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Work Smarter, Not Harder: Comparison of Visual and Trap Survey Methods for the Eastern Massasauga Rattlesnake (*Sistrurus catenatus*)

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***Abstract*.—Understanding and monitoring population demographics of rare and endangered species is important for implementing effective conservation and management programs. However, low detection rates, particularly for reptiles that are often characterized by cryptic behavior and coloration, can preclude accurate and precise demographic estimates. One such reptile is the Eastern Massasauga Rattlesnake (*Sistrurus catenatus*), which is declining in every state and province in which it is found. Past population demographic studies of this species have relied on visual mark-recapture survey methods or radio telemetry, which are labor intensive. Other common snake capture techniques (e.g., artificial cover objects, ACOs) have seen little use in Eastern Massasauga population studies. We explored the effectiveness of using ACOs and funnel traps to supplement visual survey methods for this species at a site in southwestern Michigan. Funnel traps (2.64 snakes/h) were approximately six times more efficient than visual surveys (0.41 snakes/h, *P* < 0.001) for capturing male and female massasaugas (combined), and approximately 28 times more efficient for capturing males (funnel = 2.37 snakes/h, visual = 0.084 snakes/h, *P* = 0.004; funnel = 0.263 snakes/h, visual = 0.324 snakes/h, *P* = 0.641 for males and females respectively). Wooden coverboards (1.11 snakes/h) were approximately 3.5 times more efficient than visual surveys (0.32 snakes/h) for capturing females (*P* = 0.029). We recommend the use of these trapping techniques, in addition to visual surveys, as efficient methods for capturing and monitoring Eastern Massasaugas. Our data provide guidance to allow sampling methods to be tailored according to specific study goals.**

Key Words.—artificial cover objects; catch-per-unit-effort; demography; detection; funnel traps; mark-recapture; monitoring; visual-encounter-surveys

Introduction

Monitoring populations of rare and endangered species is a priority for many management and conservation agencies (Guisan et al. 2006). However, many species of plants and animals, particularly rare and endangered species, have low detection probabilities (McArdle 1990; Parris et al. 1999; Kery 2002; Kery and Gregg 2003; Slade et al. 2003). Low detection rates can be the result of many factors including small population sizes at low densities (Morse et al. 1988), misidentification, cryptic behavior, inefficiency of survey method (Gu and Swihart 2004), and difficult survey conditions such as dense vegetation or weather (Wintle et al. 2005). In addition, adequate detection can require large investments of time and money (MacKenzie et al. 2002), which land managers might not have. Therefore, determining the most efficient and cost effective survey methods for imperiled species could be highly beneficial to conservation and management agencies.

Herpetofauna tend to be characterized by low detection probabilities. Cryptic or evasive behavior, camouflaging color patterns, and short active seasons of temperate species make detection of individuals difficult and can render estimates of population size and vital rates inaccurate or hard to obtain (Gu and Swihart 2004; Mazerolle et al. 2007). Typical sampling methods for reptiles and amphibians include drift fences in combination with pitfall or funnel traps (Fogarty and Jones 2003; Ribeiro-Júnior et al. 2008), artificial cover objects (ACOs; Crosswhite et al. 1999), auditory call surveys (Crouch and Paton 2002), night driving (Parris 1999), and visual encounter surveys (Karns 1986; Heyer et al. 1994). Factors influencing the choice of one method over another include habitat type (Doan 2003), behavior of animals (Crosswhite et al. 1999), and, simply, what is known to work (Karns 1986; Heyer et al. 1994). Depending on the amount and type of data needed to achieve study goals (e.g., one species vs. all species, sex, age, reproductive class, etc.), the specificity of the method is important (Fogarty and Jones 2003). Therefore, quantitatively comparing survey methods for different species or classes of individuals can inform study design or standard monitoring protocols.

Figure 1. Adult female Eastern Massasauga (*Sistrurus catenatus*) found via visual encounter survey in Barry County, Michigan, USA. The rattle was painted with nail polish to aid with individual identification. (Photographed by Danielle Bradke).

Eastern Massasauga Rattlesnakes (*Sistrurus catenatus*; Fig. 1) have declined across their range (Szymanski 1998; Johnson et al. 2000), and were recently listed as threatened under the U.S. Endangered Species Act (U.S. Fish and Wildlife Service 2016). Because they are ambush predators, Eastern Massasaugas are reclusive, largely sedentary, and cryptically colored, making detection extremely challenging (Parker and Plummer 1987). Eastern Massasaugas are generally associated with wetland habitats from spring to mid-summer and upland meadows in late summer (Bailey et al. 2012). Eastern Massasaugas return to wetlands before winter in search of hibernacula that typically consist of crayfish and small mammal burrows (Harding and Holman 2006). Extant populations of Eastern Massasaugas are mostly found in small isolated patches of suitable habitat surrounded by anthropogenically modified landscapes (Szymanski 1998; Szymanski et al. 2015). For many remaining Eastern Massasauga Rattlesnake populations, population dynamics and long-term viability are uncertain (Szymanski et al. 2015). This uncertainty is in large part due to low detection rates, which make mark-recapture studies time intensive (Parker and Plummer 1987). The recommended general survey method for Eastern Massasaugas is visual encounter surveys (Gary S. Casper et al., unpubl. report) and all existing population studies that have estimated vital rates (e.g., survival) have relied upon radio telemetry to collect sufficient data (reviewed in Jones et al. 2012). However, a comparison of capture techniques on a per effort basis for different survey techniques is lacking for the Eastern Massasauga.

Techniques such as funnel traps in combination with drift fences and ACOs (e.g., carpet squares and wooden boards) can be effective at capturing massasaugas, yet the efficiency and individual capture rates for these different techniques have not been directly compared (Gary S. Casper et al., unpubl. report). Comprehensive data comparing capture success on a per effort basis could warrant the use of these trapping techniques as standard survey protocol for Eastern Massasaugas (Gary S. Casper et al., unpubl. report). Here we explore the use of ACOs and drift fences with funnel traps in supplementing visual surveys by comparing capture rates (snakes/h) between the various survey methods. Our objective was to identify whether trapping methods can improve detection and enhance population and occupancy surveys for Eastern Massasaugas. We hypothesize that trapping methods will prove to be more efficient, in terms of survey effort, than visual encounter surveys; specifically, funnel traps will yield more male captures, and ACOs will yield more female captures in terms of snakes/h than visual surveys.

Materials and Methods

Our study site was a 300 ha privately-owned nature preserve, 40% of which was classified as wetland, in Barry County, Michigan, USA. The study area encompassed 12.9 ha of Prairie Fen, Wet Meadow, and nearby Upland Prairie and Old Field plant communities (Fig. 2). In May 2015, we assembled four trapping arrays throughout the study area where Eastern Massasaugas occur. Each array consisted of one drift fence, two funnel traps, seven carpet squares, and seven wooden coverboards. We buried pre-fabricated 0.9 m tall × 30.5 m long silt fencing with attached wooden posts approximately 15 cm into the soil, and we placed a funnel trap at each end.

All cover objects measured 0.6 × 1.2 m and consisted of olefin fiber indoor/outdoor carpet (placed with backing facing down) or 5.7 mm thick plywood sheets. We placed cover objects along each side of the drift fences 10 m from the fence and 5 m apart (Fig. 2). We set up trapping arrays in areas of large continuous patches of habitat (Karns 1986) where we were able to dig trenches for fences and where we had high Eastern Massasauga capture rates from four previous years of mark-recapture surveys (unpubl. data). We sampled traps between 0845 and 1700 for 42 d between 21 May and 14 August 2015, and we recorded the number of snake captures and recaptures. We determined an average trap checking time by averaging the time it took each of three researchers to check each individual trap type at each trapping array. Trap checking times did not include the time it took to travel between trapping arrays. We used number of snakes encountered and total trapping effort to calculate catch-per-unit-effort (snakes/person hour).

We conducted visual encounter surveys in habitat surrounding the trapping arrays (Fig. 2) by surveying daily between 0845 and 1700 for 50 d between 21 May and 14 August. Each surveyor recorded their search effort (i.e., total time spent actively looking for snakes), and we used total search effort to calculate catch-per-unit effort (snakes/person hour). We recorded whether encountered snakes were first captures or recaptures, and we recorded capture locations using handheld Garmin GPS units (Garmin International, Inc., Olathe, Kansas, USA).

We determined the sex of all captured Eastern Massasaugas by probing for the presence of hemipenes. We permanently marked new Massasaugas by injecting a subdermal passive integrated transponder (PIT) tag, and

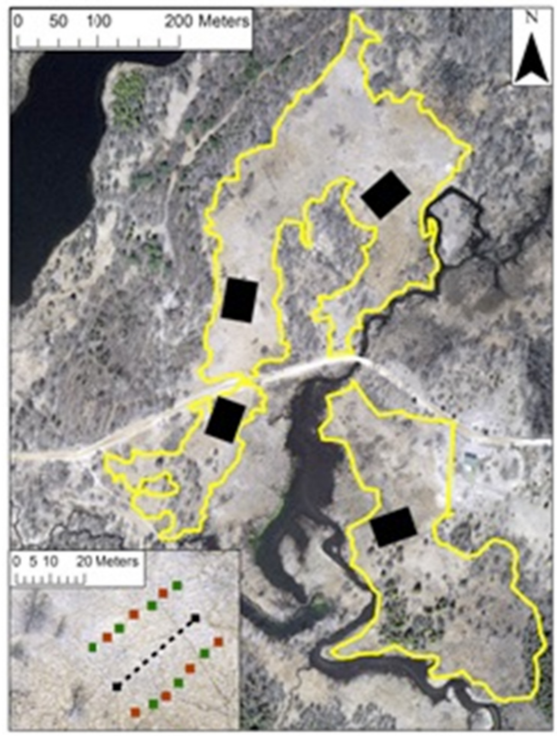

Figure 2. Map of study site in southwest Michigan, USA. Black rectangles represent Eastern Massasauga (*Sistrurus catenatus*) trapping arrays and yellow polygons encompass the visual encounter survey area. The inset displays the layout of one trap array with green squares representing carpet squares, brown squares representing coverboards, black squares representing funnel traps, and the black dashed line representing a drift fence.

we also temporarily marked snakes by applying colored nail polish on rattle segments. After processing, we released snakes at their capture sites on the same day of capture. We sanitized lab equipment according to disinfection protocols recommended by the Michigan Department of Natural Resources to prevent the spread of Snake Fungal Disease (i.e., *Ophidiomyces ophiodiicola*).

Data analysis.—For each method, we used capture and survey effort data to determine the number of Eastern Massasaugas captured per hour so that all methods were comparable. Snakes/hour included all snakes captured, regardless of whether individuals were new captures or recaptures. We pooled capture data into 12 weekly survey periods to ensure that we included all survey units and trapping arrays in each survey period. We used Poisson regression (PROC GLIMMIX, SAS v. 9.4) to test for differences in capture efficiency between capture methods based on the number of Eastern Massasaugas per hour. An example regression equation takes the form:

$$\log(\text{snakes/hour}) = \beta0 + \beta1(\text{Board}) + \beta2(\text{Carpet}) + \beta3(\text{Funnel})$$

We used Pearson χ^2 /degrees of freedom as a measure of overdispersion to validate the use of Poisson regression. All Pearson χ^2 /df values were < 1.5, illustrating that Poisson regression is an appropriate analysis for this count data (Anderson et al. 1994). Our response variable was the number of snakes/hour, with separate analyses for males, females, and both sexes combined. Explanatory variables were capture type (i.e., carpet, board, funnel trap, visual) and week was included as a random effect. We used visual surveys as the standard and all other methods were compared to this method. We used SAS v. 9.4 (SAS Institute Inc., Cary, North Carolina, USA) for all analyses, *a priori* set $\alpha = 0.05$, and reported descriptive statistics as mean ± 1 SD.

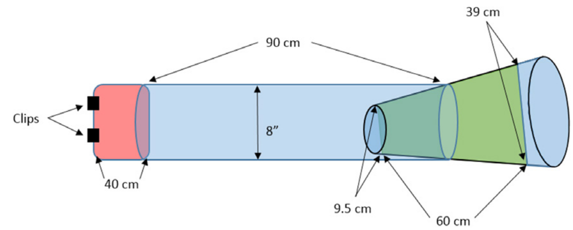

Figure 3. Schematic of funnel trap design. The majority of the trap (blue) was constructed using hardware cloth and aluminum screening laid over each other, the former to provide structure and the latter to prevent animals from getting stuck in the hardware cloth. The green trapezoid depicts a wooden board that guides animals from the drift fence into either side of the funnel. The red trap end was constructed of fine mesh aluminum screening that was rolled and secured with binder clips to set the traps. Zip ties and staples were used to fashion trap components together and spray foam was used to fill in any gaps. See Enge (1997) for additional details on trap design. Specific dimensions are presented. We loosely covered traps with fabric for shading, and we checked traps at least once daily when they were deployed.

Results

We recorded 102 Eastern Massasauga captures over 222.8 survey hours. Drift fences with funnel traps had the highest catch per unit effort with 2.64 snakes/person hour ± 4.73, followed by coverboards (1.11 snakes/person hour ± 2.27), visual encounter surveys (0.41 snakes/person hour ± 0.25), and carpets (0.12 snakes/person hour ± 0.35; Table 1). Funnel traps were biased toward male captures, which represented 90% of all funnel trap captures (n = 10). Conversely, coverboard captures were female biased, with 100% of coverboard captures (n = 8) being females. Visual encounter surveys were also female biased, with 80% of visual captures (n = 83) being females (Table 1). We only captured one Eastern Massasauga (a male) using carpets (Table 1). Although traps and ACOs were deployed from May through August, ACO captures only occurred between 9 June to 15 July (with only one capture before 24 June), and funnel trap captures only occurred between 14 July to 14 August.

When we pooled data for sexes, only funnel traps captured significantly more snakes/hour than visual surveys ($\beta = 1.74$, $P < 0.001$; Table 2), and this result was mostly driven by male captures as funnel traps also captured significantly more male snakes/hour than visual surveys ($\beta = 3.09$, $P = 0.004$). Coverboards captured significantly more female snakes/hour than visual surveys ($\beta = 1.29$, $P = 0.029$). Based on incident rates (i.e., exp[βi]), funnel traps were 21.87 times more likely than visual surveys to capture male Eastern Massasaugas and coverboards were 3.62 times more likely than visual surveys to capture female Eastern Massasaugas.

Discussion

The results of our study showcase the potential use of trapping methods (e.g., ACOs and drift fences with funnel traps) as standard protocol for more efficient monitoring of Eastern Massasauga Rattlesnakes. Different capture methods appear to target different sexes. Funnel traps were almost 22 times more likely to capture males and coverboards were 3.5 times more likely to capture females when compared to visual encounter surveys. Carpet squares were an ineffective survey method for Eastern Massasaugas. Our results do not discredit the use of visual surveys, particularly if the goal is to deter-

Table 1. Total captures of Eastern Massasauga Rattlesnakes (*Sistrurus catenatus*) using four survey methods (carpets, coverboards, drift fences with funnel traps, and visual encounter surveys) at a study site in southwestern Michigan, USA. Effort is measured in person hours surveyed.

Survey method	Total captures (unique individuals)	Male captures (unique individuals)	Female captures (unique individuals)	Total effort (hours)
Carpet squares	1 (1)	1 (1)	0	8.4
Coverboards	8 (4)	0	8 (4)	7.2
Funnel traps	10 (10)	9 (9)	1 (1)	3.8
Visual	83 (48)	17 (16)	66 (32)	203.4

mine presence/absence; however, we found that ACOs and trapping can be significantly less time intensive than visual encounter surveys and therefore could provide valuable data for population studies or monitoring when personnel are limited.

Drift fences with funnel traps appear to sample more active, mobile snakes (e.g., male Eastern Massasaugas) than boards or carpets, and may be more effective because they are actively trapping for a longer period of time than the ACOs (i.e., snakes cannot escape the traps). Male Eastern Massasaugas move a greater daily distance than females from May to August due to intensive mate searching behavior (Gillingham 1987; Moore and Gillingham 2006). This likely explains the high male capture rates observed using funnel traps. Mating behavior in this species typically occurs from July to September peaking in late August (Jellen et al. 2007). The first male Eastern Massasaugas we captured using funnel traps were on 14 July and we continued capturing males using this method through the last day of the study (14 August), which supports this hypothesis. By the same reasoning, we expect inactivity is why we did not capture many female Massasaugas using funnel traps. We found approximately half the number of male Eastern Massasaugas using funnel traps as we did using visual surveys even though funnel traps only used about 1% of the total survey time that visual surveys did. As male Eastern Massasaugas tend to be more difficult to capture than females using visual surveys (Danielle Bradke, unpubl. data), we recommend the use of drift fences with funnel traps in addition to visual encounter surveys if male captures, or even sex ratios, are sought.

The two types of artificial cover objects (boards and carpets) used in this study were not equally effective for capturing Eastern Massasaugas. Coverboards had significantly higher capture rates than visual surveys, while carpet squares did not outperform visual surveys. All female Eastern Massasaugas found using ACOs were gravid, and most were found on top of the cover object. Gravid females have an affinity for open basking sites that promote embryological development (Graves and Duvall 1993). Our data suggest that coverboards provide basking sites for female Eastern Massasaugas and are preferable to carpet squares when targeting this species.

Our results agree with Crosswhite et al. (1999), who found that traps associated with drift fences were more efficient than visual surveys for capturing snakes. On the contrary, other studies have had low success using coverboards and drift fences for capturing Massasaugas (Gary Glowacki and Ralph Grundel, unpubl. report; Daniel S. Harvey, unpubl. report). Our relatively high success may be due to placement in areas where past capture rates were high. Additionally, site specific habitat variation may contribute to differences in success, especially for coverboards.

Harvey (2005) detected non-gravid female and male Eastern Massasaugas approximately 15% of the time using time-constrained visual surveys, even when telemetry confirmed their presence in the survey area. Additionally, he found heterogeneity in detection rates based on snake temperatures (presumably due to heterogeneity in weather conditions). Our results indicate that incorporating other trapping methods into a study may increase detection rates. Furthermore, the use of multiple capture techniques has been recommended to reduce heterogeneity in capture probabilities between individuals within a population and, consequently, improve abundance estimates (Amstrup et al. 2010).

Our study highlights the benefits of ACOs and trapping methods for Eastern Massasauga Rattlesnakes, and how they can augment monitoring and mark-recapture data sets. Placement of artificial cover objects and funnel traps are at the discretion of a land manager. Specific trapping arrays used in this study were for experimental design and comparison purposes, but increasing the number of ACOs or drift fences with funnel traps would presumably increase capture yields. It is important to note that visual surveys are the only method that does not require habitat modifications (e.g., digging trenches for fences, disturbing vegetation with ACOs). One factor that we did not take into account with our catch-per-unit-effort estimates was the construction and setup time associated with trapping methods. In total, the construction and assembly of sampling arrays took four people 19.6 h total to complete, which mostly consisted of digging trenches for drift fences and constructing funnel traps. However, the construction of trapping arrays may not need to occur every season. Materials do tend to break down over multiple years (Enge 1997), yet drift

Table 2. Parameter estimates, P values (in parentheses), and overdispersion tests (χ^2 /df) for Poisson regressions comparing the rate of Eastern Massasauga Rattlesnakes (*Sistrurus catenatus*) captured (number of snakes/person hour) using various trapping methods to the rate of capture obtained through standard visual encounter surveys. Values in bold show significantly different capture rates compared with visual surveys.

	Coverboards	Carpet squares	Funnel traps	Pearson χ^2/df
Total snakes/hour	0.885 (0.097)	-1.569 (0.126)	**1.742 (< 0.001)**	1.45
Male snakes/hour	-16.396 (0.996)	-0.141 (0.916)	**3.085 (0.004)**	0.91
Female snakes/hour	**1.288 (0.029)**	-16.291 (0.993)	-0.367 (0.641)	0.60

fences, for example, can be left over winter and patched at the beginning of the next season and funnel traps can be re-used. If using trapping methods, we suggest a survey season that is at least similar to the length of this study (i.e., 12 weeks). Another point to note is that most members of the survey team in this study were very experienced at surveying herpetofauna. Surveyor experience can have a significant effect on the effectiveness of visual surveys (Heyer et al. 1994; Bailey et al. 2004). Because of this, inexperienced surveyors could benefit from using passive and active trapping techniques because experience does not determine the effectiveness of these methods (Ribeiro-Júnior et al. 2008).

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Jennifer Moore (with *Sistrurus catenatus*) is an Assistant Professor in the Biology Department at Grand Valley State University in Allendale, Michigan, USA. She began her career as an undergraduate at Northern Michigan University, and then earned an M.S. from Central Michigan University and a Ph.D. from Victoria University of Wellington, New Zealand. Jen's research focuses on spatial ecology, population demographics, and conservation and landscape genetics of at-risk species. (Photographed by Arin Thacker).