and neonates (Table 2). Similarly, Weatherhead and Prior (1992) did not distinguish between gravid and nongravid females but found that male eastern massasaugas had larger home ranges than females. Marshall et al. (2006) reported that males and nongravid females had similar size home ranges that were larger than gravid females. In contrast, Johnson (2000) found that nongravid females had the largest home range estimates followed by males and gravid females. Discrepancies among these studies are not remarkable as variability of spatial ecology parameters within cohorts and among different populations has been reported by Macartney et al. (1988) and Shine (1987). We believe differences among gravid female home range sizes can be attributed to availability of suitable gestation habitat where larger gravid female home ranges are a result of relatively lower gestation habitat availability which causes gravid females to cover larger home areas.

Our data indicate that male massasaugas have the largest spatial requirements and that an average male will require 38.3 ha of habitat based on MCP home range size. We chose to use the MCP home range size because this was the largest of our spatial use calculations and therefore represents the most conservative estimate of required space. Nongravid females were reported to have the largest spatial

requirements (41.4 ha) in New York, whereas males had the largest spatial requirements (33.3 ha) in Ontario (Weatherhead and Prior 1992, Johnson 2000). Therefore, all published data indicate that approximately 40 ha of suitable habitat is large enough for the average massasauga, but massasauga populations require more habitat than do individuals.

Population level home range data from the PSP, SCNWR, and SLNWR (MO populations) may represent the first opportunity to examine massasauga spatial ecology for populations not in decline. Therefore, using these study sites as models, we contend that 100 ha, the smallest area used by the 3 Missouri populations (Table 3), should be considered the minimal amount of habitat for sustaining a massasauga population.

MANAGEMENT IMPLICATIONS

Using our Missouri study sites as models, managers interested in restoring or enhancing habitat for massasaugas should use 100 ha as a minimum target. The mosaic of xeric and mesic habitats within this space should be open-canopy and $\leq$1,800 m across at any point, based on the mean range length for the PSP population (Table 1), which was the smallest for the Missouri populations and therefore the most conservative estimate (Johnson et al. 2000). If that is not possible, providing suitable habitat within easy traveling distance of hibernation sites (approx. 400 m) is most desirable. We interpret easy traveling distance as mean range length for our nongravid females, the cohort with the smallest range length on our Missouri study sites (Table 2).

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