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ACTIVITY PATTERNS AND SPATIAL RESOURCE SELECTION OF THE EASTERN MASSASAUGA RATTLESNAKE IN NORTHEASTERN INDIANA

FINAL REPORT
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Bruce A. Kingsbury,
John C. Marshall and Jennifer Manning

Center for Reptile and Amphibian Conservation and Management
Science Building
Indiana-Purdue University
Fort Wayne, Indiana

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EXECUTIVE SUMMARY

The Eastern Massasauga Rattlesnake, *Sistrurus c. catenatus* is being considered for federal listing as Threatened under the Endangered Species Act of 1973. Management planning for this species would greatly benefit from ecological studies conducted at local scales and in habitats where their ecology is not yet well understood. Efforts have been increased to ascertain its ecological requirements and develop proper management approaches for it, especially in habitats not yet well understood. Fens have received relatively little attention thus far in massasauga literature despite the fact that, in some regions, fens may support the largest populations of massasaugas (i.e. Indiana, Casebere 1997).

This report details findings from a four-year study (plus the current field season) of the massasauga at Cline Fen in northeastern Indiana. Patterns of movement, macrohabitat and microhabitat use were examined using radio telemetry. The results obtained for this site were also compared to findings by other researchers across the range of the subspecies.

Males exhibit the largest home ranges. One of the reasons for this is their tendency to make extensive moves in the summer to find females. Both males and nongravid females typically have two or three activity centers, and they may revisit these areas repeatedly over the activity season. Gravid females have the smallest home ranges, and usually only a single activity center. By late spring they establish themselves at a gestation site where they usually stay at until parturition in August. After giving birth, they show more extensive movements before returning to the hibernaculum. All classes of massasauga are usually, but not always, underground by mid-October.

All snakes prefer emergent vegetation for both their home range and their activity centers. Of the emergent vegetation habitats Shore Line was selected the most often with respect to its availability. This is likely due to two reasons. Most importantly, four gravid females used this habitat. Within days of their emergence form hibernation these four females moved to locations along the lake shore where they established gestation sites and remained until early August. Their use, along with the occasional use by others, likely led to the high ranking. In addition, the lake shore also only comprises a small amount of the study site (0.4%) and compositional analysis is susceptible to bias when habitat availability is low.

Management efforts should focus on maintaining the early successional stages in the wetlands and their margins. Trees and shrubs should be discouraged, but complete removal of all shrub cover is inappropriate. While many commonly used management practices are compatible with massasaugas, timing considerations are very important for avoiding take. Many techniques are best used during the winter months, save water drawdowns, which could freeze hibernating snakes. Hibernacula are critical habitat- all known hibernacula should be aggressively protected.

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INTRODUCTION

The Eastern Massasauga Rattlesnake, *Sistrurus c. catenatus* is being considered for federal listing as Threatened under the Endangered Species Act of 1973. The development of management strategies for this species would greatly benefit from ecological studies conducted at local scales and in habitats where their ecology is not yet well understood. The eastern massasauga has been reported to use a variety of habitats including wet prairies (Seigel 1986), sedge meadows and peatlands (Johnson 2000), coniferous forests (Weatherhead and Prior 1992), and meadows and old fields (Reinert and Kodrich 1982, Wright 1941, Smith 1961). This diversity in habitat use has made developing management strategies for the species more challenging.

The massasauga also inhabits fens (Kingsbury 1999), which occur in parts of the northeastern United States, the Great Lakes region and much of Canada. Fens are a wetland type that is characterized by nutrient and mineral-rich ground water, resulting from passage through glacial till, emerging upon the surface to create a continuous flow through the peatland (Casebere 1997). Fens have received relatively little attention thus far in massasauga literature despite the fact that, in some regions, fens may support the largest populations of massasaugas (i.e. Indiana, Casebere 1997).

We undertook a radiotelemetric study of massasaugas in a fen to clarify the behavior and ecology of the species in this important habitat. We examined patterns of movement and describe home range and activity center characteristics, and determine macrohabitat features associated with the eastern massasauga's habitat selection in fens. The findings of this study add to our growing knowledge of the variability in massasauga ecology, and provide a foundation for management of this species in fen habitat.

MATERIALS AND METHODS

<u>Study Site</u>

The lower areas of the study site were comprised of open water, floating sedge mats (*Carex spp.*) and extensive patches of broad and narrow-leaved cattails (*Typhus* spp.) (Figure 1). Shrubs encroached along most of the periphery of the site and often intermingled with the sedges and cattails. The southern half of the site was dominated by shrub habitat containing dogwood (*Cornus* spp.), poison sumac (*Rhus vernix*), swamp birch (*Betula nigra*), cottonwoods (*Populus* spp), tamaracks (*Larix* spp) and willows (*Salix* spp). Water flows eastward from ground seeps and flooded areas towards two bodies of water (ca. one and two ha.). A beaver dam, forming a variable shallow impoundment, intercepted much of the ground water flow heading towards a deep kettle lake (1.5 ha).

Radio Telemetry

We captured study snakes during spring emergence in 1999 and continued through the 2002 (i.e. April through October), and then into the 2003 field season. We began spring research activities with systematic searches targeting aggregations of crayfish burrows or expansions of sphagnum hummocks, both of which are known to support hibernacula (Maple and Orr 1968; Seigel 1986; Johnson 1995; Kingsbury 1999). Selected snakes were implanted intraperitoneally, using a modification of the Weatherhead and Anderka (1984) method, with temperature-sensitive radio-transmitters (Model SI-2T, Holohil Systems Inc., Carp, Ontario, 8.6g, 20 months battery life at 20°C). Selection criteria were to strive to equalize the sex ratio, taking into account that some females were gravid (i.e. preferentially selecting females), and to minimize transmitter weight to body weight ratios by selecting large adults (>200g). Glass encapsulated passive integrated transponders (PIT tags, AVID®) were implanted subcutaneously in all captures just anterior and lateral to the cloacal opening to facilitate permanent identification.

All snakes were relocated on average three times per week using a Telonics TR-4 or TR-3 receiver and hand-held “H” antennas (Telonics Inc., Mesa, Arizona). Snake locations were plotted by triangulation to known points, angle and distance to known point, or geographical positioning system (GPS). GPS was available only late in 2000 and thereafter. Due to the variability in the error of the position estimate by the GPS, it was generally used to estimate a single location, which could be marked with surveyor’s tape, to be used as a reference for subsequent movements. In rare instances dense undergrowth, and or canopy cover sufficient to limit satellite signal receiving capabilities, required use of short series of angles and distances to known points to obtain animal location data.

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Regardless of the position collection method we used, the objective was to obtain Universal Transverse Mercator (UTM) coordinates, which we then plotted on a geographically-referenced aerial photograph of the study site with the aid of the Arc View (ESRI Inc.) geographical information system (GIS) application. These points were then used to estimate the spatial use of this population.

Spatial Ecology

Seasonal ranges and activity centers—Two approaches were used to characterize seasonal range, defined here as that area of the study site used over the period of the activity season. The minimum convex polygon (MCP) method describes the area used by enclosing all observations within a polygon linking all peripheral points with no concavities in its form (Jennrich and Turner, 1969). The benefits of this approach are its simple and straight-forward nature, comparability to other studies, and inclusion of interior areas likely to acts as corridors. Shortcomings include positive correlation of polygon size with observation number, especially for small sample sizes (Worton, 1987), and inclusion of interior areas not used. We also calculated seasonal range using kernel density (KD) estimates (Worton 1989). The KD method is a non-parametric estimator of an animal's home range and is constructed in terms of a probabilistic distribution of spatial use (Worton 1989). An advantage of the KD approach is that percentile isopleths suggest concentrations of activity. A drawback is that peripheral areas are included in the range that are never used and that contain inappropriate habitat. To minimize this effect, we used 95% probability isopleths to estimate seasonal range. We used the fixed kernel method and least squares cross-validation to select the smoothing parameter to reduce bias in area estimates (Seaman and Powell 1996).

Activity centers are defined as those areas of the seasonal range experiencing concentrated use. For snakes, activity centers are not necessarily singular and central in nature, and may thus be separated by extensive, rarely visited areas. We used 50% isopleth probabilities for delineation of activity centers (e.g., Secor 1994, Tiebout and Cary 1987).

We estimated spatial movements only for animals tracked at least 70 days. Years were combined to boost sample size, but for individuals tracked multiple seasons, we randomly selected years for inclusion in spatial analyses to avoid psuedoreplication. As a

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result, seasonal range estimates, activity center estimates, and movement parameters were characterized from nine males, nine nongravid females, and eight gravid females over a four-year period (Table 1). Area estimations for MCPs, 95% isopleth KD and 50% isopleth KD were tested for normality using Kolmogorov-Smirnov tests. Equality of variances were evaluated using Levene's tests and residual plots. A MANOVA was used to compare MCPs and 95% isopleth KD among snake categories (male, female, and gravid female) and between years. ANOVA was used to evaluate activity centers. Wilks' Lambda was used in all MANOVA procedures. Tukey's HSD post hoc tests were used to determine which snake categories, if any, were different. 100% MCPs, 95% KD, 50% KD, distance moved per day, and total distance moved per season were $\log_{10}$ transformed to adhere to normality and variance assumptions of ANOVA. Alpha levels were set at 0.05. All statistical procedures were performed using SPSS (v11.0, Claritus Inc. 2001).

Movement parameters—We characterized movements made by individuals in the following manner and statistically evaluated them using a MANOVA and Tukey's HSD post hoc tests. Mean frequency of movement (%) was determined by the number of successive relocations greater than 5m apart. This distance was selected to distinguish between smaller, local adjustments in position, versus larger scale shifts to new areas. Movement per day (m) is the total distance traversed divided by the total number of days tracked. Range length (m) is the greatest distance between any two relocations and the total distance moved (m) is the sum total of all successive movements. Movements per unit time are likely underestimates of actual distances traveled, but provide indices of relative amounts of movement between snake groups.

Habitat selection— We performed compositional analysis (Aebischer et al. 1993) to assess macrohabitat selection. We selected compositional analysis for assessing habitat selection because it uses individual snakes as the sampling unit instead of pooling radio locations over individuals. Pooling data across individuals limits the inference space to that of only the radio tracked sample and not the population and is justifiable only if their behavior does not differ (Aebischer et al., 1993). In addition, the proportions of habitats available to and used by the animals must sum to one, thus an animal's avoidance of one

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habitat may seem to indicate a preference for another. Compositional analysis addresses this issue by considering all available habitats simultaneously.

Compositional analysis was conducted at two levels using MCPs and at three levels using KDs. "Seasonal range selection" is a comparison of the composition of seasonal range relative to the composition of the study site, and comparable to Johnson's (1980) second-order selection. This analysis provides information about the choices an animal makes about the area it will utilize in the context of habitat in the area. "Activity site selection" is an examination of the composition of relocation sites relative to seasonal range composition (Johnson's third-order selection). This analysis provides insights about how an animal positions itself over time within its seasonal range. Kernel densities allow for an additional level of analysis that fits between Johnson's (1980) second and third-order selection. "Activity center selection" is a comparison of the habitat found within the 50% KD to that available at the study site. Using both MCPs and KDs facilitates a qualitative comparison of macrohabitat use between these two approaches to delineating home ranges and activity centers.

We delineated habitat availability parsimoniously by placing a single rectangle around all of the seasonal ranges used at the study site (Fig. 1). With the resulting study site, proportions of habitat types available at the site level as well as at the seasonal range level could easily be quantified with the aid of Arc View (ESRI, Inc.). The study site was subdivided into macrohabitat types for habitat use analyses (see below) based on the major vegetational and hydrological features present. The seven macrohabitat types were *Old field*, agricultural field left fallow for several years, but currently under going prairie restoration efforts; *Carex tussock*, consists almost entirely of sedge tussocks (*Carex* spp.) and standing water; *Cattail*, dominated by cattails (*Typha* spp.) with some standing water and floating sedge mats; *Shrub/scrub*, dominated by *Rhus* spp., *Cornus* spp., *Populus* spp. and *Larix* spp. with significant stands of trees; *Shore line*, consists of a narrow band of habitat along the shore of the kettle lake which is dominated by rushes (*Juncus* spp.) and shrubby cinquefoil (*Potentilla fruticosa*); *Eupatorium* spp./*Solidago* spp., area thought to be previously cultivated, and dominated by these species; and *Agriculture*, a combination of hay fields, residential property and road-sides.

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Compositional analyses were performed using the Resource Selection program (Leban 1999). When overall use of habitats was non-random ($P<0.05$), habitats were ranked in order of preference and two-tailed t-tests ($P<0.05$) were utilized to determine which rankings differed significantly. A multivariate analysis of variance (MANOVA) was performed on the logarithmically transformed differences (which retain linearity, Aitchison 1989) of one habitat's proportions (e.g. individual MCP) to another's proportions (e.g. study site) to determine sex or year effects or a sex/year interaction.

2003 Activity Season Summary

This report also includes additional comments concerning the current activity season. Although this season is not complete it is still possible to determine, at least qualitatively, the degree to which this season's data corroborates and enhances our knowledge of the massasaugas ecology known from previous years of investigation. This current summary includes a description of the number and of which category (i.e. male, female, and gravid female) of snakes that are currently being studied, the current sizes of their home ranges (100% MCP only), and a qualitative description of both their macro (see above) and microhabitat (Table 1) utilization. Movement parameters were not calculated for 2003 and await the conclusion of this year's data collection. Compositional analyses were also not performed on this partial data set.

RESULTS

Spatial Ecology

Emergence from hibernation occurred typically around the middle of April, but individuals have been seen as early as late March. After emergence, massasaugas were seen moving to basking areas within a few meters of their hibernacula and tended to stay close by (i.e. within10-30m) for approximately a week. Subsequent to this initial movement, males and nongravid females migrate over a period of about two weeks to habitats where they establish activity centers (egress). These activity centers were typically located anywhere from about 200 meters to 600 meters away from the hibernacula. Gravid females tended to maintain closer proximity to their hibernacula until parturition, which occurred in late July or early August, they would then move to

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other locations, presumably to forage. Interestingly, individuals that were not gravid tended to have multiple (i.e. 2-3) activity centers, whereas all gravid snakes had only one.

Seasonal range—Seasonal range estimates ranged from 0.18ha to 15.8ha (100%MCP) and from 0.15ha to 24.48ha (95% KD) while activity center estimations ranged from 0.04ha to 5.5ha (Table 1). Year was determined not to have a significant effect on seasonal range (F=1.65,df=6, 28, P=0.17), so years were combined. MANOVA comparison of seasonal ranges indicated a significant effect of snake category (λ=0.20, F=13.33, df=4,44, P<0.001). Males typically had larger MCPs ($\overline{X}$ = 7.32 ± 1.44ha) than nongravid females ($\overline{X}$ = 3.36 ± 0.68ha), which tended to be larger than gravid females ($\overline{X}$ = 1.40 ± 0.51ha). However, males were not significantly different from nongravid females (P=0.15) but were from gravid females (P<0.001). Females also had significantly larger MCPs than gravid females (P=0.024). 95% KD followed the same trend as MCPs. Males had larger estimates ($\overline{X}$ = 12.53 ± 2.31ha) than both nongravid females ($\overline{X}$ = 5.24 ± 0.71ha) and gravid females ($\overline{X}$ = 1.03 ± 0.40ha). Additionally, males do not have significantly larger 95%KDs than nongravid females (P=0.15) but are from gravid females (P<0.001). Nongravid females also have significantly larger 95% KD than gravid females (P<0.001).

2003 Seasonal range— A total of ten massasaugas are being tracked in 2003: four females, two males, and two gravid females (Fig. 2, Table 2). However, it is still too early in the season to determine with a 100% certainty which females are gravid and which are not. Nonetheless, we estimate that at this point the female average 100% MCP area is 1.03ha, 2.52ha for the males, and 0.11ha for the gravid females.

Activity center estimations follow the same trend as the seasonal range estimations. Activity centers did not vary between years (F=0.97, df=3, P=0.43), so years were combined. Males typically had larger activity centers ($\overline{X}$ = 2.41 ± 0.55ha) than nongravid females ($\overline{X}$ = 0.89 ± 0.22ha), which tended to have larger activity centers than gravid females ($\overline{X}$ = 0.17 ± 0.08ha). ANOVA procedures indicated a significant effect of snake category (F=23.22, df=2, P<0.001). Males were not significantly different than nongravid females (P=0.085) but were from gravid females (P<0.001) and nongravid females were significantly different than gravid females (P<0.001).

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Movement parameters— Movement patterns showed no year effect, so years were combined ($F=2.02$, $df=12, 32.04$, $P=0.056$). MANOVA procedures indicated a significant effect of snake category ($\lambda=0.24$, $F=5.23$, $df=8,42$, $P<0.001$). Significant differences were found between nongravid females and gravid females for mean frequency of movement ($P=0.013$), movement per day ($P=0.024$), and total distance moved in a season ($P=0.025$). Significant differences were also found between males and gravid females for mean frequency of movement ($P=0.002$), movement per day ($P<0.001$), and total distance moved in a season ($P<0.001$). Males were significantly different from nongravid females for movement per day ($P=0.034$) and where not significantly different from nongravid females for mean frequency, range length, and total distance moved ($P=0.72$, $P=0.47$, $P=0.15$; for, respectively).

Habitat Selection

The delineated study area was 84.8 ha (including 4.18 ha of open water). The most abundant habitat type was that of shrub/scrub, which comprised 36.1% of the study site. The remaining habitat types comprised the following proportions: agriculture (35.7%), Cattails (10.7%), Old Field (9.3%), Sedge tussocks (3.5%), *Eupatorium/Solidago* (4.4%), and finally Shore Line, which comprised only 0.4% of the study site. The open water region was not considered in the analysis of macrohabitat use due to its unsuitability as habitat. No massasauga was ever seen using open water during the course of this study.

Proportions of the habitats within the MCP seasonal ranges were non-random relative to the available habitat ($\lambda=0.06$, $df=6$, $\chi^2=73.43$, $P<0.001$). A MANOVA revealed no significant effects of snake category, year, or snake category x year interaction on the composition of habitat in the seasonal ranges ($\lambda=0.23$, $df=12,18$, $F=1.26$, $P=0.32$; $\lambda=0.190$, $df=18,25.94$, $F=1.15$, $P=0.36$; $\lambda=0.14$, $df=36,42.28$, $F=0.0.66$, $P=0.90$, respectively). Compositional analysis of the MCP seasonal range selection indicated that Shore Line had significantly greater relative use followed in order by Cattails, Sedge tussocks, Shrub/scrub, which was significantly different than *Eupatorium/Solidago,* Old Field and finally Agriculture.

Proportions of the habitats within the 95KD seasonal ranges were non-random relative to the available habitat ($\lambda=0.07$, $df=6$, $\chi^2=67.97$, $P<0.001$). A MANOVA

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revealed no significant effects of year or year x snake category interaction (λ=0.19, df=18, 25.9, F=1.14, P=0.38; λ=0.08, df=36, 42.3, F=0.94, P=0.58, respectively) but did indicate a significant effect of snake category (λ=0.13, df=12,18, F=2.74, P=0.026). The only significant effect of snake category is that gravid females include significantly more *Shore Line* habitat than either nongravid females (P=0.001) or males (P=0.001). Compositional analysis of the 95KD seasonal range selection indicated that Shore Line had greater relative use followed in order by Cattails, Sedge tussocks, Shrub/scrub, which was significantly different than Agriculture, *Eupatorium/Solidago*, and finally Old Field.

Composition of relocation sites relative to MCP seasonal range composition (Johnson's third-order selection) was non-random (λ=0.46, df=6, χ^2=20.23, P<0.05). A MANOVA revealed no significant effects of snake category, year, or snake category x year interaction on the composition of habitat in the seasonal ranges (λ=0.43, F=0.79, df=12, 18, P=0.65; λ=0.36, F=0.64, df=18, 25.94, P=0.84; λ=0.085, F=0.89, df=36, 42.28, P=0.64, respectively). Compositional analysis indicated that Old Field had greater relative use than *Eupatorium/Solidago* followed in order by Sedge tussocks, Agriculture, Shore Line, Cattails, and finally Shrub/srcub. However, none of the rankings were statistically significant.

Composition of relocation sites relative to 95KD seasonal range composition was non-random (λ=0.30, df=6, χ^2=31.53, P<0.001). A MANOVA indicated no significant effect of year or a year X snake category (λ=0.11, df=18, 25.9, F=1.68, P=0.11; λ=0.03, df=36, 42.3, F=1.46, P=0.12, respectively) but did indicate a significant effect of snake category (λ=0.07, df=12,18, F=4.10, P=0.004). Post hoc tests revealed that gravid females use significantly less Cattails than nongravid females (P=0.003) but not less than males (P=0.07). In addition, gravid females use marginally less *Eupatorium/Solidago* than nongravid females (P=0.046) but again not less than males (P=0.84).

Compositional analysis of "activity center selection" indicates that proportion of habitats found with 50KDs were nonrandom relative to the available habitat (λ=0.10, df=6, χ^2=59.16, P<0.001). A MANOVA indicated no significant effects of year, snake category, or year x snake category interaction (λ=0.30, F=0.78, df=18,25.9, P=0.71; λ=0.26, F=1.47, df=12,18, P=0.22; λ=0.12, F=0.73, df=36, 42.28, P=0.83, respectively). Compositional analysis indicated that Shore Line had the greatest relative use followed

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by Cattails, Sedge Tussocks, Shrub/scrub, *Eupatorium/Solidago*, Old Field, and finally agriculture.

2003 Habitat selection—Compositional analysis was not performed on the partial data set of 2003. The following is the percentage of locations found in each habitat across all snakes: 10% in Shore Line, 15% in *Eupatorium/Solidago*, 27% in Shrub/scrub, and 48% in Cattails. No other macrohabitats are represented.

Microhabitat variables are described in Table 1 and percent cover variables for both snakes and random locations are summarized in Table 3.

Observations of Mortality

Although massasaugas do show mortality during the year, and occasionally during hibernation, overwintering mortality this winter was substantial. Four snakes never emerged from hibernation, and two apparently died shortly after emergence. Such high levels of mortality have never been seen during hibernation over numerous study sites and three different species of snake.

DISCUSSION

Spatial Use and Patterns of Activity

When examining the relative sizes of home ranges, regardless of the method used (MCP or KD), males tended to use larger areas than nongravid females and these in turn used larger areas than gravid females. However, only significant differences in home range area, (MCP or KD), were found for nongravid snakes (males and females) in comparison with gravid females. Reinert and Kodrich (1982) and Johnson (2000) found no significant differences between males and nongravid females for home range area but Weatherhead and Prior (1992) and King (1997) did find significant differences. Weatherhead and Prior's (1992) findings may be partially explained by the lack of distinction between nongravid and gravid females. The inclusion of gravid females, if any, might influence interpretation of differences between the sexes because of their sessile nature during gestation. Johnson (2000), King (1997) and this study support the conclusion that gravid massasaugas reduce activity during gestation. Reinert and Kodrich (1982) did not see the same trend with gravid females compared to other snakes for most movement parameters in Pennsylvania. However, tracking periods were short

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and snakes were force-fed transmitters, potentially inducing thermophily and reducing movement (Reinert and Cundall 1982; Lutterschmidt and Reinert 1990).

Movements within activity centers by snakes that were not gravid appeared to be short forays punctuated by periods of little activity, typical of an ambush forager. Conversely, gravid females were very sedentary in behavior and moved significantly less often and traversed significantly less area than nongravid snakes (Table1). Gravid female activity was largely restricted to shuffling between basking locations or to and from overnight refugia. Other authors have also observed a reduction in movements by gravid female pit-vipers (Viitanen 1967, Brown et al. 1982, Reinert and Zappalorti 1988, Secor 1994). However, postpartum females (early August) did make larger movements into presumably foraging areas.

Gravid females are thought to be more preoccupied with body temperature maintenance for efficient embryological development (Naulleau 1979), which may be satisfied in a smaller area than required for foraging. Keenlyne (1972) noted that gravid *C. horridus* fast during the summer when pregnant. Keenlyne and Beer (1973) noted that only 10.4 percent of the gravid female eastern massasaugas contained food items compared to 83.6 percent for males and 55.6 percent for nongravid females. Occurrence of food items in those gravid females was highest early in the spring before much egg development had taken place.

Although fall monitoring was less frequent than during the summer, ingress movements by all snakes appeared to be similar to that of egress in that they took a relatively short period to return to the general area of their hibernacula, and also seemed to utilize the same general habitat corridor. Snakes returned to the general area of their previous hibernacula by late September and remained relatively inactive subsequent to their hibernacula entrance by mid October.

Taken together, these studies of the spatial ecology of the massasauga corroborate predictions that movement and resource use between sexes and populations may very regionally and even locally. These differences are not likely due to just variation in methodology between studies. Sizes of home ranges and activity centers of snakes commonly vary with ecologically significant factors such as resource availability (Gregory et al. 1987, McCartney et al.1988), mate searching (Minton 1972, Weatherhead

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and Hoysak 1988, Duvall and Schuett 1997, Walker 2000) and reproductive condition (Brown et al. 1982, Reinert and Zappalorti 1988, Graves and Duvall 1993, Johnson 1995, King 1997).

Habitat Use

Analysis of macrohabitat use indicated snakes preferentially included emergent vegetation in their home range with the habitat along the lake shore being ranked first. This is likely due to two reasons. Most importantly, four gravid females used this habitat. Within days of their emergence form hibernation these four females moved to locations along the lake shore where they established gestation sites and remained until early August. The lake shore vegetation is generally shorter than in other areas of the site but remains adjacent to taller vegetation. It is presumed that the shorter vegetation is desirable for thermoregulation while the taller vegetation, which may provide some thermoregulatory benefits, provides a convenient retreat when cover is desirable. Their use, along with the occasional use by others, likely led to the high ranking. The lake shore also only comprises a small amount of the study site (0.4%) and compositional analysis is susceptible to bias when habitat availability is low (Pendleton et al. 1998).

Compositional analysis of activity site selection (i.e. locations versus home range) indicated that snakes, regardless of their sex or reproductive condition, did not include large portions of unsuitable habitat (i.e. agriculture) in their home range. In addition, the average seasonal range size across all individuals was 4.03ha, an area one-fifth the size found within Bruce Peninsula National Park Ontario (25ha, Weatherhead and Prior 1992) and at Cicero Swamp New York (26.2ha, Johnson 2000). Our findings approach those of Reinert and Kodrich's (1982) study in Western Pennsylvania, where snakes ranged over 1.0ha during the study. Johnson (2000) speculated that the smaller seasonal ranges in this latter study were due at least in part to differences in methodology (e.g. force-fed transmitters and/or short tracking periods). In our case, small seasonal ranges would more likely be due to the ability of snakes to meet all their life requisites (e.g. foraging, mating etc.) within the old field and meadow habitats, where hibernacula, prey and basking sites are plentiful. The preferred habitat was centrally located in the study area, so traverses across inhospitable habitat were not necessary. Marshall (2002) investigated the distribution of small mammals at this site and determined that *Microtus pennsylvanicus*,

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the primary prey of massasauga populations in Wisconsin and Missouri (Keenlyne and Beer 1973; Seigel 1986, respectively), was most abundant in the sedges and cattails. Furthermore, basking sites were plentiful and hibernacula locations were nearby as well.

Implications of 2003

The activity season of 2003 seems to be in accord with data collected in previous years. Home ranges fit the pattern of males using more area than nongravid females, which in turn use more area than gravid females (Table 2).

Habitat use also seems to be supportive of past views. Nearly 60% of all snake locations this year are within the emergent vegetation of which cattails composes the largest share (48%). However, one interesting difference from this year's data is that the *Eupatorium/Solidago* habitat is utilized more. This greater use of the *Eupatorium/ Solidago* habitat is indicative of three snakes (i.e. 308, 346, & 852) greater affinity for habitat near Cline Lake, an area largely unutilized by radio tracked snakes from previous years. This year's data begs the question of just how many snakes use Cline Lake? How important is this area? We know of two snakes that have hibernated near Cline Lake and it is likely that more do as well. Because of these recent findings we would suggest including habitat around Cline Lake in management schemes when possible.

When qualitatively assessing the microhabitat data it appears that snakes utilize large amounts of detritus and herbaceous vegetation while including some amounts of shrubs (just based on difference in mean of random and mean of snakes). It will remain important to maintain the early successional stages in the wetland and its margins.

Management Implications

At Cline Fen massasaugas prefer emergent vegetation and special care should be taken to preserve this habitat. However, any management schemes intended to protect the fauna of Cline Fen should include both emergent vegetation and upland habitat as the need for adequate wetland buffers is all too often overlooked. Despite the massasauga's heavy dependence on the emergent vegetation they were also seen using woody habitat and old fields, at times in excess of 300m from emergent vegetation. In addition, massasaugas from a nearby population (ca. 5 km) have been known to travel significant distances (i.e. >800m) through upland habitat to establish summer activity centers in old fields (personal observation). Clearly massasaugas are not restricted to emergent vegetation and we would encourage that they be managed accordingly.

Effective management of any snake species is a long-term endeavor, which is likely to evolve as knowledge of the species increases. Establishing a strong description of the natural history of a species is an essential start to the process and must be addressed at both local and regional scales. Eastern massasauga rattlesnakes are an excellent example of how valuable multiple investigations across a species' range can be to understanding the variation in ecology exhibited by snakes.

Interpreting High Mortality Over the Winter

We were impressed with the number of over winter mortalities. Of course, an immediate concern is whether our project was a factor. However, we were not doing anything differently. Also, we noted numerous accounts of turtle and frog kills this spring. Our impression as to the cause of these herpetofaunal kills, and also to the mortalities seen on site, was a combination of low water table from drought, and cold winter temperatures. Frog and turtle kills would be the result of freezing mud which is usually protected by water acting as a heat sink overhead. By extension, massasaugas occupying shallow, but normally water-filled, hibernacula may have been frozen in situ when not protected by the water table.

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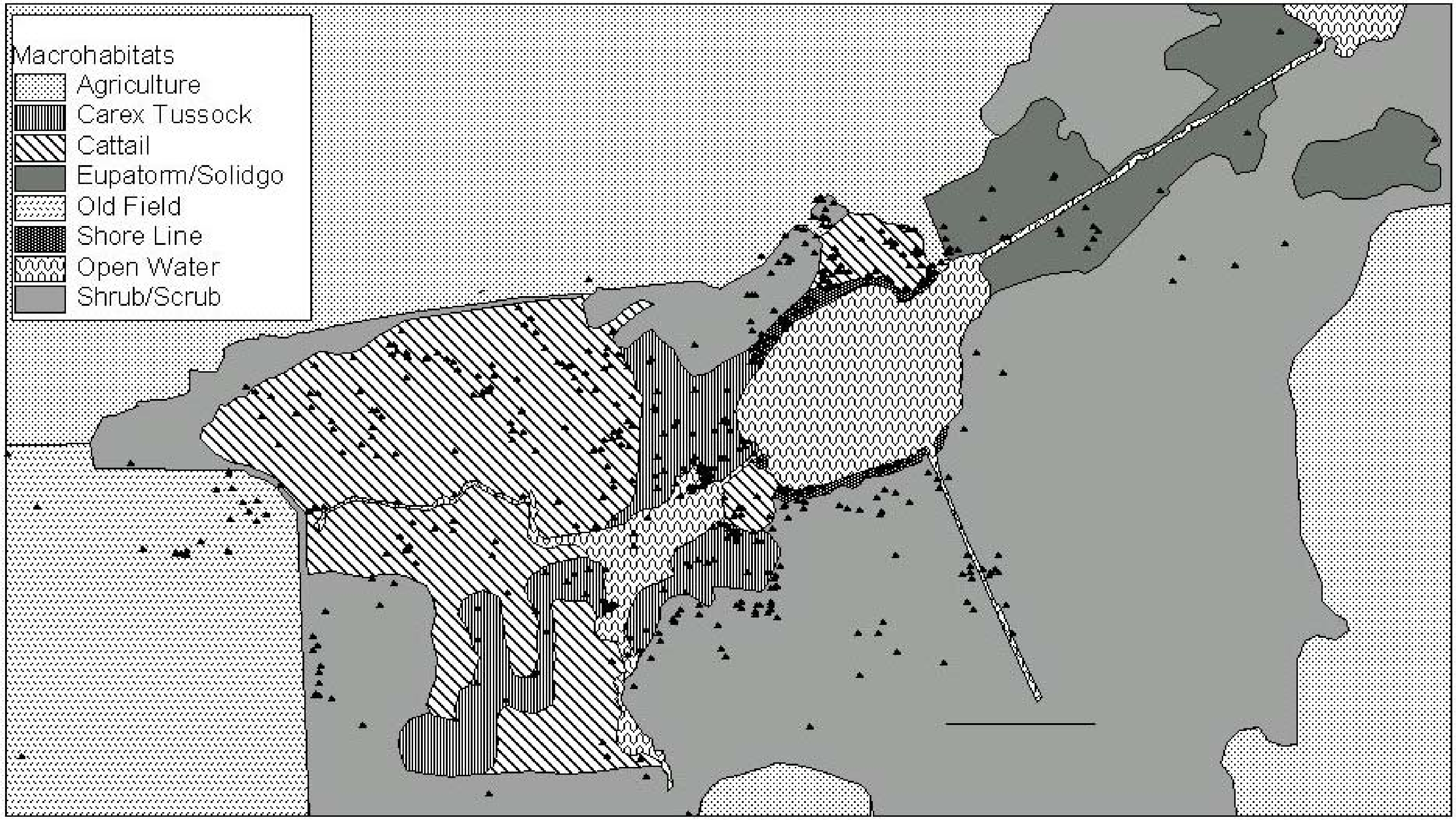

Figure 1. Snake relocations over time and macrohabitat composition. The black triangles represent individual snake locations for 1999-2002. The legend depicts the macrohabitats. See narrative for details. The scale bar represents 200m.

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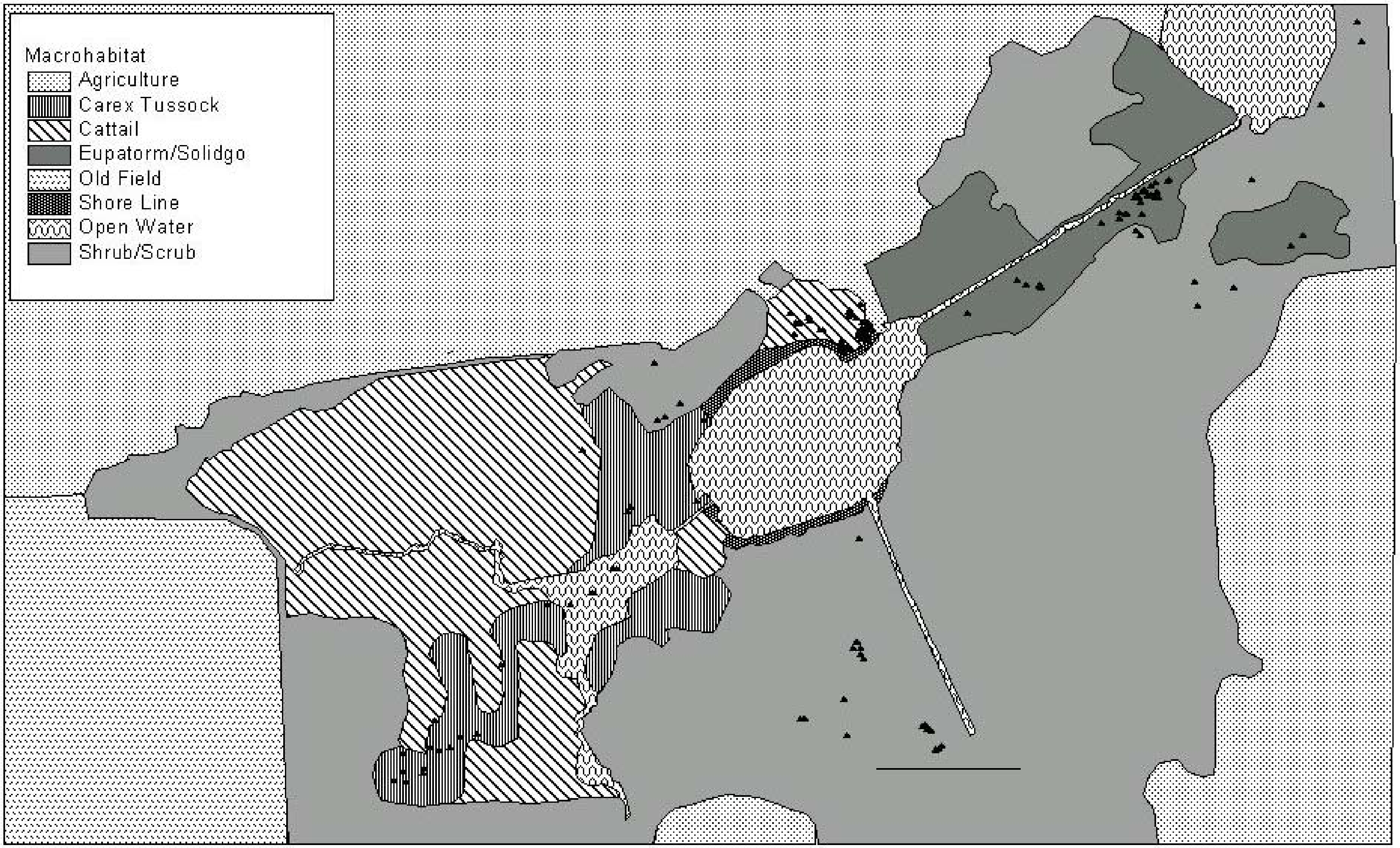

Figure 2. Relocations for snakes monitored to date in 2003. Localities are depicted as in Figure 1.

Table 1. Environmental Variables Measured For Microhabitat Analysis in 2003. Values were collected at both snake and random locations.

CANTREES	% canopy cover of woody vegetation with a dbh > 4cm in diameter based upon a visual estimate of canopy closure within a 45 degree cone around the plot
DWDYPLT	Distance to the nearest woody plant
MODALHERBS*	Estimation of the most common height of the herbaceous vegetation
MODALWDST	Estimation of the most common height of woody vegetation.

The following variables were visually estimated to the nearest 10% to quantify the composition of the 1m diameter circular plot:

CATTAIL	% cover of cattails (*Typha spp.*)
GRASS	% cover of grass
SEDGE	% cover of sedges not in a tussock
LOG	% cover of fallen tree branches
DETRITUS	% cover of detritus
BARE	% cover of bare ground
WATER	% cover of water
HERB	% cover of herbaceous vegetation
MOSS	% cover of moss
FERN	% cover of ferns
RUSH	% cover of rushes
SHRUB	% cover of all woody vegetation

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Table 2. Home range summary (MCP only) for 2003.

ID	Category*	MCP area (ha)
852	F	0.92
789	M	2.4
586	F	0.002
508	G	0.02
407	G	0.01
346	G	0.03
308	F	0.94
229	M	2.64
128	G	0.38
41	F	2.25

M: males; **F:** females; **G:** gravid females.

Note: it is still too early in the 2003 field season to determine gravid females with 100% certainty.

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Table 3. Descriptive statistics for microhabitat data for 2003. Variables were estimated to the nearest 10% then given a single number descriptor (e.g. 1=10%, 9=90%) **A**: Random points; **B**: Snake locations.

See table 1 for variable description.

A

	N	Minimum	Maximum	Mean	Std. Deviation
Cattail	61	0	8	0.66	1.590
Grass	61	0	10	2.57	3.014
Sedge	61	0	10	3.87	2.947
LOG	61	0	1	0.02	0.128
detritus	61	0	10	5.72	2.835
Bare	61	0	3	0.31	0.593
Water	61	0	10	0.43	1.596
Herb	61	0	10	4.80	2.863
Moss	61	0	7	0.72	1.439
fern	61	0	7	1.51	1.859
Rushes	61	0	8	0.56	1.511
Shrub	61	0	9	0.39	1.417

B

	N	Minimum	Maximum	Mean	Std. Deviation
Cattail	114	0	9	0.88	2.049
Grass	114	0	8	1.48	2.425
Sedge	114	0	8	2.82	2.152
LOG	114	0	1	0.02	0.132
detritus	114	2	10	6.82	2.135
Bare	114	0	3	0.27	0.584
Water	114	0	3	0.13	0.451
Herb	114	1	10	6.18	2.536
Moss	114	0	7	0.47	1.221
fern	114	0	7	1.74	1.872
Rushes	114	0	7	0.51	1.378
Shrub	114	0	9	1.04	2.032

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