Assessing the Status and Perceptions of the Eastern Massasauga Rattlesnake Population at Matthaei Botanical Gardens, Ann Arbor, Michigan

BY

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ABSTRACT

The Eastern Massasauga Rattlesnake (*Sistrurus catenatus catenatus,* EMR) was once widespread in the lower Great Lakes basin but now exists in scattered and isolated populations. The Matthaei Botanical Gardens (MBG) population in Ann Arbor, Michigan, represents one of the few remaining healthy populations. Given the EMR's threatened status under the Endangered Species Act (ESA) due to habitat loss, anthropogenic disturbances, and indiscriminate killing leading to population declines, protection is paramount. This study aimed to gather information on the status of the EMR population at the MBG. The objectives of this study were to (1) determine continued EMR presence using a validated survey technique at a selected historic population site (MBG), (2) survey residents' attitudes and awareness toward the EMR around the MBG residential area, (3) understand the distribution of EMR near MBG, (4) develop educational materials for the residents. I conducted visual encounter surveys at five search areas to determine whether the snakes were present and evaluated the search areas for potential hibernacula. The field surveys confirmed the presence of EMRs at MBG in three of the five search areas, with the greatest number of EMRs observed in Area 2. I also developed a questionnaire and distributed it over mail with accompanying educational materials to 306 residents living near the MBG property. Results indicated that the distribution of the EMR population extends beyond property boundaries and into the MBG surrounding neighborhoods. A significant proportion of respondents had favorable attitudes toward the EMR than unequivocal adverse attitudes. Moreover, more than half of the respondents acknowledged the importance of rattlesnakes in the ecosystem. However, there is still a need for more progress in education and communication efforts to correct mistaken beliefs and reduce heightened risk perceptions about the EMR.

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CHAPTER 1: INTRODUCTION

1.1 Background information:

The Eastern Massasauga Rattlesnake (EMR; *Sistrurus catenatus catenatus*) is a small-sized, thick-bodied snake with a segmented rattle on the tail tip (Harding, 1997). The EMRs coloring is rather dark and has a row of about 20-40 large, dark brown blotches outlined in black, white, or pale yellow running down the back (Figure 1). Two or three rows of dark bowtied-shaped spots alternate along the sides. The background color of the EMR ranges from gray, grayish brown, brown, or black. The head distinctly widens in front of the neck. A dark stripe bordered below by a white strip extends from the eyes toward the rear of the head (Holman, 2012). EMRs also have heat-sensitive facial pits near the front and sides of their head, between the eyes and nostrils.

Figure 1: An adult Eastern Massasauga Rattlesnake (*Sistrurus catenatus catenatus*) observed at Matthaei Botanical Gardens in 2023 Photo by Hayden Strader.

Utilizing their extraordinary sensory organs, EMRs are primarily diurnal ambush predators that wait motionless for unsuspecting prey (Ernst & Ernst, 2003). The EMR feeds mainly on small rodents and, in turn, is preyed upon by birds of prey and larger snakes (Hall, 2019). Hallock (1991) conducted a dietary analysis of over 100 preserved snakes from the Museum of Zoology at the University of Michigan and the Michigan State University Museum. All the snake specimens came from southern Michigan. Most of the diet content (77.3%) consisted of mammals; of these, (68.4%) were voles.

The EMR is cryptic and docile. This rattlesnake is a slow-moving and timid creature that prefers to bask in solitary and only strikes in self-defense or to catch prey. The EMRs first line of defense is to avoid being seen, and its earth-toned color pattern provides excellent camouflage. The EMR would rather flee into thick vegetation than choose to stand their ground. However, if bitten, people should seek prompt medical treatment despite serious complications and extremely rare fatalities (Harding, 1997).

The habitat of the EMR varies across its range. However, most habitats are composed of wet, herbaceous communities, such as wet meadows, prairies, sedge meadows, and old fields interspersed with shrubs and adjacent to mesic grasslands or lowland forests (Szymanski, 1998; Wynn & Moody, 2006). Specifically, in Michigan, the EMR is partial to habitats with wetlands adjacent to upland areas, particularly prairie fens (Holman, 2012; Legge & Rabe, 1996; Sage et al., 2006). Historically, the EMR could be found in various wetlands and nearby upland woods throughout the Michigan lower peninsula. However, agriculturalization and the draining of wetlands have fragmented EMR populations into isolated habitats (Smith, 1961; Bushey, 1978). Therefore, human habitat destruction has accelerated the fragmentation of the species into a series of isolated populations, often surrounded by extensive agricultural or suburban developments (Bushey, 1978).

The EMRs' general distribution occurs from western New York, Pennsylvania, and southern Ontario, Canada, throughout the Great Lakes region to the Midwest (Holman, 2012). EMRs were once common across much of the lower Great Lakes basin but are now often restricted to scattered and isolated colonies (Harding, 1997). In Michigan, the EMR has yet to be reported in the upper peninsula. However, it is widespread in the upper and lower thirds of the lower peninsula (Holman, 2012). Most states or provinces within the species' range have lost over 50% of their historical populations, and less than one-third of extant populations are considered secure (Szymanski, 1998).

Over the last few decades, populations of EMRs have rapidly declined. The species was listed as a federal candidate species by the U.S. Fish and Wildlife Service in 1999 (USFWS 1999). The EMR is now listed as threatened under the endangered species act (USFWS 2016). The primary factors leading to the species' decline are habitat loss and direct persecution (Szymanski, 1998; Harding, 1997). Anthropogenic disturbances and indiscriminate killing of EMRs across the great lakes region have significantly reduced their population. Unfortunately, human persecution has led to the species' overwhelming decline since European settlement. For example, McKinney (1827) wrote about the abundance and persecution of EMRs near the Fox and Wisconsin rivers. “This whole country is full of them, and so constant is the noise of their rattle” (Johnson, 2000). Official bounty systems were developed in the Midwest, in states such as Illinois, Iowa, Minnesota, and Wisconsin (Szymanski, 1998). The direct exploitation of amphibians and reptiles, until recently largely unregulated, has resulted in population declines and even localized extirpation in some cases (Harding, 1997). This situation resulted from the traditional neglect of these animals and ignorance of their habitats and populations (Harding, 1997). The EMR is generally shy and passive and offers little danger to reasonably cautious people who leave the snake alone. Similarly, EMRs found in residential areas often seek traditional habitats lost due to human development (Harding, 1997).

The EMR faced direct persecution (Bushey, 1985). Attitudes and perceptions such as human fear, dislike of snakes, and concern for safety regarding potential rattlesnake bites have resulted in people killing the EMR (Szymanski, 1998). Unfortunately, venomous snakes like the EMR are incredibly misunderstood. Current public attitudes toward snakes vary greatly. Due to fear and overall negative perception of snakes, many people have a low interest in snake conservation, and consequently, large numbers of snakes were deliberately killed (Bushey, 1985). Human-snake encounters frequently result in the death of the EMR (Whitaker & Shine, 2000, pp. 125-126). Given the species' site fidelity and ease of capture once located, the EMR is particularly susceptible to collection (Bailey *et al.,* 2011, p. 171).

EMRs are an essential part of the ecosystem. EMRs are an indicator species, and by conserving the species, we conserve natural systems that support many different plants and animals (USFWS, 2019). Similarly, the central role of reptiles in many ecosystems is rarely appreciated. Popular attention tends to focus on endothermic vertebrates rather than snakes (McDiarmid, 2012). Attitudes like this have been detrimental to the conservation of snakes since there are plenty of areas where even basic information is lacking (Mattison, 2007). Government conservation agencies considering their management are often faced with a lack of basic biological data needed to guide regulatory decisions (Harding, 1997).

Michigan, being the last stronghold for this species, has a unique opportunity to promote the conservation of the EMR. Michigan has more historical and extant EMR populations than any other state or province in the species' range (Szymanski, 1998). However, Michigan's EMR populations have also declined due to similar threats that have negatively impacted populations in other states. Specifically, Michigan has lost 33% of its historical population (Johnson et al., 2000), with most remaining confined to public land or nature preserves (Szymanski, 1998). For example, a population resides at the MBG, an area that serves as a natural habitat for the EMR. The MBG population serves as an example of an isolated population.

Snake populations are restricted to smaller and smaller fragments of habitat, becoming increasingly vulnerable to threats such as road mortality and direct exploitation (Harding, 1997). These barriers also prevent the snakes from intermixing with other individuals or populations (Kingsbury, 2002, p. 39). Similarly, fragmented populations of EMRs have potentially severed gene flow and increased genetic isolation, increasing the risk of genetic diversity loss (Anthonysamy, 2022).

New emerging threats pose a risk to further the extirpation of EMRs across their range. The EMR is vulnerable to disease in the eastern United States due to Ophidiomyces infections. Snake Fungal Disease (SFD), the most recently described fungal disease afflicting wildlife populations worldwide, is caused by Ophidiomyces ophiodiicola (Allender et al., 2018). This is worrisome because they are an essential species in the ecological community, as EMRs are both predator and prey.

This study focuses on the EMR population found at the MBG in Ann Arbor, Michigan, where they have historically occurred. The study seeks to contribute to assessing the current status of the EMR population at MBG and investigate public perceptions regarding the snake.

Despite the population at MBG appearing robust and reproducing, demographic estimates are needed to manage imperiled species such as the EMR (Crother et al., 2012). Researchers have not surveyed the species within the last five years. Therefore, information on the status and distribution of the EMR within the MBG area is needed.

I used the recommended visual encounter survey (VES) method for EMR population assessment (Karns, 1986; Heyer et al., 1994; Casper et al., 2001). VESs are used primarily to inventory taxa present at a particular site. A VES is carried out by an individual(s) who traverses a study area and records the identities of taxa as they are encountered (McDiarmid, 2012). The current survey protocol for EMR monitoring at MBG focuses on replicating techniques outlined in Casper et al. (2001).

Understanding stakeholder perspectives towards the EMR is essential to making informed decisions about conservation and management issues. In North America, public support and participation in wildlife management have emerged as a critical component to successful conservation and a challenge for the wildlife profession (Decker et al., in press). While scientific research and monitoring can offer valuable insights into the ecology and biology of a species like the EMR, they do not capture the human attitudes and behaviors towards the species. Therefore, without employing a wide array of approaches and methods from across the social sciences and the natural sciences, critical contextual factors may be obscured, and inadequate contextual understandings may lead to culturally inappropriate, socially unjust, or untenable conservation actions (Corson & MacDonald, 2012; Bennett et al., 2015).

In this study, stakeholder surveys were designed to conduct a broader societal analysis in the context of EMR conservation. We emphasize the importance of outreach in successful wildlife projects by investigating stakeholder awareness and attitudes. Information gathered can help conservation and management strategies. Ultimately, this study's results deepen our understanding of residents' attitudes and improve the conservation of the EMR in Ann Arbor, Michigan, and other residential areas.

Past efforts have been conducted on the MBG property to study the EMR population. A telemetry study conducted in 1990 focused on studying three individuals (Hallock, 1991). The study revealed that this species generally uses upland grassy habitats in the summer and lowland poorly drained sites in the fall (Hallock, 1991). In 2011, a Sustain Our Great Lakes grant program administered by the National Fish and Wildlife Foundation awarded MBG a two-year grant. The award was to assist with various restoration efforts to restore ecological integrity to the EMR habitat by controlling invasive and encouraging native plant species. Therefore, efforts focused on removing invasive woody plants, controlled burns, and native seed collection and dispersal. As a result, MBG restored roughly 350 acres of MBG land, making the area more habitable for the EMR (Parrish, 2015). Education and outreach were also a priority. Presentations, media coverage, and interpretive signs throughout the MBG property were also components in their restoration approach to benefit the EMR resident population.

The most recent efforts regarding the EMR population in the MBG involved species assessments. MBG collaborated with The Ecological Consulting Group (ECG) to monitor the EMR. The ECG surveyed selected areas in 2010, 2012, 2014, and 2015 during spring emergence (i.e., April-June). During the first sampling season, 13 EMRs were captured and marked, but recapture rates were too low to perform population estimates (Anton et al., 2010). During the second sampling season, 14 individuals were documented (Anton et al., 2011). These initial findings suggested a robust and reproducing population of EMRs at the MBG. The 2014 results were similar to 2010 regarding snake sightings per person-hour, higher probabilities early in the season, lower probabilities in forested habitats, and similar detection probabilities (DP) (Anton et al., 2014). The researchers did not report the N/Person Hr in 2010. However, 2012 results indicated a rate between 0.500-2.00 N/person Hr. In 2014, the value was between 0.009-0.05 N/person Hr. In 2015, the ECG calculated the Catch-Per-Unit of Effort (CPUE), obtained by dividing the number of snakes captured by the number of search hours expended for all units searched. The CPUE was between 0.33-2.16 (Anton et al., 2015).

The efforts of the ECG were compiled into reports that guided the premise of this project. Based on the assessment results, the ECG recommended that monitoring continue to refine and standardize a sampling protocol. Furthermore, the assessment also highlighted the importance of developing a monitoring program based on visual search methods to contribute to MBG habitat management and snake population status (Anton et al., 2010). Other recommendations included expanding surveys outside previously surveyed areas (Anton et al., 2014; Anton et al., 2015).

In light of EMR research carried out at MBG, there remains an opportunity to enhance the management of the EMR through obtaining demographic data expanding beyond MBG boundaries, and increasing public awareness. The advancement of EMR knowledge within MBG and the surrounding resident communities plays a crucial role in preserving EMR populations. Here, we applied methods from Anton et al. ((2010) to conduct VS following the protocol outlined in Casper et al. (2001). Also, we evaluated residents' attitudes and awareness of the snake through a mailed survey that included materials to educate neighbors on relevant information regarding the EMR.

CHAPTER 2: MATERIALS AND METHODS

2.1 VISUAL ENCOUNTER SURVEYS

Study area: Overview of the MBG and surrounding areas.

This study was conducted within The University of Michigan's Matthaei Botanical Gardens (MBG) at 1800 North Dixboro Road in Ann Arbor, Michigan (42.3022° N, 83.6632° W). The MBG is a 350-acre site with various display gardens, trails, and natural areas (Figure 2.1). The visitor center, conservatory, and display gardens are open to the public. MBG conducts activities and provides resources that attract visitors, from gardeners to hikers, birders, researchers, students, and volunteers. A mosaic of habitats comprises the study area. Winding trails take you through extensive deciduous woods, wetlands, numerous ponds, and a tall-grass prairie.

Figure 2.1 Aerial view of Matthaei Botanical Gardens indicating the five search areas in this study

The MBG complex of woody and wetland habitats is suitable for EMRs that historically have inhabited this area. Glaciers created the existing topography, the Huron River, and tributary streams, wetlands, and ponds approximately 12,000 years ago at the end of the last glaciation, which remained in that state until humans began excavating, filling, and grading during the 19th-20th centuries (Ann Arbor Township, 2015). Many of the results of glacial activity are still visible today and continue to shape current patterns of agriculture and residential development (The Stewardship Network, 2017). The area's fertile soils supported agricultural production after the area was opened in the early 1800s for settlement. Visitors have encountered the EMR at the MBG since the first documentation of the species' presence in 1974 by a group of researchers at the University of Michigan (Anton et al., 2010).

The MBG is uniquely positioned to promote species protection by educating the public and managing the land. As a public space six miles from downtown Ann Arbor, MBG is ideally situated to raise awareness about the importance of protecting threatened species and their habitats. MBG actively manages its forest, grassland, and wetland properties with prescribed burns and invasive species removal to promote the growth of native species such as the EMR. One example of restoration projects on the property includes the Marilyn Bland prairie, started by a graduate student in the 1960s. The project is one of the early prairie restorations in the area (The Stewardship Network, 2017).

MBG encompasses various habitats that hold significant importance for the species' survival. For example, crayfish chimneys can be found throughout the wetland areas of MBG (Figure 2.2). During the winter season, EMRs hibernate; they occupy crayfish or small mammal burrows (hibernacula). MBG also features drier upland sites critical to the species' survival. EMRs move from wetlands to drier upland sites during certain parts of the year to forage, disperse, and gestate. Suitable upland habitat types for EMRs range from forest edges and openings, savannas, and prairies to meadows, old fields, and agricultural lands (USFWS, 2018c).

Figure 2.2: Crayfish burrows that serve as hibernacula for the EMR during frigid temperatures. Photograph by Amanda Martinez at MBG, 2022.

This study followed the VES protocol used by the ECG to assess EMR started in 2010 based on Casper et al. (2001) and was organized based on the same five search areas (Figure 2.1).

Search Area 1: This area is the functional floodplain of Fleming Creek, a relatively small stream (Figure 2.3). Here, a series of wetland habitats are found with varying water levels and vegetation types, such as skunk cabbage, grasses, and sedges (Figure 2.3) (Anton et al., 2010). Channels between hummocks of varying sizes can be found on this site. During the surveys, crayfish burrows were present, which signifies potential overwintering hibernacula for the EMR.

Previous EMR surveys in Area 1

Results for the search in Area 1 indicated the presence of one female EMR on June 29th, 2010 (Anton et al., 2010). Surveys were continued in 2011; however, no snakes were found. In 2014 and 2015, search Area 1 was not surveyed for EMRs (Anton et al., 2015).

Figure 2.3: Fleming Creek (left) supports other wildlife and flows into the Huron River downstream of Dixboro Road. The image on the right shows the vegetation comprising the floodplain of Fleming Creek. Photographs by Amanda Martinez, 2023.

Search Area 2: This area is the largest and most open search area, with slightly varying topography (Figure 2.4). Search Area 2 provides an upland foraging habitat for EMRs. In the uplands are scattered conifers and deciduous trees such as oaks. Grasses primarily dominate the area, but there are also scattered bushes (Figure 2.4). Mammal burrows, rather than crayfish, are frequently spotted in this area (Anton et al., 2010).

Previous EMR surveys in Area 2

The 2010 survey conducted by ECG in Search Area 2 indicated the presence of two female and one male EMR (Anton et al., 2010). This area was searched again in 2011, 2014, and 2015 when three adult females (Anton et al., 2011), one EMR of unknown sex (Anton et al., 2014), and two EMRs of unknown sex were found (Anton et al., 2015).

Figure 2.4: An open grassy meadow of varying topography with a scattering of woody shrubs typical of the EMR habitat in search area 2. Photograph by Amanda Martinez, 2023.

Search Area 3: This area is extensive and borders search Area 1 to the east (Figure 2.1). Similarly to Area 1, the vegetation found along the east side of the unit, with Fleming Creek floodplain running N-S, are sedges, skunk cabbage, and other wetland plants (Figure 2.5) (Anton et al., 2010). The diverse vegetation changes from open wet meadows featuring hummocks and an open slurry of peat and muck to surrounding uplands. Other habitats include grasses with a mix of shrub, hardwood, and woody cover. To the north of this site is Cummings Fen, a globally rare prairie fen featuring wet meadow natural communities. This site features numerous crayfish burrows.

Previous EMR surveys in Area 3

Surveys conducted in this area found one male and three adult females in 2010 (Anton et al., 2010) and one adult male in 2011 (Anton et al., 2011), while no individuals were reported in 2014. This area was not surveyed in 2015.

Figure 2.5: Eastern skunk cabbage leaves border the trail path and covers the ground in search Area 3. Photograph by Amanda Martinez, 2023.

Search Area 4: This area is primarily dominated by grasses and woody shrubs, although softwood and hardwood trees can be found on the eastern edge (Anton et al., 2010). Area 4 has a trail (Marilyn Bland Prairie) and a labyrinth of buffalo grass. This well-established and diverse prairie area provides an upland summer habitat for the EMR (Figure 2.6).

Previous EMR surveys in Area 4.

ECG surveys in this area found three females in 2010 (Anton et al., 2010), two females in 2011 (Anton et al., 2011), and one adult of identified sex in 2015 (Anton et al., 2015). Search Area 4 was not surveyed in 2014 for EMRs.

Figure 2.6: Search area 4 is characterized by grasses with the occasional shrub and tree outlining the edge Photograph by Amanda Martinez, 2023.

Search Area 5: This search area is closest to the MBG visitor center and large parking lot (Figure 2.7). Next to the parking lot is a grassy hillside on the western edge of MBG. Adjacent to this area is Parker Brook, which feeds into Willow Pond. Willow Pond tends to have a muddy or silty bottom, and plants such as cattails and milkweed were observed growing around the edges (Anton et al., 2010). Moreover, crayfish burrows can be found near the pond's lowland margins signifying that this area is an overwintering place for the EMR. The habitat varies from upland grasses, rushes, and sedges containing a scattered mix of trees and open lowland shrub swamps.

Previous EMR surveys in Area 5

The ECG surveys of this area found five females in 2010 (Anton et al., 2010), three adult females, two juvenile females, three juvenile males, and one neonate of undetermined sex in 2011, two individuals of undetermined sex in 2014 (Anton et al., 2014), and 12 EMRs of undetermined sex were found in 2015 (Anton et al., 2015).

In addition to the VES, MBG staff and interns initiated cover object (CO) surveys in Search Area 5 in 2014 and continued them in 2015 (Anton et al., 2015). Ten corrugated roofing tin COs were placed in this area (Figure 2.8). The tin pieces were 18” x 40” (Anton et al., 2015). CO surveys were continued throughout 2015 VESs and checked during meandering searches for the EMR. No EMRs were found using this method (Anton et al., 2015).

Figure 2.7: Willow pond; in the background is the MBG visitor center. Photograph by Amanda Martinez, 2023.

Figure 2.8. Covert object (CO) 18”x 40”. Photograph by Amanda Martinez, 2023.

Methods for VES:

Methods generally followed the VES protocol for EMR by Casper et al. (2001), similar to Anton et al. (2010). Methods consider that EMRs, similar to other reptiles, are often tied to specific activity periods, habitats, or retreat sites (Heatwole, 1977; Pough, 1983). The most fruitful survey periods are during spring emergence (May) for all age classes and mid-to-late summer (August) for EMR gravid females. The preferred time of day for EMR VES is morning and evening (Casper et al., 2001). Weather conditions are best, with >50% cloud cover, less than 15 mph breeze, and temperatures between 50 and 80 degrees Fahrenheit. It is essential to monitor during this period to assess movement from prairie habitat to wetland. Surveys were conducted following recommended survey protocols, except surveys were conducted during summer with temperatures above 80 degrees Fahrenheit, and sky conditions mostly had less cloud cover than recommended.

VESs for EMR were conducted during 2022 and 2023 across the five described search areas within the MBG property (Figure 2.1). In 2022, surveys were conducted over 16 days in mid-to-late summer, corresponding to the snake gestation and birthing period (Table 3). In 2023, surveys focused on evaluating EMR presence during spring emergence and thus were exclusively performed in May (Table 5) when the air temperature was above 50 degrees Fahrenheit. Over the two field seasons, the searches were conducted by 1-2 novice searchers walking through the five designated search areas (Figure 2.1). Visual surveys encompassed traversing tall grasses and prairie fens and exploring each site's shrubbery and woodland areas. The primary objective was to inspect the sites thoroughly and identify the presence of the EMR. In addition, during VESs in 2022 and 2023, search areas were also evaluated for the presence of crayfish chimneys, signifying potential hibernacula.

Data collection:

Data was collected from a distance using non-invasive methods to minimize any potential impact on the snakes. The exact location of crayfish chimneys was recorded via GPS coordinates. For the purposes of this study, snakes were not to be handled. The following data was collected when an EMR was present during a VES:

1. exact location (GPS location)
2. photograph of the EMR, if possible
3. snout-vent length estimate

At each survey, the following data were collected regardless of the presence of an EMR:

1. Date(s)
2. Survey site location(s)
3. Start and end times
4. Start and end temperature, relative humidity, wind strength, and percent cloud cover.

2.2 STAKEHOLDER SURVEYS

The survey to assess awareness and attitudes toward the EMR consisted of 12 questions and was mailed out to 306 residents living near the MBG property in Ann Arbor, Michigan (Table 1). The survey also was to assist in collecting the best available information on the current distribution of the MBG EMR population in the surrounding residential area. The community was defined by property owners/renters who reside in the 48105 zip code from the MBG existing "burn notice list." The "burn notice list" alerts homes near the gardens of the occurrence of prescribed burns on the MBG property.

Table 1: Mailed Stakeholder Survey

Question(s)	Response options
1. Before receiving this survey, were you aware of the potential presence of the eastern Massasauga rattlesnake in your neighborhood?	Yes
	No
2. If you responded yes, do you know of anyone who has been bitten by the eastern Massasauga rattlesnake?	Yes
	No
3. Before receiving this survey, were you aware that massasaugas are a threatened species under the U.S. Endangered Species Act?	Yes
	No
4. Which statement do you believe best describes the importance of snakes in the ecosystem?	Not important
	Somewhat important
	Very important
	Unsure
5. Do you experience a positive, negative, or neutral	Positive association

association with snakes?	Negative association
	Neutral association
6. How would you rate your support for Massasauga conservation/ recovery initiatives	1
	2
	3
	4
	5
7. Please select your ideal rattlesnake population in your local area:	Healthy and abundant population, frequent sightings
	Small and isolated population, occasional sightings
	Population risks extinction, sightings are rare
	Decimated population, no rattlesnake
8. Have you seen any eastern Massasauga rattlesnakes around your home or neighborhood within the last year?	No snakes
	1-2 snakes
	3-5 snakes
	6+ snakes
9. If you have observed a massasauga, have you seen more or fewer snakes in the area than in the past five years?	More
	Less
	About the same
	Unsure
10. Please describe what the yard looks like in your home (i.e., wooded area, prairie, small mowed lawn, the property includes frontage on a lake, river, pond, or wetland)	Open-ended
11. Would you be interested in a follow-up interview to provide additional information regarding the eastern Massasauga in your residential area? Please provide contact information if available.	Yes
	No
12. If you encounter an EMR, would you want to have the EMR removed from your residential property and relocated to MBG?	Yes
	No

Survey Design:

To address the research objectives, I developed a 12-question survey to distribute over electronic mail. First, I incorporated questions previously used in surveys that measured attitudes toward snakes. For example, the question "Please select your ideal rattlesnake population in your local area" was incorporated from a previous snake survey study titled "Human *Dimensions of Timber Rattlesnake (Crotalus horridus) Management in Connecticut*." This study aimed to address gaps in knowledge about the human dimensions of timber rattlesnake management in the northeast by evaluating human factors related to timber rattlesnakes among residents near one timber rattlesnake population. Next, I formulated my own questions pertaining to each of the objectives.

Furthermore, to measure respondents' awareness of the EMR, the questionnaire began with a yes-or-no question (Table 2). Stakeholders were asked, "Were you aware of the potential presence of the EMR in your neighborhood"? Two other questions following the same format were included to inquire about awareness. I asked four close-ended questions to measure the respondents' attitudes toward the EMR. For the first question, responses were assigned to numerical values 1 to 4, indicating the importance of snakes in the ecosystem. A multiple-choice question followed, indicating the stakeholders association with snakes with 3 different options. Another questionnaire item had responses assigned to numerical values 1 to 5, indicating support for EMR conservation. The final question to measure attitude was a multiple-choice question with 4 different responses. The last three questions were to obtain information on the distribution of the EMR beyond MBG. The category began with a close-ended multiple choice question inquiring about EMR observation around the property. There were four responses to this question. Second, respondents were asked a follow-up multiple-choice question regarding observing fewer or more EMRs with four response options. The category ended with an open-ended question that asked respondents to describe their property. Before finalizing the survey instrument, it was reviewed for clarity by MBG staff who work on EMR efforts.

Letters of invitation to participate in the survey and accompanying material were developed and delivered via mail to the names and addresses of 306 residents. The invitation letter included basic information about the EMR and a request for information about EMR sightings in their residential areas. An infographic was included in the mailing to disseminate significant information about the EMR to a broad audience. The infographic provides a compilation of EMR available knowledge. It included information for the state of Michigan summarized from the Michigan Natural Features Inventory (MNFI's) MSU Extension website that incorporates known locations of the EMR sightings. Specifically, the survey focuses on understanding the EMR population adjacent to the MBG property boundaries. This is the first effort to conduct a survey to gather information from residents near MBG regarding the EMR.

Table 2: Categories being measured in the Ann Arbor stakeholder survey for EMRs

Category - Awareness	
Objective	**Question(s)**
To measure respondents' awareness of the eastern Massasauga rattlesnake, I asked the following questions:	1. Before receiving this survey, were you aware of the potential presence of the eastern Massasauga rattlesnake in your neighborhood?
	2. If you responded yes, do you know of anyone who has been bitten by the eastern Massasauga rattlesnake?
	3. Before receiving this survey, were you aware that massasaugas are a threatened species under the U.S. Endangered Species Act?
Category - Attitude	
Objective	**Question(s)**
To measure the respondents' attitudes toward the eastern Massasauga rattlesnake, I asked the following questions:	1. Which statement do you believe best describes the importance of snakes in the ecosystem?

Attitudes/perceptions and behaviors relating to the eastern Massasauga rattlesnake:	2. Do you experience a positive, negative, or neutral association with snakes?
	3. How would you rate your support for Massasauga conservation/ recovery initiatives
	4. Please select your ideal rattlesnake population in your local area:
Category - Distribution	
Objective	**Question(s)**
To analyze the distribution of the eastern massasauga beyond Matthaei botanical gardens, the following questions were asked:	1. Have you seen any eastern massasauga rattlesnakes around your home or neighborhood within the last year?
	2. If you have observed a massasauga, have you seen more or fewer snakes in the area than in the past five years?
	3. Please describe what the yard looks like in your home (i.e., wooded area, prairie, small mowed lawn, the property includes frontage on a lake, river, pond, or wetland)

3b. Survey distribution:

The survey was distributed along with the other materials on 03/13/23. The survey was closed approximately one month later due to time constraints and an adequate number of responses. All residents received a paper copy of a survey, an invitation letter with a QR code for an infographic, and a self-addressed stamped envelope.

3c. Educational materials:

This study addresses gaps in stakeholders' knowledge by providing an overview of EMR information in an easy-to-understand format. The EMR's cryptic nature can make it problematic for humans to understand. Therefore, I designed an infographic[1] beginning with a brief introduction to the EMR, highlighting its importance as a threatened species in Michigan. The

[1] Dictionary.com defines an infographic as a visual presentation of information in the form of a chart, graph, or other image accompanied by minimal text intended to give an easily understood overview, often of a complex subject.

infographic displays information about identifying an EMR and how residents can help protect the species. To design the infographic, I utilized Canva, an online graphic design tool. Overall, the infographic was designed to be visually appealing and engaging, with images, graphs, and text to convey essential information about the EMR in Michigan in a concise and digestible format.

By educating the public, people can make informed decisions about how they can safely coexist with the EMR. This, in turn, can help to reduce negative human impacts on the snake's populations, promote habitat conservation, and ultimately support the long-term survival of this species. Furthermore, with human persecution being one of the EMRs' notable threats, helping Michigan landowners understand the ecology of the EMR will curtail any wrongful deaths by humans. For example, vital physical characteristics of the snake are included to aid residents in identifying the species. On another note, relevant general information about the EMR was also disseminated. This included information about the MBG population, diet, threats, and habitat, of the EMR. The conservation status of the EMR was defined, and ways residents can assist this imperiled species were presented.

Mailed letter for Stakeholder Survey:

Dear Neighboring Resident,

I would like to invite you to participate in a survey conducted by a graduate student from the University of Michigan School for Environment and Sustainability (SEAS). The purpose of this survey is to acquire information from residents pertaining to the Eastern Massasauga Rattlesnake (EMR). The information provided will be used to understand the current distribution of the EMR range in a residential area.

Matthaei Botanical Gardens (MBG), 1800 N Dixboro Rd, Ann Arbor, MI 48105, serves as a natural habitat for the eastern Massasauga rattlesnake. This past year, we have performed snake surveys within the property boundaries to understand the population status better. We are also seeking information and assistance from neighboring residents to help us document any occurrences of EMRs in the surrounding area, as characterizing the distribution range of this population is of utmost importance. We invite you to participate in this attached survey which would allow researchers to learn about the snake population and its relationships with local residents. This is an opportunity for you to share any information on EMR sightings you may have had as a resident residing near MBG. Along with this survey, we would also like to provide you with an infographic that highlights key information pertaining to the EMR. The information you provide is invaluable for reaching conservation goals.

Thank you for your participation and willingness to help us better understand and conserve this keystone species. If you want to contact us, you can reach Amanda Martinez, project coordinator, at (224) 723-0572 or amandi@umich.edu.

Sincerely,
Amanda Martinez
SEAS M.S Candidate
The University of Michigan

SCAN ME

CHAPTER 3: RESULTS

3.1 VISUAL ENCOUNTER SURVEYS:

Results of 2022 EMR surveys:

In 16 days, and 21 search events, four EMRs were observed and documented during the 2022 surveys; this yields a naïve detection coefficient of 0.14 (Table 3). EMR presence was observed in Areas 2 and 5 (Table 4). The highest number of sightings (four EMRs) occurred in Area 2 (Figure 3.1).

Based on visual observation to estimate the age of the snakes, two EMRs were adults, and two were neonates.

Area 5:

One adult EMR was observed in Area 5 and was roughly 2 feet long.

Area 2:

The second adult EMR was a suspected gravid female of about 2.5 feet observed in a den in Area 2. A couple of days later, on 8/19, two neonate EMRs roughly 10 inches long were observed in the den area in Area 2 (Figure 3.2). However, no adults were present when neonates were observed. No EMRs were detected utilizing COs in 2022.

Table 3: Detection Coefficients for EMRs, 2022.

Search Unit	Number of Searches	Number of Searches where EMRs were Detected	Detection Coefficient
1	3	0	0
2	5	2	0.4
3	4	0	0
4	2	0	0

5	7	1	0.14
Totals	21	3	0.14

Table 4: EMR VES results from 2022: S.Hr.= Starting time of the survey, S.T.=Temperature at the beginning of the survey in °C, E.Hr. End time of the survey, E.T.= End temperature of the survey, Hum.=Humidity in %, Wind= Wind strength (in mph) and direction, Effort=Search Effort in Person Minutes, Cloud=Cloud cover in %, Effort is hours of search effort, search N= Number of snakes sightings, N/hr= Number of sightings per person by hr search,

Date	Site	S.Hr.	S.T	E. Hr.	E. T	Hum.	Wind	Cloud	Effort	N	N/hr
7/02	5	5:45 p.m.	28°	7:45 p.m	25°	38%	8.06 mph, NW	65%	120	0	0
7/03	2	6:02 p.m.	28°	7:40 p.m.	26°	43%	10.4 mph, S	27%	100	0	0
7/09	5	6:01 p.m.	26°	7:00 p.m.	25°	41%	5.02 mph, N	30%	59	0	0
7/09	1	7:00 p.m	25°	8:06 p.m.	24°	41%	5.75 mph, NE	22%	66	0	0
7/13	2	6:00 p.m.	23°	7:10 p.m.	21°	69%	8.06 mph, N	73%	70	0	0
7/26	5	4:30 p.m.	28°	6:30 p.m.	25°	47%	8 mph, N	45%	120	1	0.5
7/27	3	6:00 p.m.	28°	7:51 p.m.	24°	77%	3.45 mph, S	78%	111	0	0
8/02	5	1:47 p.m.	27°	3:24 p.m.	29°	50%	8.06 mph, W	41%	97	0	0
8/05	3	6:58 p.m.	28°	8:48 p.m.	24°	72%	6.90 mph, S	45%	110	0	0
8/09	5	5:43 p.m.	24°	7:30 p.m.	22°	54%	5.79 mph, S	73%	60	0	0
8/09	1	6:43 p.m.	22°	7:30 p.m.	22°	54%	5 mph, S	76%	47	0	0
8/15	2	3:40 p.m.	24°	5:18 p.m.	26°	43%	9.3 mph, N	67%	98	1	0.6
8/17	5	4:03 p.m.	24°	6:01 p.m.	25°	72%	6 mph, N	47%	118	0	0

8/19	2	10:50 a.m.	25°	11:50 a.m.	29°	99%	1 mph, SW	22%	60	2	2.0
8/21	2	7:54 p.m.	28°	9:00 p.m.	26°	79%	4.25 mph, S	57%	66	0	0
8/21	4	9:00 p.m.	26°	10:05 p.m.	24°	75%	5.75 mph, S	63%	65	0	0
9/09	5	4:29 p.m.	24°	6:20 p.m.	25°	49%	9.21 mph, SE	21%	111	0	0
9/22	3	3:23 p.m.	15°	4:18 p.m.	16°	47%	14.0 mph, N	38%	55	0	0
10/01	1	4:00 p.m.	21°	4: 30 p.m.	21°	33%	8.9 mph, N	46%	30	0	0
10/01	3	4: 30 p.m.	21°	5:00 p.m.	20°	34%	10 mph, N	48%	30	0	0
10/01	4	5:00 p.m.	20°	6:00 p.m.	20°	36%	10.7 mph, N	48%	60	0	0

Table 5: EMR Length and Age Estimates.

Snake Description	Location	Length
Adult EMR	Area 5	2.0 Ft
Adult EMR (suspected gravid female)	Area 2	2.5 Ft.
Neonate EMR	Area 2	10 in.
Neonate EMR	Area 2	10 in.

Figure 3.1. EMR sighting locations and coordinates from 2022-2023 VESs are shown in red.

Figure 3.2. Examples of EMR found. Left: One of two Neonates found in Search Area 2 in 2022. Note that the neonate's "button" is enlarged and outlined in a white circle. Right:

EMR open gestation site/den neonate emerged from. Photographs by Amanda Martinez, 2022.

Results of 2023 EMR surveys:

In 7 search days and ten search events, two EMRs were observed and documented during the 2023 surveys; this yields a naïve detection coefficient of .20 (Table 6). During the 2023 survey season, EMR sightings were made in Areas 1 and 5, one in each area (Table 7). 2023 surveys were made exclusively during May, coordinating with the EMRs' spring emergence. Weather conditions during surveys were appropriate and conducive for seeing snakes. This was evidenced by multiple observations of northern ribbon snakes and several eastern garter snakes encountered during every survey. Notably, both EMRs were observed in wetland habitats in the two sites. Furthermore, both EMRs were observed basking amongst sedges and skunk cabbages. The first adult EMR was found off the Mairlyn bland trail in search Area 1 on 05/04 and was less than 3 feet long. The EMR was observed close to the bridge over Fleming Creek, basking on top of the thick cover provided by the fen (Figure 3.3). The trail descends into and follows the west side of Fleming Creek. The snake exhibited a bright orange coloration, likely due to the high iron content in groundwater that the EMR comes into contact with during underground hibernation. The second EMR was found in search Area 5, which was roughly three feet, and found alongside Parker Brook, basking on a peat mound (Figure 3.4). Due to its wetland setting, the surface of this turf trail is often wet, suitable for EMRs to inhabit. No EMRs were found under COs in 2023.

During 2022 and 2023 VESs, crayfish chimney coordinates were also collected. This yielded twenty-one potential EMR hibernacula locations in the form of crayfish burrows (Figure 3.5).

Upon mapping the collected data, a notable trend emerged, revealing that the potential hibernacula were concentrated in close proximity to waterways. For example, a high concentration of crayfish chimneys can be found alongside Fleming Creek.

Table 6: Detection Coefficients for EMRs, 2023.

Search Unit	Number of Searches	Number of Searches where EMRs were Detected	Detection Coefficient
1	3	1	0.33
2	1	0	0
3	1	0	0
4	1	0	0
5	4	1	0.25
Totals	10	2	0.20

Table 7: EMR VES results from 2023: S.Hr.= Starting time of the survey, S.T.=Temperature at the beginning of the survey in °C, E.Hr. End time of the survey, E.T.= End temperature of the survey, Hum.=Humidity in %, Wind= Wind strength (in mph) and direction, Effort=Search Effort in Person Minutes, Cloud=Cloud cover in %, Effort is hours of search effort, search N= Number of snakes sightings, N/hr= Number of sightings per person by hr search,

Date	Site	S.Hr.	S.T.	E. Hr.	E. T	Hum.	Wind	Cloud	Effort	N	N/hr
5/04	1	11:00 am	13°	12:30 pm	16°	58%	5 mph SE	47%	90	1	0.7
5/05	1	11:05 am	16°	12:05 pm	17°	44%	8 mph N	42%	60	0	0
5/05	2	12:05 pm	17°	2:05 pm	19°	41%	8 mph N	45%	120	0	0
5/06	3	12:35 pm	19°	3:35 pm	21°	42%	13.2 mph SW	80%	180	0	0
5/09	5	9:02 am	12°	10:19 am	14°	46%	7 mph S	20%	77	0	0
5/11	5	10:41 am	23°	11:40 am	25°	45%	4 mph NE	65%	59	1	1.0
5/15	5	10:00 am	16°	11:02 am	18°	35%	3 mph NE	33%	62	0	0

5/15	4	11:02 am	18°	12:02 pm	19°	40%	3.728 mph NE	31%	60	0	0
5/19	1	10:13 am	17°	11:00 am	19°	46%	12.79 mph NE	80%	47	0	0
5/19	5	11:00 am	19°	12:09 pm	22°	48%	12 mph NE	81%	69	0	0

Figure 3.3: Adult EMR found in search Area 1 off the Mairlyn bland trail at MBG close to a bridge in 2023. Photograph by Hayden Strader.

Figure 3.4: Large adult EMR found in search Area 5 alongside Parker Brook at MBG in 2023. Photograph by Hayden Strader.

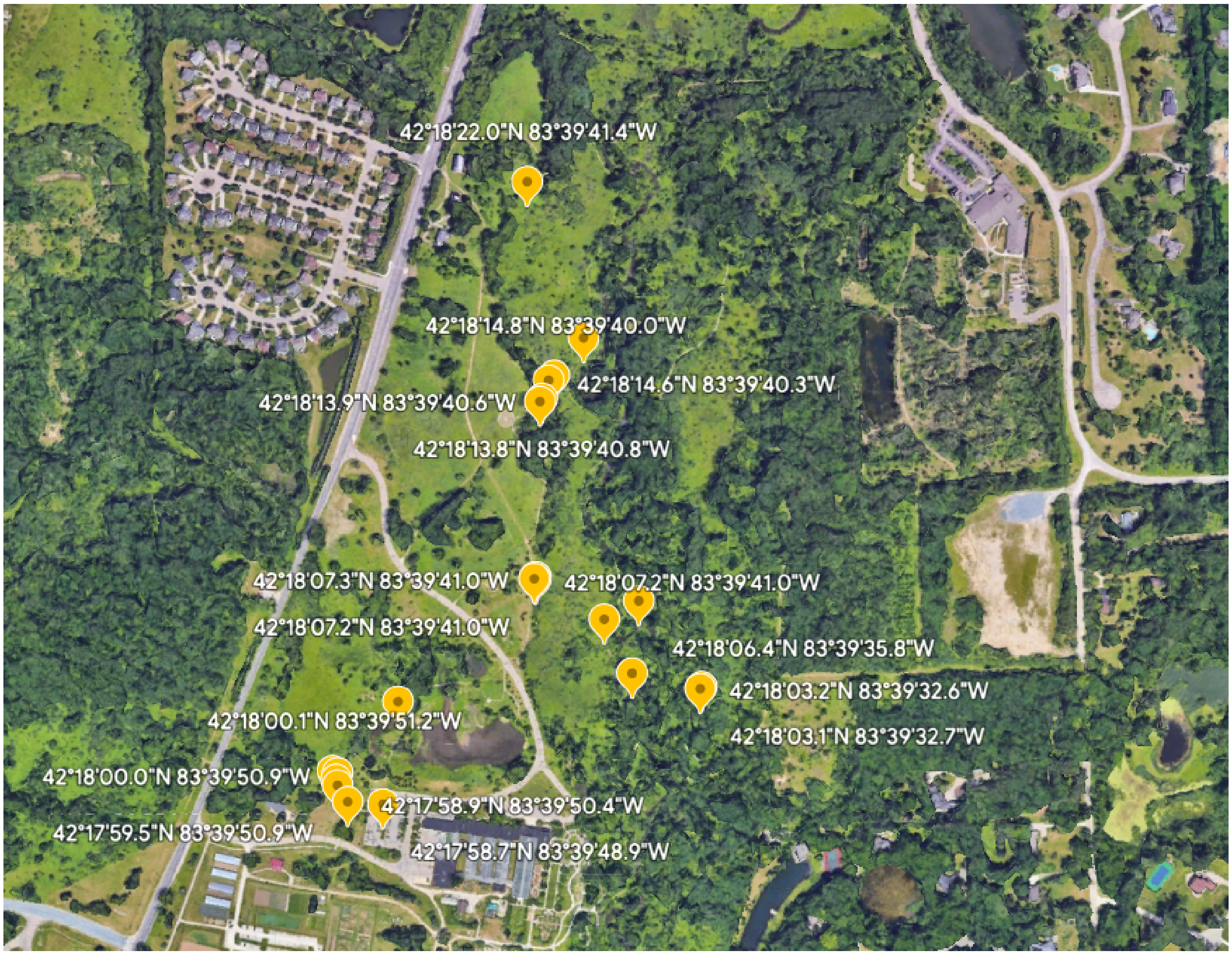

Figure 3.5. Map indicating potential EMR hibernacula: Crayfish burrow locations and coordinates are shown in yellow.

3.2 STAKEHOLDER SURVEYS

From the 306 survey questionnaires submitted to stakeholders, 119 were returned, and 101 fully completed were retained for subsequent analysis. The 18 returned surveys were excluded from further analyses due to: (i) responses with unanswered questions and (ii) illegible or inconsistent responses. Therefore, the response rate for the 2023 stakeholder survey was 33%

The infographic presented in Figure 3.6 was created with the aim of increasing public awareness and promoting the conservation of the EMR. Highlighted in the infographic is a graphic image of an EMR with its physical characteristics featured. The other large image part of the infographic depicts the EMR known Michigan locations on a map of the state of Michigan. Other content includes general information such as habitat, diet, status, and, lastly, ways residents can help with EMR conservation.

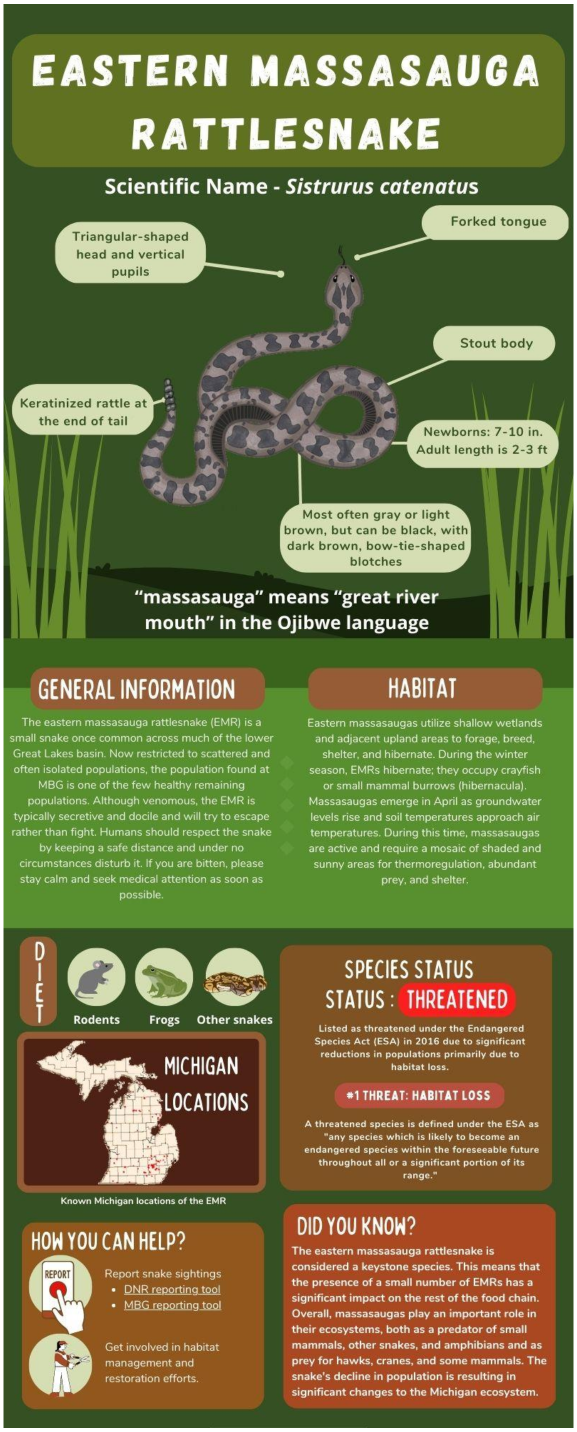

Figure 3.6. An infographic of the Massasauga was distributed along with the survey to 306 residents in the neighborhood of Matthaei Botanical Gardens.

The survey results highlight varying levels of awareness, attitudes, and preferences concerning the EMR among residents living in areas with potential EMR presence (Table 5). Awareness: More than 80% of residents indicated they knew of a possible EMR presence in their residential area (question 1). Also, most residents (96%) indicated that despite being aware of the EMR, they were not personally aware of anyone whom an EMR has bitten (question 2). Regarding the current federally listed status of the EMR, more than half of the residents (58%) indicated that they were unaware of the EMR listing as a threatened species under the U.S. Endangered Species Act (question 3).

Table 5: Stakeholder survey results:

Question(s)	Responses (N=101)	Percentage
Before receiving this survey, were you aware of the potential presence of the eastern Massasauga rattlesnake in your neighborhood?	Yes	83.2%
	No	16.8%
If you responded yes, do you know of anyone who has been bitten by the eastern Massasauga rattlesnake?	Yes	4.0%
	No	96.0%
Before receiving this survey, were you aware that massasaugas are a threatened species under the U.S. Endangered Species Act?	Yes	41.6%
	No	58.4%
Which statement do you believe best describes the importance of snakes in the ecosystem?	Not important	1.0%
	Somewhat important	25.7%
	Very important	55.4%
	Unsure	17.8%
Do you experience a positive, negative, or neutral association with snakes?	Positive association	25.7%
	Negative association	27.7%
	Neutral association	46.5%
How would you rate your support for Massasauga conservation/ recovery initiatives	1	7.9%
	2	10.9%
	3	30.7%
	4	27.7%
	5	22.8%
Please select your ideal rattlesnake population in your local area:	Healthy and abundant population, frequent sightings	11.9%
	Small and isolated population, occasional sightings	58.4%
	Population risks extinction, sightings are rare	11.9%
	Decimated population, no rattlesnake	11.9%
Have you seen any eastern Massasauga rattlesnakes around your home or neighborhood within the last year?	No snakes	82.2%
	1-2 snakes	15.8%
	3-5 snakes	2.0%
	6+ snakes	0.0%
If you have observed a massasauga, have you seen more or fewer snakes in the area than in the past five years?	More	14.5%
	Less	12.9%
	About the same	20.0%
	Unsure	43.5%

Please describe what the yard looks like in your home (i.e., wooded area, prairie, small mowed lawn, the property includes frontage on a lake, river, pond, or wetland)	Responses varied	
Would you be interested in a follow-up interview to provide additional information regarding the eastern Massasauga in your residential area? Please provide contact information if available.	Yes	20.8%
	No	79.2%
If you encounter an EMR, would you want to have the EMR removed from your residential property and relocated to MBG?	Yes	72.3%
	No	27.7%

Attitude:

Over half (55.4%) of the respondents believed snakes are a very important part of the ecosystem, (25.7%) believed snakes to be somewhat important, and (17.8%) were unsure of the snakes' importance. Only one respondent (1%) believed snakes to be unimportant in the ecosystem (question 4). Most residents (46.5%) expressed feeling a negative association with snakes, (27.7%) defined their association as neutral, and the least number of residents (25.7%) expressed having a positive association with snakes (question 5). The residents' responses regarding support for EMR conservation/ recovery issues were split between very low, to very high. The majority (30.7%) of residents expressed a moderate level of support in terms of EMR conservation. The lowest percentage of residents (7.9%) indicated their support for EMR conservation as very low (question 6).

Preferences for EMR population size in the area also varied among respondents. Over half of the responses (58.4%) indicated a preference for small and isolated populations of EMRs with occasional sightings. In comparison, a much lower percentage of residents expressed a desire for a healthy and abundant population with frequent EMR sightings (17.8%). An equal percentage of residents (11.9%) preferred a population that risked extinction, where sightings were rare, and a decimated population in which no EMRs existed (question 7).

Distribution of EMRs:

When residents were asked about their knowledge of the presence of EMRs in their respective neighborhoods, we gained information regarding the distribution of the population outside MBG property boundaries. Although most (82.2%) residents indicated not having observed EMRs in their residential areas within the last year, while (15.8%) of the responders indicated having observed the presence of 1-2 EMRs in their neighborhood, and few residents (2%) indicated they had observed as many as 3-5 EMRs (question 8). A total of 18 EMR locations were reported in residential areas beyond the boundaries of MBG (Figure 3.7)

Based on the respondent's observations of EMRs, most (43.5%) were unsure whether there was an increase or decrease in the snake population in the area compared to the past five years. A smaller percentage indicated observing about the same number of EMRs, (14.5%) observed more EMRs, and the smallest percentage (12.9%) indicated observing fewer snakes (question 9).

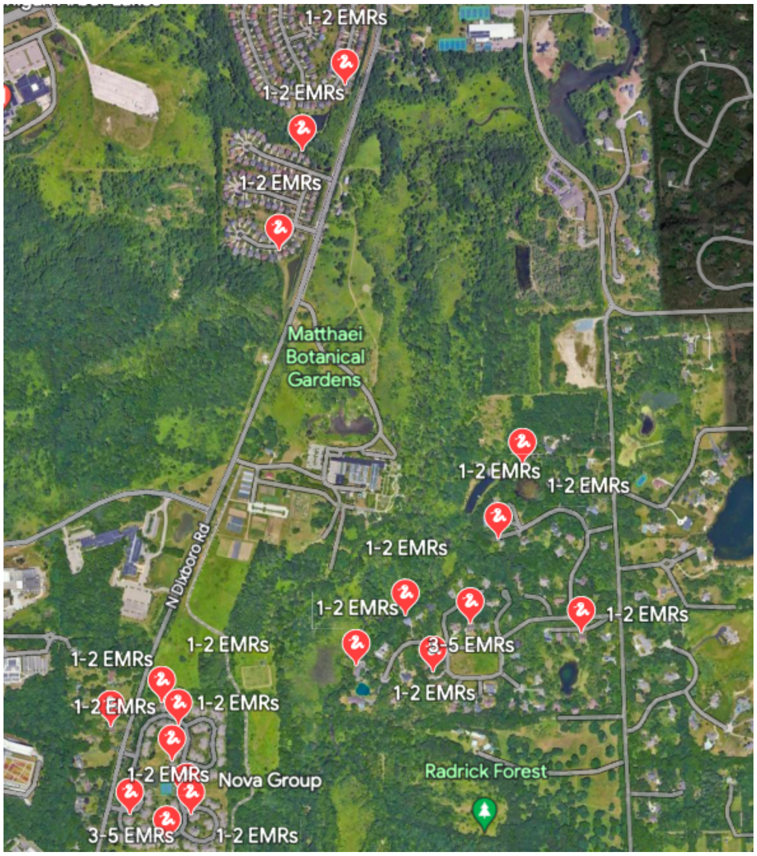

Figure 3.7: Map of the 18 EMR locations outside MBG based on the questionnaire.

CHAPTER 4: DISCUSSION AND CONCLUSIONS

4.1 VISUAL ENCOUNTER SURVEYS

VESs in 2022 and 2023 recorded the presence of six EMRs at three of the five historical sites evaluated (Areas 1, 2, and 5) (Figure 2.1). When examining the capture rates across different years, it becomes apparent that there is variation in the frequency of snake encounters. Rates for 2022 were between 0.5-2.0 N/Person Hr and for 2023 between 0.7-1.0 N/Person Hr. The comparable rates suggest a degree of stability in the EMR population over time. Based on the available information, the number of EMRs observed through VESs in 2022-23 is generally lower than the findings of previous studies. In 2012, the search effort rate reported by the ECG ranged from 0.500 to 2.00 N/person Hr. Subsequently, in 2014, the capture rate was between 0.009 and 0.05 N/person Hr. The CPUE values calculated in 2015 range from 0.33 to 2.16. These differences can be attributed to a combination of factors, including observer methodology, environmental conditions, snake behavior, distribution patterns, and changes in the ecosystem. It is essential to consider these factors when interpreting trends in monitoring data and drawing conclusions about the status and behavior of the snake population over time.

The results from the 2023 and 2022 surveys indicate lower naïve detection coefficients for the EMR populations than in previous studies. Detection coefficients refer to how likely it is to detect snakes during monitoring efforts. The 2015 survey exhibited a naïve detection coefficient of 0.45, while the 2022 and 2023 surveys reported coefficients of 0.14 and 0.20, respectively. This variability in detection rates suggests fluctuations in EMR presence and activity over time. While the 2015 survey captured a greater proportion of the population, the 2022-23 surveys observed lower detection rates, suggesting possible changes in EMR behavior or distribution.

Several factors could contribute to the observed variability within this study and compared to previous years in detection coefficients. The differences in survey methodology and design between the survey years could also contribute to the observed differences in detection coefficients. Variations in search effort, survey timing, and data collection protocols might influence the observed detection rates. Careful consideration of these methodological aspects is crucial when interpreting the results and comparing detection coefficients across different survey years.

The use of wetland habitats during this time of year is consistent with EMRs across their range. The EMR was often associated with forest edge and scrub-shrub wetlands (Degregorio et al., 2011). The seasonal changes in habitat utilization observed in this study are similar to what other EMR studies have found. For example, EMRs observed in Missouri (Seigel, 1986) and Ohio (Conant, 1938) frequented low, poorly drained soils in the spring and fall and upland, dry areas in the summer (Hallock, 1991). Search Areas 5 and 1 are lowland areas that are poorly drained. Much of these sites' ground is saturated with water, and there are openings between grasses and sedges for EMRs to bask (Figure 4.1). Moreover, understanding habitat selection across multiple scales (Sperry & Weatherhead, 2009) and the geographic range of a species (Shine, 1987) is essential to successful conservation.

The concentration of crayfish chimneys around wetland areas, signifying potential hibernacula, is noteworthy. This observation carries ecological significance as it aligns with the habitat preferences and ecological requirements of EMRs. Wetlands often play a crucial role in providing the necessary environmental conditions for EMR hibernation, as they can help regulate temperature, moisture levels, and overall habitat suitability.

Figure 4.1 Example habitat of EMR observations in May 2023. A peat mound is pictured in the background of the image. Photograph by Amanda Martinez.

Results of this study confirmed that open uplands such as search Areas 2 and 5 constitute important gestation sites for EMR ar MBG. This was reported by ECG based on 2014 surveys, noting that important gestation sites were in open uplands (Anton, 2014). Furthermore, the identification of an adult gravid female in a den in Area 2 supports the notion that this location might serve as a crucial breeding habitat. The subsequent observation of neonates in the same area suggests successful reproduction within this specific microhabitat.

The EMR observations in Search Area 2 during 2022 VESs were particularly significant because sightings suggested reproducing EMRs here. Furthermore, a suspected gravid EMR female was located in a den, and two neonate EMRs were at Area 2 (Figure 3.3). Two neonates were identified in the 2022 VESs, and it is assumed that the population of EMRs at MBG is reproducing. Given the high thermoregulation requirements of gravid EMR females, it is logical that the suspected gravid female EMR was discovered in search Area 2, the most open area. Gravid female EMRs tend to relocate to warmer and more exposed sites during summer until they give birth (Johnson, 2000). The properties of these gestation sites vary depending on location, although all exhibit below-average canopy cover and open canopy areas for thermoregulation and gestation (Johnson, 1995). Also, the identification of reproducing EMRs in Area 2 indicates that it likely provided suitable conditions for their survival, including appropriate hibernation sites, foraging opportunities, and habitat quality conducive to reproduction. Gravid female EMRs maintain high body temperatures to facilitate embryo development. This is achieved by seeking out open areas for basking, as described by Johnson

(2000). This preference for drier and more open habitats is most prominent during the summer months, as noted by Johnson (2000). The timing of EMR births typically spans from mid-August to early September, as reported by Wright (1941) and Seigel (1986). Notably, the observation of two neonate EMRs on August 19th (Table 3) strongly suggests that the gravid female gave birth in August, which is consistent with healthy EMR populations.

Gravid EMRs tend to inhabit gestation sites until parturition, generally occurring in late summer from mid-July to mid-September (Rouse & Willson, 2002). During the birthing process, female EMRs seek out abandoned animal burrows or brush piles, where they give birth to a brood of 5 - 20 hatchlings. After the birthing period, these hatchlings might spend several days in proximity to their mother before dispersing, as explained by Harding (2000). This behavior accounts for the independent observations of the two neonates. The den site itself, indicated by the presence of an animal burrow with a wood pile atop it (Figure 3.3), is consistent with gestation sites used by other EMRS. Additionally, the ability of EMR populations to coexist with low to moderate levels of human disturbance, as evidenced by gravid females using gestation sites near human trails, echoes the findings of Parent and Weatherhead (2000). Identifying a den site adjacent to a maintained trail at MBG reaffirms this aspect of EMR adaptability.

In conclusion, the study conducted in 2022 and 2023 sheds light on the dynamics of the EMR populations at MBG and their relationship with the surrounding ecosystem. The presence of EMRs at multiple historical sites indicates their persistence in the face of changing environmental conditions. Analysis of capture rates across different years reveals intriguing patterns of snake encounters, suggesting the influence of various factors such as environmental conditions, snake behavior, and observer efforts. Despite these variations, the comparable rates observed in 2022 and 2023 suggest relative stability in the EMR population over time.

Identifying potential hibernacula in wetland areas highlights the alignment of these habitats with EMR ecological requirements. Overall, results from the 2022 and 2023 surveys were comparable to results from similar studies and provided information indicating that the EMR population at MBG may have excellent or good viability. The presence of gravid females in areas like Search Area 2, known for its open uplands, underscores the importance of such habitats in the reproduction of EMRs. Detecting neonates in close proximity further suggests that successful reproduction occurs within these microhabitats. The 2022 surveys revealed noteworthy observations of gravid females seeking warmer and more exposed locations for parturition, consistent with the behavior described by previous research. These observations align with the expected birth timing for EMRs and highlight the adaptability of these snakes to coexist with moderate human presence.

Limitations of the study

Massasauga sightings by VES in this study most likely underestimate the snake population abundance in the search areas due to poor researcher experience and limited search effort. The main limitation is the searcher's lack of experience surveying snakes before this study, which could result in low detection rates of EMRs. A more extended training period would have improved the reliability of survey results, which was not possible in preparation for this thesis. Moreover, because they are ambush predators, EMRs are reclusive, largely sedentary, and cryptically colored, making detection challenging (Bailey *et al.,* 2011). Therefore, surveyors face an added difficulty because of the EMRs' cryptic nature, which requires extensive prior training.

Due to the cryptic nature of EMR, to determine population status and trend estimates, monitoring should be constant and continuous, and while this occurs, management/restoration of the habitats should continue. EMR surveys should also consider using supplemental survey methods in tandem with VESs. For example, incorporating drift fences with funnel traps as standard protocol for EMR monitoring is an efficient method for capturing and monitoring EMRs (Bartman et al., 2016). The following steps would be to obtain a population estimate through mark-recapture studies. This ensures MBG can get an official population count of their EMRs. Other recommendations include additional investigation of the use and effectiveness of cover objects for indicating EMR presence. Although EMR presence was never detected using cover objects, cover board surveys can supplement visual surveys and increase the chances of detecting EMRs at a site (Bartman et al., 2016).

Another limitation associated with VES in this study is the potential for double counting. Since the EMRs were not marked, it is possible that the snakes observed were counted more than once as the surveyors revisited the same areas. Without individual marking or identification, distinguishing between newly encountered snakes and those previously observed becomes challenging. Consequently, the data might inadvertently include duplicates. This problem can be alleviated by concentrating the search effort on one day. By conducting an intensive survey effort within a limited period, the likelihood of encountering the same snakes repeatedly across multiple survey sessions would be reduced. This approach can help minimize the chances of double counting, as snakes observed on the same day are less likely to be counted again in subsequent sessions.

4.2 STAKEHOLDER SURVEYS

Overall, the results of this study suggest that a majority of MBG neighbors have a favorable attitude rather than an adverse attitude toward the EMR and understand the importance of rattlesnakes in the ecosystem. However, we found that there is still more progress to be made in terms of education and communication efforts to correct mistaken beliefs and reduce heightened risk perceptions about the EMR. Specifically, there was a deficient level of knowledge regarding the status and, thus, policies protecting the EMR. However, knowledge or awareness of existing regulations does not always appear to stop people from killing snakes (Whitaker & Shine, 2000).

Based on the results of this study, the current distribution of the MBG EMR population extends beyond property boundaries and into the surrounding neighborhoods. For example, numerous residents from a condominium located at 1301 Laurel View Dr, Ann Arbor, MI 48105, next door to MBG, reported encounters with EMRs at their residences. The fact that residents from the condominium complex have reported encounters with EMRs indicates that these snakes are present in and around residential areas. These areas provide suitable hiding spots, such as under porches, decks, or garden areas, where the snakes can find shelter and prey. The property complex, designed for various condos, is located on the northeastern side of Ann Arbor, adjacent to Dixboro Rd. It holds ecological significance due to its proximity to Fleming Creek, which serves as a potential corridor for EMRs to traverse between different habitats.

Additionally, with the condominium being adjacent to MBG, the complex has access to an MBG trail and Radrick Forest. Radrick Forest, being a wooded area, would provide a habitat suitable for the EMR. They are known to inhabit areas with diverse vegetation and undergrowth, which offer hiding spots and opportunities to ambush prey. Similarly, the interface between forested areas and open spaces can be attractive to snake populations as they provide a mix of conditions from both environments. Furthermore, snakes can utilize the shelter of the forest while still having access to sunny open areas for basking. Additional surveys should be conducted to investigate the species' distribution outside MBG further.

Results from this study suggest that the residents need outreach and education strategies that provide information and direct experiences with snakes. There have been previous reports of sightings by the neighborhood residents. For example, in 2020, an incident was described in which a neighbor discovered an EMR sunning itself on their driveway. The resident mentioned that another neighbor placed the EMR in a cardboard box and showed it to others, particularly those with children, to educate them about the species. A private newsletter documenting the story was mailed back in a self-addressed envelope, crediting its confirmation. This recent report further verifies the need for educating residents about the EMR. Previous researchers have made similar conclusions regarding the beneficial impacts of a planned, guided snake encounter (Christoffel, 2007; Lo et al., 2012; Morgan & Gramann, 1989; Skupien et al., 2016).

Guided encounters can help to alleviate fear associated with snakes and increase public awareness and understanding. Human persecution has long been recognized to contribute to the population decline of this species (Bailey *et al.,* 2011). By providing educational information and interactive experiences, guided snake encounters can help people better appreciate snakes and their role in the ecosystem.

To address stakeholders' apparent curiosity about the conservation of the EMR in Ann Arbor, I recommend that MBG develops educational programs targeted at the average Ann Arbor resident. As mentioned earlier, this may involve holding workshops or developing accurate educational materials concerning actions people can take to reduce snakebite risk and appropriate actions to take should a person encounter an EMR in their home. Furthermore, despite residents indicating they support the conservation of the species, there is still uncertainty regarding sharing their homes with the EMR. Specifically, a large proportion of respondents (73.2%) indicated that if they encounter an EMR at their residential property, they would like it removed/relocated to

MBG (question 12). However, this is to be expected, considering that the Michigan DNR receives several calls each year reporting an EMR in or near a human dwelling and requesting assistance to remove it (USFWS, 2016). One possible solution presented to the neighbors was the relocation of the EMR to MBG by MBG staff. In one recent study, EMRs relocated 200 meters (656 feet) from the capture point, did not exhibit abnormal movement or basking behavior, and did not return to the capture site (Harvey et al., 2014).

Conclusion:

The current research aimed to (1) determine continued EMR presence using a validated and novel survey technique at a selected historic population site (MBG) in Ann Arbor, Michigan, (2) Survey residents' attitudes and awareness toward the EMR in a residential area, (3) further understanding the distribution of EMR near MBG, (4) develop educational materials for the residents.

The EMRs listing as a threatened species has prompted conservation efforts range-wide, especially in Michigan, the last stronghold for this species. According to the USFWS, nearly 40 percent of known populations are now extirpated, and the status of an additional 15 percent is uncertain (USFWS 2016). Hence, it is essential to monitor existing populations of EMRs and promote their vitality in the areas they inhabit. This information can significantly assist Michigan in safeguarding the species. Through my research, I established the presence of EMR at three out of the five search areas surveyed at MBG. Furthermore, evidence of a reproducing population was found. However, due to the cryptic nature of the EMR, these sightings represent a low proportion of the resident population in these areas.

Evaluating the attitudes and awareness of neighbors of MBG concerning the EMR aids in species conservation. This is significant as anthropogenic disturbances have greatly impacted the EMR population. Specifically, through surveys, MBG neighbors provided information on the distribution of the EMR MBG population, giving evidence that the MBG population of EMRs extends beyond property boundaries and into residential areas, with the highest concentration of EMRs found on Laurel View Dr. Additionally, the survey begins a collaborative relationship with neighbors encouraging the residents to live harmoniously with EMRs. MBG should continue collaborating with neighbors to promote the conservation of the species.

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