Assistance with the Eastern Massasauga (*Sistrurus catenatus*) Population Survey and Education and Outreach for the Camp Grayling Joint Military Training Center 2019

Prepared By:

Yu Man Lee
Michigan Natural Features Inventory
Michigan State University Extension
P.O. Box 13036
Lansing, MI 48901-3036

Prepared For:

Michigan Department of Military and Veterans Affairs
Michigan Army National Guard – Jonathan Edgerly
Camp Grayling Joint Military Training Center – Carla Lange, Matthew Kleitch, Cullen Haesler

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Eastern Massasauga Overwintering Habitat at Camp Grayling JMTC. Photo by Yu Man Lee.
Eastern Massasauga (*Sistrurus catenatus*) at Camp Grayling JMTC. Photo by Kristin Wildman.

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Introduction

The eastern massasauga (*Sistrurus catenatus*) is a small, thick-bodied rattlesnake that generally inhabits shallow, open or early successional wetlands and adjacent open uplands as well as forested wetland and upland habitats in Illinois, Indiana, Iowa, Michigan, Minnesota, New York, Ohio, Pennsylvania, Wisconsin, and Ontario (Harding and Mifsud 2017, Szymanski 1998, Szymanski et al. 2016). The species was once considered common throughout its range, but its populations have severely declined. 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 or self-sustaining (i.e., demographically, genetically, and physiologically robust with a level of persistence given its habitat conditions and risk or beneficial factors) (Szymanski 1998, Szymanski et al. 2016). As a result, the eastern massasauga was listed as a federally threatened species by the U.S. Fish and Wildlife Service (USFWS) in 2016 (USFWS 2016). The primary threat that has led to this species' decline has been habitat loss and modification from agricultural, residential, and urban development; vegetative succession; invasive species; habitat fragmentation from roads and bridges; and hydrological alterations (Szymanski 1998, Szymanski et al. 2016). Other factors that pose risks to the species include habitat management practices (e.g., prescribed fire, mowing), road mortality, persecution, collection, predation, disease, and climate change (Szymanski 1998, Szymanski et al. 2016).

Michigan is considered to be the last stronghold for this species, containing more historical and extant massasauga populations than any other state or province within the species' range (Szymanski 1998). Therefore, the long-term viability and persistence of this species in Michigan has important implications for conservation and recovery of this species range wide. However, eastern massasauga populations in Michigan also have declined due to similar threats that impact populations in other parts of the species' range. As a result, the eastern massasauga has been designated a species of special concern and a Species of Greatest Conservation Need (SGCN) in Michigan (Derosier et al. 2015).

Identifying priority massasauga populations and associated management needs will help ensure that viable populations are maintained and protected to sustain the species in perpetuity in Michigan. The eastern massasauga population within and around the Camp Grayling Joint Maneuver Training Center in north-central Michigan has been identified as a priority population to maintain and protect in the state. This designation as a priority population is based on the long history and large number of eastern massasaugas that have been documented at this site through incidental observations, targeted surveys, and radio-telemetry research as well as the presence of extensive habitat within and around Camp Grayling. However, information on the size and demographics of the massasauga population at Camp Grayling is not available.

To better inform management of this population, the Michigan Department of Military and Veterans Affairs (DMVA) initiated a long-term mark-recapture study in 2018 to assess and monitor the size, demographics, and status of the eastern massasauga population at Camp Grayling. Michigan Natural Features Inventory (MNFI), a program of Michigan State University Extension (MSUE), was contracted by the DMVA in 2018 and 2019 to provide technical assistance with designing, planning, and conducting the eastern massasauga population study at Camp Grayling. In 2019, MNFI also provided assistance with two eastern massasauga education and outreach events in northern Michigan. This report summarizes MNFI's project activities and results in 2019 as well as initial results from the massasauga population surveys at Camp Grayling in 2018 and 2019.

Methods

Project Objectives

The purpose of this project is to provide technical assistance to the DMVA to help plan, prepare, and implement a long-term eastern massasauga population study at Camp Grayling and assist with eastern massasauga education and outreach. This was accomplished by addressing the following objectives:

1) Work with DMVA/Camp Grayling staff and other partners to plan, prepare, and conduct the 2019 eastern massasauga population survey at Camp Grayling.
2) Work with DMVA/Camp Grayling staff to review the 2019 population survey after it has been completed and provide feedback, help identify and resolve issues, and identify opportunities for improving the study.
3) Obtain and review eastern massasauga survey and locational data from the Camp Grayling population survey from the DMVA/Camp Grayling, and provide feedback and assistance with data compilation and processing.
4) Enter survey and locational data on eastern massasaugas and other rare species documented during the Camp Grayling eastern massasauga population survey into the Michigan Natural Heritage Database.
5) Provide DMVA/Camp Grayling assistance with two massasauga-related education and outreach programs or presentations.
6) Prepare and submit a brief final report summarizing project activities and results.

Study Area

The Camp Grayling Joint Maneuver Training Center is located in Grayling, Michigan. The National Guard base spans nearly 60,000 ha (~147,000 ac) in Crawford, Kalkaska and Otsego counties in the northern Lower Peninsula of Michigan (Figure 1). The base is divided into a North Camp and South Camp, lying approximately northeast and southeast of the City of Grayling and Interstate-75, respectively (Figure 1). Camp Grayling is located on land owned by the Michigan Department of Natural Resources (DNR) and leased to the Michigan National Guard. As such, active air and army training regularly occurs at the base, but portions of the base are also open to the public for recreation including hunting, fishing, and snowmobiling. The Michigan DNR and DMVA/National Guard also collaborate to manage the natural resources at Camp Grayling including conducting or facilitating wildlife surveys and research, habitat inventory and management, and other environmental projects.

Camp Grayling is comprised of a diverse array of natural communities which provide habitat for numerous wildlife species, including several which are protected by federal or state laws. These include the eastern massasauga (federally threatened, state special concern), Blanding's turtle (*Emydoidea blandingii*, state special concern), wood turtle (*Glyptemys insculpta*, state special concern), Houghton's goldenrod (*Solidago houghtonii*, federally and state threatened), and rough fescue (*Festuca altaica*, state threatened). Natural communities that have been documented within Camp Grayling include wetlands such as northern fen, poor fen, northern wet meadow, bog, intermittent wetland, northern shrub thicket, and rich conifer swamp, and upland community types such as dry, dry-mesic, and mesic northern forests, pine

barrens, and mesic sand prairie (Higman et al. 1994, Higman et al. 2005, Kost and Cohen 2005). The forests in Camp Grayling are composed of numerous deciduous and coniferous species, including oak (*Quercus* spp.), maple (*Acer* spp.), quaking aspen (*Populus tremuloides*), red pine (*Pinus resinosa*), jack pine (*Pinus banksiana*), black spruce (*Picea mariana*) and arborvitae (*Thuja occidentalis*) (DeGregorio 2008).

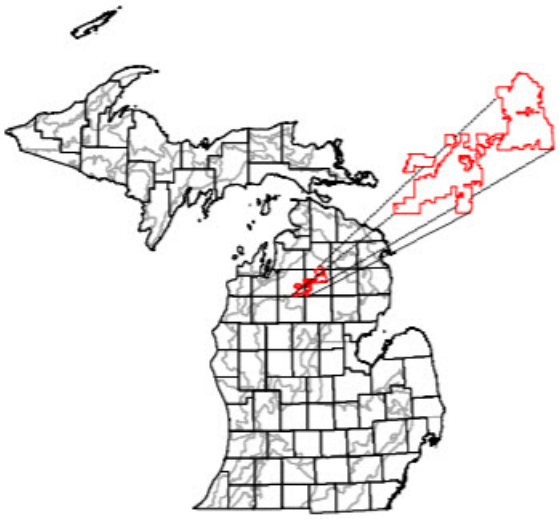

Figure 1. Location of Camp Grayling Maneuver Training Center in Northern Lower Michigan.

The eastern massasauga population surveys at Camp Grayling in 2018 and 2019 focused on four areas within South Camp that contain known hibernacula for eastern massasaugas based on previous surveys and research. These areas are referred to as the Blue Area (STA9 South), Yellow Area (STA9 North), Red Area (Ranges West), and Green Area (Ranges East). These areas range in size from about 8-19 ha (19-47 ac) (Table 1). Natural communities or habitats within these areas include rich conifer swamp, northern shrub thicket dominated by speckled alder (*Alnus incana rugosa*), dry northern forest dominated by young jack pine, and pine barrens. Portions of the Blue and Yellow Areas were burned in a large fire in May 2010.

Table 1. Summary of areas that were surveyed as part of the eastern massasauga population study at the Camp Grayling Joint Military Training Center in Grayling, Michigan.

Survey Area	Size of Area (Hectares/ha)	Size of Area (Acres/ac)	Survey Years
Blue Area (STA9 South)	18.1	44.7	2018, 2019
Yellow Area (STA9 North)	19.1	47.2	2018, 2019
Red Area (Ranges West)	10.4	25.6	2018, 2019
Green Area (Ranges East)	7.6	18.9	2018, 2019
TOTAL	55.2	136.4	2018, 2019

Eastern Massasauga Population Survey Planning, Preparation and Implementation

The eastern massasauga population study at Camp Grayling was initiated in 2018 and is planned to be conducted for at least five years and potentially longer. The population surveys to date were conducted during May 7-11, 2018 and May 6-10, 2019. The population study has consisted of surveying, capturing, marking, and releasing eastern massasaugas observed during a one-week period in early spring (i.e., typically the first week in May) when snakes are emerging from their hibernacula. Surveys consisted of visual encounter surveys in which teams of trained volunteers walked slowly through delineated survey areas with known massasauga hibernacula and look for snakes basking, resting, or moving on the ground or on or under vegetation or cover objects (e.g., downed woody debris) or emerging from burrows. For each massasauga observed in the field, data on the location, weather conditions, behavior, and/or body temperature of the snake were collected, and each snake was photographed whenever possible. Other snakes observed during the surveys also were recorded.

Massasaugas observed in the field were captured with snake tongs, placed into pillowcases and plastic buckets, and transported to the lab for processing. In the lab, each massasauga was measured, weighed, sexed, marked by injecting a passive integrated transponder (PIT tag) subcutaneously, and photographed. Total length (cm) of each snake was measured using a squeeze box and a measuring tape (Quinn and Jones 1974). Tail length (cm) was measured with a measuring tape and the number of subcaudal scales was counted while the upper body of the snake was safely restrained in a transparent snake/PVC tube (Hileman 2016). Snout-vent length (cm) was calculated by subtracting tail length from total length. Mass or weight of each snake was determined by weighing and subtracting the weight of the pillowcase from the weight of the snake in the pillowcase using Pesola scales in 2018 and a digital scale in 2019. The sex of each snake was determined by probing (Schaefer 1934) and adult females were palpated to determine if they were gravid and approximate number of embryos while the snake was restrained in a snake tube. The age class of snakes was recorded as adult, sub-adult/juvenile, and neonate/young (note: neonate and young were two separate age class designations in 2018 but was changed to just neonate in 2019). These age class designations were first assigned in the lab during the survey and then reviewed and potentially revised afterwards based on the following snout-vent lengths (SVL): 1) adult - $\geq$42 cm SVL for females, $\geq$43 cm SVL for males; 2) sub-adult/juvenile – 27-41 cm SVL for females, 27-42 cm SVL for males; and 3) neonate/young snakes – 18-26 cm SVL. It is important to note these age class designations are based on age class-SVL estimates from other massasauga studies in the literature (i.e., Bradke and Kiel 2013, Bradke et al. 2018a), but these estimates or distributions need to be reviewed and may need to be revised for Camp Grayling. Snakes were examined for visible signs of snake fungal disease (SFD) and swabbed for snake fungal disease testing. Blood samples were collected from the caudal veins of captured snakes for genetic analysis. The rattles of the snakes were painted with fingernail polish to easily identify snake recaptures in the field during the week. Snakes were processed in the lab and released at their original capture sites typically within 4-8 hours (and no more than 24 hours) of when they were captured. Data were entered in the field and lab using a customized Survey 123 application and Samsung tablets. Detailed protocols of the 2019 field survey methods and lab procedures are provided in Appendix 1.

The Camp Grayling eastern massasauga population surveys have been conducted by MNFI and DMVA/Camp Grayling staff as well as trained volunteers comprised of natural resource and other professionals (e.g., wildlife biologists, forest or other natural resource managers, academic researchers, zoo staff, and environmental consultants), university students, and other interested people/citizen scientists. In 2018 and 2019, the volunteers were divided into four

teams for the week-long survey. Each team consisted of 2 team leaders and typically 4-9 volunteers. The team leaders had previous experience with surveying and handling massasaugas and/or other rattlesnakes and received training on the survey and data collection protocols prior to the start of the survey. Each team was assigned one of the four areas to survey each day of the week-long survey, and the teams rotated through the areas so that each team surveyed all four areas at least once during the week. Each area was surveyed for about 2.5-3 hours in the morning (generally between 9 am - 12 pm) and about 3 hours in the afternoon (generally between 2 pm – 5 pm) each day of the survey. Surveys were conducted under appropriate weather conditions when massasaugas were expected to be active and/or visible (i.e., between 50/55-80°F [10/13-27ºC], wind less than 15 mph, no or light precipitation). In the lab, one to two teams of two people (i.e., one snake handler, one data collector/tablet handler) were responsible for snake processing and data collection and were trained on the lab procedures prior to the survey. One to two additional staff and/or volunteers assisted in the lab with transporting snakes and/or disinfecting snake handling equipment.

Michigan Natural Features Inventory staff provided DMVA assistance with planning, preparing, and conducting the 2019 eastern massasauga population survey at Camp Grayling. MNFI assistance with planning and preparing for the 2019 survey consisted of participating in planning meetings, conference calls, and site visits with DMVA staff and other partners to review the 2018 field survey, lab procedure, and data collection protocols for the massasauga population study and provide recommendations to resolve issues and improve the study in 2019. MNFI staff worked with DMVA staff to review the field and lab supplies and equipment from the 2018 population survey and determine supplies and equipment that needed to be purchased for the 2019 survey. MNFI staff assisted with identifying, recruiting, and training survey volunteers and team leaders, and helped train Camp Grayling staff on the field survey, lab procedures, data collection, and massasauga handling protocols as well. MNFI staff also assisted with leading survey teams, conducting massasauga surveys, capturing and releasing snakes in the field, processing captured snakes in the lab, obtaining samples from them, collecting and recording data in the field and lab, and other providing other technical, logistical, and/or administrative support during the survey as needed. After completion of the 2019 survey and review of the survey data, MNFI staff participated in post-survey meetings, emails, and/or conference calls and provided feedback on the survey and suggestions for addressing any issues that arose during the 2019 survey and improving surveys in the future.

Eastern Massasauga Population Data Review and Compilation

In 2018 and 2019, field and lab data from the eastern massasauga population surveys at Camp Grayling were collected and stored in customized Survey 123 applications that were specifically developed for the population study by DMVA personnel. Field surveyors and lab personnel entered data into the Survey 123 applications using Samsung tablets in the field and lab during the week-long eastern massasauga population survey. DMVA staff uploaded the field and lab data into the applications' online geodatabases every evening after the day's field surveys and lab processing were completed or the morning after the surveys and lab processing were completed during the week. After the week-long surveys were completed, DMVA staff exported and downloaded shapefiles from Survey 123 applications' geodatabases with the spatial and/or tabular data from the massasauga field surveys and lab processing and conducted an initial inspection of the data.

MNFI staff provided assistance with reviewing and compiling the field survey and lab data from the eastern massasauga population surveys at Camp Grayling in 2018 and 2019. DMVA staff provided MNFI with ArcMap projects containing shapefiles with the field and lab data. MNFI staff reviewed the shapefiles and associated tabular and spatial data and photos of the snakes, looked for errors and inconsistencies in the data and missing data, and corrected these errors when possible. Tabular or attribute data from the 2018 and 2019 shapefiles were exported to Excel spreadsheets and were combined, standardized, and summarized. Review of these data helped to identify aspects of the study that could potentially be improved for future surveys.

Updating the Michigan Natural Heritage Database

MNFI staff updated the Michigan Natural Heritage Database with information from the 2018 and 2019 eastern massasauga population surveys at Camp Grayling. The Michigan Natural Heritage Database is the most comprehensive database available on the status and distribution of Michigan's rare animals, plants, and natural communities. The Natural Heritage Database is utilized by a variety of stakeholders, including federal, state, and local government agencies, private companies, environmental consultants, non-profit/conservation groups, academic researchers, public and private landowners, and others, to help inform and guide conservation decisions. Data obtained from the DMVA/Camp Grayling on the numbers, locations, and dates of observations of eastern massasaugas that were documented during the 2018 and 2019 massasauga population surveys at Camp Grayling were reviewed, compiled, and entered into the Natural Heritage Database to update the existing eastern massasauga element occurrence (EO) or population documented in the database. Additional information including the sex and age class of the snakes, names of the observers, and circumstances of the observations were entered into the database. Observations of other rare species documented during the 2018 and 2019 massasauga population surveys also were entered into the Natural Heritage Database to add new element occurrences or update existing element occurrences to the database.

Eastern Massasauga Education and Outreach

Michigan Natural Features Inventory provided assistance with two massasauga-related education and outreach programs or presentations in 2019. One program was for the Spring Meeting of the Michigan Society of American Foresters (SAF) which was held on April 18-19, 2019 in Grayling at Kirtland Community College and Camp Grayling. The second program or presentation was at the Kirtland's Warbler Festival in Roscommon on June 1, 2019. MNFI staff coordinated with Camp Grayling staff and the organizers of these two events to determine the desired content and format and/or field sites for the presentations. Camp Grayling staff provided MNFI with previous presentations and other background materials or information to assist with these presentations. MNFI developed and conducted these outreach programs/presentations and developed and provided an informational handout for the SAF meeting at their request.

Results

Eastern Massasauga Population Survey Planning, Preparation and Implementation

Survey Planning and Preparation

Michigan Natural Features Inventory staff provided DMVA assistance with planning, preparing, and implementing the 2019 eastern massasauga population survey at Camp Grayling. MNFI assistance with planning and preparing for the 2019 survey consisted of participating in two planning meetings in the Lansing area (i.e., January 24 at the DMVA/Joint Forces Headquarters/Reserve Forces Support Center, and March 8 at the DLZ office), an additional planning meeting/site visit at Camp Grayling (March 18), and three conference calls (April 22, April 29, May 1) with DMVA staff (i.e., Jonathan Edgerly with Michigan Army National Guard; Carla Lange, Cullen Haesler, and Darcia Little with Camp Grayling) and other partners (i.e., Mike Ravesi with Connecticut Department of Energy and Environmental Protection [formerly with DMVA/Camp Grayling]; Amy Bleisch with Michigan Department of Natural Resources; Steve Metzer and Natalie Dingledine with DLZ). MNFI staff also communicated and coordinated with DMVA staff and other partners through numerous emails. The planning meetings in the Lansing area focused on reviewing the 2018 massasauga survey and feedback from the volunteers; discussing and planning the 2019 survey schedule, protocols, and logistics (e.g., daily schedule, contingency plans in case of inclement weather for surveys, survey team structure and team leaders, naming convention of survey teams and snake observations and locations, volunteer recruitment and communication, information packets for the volunteers, data collection and management with the tablets, and data processing and analysis); and identifying and assigning tasks and responsibilities. The planning meeting/site visit at Camp Grayling on March 18 and subsequent conference calls and emails focused on reviewing and finalizing the 2019 survey schedule and field and lab protocols, training the DMVA/Camp Grayling staff on the field survey and lab protocols, reviewing supply and equipment needs, identifying additional supplies and equipment that needed to be purchased, and reviewing and finalizing the field survey and lab data forms (i.e., search effort form, field/EMR survey form, lab effort/survey form, and release effort form) and data fields for the Survey 123 applications on the tablets. MNFI staff worked with Camp Grayling staff to develop a spreadsheet/checklist of tasks, timeline, and supplies to help with planning and coordination. MNFI staff and Camp Grayling personnel reviewed and finalized the volunteer list and schedule, the survey teams/team leaders and schedule for the survey, the team leader and volunteer check-in and orientations on the Sunday before the start of the survey, the federal permit/agent of the state requirements, and other logistics during a series of conference calls and emails in late April and early May prior to the start of the 2019 survey.

Based on feedback from 2018 and these discussions and planning efforts, MNFI worked with Camp Grayling staff and other partners to identify and implement a number of changes and/or additions to the 2019 survey protocol, data collection forms or fields, and schedule/logistics for the survey (Appendices 1 and 2). Changes to the survey teams in 2019 included limiting team sizes to between 4 and 9 people, having two team leaders (i.e., one main snake handler and one data recorder/tablet handler but both team leaders were trained on snake handling and data collection protocols) for each team instead of one team leader, and assigning team names based on the area they were surveying that day so team names would change every day (e.g., Team A would survey the Blue Area and be called the Blue Team on Monday, would survey the Yellow Area and be called the Yellow Team on Tuesday, would survey the Red Area and be

called the Red Team on Wednesday, etc.). Substrate or soil temperature, wind speed, and humidity (at ground level) were added to the 2019 search effort form (Appendix 1). Several substantial changes or additions were made to the EMR field survey form and protocol in 2019 including the following: 1) changing the snake ID field (and location ID) for massasauga and other snake observations to Day-Month-Year-Survey Area-Time of Observation (e.g., 07MAY2019Blue1630) and having this auto-populated by the application; 2) recording a snake ID for all snake including non-massasauga observations; 3) capturing all massasaugas observed in the field including recent recaptures in order to scan and obtain PIT tag numbers if present to identify individual snakes, and releasing recent recaptures (i.e., massasaugas that had already been captured and processed earlier in the week) at capture sites immediately after confirming their PIT tag numbers, presence of paint on the rattle, and recapture status with lab personnel; 4) recording whether massasauga recaptures were previously captured in 2018 and/or 2019; and 5) recording head, mid-body, and tail temperatures of massasaugas found in the field with an infrared thermometer/thermal infrared gun, temperature of the surface of the ground where massasaugas were found with a thermal infrared gun, and sub-surface temperatures (i.e., soil temperature ~15-20 cm/6-8 inches below the surface) at massasauga capture sites with a soil thermometer/probe (Appendix 1). Changes and additions to the lab procedures and data form in 2019 included the following: 1) writing the snake ID on the Styrofoam/polystyrene sheets in the squeeze box for the snake photos; 2) using a digital bench scale to weigh the snakes and pillowcases instead of Pesola scales; 3) collecting swab samples to test for snake fungal disease from all the massasaugas that were processed; 4) collecting blood samples from only a subset of the snakes that were processed; 5) painting the rattles of all processed snakes with only one paint (fingernail polish) color for the week instead of painting different colors for each day of the survey week (and different snakes in some cases) in 2018; and 6) disinfecting all equipment and supplies in the lab that comes in contact with snakes with a 70% ethyl alcohol solution instead of a bleach solution (Appendix 1). A separate Release Effort Form was added in 2019 to record data when massasaugas were released at their capture sites after lab processing. Changes to the survey schedule and logistics in 2019 included the following: 1) providing additional information in the volunteer packets; 2) having the team leaders attend a longer orientation on Sunday prior to the start of the survey which included visiting the survey areas; 3) assigning each tablet to a survey area or the lab instead of assigning them to a survey team and associating the tablet login to the survey area; 4) having the team leaders check in their backpacks and tablets with Camp Grayling staff at the end of each day so that the supplies in the backpacks could be checked and replenished, survey data on the tablets could be uploaded to the online geodatabase each night/next morning, and the backpacks and tablets were all ready for the next day's survey; and 5) having a debrief session with team leaders, lab personnel, and MNFI and/or Camp Grayling staff at the end of each day to discuss and resolve any issues encountered in the field or lab.

Survey Implementation

Michigan Natural Features Inventory assisted with coordinating and conducting the eastern massasauga survey from May 6-10, 2019 by having four staff (one seasonal technician, Dan Earl, and three AmeriCorps members, Frank Schroyer, Courtney Ross and Zack Pitman) help lead three of the survey teams and one to two staff people (one permanent staff, Yu Man Lee, and one AmeriCorps member, Frank Schroyer) help with processing snakes in the lab (Figure 2, Appendix 3). MNFI staff helped document and/or capture 19 of 30 massasaugas found in the field and helped process and collect data and samples from 22 of 24 massasaugas in the lab during the 2019 survey. MNFI staff worked with DMVA staff and other partners to organize and provide the training/orientation for the team leaders and survey volunteers on May 5, 2019. MNFI staff also helped provide training to Camp Grayling staff on handling and capturing

massasaugas in the field (Figure 3). MNFI staff provided other technical, logistical and/or administrative support during the survey such as identifying additional supplies needed and helping to adjust the survey teams and schedule due to changes in volunteers' schedules and inclement weather. Survey schedule changes included delaying the surveys on the morning of May 9 due to rain and cancelling the surveys on May 10 due to snow and cold temperatures.

Post-Survey Evaluation

After completion of the 2019 survey, MNFI staff participated in post-survey communications with Camp Grayling staff and other survey organizers and provided feedback and suggestions for addressing issues that arose during the 2019 survey and improving surveys in the future. Suggestions included providing more time for team leaders to meet with their team members prior to the start of the survey (e.g., between orientation and dinner on Sunday prior to the start of the survey); sending some basic information about the survey and field protocol to the volunteers ahead of time especially to those who are not planning to attend the Sunday orientation; making a few changes to the map display of the survey areas on the tablets such as just displaying the area boundaries and removing the shading within the areas, adding a north arrow, and locking the tablet screen; and emphasizing to team members the importance of staying together and within the area boundaries and listening to the team leaders during the survey. Additionally, Camp Grayling staff sent a thank you note and online survey to all the study participants after the 2019 population survey was completed to obtain feedback and suggestions for improving the study in the future. MNFI staff will work with Camp Grayling staff to review and discuss the feedback and suggestions from participants to plan and prepare for the 2020 survey.

Figure 2. Photos of Mike Ravesi and MNFI staff/AmeriCorps member, Frank Schroyer, processing an eastern massasauga in the lab during the 2019 eastern massasauga population survey at Camp Grayling Joint Military Training Center in Grayling, Michigan.
(Photos by Yu Man Lee)

Figure 3. Photos of DMVA/Camp Grayling staff receiving training and practicing capturing an eastern massasauga safely in the field during the 2019 eastern massasauga population survey at the Camp Grayling Joint Military Training Center in Grayling, Michigan. (Photos by Yu Man Lee)

Eastern Massasauga Population Data Review and Compilation

2018 Survey Results

The number of eastern massasaugas documented during the 2018 population survey was much higher than the number documented during the 2019 survey. During the 2018 survey, a total of 81 eastern massasauga observations were documented, of which 72 represented unique individuals that were captured and processed in the lab, 7 were resightings or recaptures of snakes that had been captured and processed earlier in the week, and 2 escaped and were not captured (Table 2, Figure 4). Of the 72 unique individual snakes that were captured, 48 were adults (24 females, 24 males), 15 were subadults or juveniles (5 females, 9 males, 1 unknown), and 9 were neonate or young snakes that had been born the previous summer/fall (5 female, 3 male, 1 unknown) (Table 3). These resulted in a total of 36 male snakes, 34 female snakes (6 gravid), and 1 unknown. In 2018, the numbers of massasaugas observed in each survey area were again similar, with 21 unique individual snakes found in the Green Area, 19 in the Blue Area, 17 in the Red Area, and 16 in the Yellow Area (Table 4). In addition to massasaugas, 5 observations of the state special concern smooth green snake (*Opheodrys vernalis*) as well as 3 observations of eastern hog-nosed snakes (*Heterodon platirhinos*), 2 observations of northern ribbon snakes (*Thamnophis saurita/sauritus septentrionalis*),12 observations of eastern garter snakes (*Thamnophis sirtalis sirtalis*), and 1 observation of a common five-lined skink (*Plestiodon fasciatus*) were documented during the 2018 survey.

2019 Survey Effort

A total of 46 people participated in the eastern massasauga population survey at Camp Grayling in 2019. Of these, 39 people assisted with field surveys in the four study areas. Team sizes ranged from 4-8 people per team/area/day with a total of 19-30 people conducting the surveys across all four search areas each day (Appendix 3). Five people assisted with processing snakes in the lab, and five people assisted with transporting team members/surveyors and captured massasaugas between the survey areas and the lab and providing logistical support. Survey participants included DMVA staff, Department of Defense/U.S. Navy staff from outside Michigan, MNFI staff/AmeriCorps members, DLZ staff, current/former Michigan DNR staff, staff/students from Grand Valley State University and two other universities, staff from the Indiana Chapter of The Nature Conservancy, several additional AmeriCorps members, environmental consultants, and zoo personnel. Six of the survey volunteers were from outside Michigan (e.g., Indiana, Pennsylvania).

2019 Survey Results

During the 2019 survey, a total of 30 eastern massasauga observations were documented, of which 26 snakes were captured and 4 escaped and were not captured (Table 2). Of the 26 snakes that were captured, 24 were unique individuals that were brought to the lab for processing, of which 19 were new or initial captures in 2019 and 5 were recaptured snakes from the 2018 survey (Table 2, Figure 5). The two snakes that were captured in the field but were not brought to the lab for processing were recaptures of the same snake that had been captured earlier in the week in 2019 (i.e., snake with PIT tag ID 096531773 was first captured and tagged on May 6 and recaptured and released in the field on May 7 and 9). Of the 24 unique individuals that were captured during the 2019 survey, 14 were adults, 9 were sub-adults or juveniles, and 1 was a neonate or young snake that had been born the previous summer/fall (Table 3). It is important to note that if the age class estimates or distributions for massasaugas at Camp Grayling are revised, the age class designations and summary from the 2018 and 2019 surveys

may change. The 24 snakes captured in 2019 were comprised of 12 males and 12 females (2 gravid) (Table 3). The numbers of massasaugas found in the survey areas were similar, with 7 unique individuals found in the Blue and Yellow Areas, 6 unique snakes found in the Green Area, and 4 unique snakes found in the Red Area (Table 4). In addition to eastern massasaugas, two observations of the state special concern smooth green snake (*Opheodrys vernalis*) as well as 7 observations of eastern hog-nosed snakes (*Heterodon platirhinos*), 1 observation of an eastern milk snake (*Lampropeltis triangulum*), 1 observation of a northern ribbon snake (*Thamnophis saurita/sauritus septentrionalis*), and 10 observations of eastern garter snakes (*Thamnophis sirtalis sirtalis*) were documented during the 2019 survey.

Combined 2018-2019 Survey Results

Overall, to date, a combined total of 91 different or individual massasaugas have been captured and marked during the 2018 and 2019 population surveys at Camp Grayling (Table 2). A total of 14 recaptures of 12 different snakes have been documented across the two years (Table 2). Seven of the snakes were recaptured once or twice within the same year (i.e., within 2018 or 2019). Four of the snakes were initially captured in 2018 and recaptured once in 2019. One snake was recaptured once in 2018 and recaptured again in 2019. Six additional observations of massasaugas were documented in 2018 or 2019 but the snakes were not captured. The highest number of massasaugas have been found in the Green Area (26 snakes) followed by the Blue Area (24 snakes), Yellow Area (23 snakes), and Red Area (18 snakes) (Table 4). However, the density of snakes found was highest in the Green Area (1.38 snakes/acre) followed by the Red Area, and then the Blue and Yellow Areas with similar densities (Table 4).

The demographics of the 91 massasaugas that were captured and marked in 2018 and 2019 consisted of 59 adult snakes (31 females, 28 males), 22 subadult or juvenile snakes (6 females, 14 males, 2 unknown), and 10 neonate or young snakes (6 females, 3 males, 1 unknown) that had been born the previous summer/fall (Table 3). Eight of the adult females (6 of 24 [25%] in 2018, 2 of 9 [22%] in 2019) were gravid. One female was gravid in 2018 and was recaptured in 2019 and was not gravid. The mean total lengths, snout-vent lengths, tail lengths, mass, and subcaudal scale counts of adult, subadult/juvenile, and neonate/young massasaugas that were captured and processed in the lab in 2018 and 2019 are provided in Table 5.

Additionally, a total of 75 blood samples (61 in 2018, 14 in 2019) were collected from 72 (79%) of the 91 unique individual snakes captured in 2018 and 2019. Three of the snakes initially captured in 2018 and recaptured in 2019 had blood samples collected in 2018 and 2019. Only five (5%) of the captured snakes (2 in 2018, 3 in 2019) had visible signs of snake fungal disease (SFD) (e.g., discolored or raised scales or lesions on the head and/or body). One snake recaptured in 2019 had visible signs of SFD but did not have visible signs of SFD when it first captured in 2018. One snake had visible signs of SFD when it was captured in 2018 and 2019. A total of 26 swab samples for SFD (2 in 2018, 24 in 2019) were collected from 25 (27%) of the snakes captured in 2018 and 2019. The snake that had visible signs of SFD in 2018 and 2019 had swab samples collected in both years.

Data Inconsistencies, Gaps or Errors

Review of the 2018 and 2019 field and lab data revealed some inconsistencies, gaps, and errors or potential errors in the data and/or procedures. However, overall, these data inconsistencies, gaps, and/or errors or potential errors were minor and limited, were easily resolved, and/or could be resolved in the future with changes to the protocols. These data inconsistencies, gaps and/or errors/potential errors included the following:

1) Missing team leader names and/or number of people on survey team recorded instead in a few cases. Also missing snake or tablet handler names in the lab data in a few cases.

2) Field data indicated snakes observed in the field had paint on the rattle when snakes were new captures (in 2018 and 2019) or were not massasaugas (in 2019 only). Additionally, data indicated one recapture in 2019 did not have paint on the rattle when the snake should have had paint on its rattle.

3) Missing some data on snake captures in the field in a few cases (i.e., head, body, tail temperatures; snake behavior; surface/ground temperature).

4) Need to add wind speed and humidity data back to field survey form (was included as specific fields in the 2018 data but did not see in the 2019 data).

5) Missing some photos of snake captures in the field, especially in 2018 (not sure if this was due to tablet malfunction or some other reason). Some of the lab photos were blurry and hard to see coloration or dorsal pattern of the snakes.

6) PIT tag numbers were not recorded in the field or recorded in the wrong place (in 2018) for a few of the snakes. These were able to be resolved except for a missing PIT tag number for one snake captured and processed in 2018 (i.e., T3STA9NEMR3-9MAY).

7) Uncertainty or inconsistency in a few of the gender/sex and/or age class designations were found. The sex of two adult snakes were recorded as “Unknown” in 2018 but the tail lengths were very long and were likely males. These snakes were included as males. The sex of one neonate snake and one sub-adult snake in 2018 were recorded as “Unknown” and were not changed. Additionally, one adult male captured in 2018 had a recorded tail length of 4.8 cm, one adult female in 2019 had a recorded tail length of 5.1 cm, and one female recorded as an adult in 2019 had a SVL of 38.5 cm. These measurements seem either a little short or a little long for their gender or age class designations. These could be normal, outliers, or potential errors. Due to this uncertainty, at this time, these designations were not changed. Also, one snake (PIT tag ID: 840.282.070) that was initially captured in 2018 and recaptured in 2019 was recorded as a sub-adult female in 2018 but a sub-adult male in 2019. This gender of this snake was changed to unknown for now until it can be verified.

8) Recaptures of massasaugas in 2019 that were initially captured in 2018 revealed inconsistencies in the saddle descriptions and a few of the snake measurements. Saddle descriptions for all five snakes captured in 2018 and recaptured in 2019 varied between 2018 and 2019. The saddle descriptions in 2018 and 2019 included a few of the same components but contained additional and/or different saddle descriptions. The tail length of one snake was shorter in 2019 than the length recorded in 2018. The subcaudal scale count of four snakes recaptured in 2019 were the same or similar (i.e., within 1 or 2) as the subcaudal scale counts in 2018, but the subcaudal scale count for one of the recaptured snakes was seven scales less in 2019 than in 2018.

Table 2. Summary of eastern massasaugas (EMRs) that were observed and/or captured during the 2018 and 2019 eastern massasauga population surveys at the Camp Grayling Joint Military Training Center in Grayling, Michigan.

EMR Observations / Captures	2018	2019	2018-2019 Combined
Number of EMR Observations (includes Captures & Sightings)	81	30	111
Number of EMR Captures (includes New Captures & Recaptures)	79	26	105
Number of EMR Unique Individuals/ New Captures	72	19	91
Number of EMR Recaptures (# Unique individuals recaptured)	7 (7)	7 (6)	14 (12)[1]
Number of EMR Recaptures Within Same Survey Year	7	2	9
Number of EMR Recaptures from Previous Survey Years	-	5	5
Number of EMR Sightings Only (Not Captured)	2	4	6

[1]Number of unique individuals that have been recaptured in 2018 and 2019 combined was 12 and not 14 because one of the snakes was recaptured in 2018 and again in 2019 and one snake was recaptured twice in 2019.

Table 3. Summary of eastern massasauga (EMR) captures from the 2018 and 2019 eastern massasauga population surveys by age class and sex at the Camp Grayling Joint Military Training Center in Grayling, Michigan.

EMR Captures	2018	2019	2018-2019 Combined[5]
Total Number of EMR Captures	72	24[4]	91
Number of EMR Adults	48	14[1]	59
Number of Adult Females (# Gravid Females)	24 (6)	9[2] (2[3])	31 (8[3])
Number of Adult Males	24	5[3]	28
Number of Adults – Unknown Sex	0	0	0
Number of EMR Subadults / Juveniles	15	9[2]	22
Number of Subadult Females	4	2	6
Number of Subadult Males	9	6[3]	14
Number of Subadults – Unknown Sex	2	1[3]	2
Number of EMR Neonates / Young	9	1	10
Number of Neonate/Young Females	5	1	6
Number of Neonate/Young Males	3	0	3
Number of Neonate/Young– Unknown Sex	1	0	1

[1]Includes 3 recaptures from 2018 that were new captures/captured for first time in 2019

[2]Includes 2 recaptures from 2018 that were new captures/captured for first time in 2019

[3]Includes 1 recapture from 2018 that were new captures/captured for first time in 2019

[4]Includes 5 recaptures from 2018

[5]Combined totals for 2018-2019 only include unique individuals and do not include recaptures

Table 4. Summary of eastern massasaugas (EMRs) that were observed and captured during the 2018 and 2019 eastern massasauga population surveys by survey area at the Camp Grayling Joint Military Training Center in Grayling, Michigan.

Survey Area	Size of Area (acres)	2018		2019		2018-2019 Combined		
		Number of EMR Observations/ Captures	Number of Individual Snakes	Number of EMR Observations/ Captures	Number of Individual Snakes	Number of EMR Observations/ Captures	Number of Individual Snakes	Density of Snakes[1] (#/ac)
Blue Area (STA9 South)	44.7	20	19	10	7	30	24	0.54
Yellow Area (STA9 North)	47.2	16	16	9	7	25	23	0.49
Red Area (Ranges West)	25.6	24	15	5	4	29	18	0.70
Green Area (Ranges East)	18.9	21	22	6	6	27	26	1.38
TOTAL	136.4	81	72	30	24	111	91	0.67

[1]Approximate or estimated density of snakes based on number of snakes captured within that unit and size of the survey area. However, survey effort (e.g., amount of time/person-hours surveyed and proportion of area surveyed) should be reviewed and density estimates may need to be revised to take into account survey effort. Additionally, survey areas are known massasauga hibernacula and massasaugas tend to cluster and likely occur in higher densities in these areas compared to active season habitats.

Table 5. Mean, standard deviation (SD), range, and sample size (n) for total length (cm), snout-vent length (SVL, cm), tail length (cm), mass (g), and number of subcaudal scales for eastern massasaugas captured at the Camp Grayling Joint Military Training Center in Grayling in north-central Michigan in 2018 and 2019.

Age Class	Sex		Total Length (cm)	Snout-Vent Length (cm)	Tail Length (cm)	Mass (g)	Subcaudal Scale Count
Adult							
	All - Females, Males, and Unknown	Mean SD Range *n*	55.7 6.79 42.5-77.8 59	50.7 6.03 38.5-70.1 59	5.0 1.09 3.3-7.7 59	176.4 69.08 90-350 59	24 2.9 19-30 59
	Females	Mean SD Range *n*	52.5 5.05 42.5[2]-63 31	48.3 4.88 38.5[2]-58.9 31	4.2 0.42 3.3-5.1 31	140.0 40.88 90-235 31	22 1.4 19-26 31
	Males	Mean SD Range *n*	59.3 6.73 47.5[1]-77.8 28	53.3 6.19 42.7[1]-70.1 28	6.0 0.69 4.8[1]-7.7 28	216.7 72.00 95[1]-350 28	27 1.7 24-30 28
Subadults / Juveniles							
	All - Females, Males, and Unknown	Mean SD Range *n*	36.1 4.88 30.2-44 22[3]	32.6 4.34 27-40 22	3.5 0.71 2.5-4.8 22	47.8 18.9 26-76 22	26 2.6 20-31 22
	Females	Mean SD Range *n*	37.5 6.02 30.5-44 6	34.1 5.30 28-40 6	3.4 1.00 2.5-4.8 6	52.3 23.47 26-76 6	25 3.9 21-31 6
	Males	Mean SD Range *n*	35.7 4.67 30.2-43.2 14	32.0 4.15 27-38.6 14	3.6 0.57 3.0-4.6 14	47.8 17.96 30-75.4 14	27 1.1 25-29 14
Neonates / Young							
	All - Females, Males, and Unknown	Mean SD Range *n*	24 2.47 20.3-27.3 10	21.7 2.44 17.8-25 10	2.3 0.33 1.6-2.8 10	17.1 4.38 10-25 10	25 3.9 20-32 10

[1]Next lowest total length was 51.0 cm, next lowest SVL was 45.7 cm, next lowest tail length was 5.1 cm, and next lowest mass was 119 g.

[2]Next lowest total length was 45.2 cm, and next lowest SVL was 41.7 cm.

[3]Sample size includes 2 subadults of unknown sex.

Figure 4. Photos of a subset of the eastern massasaugas captured in the field during the 2018 eastern massasauga population survey at Camp Grayling Joint Military Training Center in Grayling, Michigan. (Photos by Kristin Wildman, Roshelle Hall and Rachel McKee).

Figure 5. Photos of a subset of the eastern massasaugas captured in the field and processed in the lab during the 2019 eastern massasauga population survey at Camp Grayling Joint Military Training Center in Grayling, Michigan. (Photos by Dan Earl, Courtney Ross, Roshelle Hall, Zack Pitman, Steven Crescenzo, Rachel McKee and Jennifer Moore).

Updating the Michigan Natural Heritage Database

Massasauga observations and locations from the 2018 and 2019 population surveys at Camp Grayling were mapped and entered into the Michigan Natural Heritage Database. The individual point locations as well as the four survey/hibernacula areas were mapped and entered in the database along with the corresponding observation data. This information updated the eastern massasauga population or element occurrence (EO ID 12283) that had previously been documented in the database which includes Camp Grayling, Portage Creek and surrounding habitat (MNFI 2020). This element occurrence or population has been ranked as having excellent estimated viability (i.e., EO rank of A) which indicates that, based on currently available information about the condition, size, and landscape context of the EO, the population is believed to have an excellent probability of persisting, if current conditions prevail, for a defined period of time, typically 20-100 years (NatureServe 2020). This population or EO was ranked as having excellent estimated viability because of the large number and frequency of massasaugas that have been documented and the long history of documented occurrences at this site (i.e., first documented at this site in 1957), the extent of this population and suitable habitat within and surrounding Camp Grayling, evidence of reproduction/recruitment and multiple age classes, and the protected status of this site as state forest land and active military training center (i.e., protected from development and managed for natural resources, biodiversity and/or threatened and endangered species) (MNFI 2020).

The seven observations of the state special concern smooth green snake that were documented during the 2018 and 2019 massasauga population surveys also were mapped and entered into the Michigan Natural Heritage Database (NHD). These observations represented a newly documented element occurrence or population of this species in the NHD (EO ID 23663) (MNFI 2020). This smooth green snake population or EO was ranked as having excellent to good estimated viability (EO rank of AB) indicating that, based on currently available information about the condition, size, and landscape context of the EO, the population is believed to have at least a good probability of persisting, if current conditions prevail, for a defined period of time, typically 20-100 years (NatureServe 2020). This range rank is assigned when further information indicating the degree of viability (i.e., differentiation between A/excellent or B/good) is lacking (NatureServe 2020). This population/EO was ranked as having excellent to good estimated viability because of the number and frequency of observations of smooth green snakes that have been documented over a short period of time, the extent of suitable habitat that appears to be available for the species within and surrounding Camp Grayling, and the protected status of this site (MNFI 2020). Additional information on the status, distribution and extent of this population is needed to better determine its viability.

Eastern Massasauga Education and Outreach

Michigan Natural Features Inventory provided two massasauga-related education and outreach programs or presentations in 2019. One program was for the Spring Meeting of the Michigan Society of American Foresters (SAF) which was held on April 18-19, 2019 in Grayling at Kirtland Community College and Camp Grayling. The meeting was attended by 165 people. MNFI staff developed and presented an approximately 30-minute indoor presentation to the Michigan SAF at Kirtland Community College on April 18. This presentation focused on the life history, research and management of eastern massasaugas at Camp Grayling, with an emphasis on how the species is adapted to and responds to wildfire and timber harvests. MNFI staff also developed and presented four 30 to 45-minute presentations to four different small groups at an occupied massasauga site at Camp Grayling as part of a field tour on the morning of April 19.

The field presentation focused on management of eastern massasauga habitat at Camp Grayling using clearcuts and wildfire and best management practices for massasaugas. Both the indoor and field presentations were based on and incorporated information from previous research on this topic that had been conducted at Camp Grayling by Dr. Bruce Kingsbury and his graduate students (DeGregorio 2008, Ravesi 2016). MNFI staff also was asked to share information with field tour participants about the importance of reporting observations of plants and animals, especially rare, threatened and endangered species, to help inform forest management and biodiversity conservation and different options available for reporting their observations. MNFI staff developed a handout summarizing different mobile or online applications that are available for reporting plant and animal observations in Michigan (Appendix 4) and distributed it during the field presentation. A pdf of the indoor Powerpoint presentation and a pdf of the field trip handout were distributed to meeting participants after the meeting.

The second massasauga outreach program or presentation was at the Kirtland's Warbler Festival at the CRAF Center in Roscommon on June 1, 2019. MNFI staff conducted a 1-hour presentation on Kirtland's warbler and eastern massasauga management at Camp Grayling for Huron Pines as part of the Kirtland's Warbler Festival. Approximately 30-40 people attended the presentation. The Powerpoint presentations for this event and for the Michigan SAF meeting will be provided to DMVA/Camp Grayling staff.

Discussion

Sustaining eastern massasaugas in perpetuity in Michigan will require maintaining and protecting viable or potentially viable populations in Michigan for the long term. While all extant populations of eastern massasaugas in Michigan are important to conserve, this may not be feasible given the large number and extent of these populations in the state, the vulnerable status and the nature and/or extent of threats facing some of these populations, and limited resources for management and conservation efforts. Identifying and maintaining priority populations distributed throughout the state will provide resiliency, representation and redundancy and help ensure the eastern massasauga continues to persist in Michigan for the long term. The massasauga population within and around Camp Grayling has been identified as a priority population in Michigan (Lee and Enander 2015). The long-term massasauga population study that was initiated at Camp Grayling in 2018 will provide baseline data on the estimated size or abundance and demographics of this population. This study also provides information on the locations, abundance, and habitat conditions of massasauga hibernacula and dynamics of snake emergence at Camp Grayling. The landscape genetic analysis of blood samples collected from this study will provide information on the genetic structure and connectivity of this population. Testing for snake fungal disease will provide data on the prevalence of this disease. These results will provide important information on the status, ecology, health, and long-term viability of the massasauga population within and around Camp Grayling. This information is critical for developing and implementing appropriate and effective management strategies for conserving this population.

Results from the 2018 and 2019 surveys are comparable to results from similar studies and provide initial evidence that the eastern massasauga population at Camp Grayling may have excellent or good viability. A total of 105 captures (including recaptures) of 91 unique individuals (72 in 2018 and 24 in 2019) have been documented to date after only about eight days of

surveys (4.5 days in 2018 and 3.5 days in 2019). These include individuals of all age classes including neonate and juvenile or sub-adult snakes which provide evidence of population recruitment and potential viability. The numbers of massasaugas captured in 2018 and 2019 at Camp Grayling (79 captures in 2018, 26 captures in 2019) are comparable to or higher than the numbers of captures during all but two years of a similar annual, week-long, "blitz-style," mark-recapture survey of a massasauga population in Cass County in southwest Michigan between 2009 and 2016 (i.e., number of captures ranged from 12-53 except for 116 snakes in 2012 and 2016) (Eastern Massasauga Species Survival Plan pers. comm.). The number of adult massasaugas captured during the 2018 survey at Camp Grayling (i.e., 48) also was within the range of the numbers of adult snakes captured during annual surveys of that same massasauga population in Cass County (i.e., 39-87 snakes between 2011-2016 across 64.3 ha) (Hileman et al. 2018) and a massasauga population in Barry County (e.g., 40 adults captured in 2013, 47 adults captured in 2014 across 20 ha) during the active season (i.e., April/May-August/October) (Bradke and Kiel 2013, Bartman and Kudla 2014). These capture rates generated adult abundance estimates of 84-140 adults between 2011-2016 for the Cass County population (Hileman et al. 2018) and 148 adults (95% CI=102-295) in 2012 for the Barry County population (Bradke et al. 2018a). Although these adult abundance estimates seem fairly small, population viability analyses of the Cass County and Barry County massasauga populations based on these estimates and other demographic parameters found that these populations have low or zero probability of extinction over the next 50-100 years (Bradke et al. 2018b, Hileman et al. 2018). Additional capture and demographic data and analyses are needed to estimate adult abundance and viability of the massasauga population at Camp Grayling, but these parameters may be similar to those of the massasauga populations in Cass and Barry counties.

In terms of estimating the size or abundance of the massasauga population at Camp Grayling, it is important to keep in mind that the population survey currently only focuses on four areas (or two main areas split into four smaller units) with snake hibernacula. Focusing surveys on these four areas helps facilitate thorough coverage of these areas and increases the likelihood of finding snakes. However, there are likely additional hibernacula or overwintering areas that massasaugas are using within Camp Grayling. As a result, the current surveys may be estimating the size or abundance of only a portion of the massasauga population at Camp Grayling. Understanding the abundance and densities of massasaugas in the hibernacula areas that are currently being surveyed will provide insights though that could be applied to other hibernacula areas within Camp Grayling and potentially other populations in Michigan.

Bradke et al. (2018a) and Faust et al. (2011) provide additional thoughts that should be considered regarding the size and potential long-term viability of the massasauga population at Camp Grayling. Bradke et al. (2018a) estimated the effective population sizes (N_e) of the massasauga populations at the Cass County and Barry County sites and found that they were very small and only about one-third of the census population sizes (N_c) (i.e., N_e = ~30 individuals, N_c = 108 individuals/ adults, N_e/N_c ratio=0.27 at the Cass County site; N_e = ~44 individuals, N_c = 148 individuals/ adults, N_e/N_c ratio=0.30 at the Barry County site). Census population size is the number of individuals or reproductively mature adults in a population (Luikart et al. 2010). Effective population size is the number of reproducing (breeding) individuals who contribute offspring to the next generation in a population. The effective population sizes at the Cass and Barry County sites were below the minimum thresholds generally recommended to avoid extinction (Bradke et al. 2018a). N_e < 50 or 100 individuals are considered vulnerable to inbreeding depression in the short term (i.e., within 5 generations) (Franklin 1980, Soule 1980, Frankham et al. 2014), and N_e < 500 or 1,000 risk reduced adaptive potential from genetic drift and long-term viability (Franklin 1980, Frankham et al. 2014). However, Bradke et al. (2018a) added that despite these low effective population sizes, high

levels of inbreeding or relatedness were not detected in either of these study populations, but cautioned that these populations could become increasingly vulnerable to extirpation due to unpredictable threats such as disease and climate change. Effective population size of the Camp Grayling massasauga population could potentially be determined from genetic analysis of the blood samples collected from captured snakes during the population survey.

Faust et al. (2011) developed a demographic model or population viability analysis model that was used to evaluate and compare the relative health or relative risk of quasi-extinction of populations across the eastern massasauga's range. The main model output that was used to compare populations was the probability of quasi-extinction, which was defined as the number of model iterations in which the female population dropped below 25 individuals within 25 years (which would represent a total massasauga population of 50 individuals at a site assuming an equal population sex ratio) (Faust et al. 2011). The quasi-extinction threshold provides a benchmark for when a population might begin to experience the negative impacts of small population dynamics such as genetic drift, inbreeding depression, susceptibility to demographic stochasticity and random events, etc. (Ginzburg 1982) and may be insufficient to ensure persistence of the species. The baseline demographic model was most sensitive to adult non-postpartum survival (survival rate for a sexually mature female who has not just given birth) and about equally sensitive to pre-adult (first year and juvenile) survival rates and rates related to reproduction (i.e., probability of breeding, mean litter size) (Faust et al. 2011). Factors that were able to change the theoretical population from growing to declining included late-stage vegetative succession, high or moderate habitat fragmentation, total or moderate habitat loss, water fluctuation, and post-emergent fire (Faust et al. 2011). These were the factors that experts estimated to have the most severe impact on eastern massasauga population dynamics (Faust et al. 2011). Although this model is most appropriately used for comparisons between populations rather than absolute predictions of a population's viability for a given site (Faust et al 2011), it provides important insights into factors that should be considered when assessing long-term viability of the Camp Grayling population.

The size measurements for the adult massasaugas captured in 2018 and 2019 were slighly smaller than measurements from other studies, but the size measurements for subadults and neonates were generally comparable or slightly larger than other studies. Mean snout-vent length (SVL) for adult females captured during the Camp Grayling population study in 2018 and 2019 was 48.3 cm (SD=4.88) compared to 51.6 cm (SD=5.8) for a population in Barry County, Michigan (Bradke and Kiel 2013), 54.2 cm ($\pm$6.0 cm) for a population in New York (Johnson et al. 2016), and 57.0 cm (SD=4.39) for a population in Illinois (Dreslik 2005). Similarly, mean SVL for adult males at Camp Grayling in 2018-2019 was 53.3 cm (SD=6.19) compared to 54.7 cm (SD=6.8) for the Barry County population (Bradke and Kiel 2013) and 58.9 cm (SD=5.86) for the Illinois population (Dreslik 2005). However, mean SVL for subadult females and subadult males at Camp Grayling in 2018-2019 were 34.1 cm (SD=5.3) and 32.0 (SD=4.15), respectively, compared to 33.0 cm (SD=5.5) and 34.4 cm (SD=4.2) for the Barry County population (Bradke and Kiel 2013) and 30.6 cm (SD=6.81) and 31.4 cm (SD=3.8) for the Illinois population (Dreslik 2005). Mean mass for adult females and adult males at Camp Grayling in 2018-2019 were 140 g (SD=40.88) and 216.7 g (SD=72.0), respectively, compared to 219.5 g (SD=56.76) and 253.3 g (SD=82.11) for the Illinois population (Dreslik 2005). Mean mass for subadult females and subadult males for the Camp Grayling study in 2018-2019 were 52.3 g (SD=23.47) and 47.8 g (SD=17.96), respectively, compared to 42.1 g (SD=33.50) and 42.9 g (SD=38.49) for the Illinois population (Dreslik 2005). One reason that may have contributed to these potential differences is related to how age classes were designated in these other studies. Females were designated as adults in this study based on SVL $\geq$42 cm and adult males had SVL $\geq$43 cm. Bradke and Kiel (2013) used the same SVL measurements for designating adult females and males but Dreslik

(2005) designated adult females with SVL ≥46.9 cm and adult males with SVL ≥49.7 cm. Bradke (2017) and Bradke et al. (2018a) designated adult females with SVL ≥45.1 cm and adult males with SVL ≥43.3 cm. Dreslik (2005) defined neonates as having only a pre-button or button on the rattle whereas our designation was based on SVL and included some snakes with a button plus one rattle segment. Additional data and analysis are needed to evaluate and verify these trends. The SVL measurements for age class designations for this study also should be reviewed to determine if appropriate and if they need to be revised.

The massasauga population study at Camp Grayling provides additional information on the effectiveness of this survey approach for estimating and monitoring massasauga population size and demographics as well as resources needed to implement this type of study, which will help guide similar efforts at other populations. The “blitz-style” mark-recapture survey approach that has been utilized in the Camp Grayling massasauga population study has only been implemented at four other sites in Michigan (in Cass, Barry, Lenawee, and Mackinac counties) recently. Of these, only the surveys at the Cass County site have focused primarily on surveying for snakes during the spring emergence period. These surveys also consist of annual, week-long, blitz-style surveys using teams of trained surveyors although additional surveys during the active season also have been conducted at this site. The blitz-style surveys seem quite effective at finding and capturing large numbers of snakes given adequate survey effort, appropriate timing of the surveys (e.g., during peak snake emergence if surveys are focused on hibernacula), and suitable weather conditions during the surveys (Bradke and Kiel 2013, Bartman and Kudla 2014, Bradke et al. 2018a, Hileman et al. 2018). Survey effort was similar but weather conditions during the massasauga survey at Camp Grayling in 2019 were less suitable than in 2018 and not suitable for surveys on two of the days which resulted in cancellation of the surveys on those days and overall fewer snakes captured in 2019.

Having a core group of surveyors that return year after year help provide continuity and ensure observers are experienced and well-trained on the survey and data collection protocols. The annual massasauga blitz surveys at the Cass County site have been conducted by a core group of approximately 20-25 staff from a number of zoos across the massasauga’s range who have committed to helping with the surveys, with additional volunteers joining the survey for 1-3 days during the week each year. This has typically resulted in four survey teams of about 5-8/9 people per team per day. Survey effort in terms of the number of observers and team sizes during the 2018 and 2019 massasauga surveys at Camp Grayling was similar to survey efforts during the surveys at the Cass County site except that Camp Grayling does not have a formal core group of field surveyors. About two-thirds of the surveyors in 2019 were new to the Camp Grayling survey although several of these people had prior experience working with massasaugas at other sites. Several of the team leaders and members did return to help with surveys at Camp Grayling in 2019 and have expressed interest in participating in the surveys in the future annually or as frequently as possible. This could help develop and provide a core group of experienced team leaders and surveyors for this study which would be beneficial. Having 24-32 surveyors (i.e., 6-8 people per team) per day for the surveys at Camp Grayling would be ideal given the size of the survey areas and amount of time for the surveys.

In addition to changes to the survey and lab protocols and logistics that were made in 2019 and suggestions provided in the post-survey evaluation results section of this report, the following recommendations are provided for the 2020 survey to address some of the data inconsistencies, gaps, and potential errors that were identified in the 2018 and/or 2019 data:

1) Spend more time reviewing the survey and data collection protocols and Survey 123 field data forms with team leaders to ensure they are comfortable using the tablets and data collection in the field is accurate, consistent, and complete.
2) Review field protocol and data forms to enhance ability to document survey effort in the field, including recording start and end times for the morning and afternoon survey periods, number of surveyors per survey period, and amount of time not actively surveying for snakes to deduct from survey time/duration. Consider recording some of these data on hard copy data forms as backup or complement to Survey 123 forms.
3) Add wind speed and humidity to field data forms if currently not included.
4) Consider adding taking photos of the habitat in which snakes were found to the field protocol.
5) Review ability to scan and read PIT tags of recaptured snakes in the field.
6) Review field and lab data forms to ensure PIT tag numbers are entered in the proper fields and are entered correctly in the field and lab.
7) Review and discuss lab processing and data collection protocols with all lab personnel prior to start of the survey to ensure data are collected accurately, consistently, and completely. Develop keys, guides or lab manual/guide to help standardize data collection (e.g., for counting subcaudal scales, rattle descriptions, saddle descriptions).
8) Review and determine snout-vent length ranges for age class designations for adult males, adult females, sub-adults/juveniles, and neonate/young or first-year snakes.
9) Review and discuss use of saddle descriptions for identifying snakes and how to increase consistency in saddle descriptions.
10) Have field and lab data from 2018 and 2019 available in the lab so that data can be accessed and consulted during snake processing, particularly for recaptures.

Camp Grayling will be conducting the third year of the eastern massasauga population study in 2020 from May 3-8. Field survey and lab processing protocols and methods will be similar to those employed during the surveys in 2018 and 2019 with potential changes based on lessons learned from the 2019 survey and recommendations from DMVA staff and MNFI staff and provided in this report. Results from the genetic analyses of the blood samples and testing for SFD from the swabs may be available in 2020. After the 2020 survey, efforts to analyze the data to generate estimates of population size or adult abundance may be initiated. Additional analysis of the demographic data also is warranted. Results from the population surveys, genetic analyses, and/or SFD testing will help identify management needs and concerns for the massasauga population at Camp Grayling.

Finally, use of volunteers for the Camp Grayling massasauga population study has raised awareness and understanding of this species which helps promote management and conservation of this species at Camp Grayling and other locations around the state. Examples of this impact include volunteers returning or expressing an interest in returning to assist with surveys in 2019, 2020 and future surveys as well as volunteers recruiting additional people (i.e., family, friends, colleagues) and/or travelling long distances to help with the surveys. A few volunteers also have expressed interest in donating supplies (e.g., pillowcases) for the massasauga survey. Two volunteers who helped with the Camp Grayling surveys in 2018 and 2019 have joined the Michigan Eastern Massasauga Working Group to assist with statewide conservation efforts for this species. Increasing awareness, support, and resources is critical for eastern massasauga conservation and recovery in Michigan and range wide.

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References Cited

Bartman, J. and N. Kudla. 2014. Mark recapture population study of the eastern massasauga rattlesnake: Effects of prey abundance on habitat use. Report to Grand Valley State University, Allendale, MI. 12 pp.

Bradke, D.R. 2017. Effective population size, demography, and viability of eastern massasaugas (*Sistrurus catenatus*) in southwest Michigan. M.S. Thesis, Grand Valley State University, Allendale, MI. 138 pp.

Bradke, D. and B. Kiel. 2013. Population demography of eastern massasauga rattlesnakes in relation to habitat management. Report to Grand Valley State University, Allendale, MI. 13 pp.

Bradke, D. R., E. T. Hileman, J. F. Bartman, L. J. Faust, R. B. King, N. Kudla, and J. A. Moore. 2018a. Implications of small population size in a threatened pitviper species. Journal of Herpetology 52(4):387-397.

Bradke, D. R., R. L. Bailey, J. F. Bartman, H. Campa, III, E. T. Hileman, C. Krueger, N. Kudla, Y. Lee, A. J. Thacker, and J. A. Moore. 2018b. Sensitivity analysis using site-specific demographic parameters to guide research and management of threatened eastern massasaugas. Copeia 106(4):600-610.

DeGregorio, B. A. 2008. Response of the eastern massasauga rattlesnake (*Sistrurus c. catenatus*) to clearcutting. M.S. Thesis, Purdue University, Ft. Wayne, IN. 72 pp.

Derosier, A. L., S. K. Hanshue, K. E. Wehrly, J. K. Farkas, and M. J. Nichols. 2015. Michigan's Wildlife Action Plan. Michigan Department of Natural Resources, Lansing, MI. www.michigan.gov/dnrwildlifeactionplan

Dreslik, M. J. 2005. Ecology of the eastern massasauga (*Sistrurus catenatus catenatus*) from Carlyle Lake, Clinton County, Illinois. Dissertation, University of Illinois, Urbana-Champaign, IL. 393 pp.

Faust, L. J., J. A. Szymanski, and M. Redmer. 2011. Range wide extinction risk modeling for the eastern massasauga rattlesnake (*Sistrurus catenatus catenatus).* Final report to the U.S. Fish and Wildlife Service, Minneapolis, MN. Lincoln Park Zoo, Chicago, IL. 67 pp.

Frankham, R., C. J. Bradshaw, and B. W. Brook. 2014. Genetics in conservation management: revised recommendations for the 50/500 rules, Red List criteria and population viability analyses. Biological Conservation 170:56–63.

Franklin, I. R. 1980. Evolutionary change in small populations. Pp. 135–149 in M. E. Soule´ and B. A. Wilcox (eds.), Conservation Biology: An Evolutionary-Ecological Perspective. Sinauer Associates, USA.

Ginzburg, L. R, L. B. Slobodkin, K. Johnson, and A. G. Bindman. 1982. Quasi-extinction probabilities as a measure of impact on population growth. Risk Analysis 2(3): 171-181.

Harding, J. H. and D. A. Mifsud. 2017. Amphibians and reptiles of the Great Lakes region, revised edition. University of Michigan Press, Ann Arbor, MI. 408 pp.

Higman, P. J., D. L. Cuthrell and M. J. Monfils. 2005. Re-assessment of Known Occurrences and Additional Surveys for Rare Species at Camp Grayling Maneuver Training Center. Report for the Michigan Dept. of Military and Veterans Affairs, Camp Grayling, Michigan. Michigan Natural Features Inventory report number 2005-07. 16pp + appendices.

Higman, P. J., P. J. Comer, M. R. Penskar, M. L. Rabe, D. A. Albert, J. T. Legge, T. R. Leibfreid, L. J. Scrimger, and M. B. Austin. 1994. Final Report for a Floristic and Natural Features Inventory of Camp Grayling Military Reservation, Grayling, Michigan. Report to Michigan Department of Military Affairs and Michigan Department of Natural Resources, Wildlife Division, Lansing, MI. Michigan Natural Features Inventory report number 1994-08. 112pp. + 10 appendices.

Hileman, E. T. 2016. Filling in the gaps in demography, phenology, and life history of the eastern massasauga rattlesnake (*Sistrurus catenatus*). Dissertation, Northern Illinois University, Dekalb, IL. 134 pp.

Hileman, E. T., R. B. King, and L. J. Faust. 2018. Eastern massasauga demography and extinction risk under prescribed fire scenarios. The Journal of Wildlife Management 82(5):977-990.

Johnson, B. D., J. P. Gibbs, K. T. Shoemaker, and J. B. Cohen. 2016. Demography of a small and isolated population of eastern massasauga rattlesnakes (*Sistrurus catenatus*) threatened by vegetative succession. Journal of Herpetology 50:534–540.

Kost, M. A. and J. G. Cohen. 2005. A Reassessment of High Quality Natural Communities on Camp Grayling. Report for Michigan Dept. of Military and Veterans Affairs, Camp Grayling, MI. Michigan Natural Features Inventory report number 2005-11. 124pp.

Lee, Y. and H. D. Enander. 2015. Developing an Eastern Massasauga Conservation Plan for Michigan – Phase I. Michigan Natural Features Inventory Report No. 2015-10, Lansing, MI. 51 pp.

Luikart, G., N. Ryman, D. A. Tallmon, M. K. Schwartz, and F. W. Allendorf. 2010. Estimation of census and effective population sizes: the increasing usefulness of DNA-based approaches. Conservation Genetics 11:355–373.

Michigan Natural Features Inventory. 2020. Biotics 5 – Michigan's Natural Heritage Database. Lansing, Michigan.

NatureServe. 2020. Biotics 5.12.5 / Michigan.

Quinn, H. and J. P. Jones. 1974. Squeeze box technique for measuring snakes. Herpetological Review 5:35.

Ravesi, M. J. 2016. Timber harvest and prescribed fire as tools for massasauga conservation. M.S. Thesis, Purdue University, Fort Wayne, IN. 91 pp.

Schaefer, W. H. 1934. Diagnosis of sex in snakes. Copeia 1934:181–181.

Soule´, M. E. 1980. Thresholds for survival: maintaining fitness and evolutionary potential. Pp. 151–169 in M. E. Soule´ and B. A. Wilcox (eds.), Conservation Biology: An Evolutionary-Ecological Perspective. Sinauer Associates, USA.

Szymanski, J. A. 1998. Status assessment for the eastern massasauga (*Sistrurus c. catenatus*). U.S. Fish and Wildlife Service, Fort Snelling, MN. 19 pp + apps.

Szymanski, J. A., C. Pollack, L. Ragan, M. Redmer, L. Clemency, K. Voorhies, and J. JaKa. 2016. Species status assessment for the eastern massasauga rattlesnake (*Sistrurus catenatus*). SSA Report Version 2. 117 pp.

United States Fish and Wildlife Service (USFWS). 2016. Endangered and Threatened Wildlife and Plants; Threatened Species Status for the Eastern Massasauga Rattlesnake. Federal Register, Vol. 81, No. 190, September 30, 2016, Rules and Regulations: 67193-67214.

Appendices

Appendix 1. Detailed Survey and Lab Protocol for Eastern Massasauga Population Study at Camp Grayling Joint Military Training Center in Grayling, Michigan.

EASTERN MASSASSAUGA (EMR) SURVEY WORK
Camp Grayling
Detailed Survey and Lab Protocols
(adapted from comprehensive field protocols developed by Illinois Natural History Survey, Edward Lowe Foundation)

SURVEY LOGISTICS:

1. Survey participants will be assigned to teams of 4-9 people, led by two team leaders. At least one team leader will consist of an experienced EMR field biologist comfortable with handling snakes. The other team leader will be responsible for navigating and recording data using the tablet. Both team leaders will assist with coordinating volunteers on their respective survey teams and helping the team survey within the boundary. Team leaders also will record survey routes using the Track setting and EMR locations using a handheld GPS unit.

2. We will be surveying in four areas on Camp Grayling property:
    a. Yellow (STA9 North)= 47.2 acres
    b. Blue (STA9 South) = 44.7 acres
    c. Red (Ranges West) = 25.6 acres
    d. Green (Ranges East)= 18.9 acres

SURVEY METHODS:

General Field Survey Approach:

1. Visual search (random): All team members should spread out and slowly walk across site. Each team member should move separately to maximize search area; inexperienced surveyors may want to stay close to experienced surveyors, especially at the beginning. Team members should survey approximately utilizing a meander approach along approximate transects. Move slowly and carefully, making frequent stops to visually scan the surrounding habitat. Especially inspect the bases of all shrubs, moss hummocks, root systems, and logs. We may also try line transect surveying depending on terrain and numbers – we will brief everyone on that at our first training. These efforts are targeted towards overwintering habitat. Both team leaders will survey along the boundaries of the survey area and team members will survey between them. Stay within visual and auditory contact with their team and team leaders.

DURING A SURVEY SESSION IN THE FIELD:

1. **MASSASAUGA SEARCH EFFORT SHEET**
    a. AT START: / START METRICS OF EACH SURVEY SESSION (MORNING AND AFTERNOON)
        i. Measure and record basic site information (Search Effort form)
            1. Team Leader's Name(s)
            2. Name of Data Recorder
            3. State Date & Time – automatically populated
            4. Unit= survey area – drop down menu
                a. Yellow / STA9 North (STA9N)
                b. Blue / STA9 South (STA9S)
                c. Red / Ranges West (RangeW)
                d. Green / Ranges East (RangeE)
            5. Survey start location – automatically recorded

ii. Measure weather information
    1. Ambient Temp - Shaded air temp (Kestrel): lay Kestrel on ground, in shade of tree or something (your body). If the kestrel has been sitting in a backpack, spin it around a few times first to get an accurate reading.
    2. Substrate temp (soil thermometer): insert thermometer probe barely into soil – at SURFACE (within 1-2 in)
    3. Wind speed (Kestrel): hold Kestrel up; after 10 seconds, record average wind speed
    4. Humidity (Kestrel); on the ground
    5. Cloud cover (judgment call): 0, 25, 50, 75, 100%
    6. Precipitation (judgment call): None, drizzle, moderate rain, heavy rain, fog

b. DURING SURVEY: each surveyor should track
    i. Break time = time spent not looking for EMR
    ii. Record individuals of other snake species –number & species seen

c. AT END: - STOP METRICS
    i. SAME AS START METRICS
    ii. Record weather information
    iii. Record each person's time out and break/penalty times
    iv. Calculate each observer's total minutes and total survey time (can do this back in lab/office) – TOTAL SEARCH TIME
    v. Comments as needed

3. UPON EMR ENCOUNTER

a. Notify Team Leaders and TEAM stops survey! Gather around EMR.
b. If snake is agitated or can flee to a burrow, capture it using CAPTURE PROTOCOLS (see below) ****Snakes should only be captured by designated team leaders/EMR snake handlers****
c. Do not pursue snake if doing so will harm the snake.
d. If capture is not possible, as much data as possible should be recorded in the field on the individual in the EMR Field Effort Form 2019
e. **EMR FIELD SURVEY FORM;** if snake is still/calm:
    i. Record Thermal Data
        1. Infrared thermometer for Head, Mid-Body, and Tail temps (^{o}C); if head or tail are not visible, leave blank
        2. Surface Temp (Thermal Laser Gun), Sub-surface Temp (Soil Thermometer) – after snake is captured
    ii. Record Behavioral Data
        1. Check all boxes that apply
    iii. Photograph snake in situ (if possible)
    iv. Capture the snake following the CAPTURE PROTOCOLS (below)
    v. After snake has been captured and placed in pillowcase, safely scan snake through pillowcase or bucket with PIT tag reader (has to be within 2 inches) to determine if it is a new snake or recapture.
        1. <u>New Capture</u> – Brand new snake; no PIT tag. Bring to lab for processing.
        2. <u>Recapture from Previous Year</u> – Snake was captured during previous year of Camp Graying population study or earlier massasauga studies but first time captured this year/current year of survey. Snake has a PIT tag. Record PIT tag on field form. Bring to lab for processing.
        3. <u>Recapture from Current Year</u> – Snake was already captured and processed this week during current year's survey. Snake has a PIT tag and should have paint/fingernail polish on the rattle. Record PIT tag number, capture data and location, call into lab, and release after info has been collected and photo of snake has been taken. Do not need to bring to lab for processing. If not sure, call into lab.

vi. Record Environmental Data
    1. Environmental conditions at time of capture
    2. Humidity (Kestrel), Wind speed (Kestrel)
    3. Surface temperature using soil thermometer (within top 1-2 inches)
vii. Record Capture Data
viii. Mark the capture site with survey flagging labeled with sharpie with Snake ID in format below, note color of flagging on survey form.
    1. Snake ID format: Day-MONTH (spelled out)-YYYY – Survey Area (Red/Yellow,etc.) – Time
        i. Ex. 07May2019Green1050 - Indicates snake captured on 7 MAY in Green Area at 10:50 am
ix. Mark a snake waypoint in your GPS
    1. Use handheld GPS unit to mark this waypoint following same format above
    2. Doing so will enable easier return of snake to capture site after processing

f. After EMR has been captured and secured in pillowcase and bucket and necessary data have collected, continue surveying.
g. EMR that are captured and processed in the lab will be marked via nail polish on rattle segments before release back at capture site. If you encounter a marked EMR, temporarily capture (using methods below, pillowcase, bucket, etc.) it and scan using your PIT tag scanner. When IDed, fill out an EMR Field Survey Form (capture and release data, environmental data, morpho data where possible, behavioral data). Collect an ID photo that clearly displays snake's markings. If you encounter a snake that has polish but has no PIT tag, capture it and bring it to lab.
h. If a dead animal is encountered, collect it carefully (many reported rattlesnake bites occur with alleged dead individuals!); collect capture data and mortality data and bag & bring to lab for processing.

4. CAPTURE PROTOCOLS **Snakes should only be captured by experienced, trained Camp Grayling EMR snake handlers:**

a. Drape pillowcase over open bucket/bucket opening.
b. Using Gentle Giant snake tongs, pick up snake between mid-body and back 1/3 of body.
c. Transfer snake into the bucket.
d. Pull one open end of the pillowcase across the bucket opening/lip and place the lid on the bucket over the pillowcase.
e. The ends of the pillowcase opening will now be outside of the bucket. Tie a knot in the pillowcase.
f. Record Snake ID (using format for capture flagging) on a piece of flagging tape and tie it around the knot of the pillowcase above the knot.
g. Place snake in pillowcase in the bucket and continue surveying until the designated stop time; if survey period is long, may want to return snake to vehicle or call lab for pickup.
h. Can keep 1-3 snakes per bucket. Put divider (e.g., paper plate) between snakes in bucket.
i. Carry snakes in buckets with you during survey unless hot or cold. Call lab (Range 8) for pick up. Bring snakes to lab within 2 hours of capture.
j. Call lab (Range 8) of each snake capture.
k. Flag buckets with EMRs with Survey Area Name (color) and number of snakes in bucket.
l. Designate team member who will run snakes to Snake Runners to bring to lab/Range 8.

AFTER ECOLAB PROCESSING

1. The snakes will be returned to the field at the next surveying session or after processing has been completed at the end of each day and released at the same location; remove flagging tape when snake is returned to capture site.
2. Fill out Release Effort Form on tablet.
    a. Date, time, location – automatic
    b. Snake Handler – person who returns it

c. Tablet Handler
d. Snake ID (2x)
e. Flag retrieve? - Y/N

LAB PROCEDURE:

1) **Snake Handler and Tablet Handler** - Decide who will be Snake Handler and Tablet Handler and record names on lab form on tablet.
2) Snake Handler (and Tablet Handler) will wear disposable gloves when handling snakes.
3) **PIT tag ID & New Capture/Recapture** - Scan snake through pillowcase or bucket to see if new or recapture snake. If snake is a recapture and has a PIT tag, record PIT tag ID number on lab form.
4) **Snake ID** - Remove flagging with Snake ID around pillowcase. Record Snake ID on lab form.
5) Place thin Styrofoam sheets in squeeze box to cover foam. Replace for each snake.
6) Write Snake ID on squeeze box Styrofoam sheets.
7) **Mass** - Weigh snake and pillowcase. Record weight (snake + bag) in grams.
8) Place snake in pillowcase back in bucket. Place lid back on bucket with knot and ends of pillowcase outside the lid. Untie the pillowcase know. Remove bucket lid.
9) Use snake tongs to pick up pillowcase and place into squeeze box. Use tongs to shake snake out of pillowcase into squeeze box. Use tongs to remove pillowcase from squeeze box.
10) **Snake Photo in Lab** - Use tablet to take photo of snake in squeeze box with Snake ID in photo.
11) **Mass** - Weigh pillowcase in grams. Record weight in Lab Data form on tablet. App automatically calculates snake mass (weight of snake in pillowcase minus weight of pillowcase).
12) Carefully place squeeze box plexiglass lid/cover on snake. Place pressure on snake to push snake into foam so that the snake is still and not moving under the plexiglass lid. Make sure the snake's body is stretched out as much as possible to facilitate more accurate total length measurement.
13) **Saddle Description -** Record saddle description. (Posterior – back, anterior – front)
14) **Total Length** - Use permanent marker or dry erase marker to draw snake length/outline of snake's body (down the center of the body) from the tip of the snout to the base of the rattle. Remove plexi-glass lid/cover. Measure total length of line using measuring tape (flexible measuring tape – e.g., for sewing). Measure 2-3 times to make sure total length measurement is as accurate as possible.
15) Tube snake in the squeeze box. Select appropriately sized transparent plastic/PVC tube so that upper part of snake's body is snug in the tube and the snake can't turn around or back out of the tube. Hold snake's body and tube firmly at the end of the tube so that snake can't back out of tube or turn around.
16) **PIT tag ID** – While upper part of snake's body is in tube, scan snake's body for PIT tag (both sides just in case). If snake is a recapture and has a PIT tag, record PIT tag ID number on lab form.
17) **Tail Length** - Measure tail length (cm, from vent to base of rattle). Record on lab form.
18) **Snout-Vent Length** – After recording total length and tail length on lab form, app will automatically calculate Snout-Vent Length (cm) (length from tip of snout to vent).
19) **Subcaudal Scale Count** - Count the number of subcaudal scales (scales between the vent and base of the rattle). If there is a split scale below the vent, skip/do not count for subcaudal count; at the end by base of rattle – count split scales at the end, include in total count.

20) **Rattle Description** – Describe the rattle segments in terms of B (original button) or T (terminal rattle segment/not original button) + number of rattle segments, include bottom black rattle segment (e.g., B+2 or T+5).

21) **Sex/Gender** - Sex snake by probing. Select appropriately sized metal probe (smaller is better than too big) and slowly and gently insert into the posterior region of the snake vent on either side of the snake vent. If a male snake, probe will be able to be easily inserted up to 5-6 cm into the hemipenis sheaths on either side of the vent. If a female, a membrane covers this region and probe will not be able to be inserted. May help to coat probe with some Vaseline or KY jelly before inserting probe.

22) **Gravid and Number of Embryos** – If adult female, palpate snake to see if snake is gravid, and if so, count number of embryos. May be difficult to feel/count embryos in some females given early in the season.

23) **Age Class** - Record age class (adult, subadult/juvenile, neonate/young) based on size/appearance of snake and snout-vent length measurements. Review and check age class designations.

24) **Snake Fungal Disease (SFD)** - Look for visible signs of SFD (e.g., lesions, raised/hardened/discolored/peeling scales) along entire body and head.

25) **SFD Swab Samples** - Swab for SFD. 5 swab locations minimum using separate swabs – left dorsal, left flank, right dorsal, right flank, vent. Swab any lesions – one swab per lesion. (For five swabs, one pass. Slow forceful swab/roll. Multiple passes okay. For lesions, swab so lesion materials can be scraped off if possible). Swab along entire length of untubed portion of snake minus rattle (pull out additional part of snake if comfortable). Put swabs in all separate vials Label each vial with location (vent, LD, LF, RD, RF) and snake PIT tag number. Put all vials in a plastic bag and label bag with PIT tag number/sticker. Keep samples cool. Throw in freezer.

26) **PIT tag ID** - If new snake, inject PIT tag subcutaneously on lower left side of body of snake. Clean area with alcohol swab first. Insert PIT tag in direction with scales. Seal opening with VET bond or Super glue. Check PIT tag number with PIT tag reader. Record PIT tag number on lab form. If already PIT tagged, record PIT tag number on lab form.

27) **Blood Sample** – Collect blood sample if needed. Take blood sample from caudal vein in tail below vent. Check if snake has already had blood sample collected prior to collecting sample.

28) **Paint Rattle** – After snake has been processed, paint rattle with fingernail polish. One color for the week. Make sure rattle paint is dry before putting snake back in pillowcase.

29) Return snake to pillowcase and tie flagging with Snake ID to pillowcase right above the knot. To return snake to pillowcase, place pillowcase into bucket and drape opening of pillowcase over opening of bucket. Place tail and posterior end of snake into pillowcase and remove hand that was holding snake and tube. Snake will slide down out of tube into the pillowcase. Use snake tong and/or snake hook to pick up one side of pillowcase and drape over other side/end of pillowcase to close the pillowcase. Place lid on bucket with ends of the pillowcase sticking out the side of the lid. Tie secure knot around ends of the pillowcase, and tie flagging with Snake ID to pillowcase above the knot. Place pillowcase with snake back into bucket and secure lid.

30) Buckets with snakes that have been processed should be set aside and/or marked ready to be returned to field to release snakes at capture sites.

31) Decontaminate or disinfect snake tongs, snake hook, measuring tape, squeeze box (sides and lid), metal probe for sexing snake, and anything else that touched the snake using ethyl alcohol (70%) in spray bottle in the lab instead of bleach solution. Disinfect snake tubes by soaking in bleach solution for 5 minutes, rinsing in water, and drying on a rack or setting outside to dry. Snake tubes also could be sprayed with ethyl alcohol solution, rinsed, and dried.

32) After snakes have been released back at capture sites in the field, wash pillowcases in which snakes were stored and transported with laundry detergent and bleach and wipe down buckets with ethyl alcohol (70%) spray solution or bleach wipes/spray solution.

Appendix 2. Daily schedule for 2019 eastern massasauga population survey at Camp Grayling Joint Military Training Center in Grayling, Michigan.

Daily Schedule for EMR Population Survey, CGJMTC, May 5 – 10, 2019

Sunday, May 5:

12:00 – 2:30	pm	Orientation of the eight Team Leaders, Snake Handers and Tablet Handlers (Range 8)
3:30 – 4:30	pm	Arrive at Camp Grayling. Go to Building 353 to sign in, pick up key to your barracks. Pick up volunteer information packets. Review and sign liability waiver and confidentiality agreement.
4:30 – 5:45	pm	Orientation for Volunteers **(**Building 353) 5:45 – 6:30 pm Move into Barracks
6:30 – 8:00	pm	Dinner (Building 48M)

Monday, May 6:

8:00 – 8:45	am	Breakfast (Building 48M)
8:45 - 9:00	am	Drive to Building 545
9:00 - 9:30	am	UXO safety brief (Building 545)
9:30 – 9:45	am	Drive to Range 8 parking lot
9:45 – 10:30	am	Q & A for Tablet Handlers; free time for everyone else. (Range 8)
10:30	am	Backpacks are distributed to field team leaders
10:30 – 12:00	pm	Morning field session
12:00 – 1:30	pm	Lunch (Range 8)
2:00 – 5:00	pm	Afternoon field session
5:00	pm	Backpacks are returned to CGJMTC staff (Range 8)
6:30 – 8:00	pm	Dinner (Building 48M)

Tuesday – Thursday, May 7-9:

8:00 – 8:45	am	Breakfast (Building 48M)
9:00	am	Backpacks are distributed to field team leaders
9:00 – 12:00	pm	Morning field session
12:00 – 1:30	pm	Lunch (Range 8)
2:00 – 5:00	pm	Afternoon field session
5:00	pm	Backpacks are returned to CGJMTC staff (Range 8)
6:30 – 8:00	pm	Dinner (Building 48M)

Friday, May 10:

8:00 – 8:45	am	Breakfast (Building 48M)
9:30 – 12:00	pm	Morning field session
12:00	pm	Backpacks are returned to CGJMTC staff (Range 8)
12:00 – 1:30	pm	Lunch (Range 8)

Adjourn and safe travels!
We hope to see you next year.

Appendix 3. Roster for field survey teams and lab teams for 2019 eastern massasauga population survey at Camp Grayling Joint Military Training Center in Grayling, Michigan.

MONDAY 6 May				
Blue Team	Red Team	Yellow Team	Green Team	**Lab**
Nathan Herbert	Roshelle Hall	Dan Earl	Steve Crescenzo	Mike Ravesi
Frank Schroyer	Zack Pitman	Courtney Ross	Rachel McKee	Yu Man Lee
Amy Bleisch	Katelyn Gutwein	Patty Lyman	Matt Sand	Jennifer Moore
Aaron Hogate	Jennifer Manning	Daughter Lyman	Susan Thiel	
Megan Sanders	Kyler Moran	David Haesler	Maggie Wernet	
Steve Rice	Doug Holem	Jim Kolar	Ethan Morris	
Matthew Leone	Ryan Holem	Lindsay Walls	Parker Maynard	
Alyssa Swinehart		Jenny Kovach		
TUESDAY 7 May				**GVSU**
Green Team	Blue Team	Red Team	Yellow Team	Eric M
Nathan Herbert	Roshelle Hall	Dan Earl	Steve Crescenzo	Alyssa Swinehart
Amy Bleisch	Zack Pitman	Courtney Ross	Rachel McKee	Jenny Kovach
Aaron Hogate	Katelyn Gutwein	Chris Petersen	Matt Sand	**Lab**
Megan Sanders	Jennifer Manning	Paul Block	Ken Rouston	Mike Ravesi
Steve Rice	Craig Kasmer	Jim Kolar	Maggie Wernet	Yu Man Lee
David Haesler	Doug Holem	Lindsay Walls	Ethan Morris	Jennifer Moore
	Ryan Holem			Frank Schroyer
WEDNESDAY 8 May				**GVSU**
Yellow Team	Green Team	Blue Team	Red Team	Eric M
Nathan Herbert	Roshelle Hall	Dan Earl	Steve Crescenzo	Alyssa Swinehart
Frank Schroyer	Zack Pitman	Courtney Ross	Rachel McKee	Jenny Kovach
Amy Bleisch	Katelyn Gutwein	David Haesler	Matt Sand	Jennifer Moore
Aaron Hogate	Jennifer Manning	Jim Kolar	Susan Thiel	**Lab**
Megan Sanders	Steve Sendek	Lindsay Walls	Maggie Wernet	Mike Ravesi
Steve Rice		Jonathan Edgerly	Ethan Morris	Yu Man Lee
THURSDAY 9 MAY				
Red Team	Yellow Team	Green Team	Blue Team	**Lab**
Nathan Herbert	Roshelle Hall	Dan Earl	Steve Crescenzo	Mike Ravesi
Frank Schroyer	Zack Pitman	Courtney Ross	Rachel McKee	Yu Man Lee
Amy Bleisch	Katelyn Gutwein	David Haesler	Matt Sand	
Aaron Hogate	Jennifer Manning	Colleen Haesler	Maggie Wernet	
Steve Rice	Brian Huggett	Jim Kolar	Ethan Morris	
		Lindsay Walls	Eric McCluskey	
FRIDAY 10 May				
Blue Team	Red Team	Yellow Team	Green Team	**Lab**
Nathan Herbert	Roshelle Hall	Dan Earl	Steve Crescenzo	Mike Ravesi
Frank Schroyer	Zack Pitman	Courtney Ross	Rachel McKee	Yu Man Lee
Aaron Hogate	Katelyn Gutwein	David Haesler	Maggie Wernet	Amy Bleisch
Ken Rouston	Jennifer Manning	Colleen Haesler	Ethan Morris	
		Lindsay Walls	Susan Thiel	

Appendix 4. Informational handout on mobile or online applications for reporting observations of rare and common plant and animal species developed and distributed by MNFI staff during Michigan Society of American Foresters Annual Meeting's field tour of Camp Grayling Joint Military Training Center in Grayling, Michigan.

Michigan Natural Features Inventory
Discover. Define. Deliver.

MICHIGAN STATE UNIVERSITY | Extension

Michigan's Forests and Biodiversity Needs YOUR Help!

The quality of every human life is inextricable linked to the natural world. Michigan's rich forests and biodiversity provide food, shelter, medicine, recreation, and aesthetic enjoyment. Our beautiful natural features also play an important part in our cultural traditions. Our ecosystems protect air and water quality, groundwater recharge, nutrient cycling, and soil formation – all essential to health and to our state's economy. Conservation of Michigan's plants and animal species, the natural communities they compose, and the ecosystems in which they live depends on high quality data. Maintaining sustainable and healthy forests also depend on such data. You can contribute data to help conserve biodiversity and maintain sustainable and healthy forests in Michigan! Here are some organizations that need your help and/or apps which you can use to report your data.

Michigan Department of Natural Resources – Eyes in the Field

The Michigan Department of Natural Resources is inviting Michigan residents to contribute to conservation efforts by reporting their fish and wildlife observations with its new Eyes in the Field application. The app includes forms for reporting observations of diseased wildlife, tagged fish, mammals such as cougars and feral swine, fish such as sturgeon, birds such as wild turkeys, and reptiles and amphibians such as eastern massasauga rattlesnakes and turtles. Additional observation forms will be added in the future.

To report their data, users select an observation location point on a map and submit other details, including habitat type and appearance of the animal, depending on the type of observation. Observers also can submit photos, videos and audio files through the application. For more information and to access the app, visit michigan.gov/eyesinthefield.

Eastern Massasauga

Michigan Natural Features Inventory (MNFI)

You can report observations of endangered, threatened or special concern plant and animal species to MNFI by using the following link to our online reporting form below, or download a PDF form for special species and other types of reporting - https://mnfi.anr.msu.edu/species/report. Information is validated before being entered into the natural heritage database. A complete list of endangered, threatened, and special concern species can be found on MNFI's website at https://mnfi.anr.msu.edu/.

Midwest Invasive Species Information Network (MISIN)

The Midwest Invasive Species Information Network (MISIN) is a regional effort to develop and provide early detection and response resources for invasive species. Our goal is to assist both experts and

citizen scientists in the detection and identification of invasive species in support of successful management. To learn more about MISIN and report observations of invasive species using the MISIN app, visit their website at https://www.misin.msu.edu/. You can download the MISIN app from Google Play and Apple iTunes Store.

Hemlock Wooly Adelgid

Michigan Herp Atlas

Blanding's Turtle

The purpose of the Michigan Herp Atlas Project is to collect observation data about Michigan's native amphibians and reptiles (collectively known as herpetofauna or "herps") so we can document their distribution and changes in their populations statewide. Through the database, citizens can record their own past and present observations to help assess changes in populations over time and measure species health. The Michigan Herp Atlas Project is a Michigan Department of Natural Resources project administered through Herpetological Resource and Management. You can learn mor e about the Michigan Herp Atlas at https://www.miherpatlas.org/. Mobile app, Mobile Mapper, is available through Google Play and iTunes Store.

iNaturalist

iNaturalist provides a place to record and organize nature findings, meet other nature enthusiasts, and learn about the natural world. You can record observations of all plant and animal species using the iNaturalist app available through Google Play and iTunes Store. Every observation can contribute to biodiversity science, from the rarest butterfly to the most common backyard weed. All you have to do is observe. For more info, visit https://www.inaturalist.org/.

Sugar Maple

eBird

eBird data document bird distribution, abundance, habitat use, and trends through checklist data collected within a simple, scientific framework. Birders enter when, where, and how they went birding, and then fill out a checklist of all the birds seen and heard during the outing. eBird's free mobile app allows offline data collection anywhere in the world, and the website provides many ways to explore and summarize your data and other observations from the global eBird community. eBird is managed by the Cornell Lab of Ornithology. For more info, visit https://ebird.org/home. App ava ilable through Google Play and iTunes Store.

American Woodcock