Monitoring of Eastern Fox Snakes (*Pantherophis gloydi*) in Response to Habitat Restoration at Sterling State Park in Southeast Michigan

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EXECUTIVE SUMMARY

The Eastern Fox Snake (*Pantherophis gloydi*) is a state threatened snake in Michigan that primarily inhabits emergent wetlands along Great Lakes shorelines and associated nearshore areas along southern Lake Huron, the Detroit River, Lake St. Clair and western Lake Erie. A population of Eastern Fox Snakes occurs in Sterling State Park in Monroe, Michigan. Since 2003, the Michigan Department of Natural Resources' (MDNR) State Park Stewardship Program has been actively restoring portions of Sterling State Park's landscape to native lakeplain prairie and Great Lakes marsh. In coordination with the State Park Stewardship Program, Michigan Natural Features Inventory (MNFI) initiated a monitoring and radio-telemetry study of the Eastern Fox Snake population at Sterling State Park in 2003 and continued the study in 2004 and 2005 to assess impacts of the habitat restoration efforts on the fox snake population in the Park. The goal of this monitoring program is to detect a biologically significant change in the Eastern Fox Snake population in areas targeted for habitat restoration in the park.

Similar to work conducted in 2003 and 2004, mark-recapture surveys and radio-telemetry were conducted in 2005 to collect data on fox snake presence, relative abundance, movement, and habitat use to assess impacts on fox snake populations in management units undergoing active restoration during and after habitat management activities. Line-transect and time-constrained visual encounter surveys were conducted in all nine management units within Sterling State Park from 7 August to 5 September 2005. Additional visual encounter surveys were conducted in five management units on 12 May and 14 and 19 June. These resulted in about 91 total hours of field surveys for Eastern Fox Snakes in Sterling State Park in 2005. Four Eastern Fox Snakes were radio-tracked on a weekly or bi-weekly basis from 5 April to 18 September. Tissue samples (i.e., scale clippings) also were collected in 2005 for future genetic analysis.

Field surveys in 2005 resulted in a total of only six Eastern Fox Snake observations, of which only five were captured. The five captured snakes were all new, unmarked snakes. Five of the six fox snake observations were documented during additional visual encounter surveys in June, and one snake was found incidentally in September while tracking a transmittered snake. No fox snakes were documented during line-transect and time-constrained surveys in 2005. An additional new fox snake was found and captured by park staff in June 2005. Fox snakes were found in only three of the nine management units in the Park, consisting of two snakes in the Interpretive Kiosk Unit and four snakes in the Corps CDF and Facilities units. The habitats in which the fox snakes were found include old field, palustrine scrub-shrub, and upland scrub-shrub along the edge of a paved nature trail.

Similar to survey and radio-telemetry results in 2003 and 2004, the Eastern Fox Snakes that were found during surveys or were radio-tracked in 2005 primarily utilized open upland and wetland habitats such as old field, palustrine emergent wetland, and palustrine scrub-shrub habitats, and were all located primarily along the dike or along the edge of the lagoons and generally near the water or emergent wetland's edge (i.e., generally within 1-3 m but further away in some cases). Snakes were often found in or under open or thick grass, shrubs or dense emergent vegetation, on or along the side of paved trails, in or under concrete slabs or rock riprap along the shore of the open water lagoons, underground in tree root networks or burrows, or on the surface or underground along the embankment of the dike. Again, cover was very important for the fox snakes in the study. The radio-telemetry results from 2005 also indicate that fox snakes may exhibit some site fidelity and return to the same hibernation site from one winter to the next. Telemetry results from 2005 also suggest fox snakes may emerge from their overwintering sites a little later in the spring than other snakes, and may stay near their overwintering sites for some time after emergence. Fox snakes also may enter their overwintering sites earlier than expected (i.e., around or by mid-September).

Although survey results from 2003-2005 may not be conclusive in determining potential impacts of habitat restoration efforts on the fox snake population in Sterling State Park in terms of relative abundance because of small sample sizes, survey and radio-telemetry results to date suggest that fox snake use of particular management units within the park may have been impacted to some degree. A majority of the radio-telemetry locations and locations at which fox snakes were found during surveys occurred in areas that had undergone some habitat restoration but generally had not been dramatically altered. Prior to this study, Eastern Fox Snakes had been documented in these management units as well as other units in the Park which have undergone substantial alterations due to habitat restoration activities, such as the Campground

Restoration Unit. Surveys and radio-telemetry from 2003-2005 did not document any fox snakes in this management unit, but Park staff and contractors reported seeing at least one fox snake in this unit during the study.

Finally, although study results from Sterling State Park in 2003-2005 indicate that Eastern Fox Snakes can inhabit highly disturbed and actively managed sites, the long-term viability of this population remains unknown. The fox snake population within the park continues to face a number of threats including highly degraded and limited habitat (at least currently); population isolation; road mortality; intentional and unintentional killing, harassing or disturbance by people; incidental take or impacts due to park management activities (e.g., mowing of large areas reduce or minimize areas with sufficient cover for shelter, foraging, dispersal, and safe passage or protection from predators); and predation. The ongoing restoration efforts may create additional habitat for fox snakes in the future, but also can pose threats to the park's fox snake population in the short term. Efforts to minimize threats to the fox snake population within Sterling State Park should continue. Since fox snakes have been found primarily in the Hunt Club, Interpretive Kiosk and Facilities units during this study, consideration of management activities and ways to minimize potential adverse impacts on Eastern Fox Snakes is especially warranted in these units. Continued monitoring of Eastern Fox Snakes at Sterling State Park also should continue. A study funded by the Michigan DNR's Wildlife Division was initiated in 2006 to continue the fox snake monitoring and radio-telemetry study at Sterling State Park. This study has been conducted in conjunction with a similar study of Eastern Fox Snakes at The Nature Conservancy's Erie Marsh Preserve, located about 10 miles south of Sterling State Park. Sharing and comparing results among the two study sites will provide additional insight into Eastern Fox Snake ecology and response to habitat management activities.

Table of Contents

List of Tables

List of Figures

List of Appendices

INTRODUCTION

The Eastern Fox Snake (*Pantherophis gloydi*) is a fairly large (36-67 in / 91-168 cm), boldly patterned snake that primarily inhabits emergent wetlands and adjacent uplands along Great Lakes shorelines and associated large rivers and impoundments. The known range of this species is restricted to the shoreline and nearshore areas along southern Lake Huron from Saginaw Bay in Michigan and Georgian Bay in Ontario south to the Detroit River and Lake St. Clair and along northern and western Lake Erie from Norfolk County in Ontario to Wayne and Monroe counties in Michigan and Erie County in Ohio (Harding 1997). The Eastern Fox Snake is primarily associated with open wetlands dominated by herbaceous vegetation but also will utilize drier habitats such as vegetated dunes and beaches and open woodlands (Harding 1997). The species also appears to be able to utilize areas that have experienced some level of human disturbance including farm fields, pastures, woodlots, vacant urban lots, rock riprap, ditches, dikes, and residential homes (Harding 1997).

Little is known about the life history and ecology of the Eastern Fox Snake; much of it is presumed to be similar to that of the Western Fox Snake (*Pantherophis vulpina*) and other snakes in its genus (Evers 1994). Eastern Fox Snakes typically are active from mid-April to October with peak activity in May and June (Evers 1994, Harding 1997). Eastern Fox Snakes are usually found near water and can swim long distances in open offshore waters and between islands (Harding 1997). They feed primarily on small mammals, particularly meadow voles (*Microtus pennsylvanicus*) and deer mice (*Peromyscus maniculatus*), but also will eat bird eggs and nestlings, earthworms, insects, and frogs (Harding 1997). Eastern Fox Snakes probably breed annually, with breeding occurring in June and early July (Ernst and Barbour 1989, Harding 1997). Eggs are usually laid in late June or July in soil, woody debris, decaying vegetation, or animal burrows (Ernst and Barbour 1989, Harding 1997). Hatching occurs from mid-August to early October (Harding 1997). Eastern Fox Snakes hibernate in abandoned small mammal burrows, muskrat lodges, or other suitable shelters (Ernst and Barbour 1989, Harding 1997).

The Eastern Fox Snake has declined in many areas where it was once abundant but can be locally common in areas where extensive habitat is still available (Harding 1997). This species has been reported from only approximately 40 sites in Michigan, and only about half of those sites have had fox snakes reported within the last 10 years (Michigan Natural Features Inventory 2006). The primary threats to this species are habitat loss and degradation, human persecution, and collection for the commercial pet trade (Evers 1994, Harding 1997). Much of the fox snake's habitat has been ditched or drained for agricultural, residential, recreational, or industrial development (Lee 2000). The remaining suitable habitats continue to be threatened by the same factors as well as pollution and other forms of habitat degradation such as the spread of invasive plant species (Lee 2000). Eastern Fox Snakes also are threatened by increased road traffic and road density associated with development (Lee 2000). Additionally, Eastern Fox Snakes are often mistaken for venomous snakes such as the Eastern Massasauga (*Sistrurus catenatus catenatus*) and Copperhead (*Agkistrodon contortrix*) (which does not occur naturally in the wild in Michigan), and are often killed. As a result of its decline and ongoing threats to its persistence, the Eastern Fox Snake has been listed and given protection as a state threatened species in Michigan.

A population of Eastern Fox Snakes is known from Sterling State Park in Monroe County in southeast Michigan. In 2003, the Michigan Department of Natural Resources' (MDNR) State Park Stewardship Program initiated an extensive ecological restoration effort at Sterling State Park to restore a large portion of the Park's landscape to native lakeplain prairie and Great Lakes marsh. Lakeplain prairie and Great Lakes marsh are rare and unique natural communities that provide suitable habitat for a number of rare plant and animal species including the Eastern Fox Snake. These natural communities or habitats were once common along the Great Lakes shoreline in southeast Michigan prior to European settlement but have been greatly reduced in acreage and extensively altered due to agricultural, industrial, residential and recreational development (Albert and Kost 1998, Albert 2001). Disruption of natural ecosystem processes, such as altered hydrology and fire suppression, and invasion by exotic plants such as common reed (*Phragmites australis*), purple loosestrife (*Lythrum salicaria*), and reed canary grass (*Phalaris arundinacea*) also have contributed to the loss and degradation of these natural communities (Albert and Kost 1998, Albert 2001). Lakeplain prairie and Great Lakes marsh habitats still occur in Sterling State Park but only in small, degraded remnants due to development and management for recreational use, hydrological manipulations, and the spread of invasive plants. Restoration efforts at Sterling State Park have been

ongoing since 2003. These efforts have included spraying invasive plants with herbicides, prescribed burning, debris removal, extensive site preparation, mowing, seed collection, and planting native prairie vegetation.

In 2003, in cooperation with the State Park Stewardship Program, the Michigan Natural Features Inventory (MNFI) initiated a monitoring and radio-telemetry program for the Eastern Fox Snake in conjunction with the habitat restoration efforts at Sterling State Park. Eastern Fox Snakes had been found in many of the areas targeted for habitat restoration in the Park. The goal of this monitoring program is to detect a biologically significant change in the Eastern Fox Snake population in areas targeted for habitat management treatments in the Park. The specific objectives of this project are to (1) survey and document presence/absence, and estimate absolute and/or relative abundance of Eastern Fox Snakes in all management units within the Park, particularly those undergoing active management; (2) collect baseline population data for statistical comparison with data from subsequent years; (3) collect tissue and/or blood samples for future genetic analysis of the Park's Eastern Fox Snake population; (4) determine movement patterns and investigate ecology particularly timing of emergence and hibernation of Eastern Fox Snakes within the Park; and (5) produce baseline geographically referenced habitat and snake distribution data for comparison with post-management data. This study will provide baseline information with which to assess the effects of the habitat restoration efforts on the resident Eastern Fox Snake population in Sterling State Park (e.g., is population increasing, decreasing or remaining constant) and provide data for future adaptive management. This study also will enhance our knowledge of Eastern Fox Snake life history and ecology and potential impacts of land management activities on this species.

Surveys for Eastern Fox Snakes were conducted at Sterling State Park in 2003 immediately prior to and during initiation of habitat restoration efforts and continued in 2004 and 2005 after extensive habitat restoration activities had been conducted in the Park. Radio-tracking of a small sample of Eastern Fox Snakes and collection of blood and/or tissue samples also were conducted during 2003 - 2005 in addition to monitoring surveys. Results from the fox snake surveys and radio-telemetry conducted in 2003 and 2004 suggested that fox snake numbers within Sterling State Park may not have been dramatically impacted by initial habitat restoration activities although fox snake use of particular management units may have been impacted to some degree (Lee 2004). However, results from 2003 and 2004 were inconclusive due to limited data (i.e., small sample sizes, short time frame and little pre-treatment data) (Lee 2004). Additional surveys and radio-telemetry and a long-term monitoring effort are needed to further assess the short- and long-term impacts of habitat restoration efforts on the Eastern Fox Snake population within Sterling State Park. Limited surveys and radio-tracking continued in 2005 with funding from the State Park Stewardship Program. This report summarizes project activities and results from 2005 and also provides comparisons with study results from 2003 and 2004.

STUDY AREA

Sterling State Park is a 405-ha (1,000-acre) park located along the Lake Erie shoreline in Monroe County, Michigan in the southeast corner of the state approximately 61 km (38 mi) south of Detroit and 39 km (24 mi) north of Toledo, Ohio (Figure 1). Based on regional landscape ecosystem classifications of Michigan (Albert 1995), Sterling State Park is located within the Maumee Lake Plain of the Washtenaw sub-section. This region is a flat, clay lake plain dissected by broad glacial drainageways of sandy soil (Albert 1995). Historically (*circa* 1800), Sterling State Park was comprised primarily of Great Lakes marsh with a band of wet or lakeplain prairie and a small area of mesic southern forest in the northwest portions of the Park. Additional information on the historical and current land cover in Sterling State Park can be found in Olson (2002) and Lee (2004).

Alteration of the historical land cover within Sterling State Park has been extensive (Olson 2002). Much of the marsh habitat was initially drained for agricultural use and then was dredged to create channels and a diked area that historically controlled water levels for transportation access and later hunting access. Extensive dredging occurred in the 1950's and 1960's to create open water lagoons and upland areas in the park for recreational use (Olson 2002). A confined disposal facility (CDF) was constructed by the U.S. Army Corps of Engineers in the early 1980's by dredging portions of the marsh in the northeast corner of the park. Soil from the construction of the CDF was placed throughout the park, raising the elevation of portions of the park and creating many spoil piles, berms and a series of small "islands" in the

Figure 1. Map showing general location of Sterling State Park in Monroe County, Michigan, as indicated by the red star.

marsh immediately west of the CDF (Olson 2002). The upland areas in the park also were once farmed (Olson 2002).

Given these widespread alterations, the land cover within Sterling State Park has dramatically changed. The wetlands in Sterling State Park are currently a mix of open water lagoons, mud flats, floating aquatics and small remnants of Great Lakes marsh and lakeplain prairie. The upland areas are primarily open and comprised of a mix of natural habitat and areas developed or managed for recreational use. The inland areas that once supported lakeplain prairie are now primarily old fields with various spoil piles, berms and debris (Olson 2002). The mesic southern forest that once occupied the farthest inland portions of Sterling State Park is almost completely gone. The small patches or strips of forest that remain in the park occur along a raised dike/paved trail and the edge or perimeter of open upland and wetland habitats. Sugar maple (*Acer saccharum*), boxelder (*Acer negundo*), cottonwood (*Populus deltoides*), willows (*Salix* spp.), ash (*Fraxinus* spp.), and dogwood (*Cornus* spp.) commonly occur in the forested habitats. Invasive species such as purple loosestrife, common reed or *Phragmites,* and reed canary grass can be found throughout the park. Sterling State Park is heavily used for recreation and contains a number of developed or managed recreational facilities including roads, paved parking lots, paved trails, interpretive area, mowed grass, landscaped areas, boat launch, buildings, playground, beach and campground. Water levels are no longer controlled anywhere in the park, although dikes, ditches, culverts and rock riprap along the lagoons and portions of the Lake Erie shoreline continue to influence hydrology within the park.

Sterling State Park has been divided into nine management units. These include the following: Headquarters (HQ), Bean Field (BF), Campground Restoration (C), Corps Volcano (V), Hunt Club (HC), Interpretive Kiosk (IK), North Lagoons (NL), Corps CDF (CDF) and Facilities (F) (Figure 2). Of these, the following six units have been targeted for habitat restoration efforts: Bean Field, Corps Volcano, Campground Restoration, North Lagoons, Hunt Club and Interpretive Kiosk. The remaining three management units, Headquarters, Facilities and Corps CDF, have not been targeted for active restoration, although some patches of *Phragmites* along the lagoons on the west side of the Facilities Unit were sprayed in 2003. Brief descriptions and photographs of habitat types in each of the nine management units in 2003 and 2004 prior to and after initiation of habitat restoration activities are provided in Lee (2004).

Habitat conditions in 2005 were generally similar to conditions in 2004 in most management units except for a few units which are still undergoing active habitat restoration. During the fox snake surveys in 2004, most of the Campground Restoration Unit consisted of bare dirt and lacked vegetative cover except for some old field and emergent marsh habitats along the northern, eastern and southern edges of the unit. In 2004, most of the Campground Restoration Unit was graded down to historical contours to restore Great Lakes marsh transitioning inland to lakeplain prairie. The Campground Restoration Unit was planted in 2004 and 2005, and more vegetation was present in the unit during surveys in 2005 but vegetative cover was still fairly sparse in a large portion of the unit. The amount of *Phragmites* has been significantly reduced in the North Lagoons, Campground Restoration, Corps Volcano, Hunt Club, Interpretive Kiosk and Facilities units compared to conditions in 2003. Spraying with herbicides and/or burning have continued though in portions of several units to continue to control *Phragmites*. Herbicide spraying, burning, planting, and/or mowing also have continued in the Interpretive Kiosk Unit to restore lakeplain prairie to parts of the Unit.

METHODS

Visual Encounter Surveys

Similar to surveys conducted in 2003 and 2004, surveys for the Eastern Fox Snake in 2005 were conducted in all nine management units within Sterling State Park including the six units that have been targeted for restoration (i.e., Bean Field, Corps Volcano, Campground Restoration, North Lagoons, Hunt Club and Interpretive Kiosk) and the three units not currently targeted for active restoration (i.e., Headquarters, Facilities and Corps CDF). Due to the lack of access to the interior of the Corps CDF Unit, surveys were conducted outside the fence along the perimeter of the unit. Surveys in the North Lagoons Unit were conducted only along the southern and eastern perimeters of the unit due to limited access (i.e., narrow strips of dense emergent vegetation separated by deep water in the lagoons). Surveys in the Facilities Unit were concentrated along the western and southern boundaries of the unit and generally avoided areas that are highly developed or heavily used for recreation (e.g., campground, playground, parking lot, etc.). Surveys in the Hunt Club Unit were

Figure 2. Map of habitat management units in Sterling State Park, Monroe County, Michigan.

conducted along the dike or paved trail and in areas with habitat that were accessible along the edge of the lagoon.

Eastern Fox Snakes were surveyed in 2005 using line-transect and time-constrained visual encounter surveys (VES) similar to those that had been conducted in 2003 and 2004. For the line-transect VES, multiple transects of 150 m were systematically placed and surveyed within each unit. Sampling effort in terms of the number of survey transects within each unit was proportional to the size of the unit or the amount of suitable and accessible habitat within each unit (i.e., ~1 transect per 1.5 ha) (Table 1). Survey transects were geographically distributed throughout each unit and in areas that represented the range of habitat types within each unit whenever possible. The survey transects were established in 2003, and the location of each survey transect was recorded using a hand-held Global Positioning System (GPS) unit (Garmin 12XL) (Appendix I; for GPS locations, see Lee 2004). The same transects were located and surveyed in 2004 and 2005. In a few management units, one or two transects or portions of transects had to be moved slightly to nearby habitat due to the presence of tall, dense vegetation. Transects were located and marked with plastic flagging and wire flagging stakes in early August 2005 for field surveys.

In 2005, line-transect visual encounter surveys were conducted from 7 August to 5 September. A total of four transect surveys were conducted in each management unit during this time period (Table 1). The surveyor and the order in which management units were surveyed were randomly assigned to minimize survey bias. Transect surveys consisted of one or two surveyors slowly walking along a transect and visually searching for basking individuals as well as individuals under cover on both sides of the transect. All transects in each unit were surveyed during each visit.

Time-constrained visual encounter surveys also were conducted in each management unit in 2005 during the same time period as the line-transect surveys. A total of four time-constrained VES were conducted in each management unit (Table 1). Time-constrained surveys were generally conducted immediately after transect surveys within each unit. Time-constrained surveys consisted of one or two surveyors meandering or slowly walking through areas with suitable habitat within each unit and visually searching for basking individuals as well as individuals under cover for a prescribed period of time per survey. Time-constrained survey durations ranged from 0.5 to 1.7 person-hours (i.e., 30-100 minutes), and were generally proportional to the size of the unit and the amount of available habitat within the unit (Table 1). The time-constrained survey durations or time limits used during the surveys in 2005 were established in 2004 and were slightly higher but comparable to time constraints utilized in 2003 (i.e., 20-90 minutes).

Additional visual encounter surveys for Eastern Fox Snakes were conducted in 2005 on 12 May and 14 and 19 June in five of the nine management units (Table 1). The purpose of these surveys was to find additional fox snakes for radio-telemetry, population estimation and tissue sample collection. These surveys also were conducted in the spring to investigate the effectiveness of spring surveys compared to late summer/early fall surveys. Surveys generally consisted of 1-2 surveyors walking through areas with suitable habitat and visually searching for snakes above ground and under cover.

All visual encounter surveys were conducted between 8 am and 7 pm during appropriate weather and survey conditions when the snakes were likely to be active or visible. An Eastern Fox Snake monitoring field form was developed and completed for each survey visit (Appendix II). Information on survey dates, times, duration, weather conditions, transects, macrohabitat, microhabitat and snake observations was recorded on these field forms.

Snake Observations

All Eastern Fox Snakes and other snakes and herpetofauna observed during field surveys were documented. Similar data were recorded in 2005 as in 2003 and 2004. The behavior, estimated length, and age class of each observed snake were recorded whenever possible. The macro- and microhabitats in which each snake was found also were recorded. The behavioral, macrohabitat, and microhabitat classifications used in this study have been used in other snake studies (Kingsbury 2001, Kingsbury et al. 2001). Snake behavioral classifications included basking, resting, courting, mating, foraging, traveling, and unknown. Macrohabitat classifications were based on National Wetland Inventory (NWI) classifications (Cowardin et al. 1979) and included palustrine forested wetland (PFO), palustrine scrub-shrub wetland (PSS), palustrine, sedge-dominated emergent wetland (SDG), palustrine, cattail-dominated emergent wetland (CAT), upland forest (UFO), upland scrub-shrub (USS), and old field (OLD). Microhabitat classifications included shrub, sedge, grass, rock, log, herb (herbaceous/not grass), bare, island (small hummock in open water), detritus, and other. More specific macro- and

Table 1. Summary of visual encounter surveys conducted by Michigan Natural Features Inventory for Eastern Fox Snakes at Sterling State Park in Monroe County, Michigan in 2005.

Management Unit	Area	Line -Transect VES		Time-Constrained VES		Additional VES	
	ha (ac)	# Transects	Dates	Time (mins)	Dates	# Surveys	Dates
Headquarters	7 (17)	2	8/7, 8/15, 8/26, 8/30	30	8/7, 8/15, 8/26, 8/30	0	
Bean Field	32 (80)	16	8/7, 8/15, 8/25, 9/5	60	8/7, 8/15, 8/25, 9/5	0	
Corps Volcano	35 (88)	20	8/7, 8/17, 8/26, 9/2	90	8/7, 8/17, 8/26, 9/2	0	
Campground Restoration	44 (109)	14	8/11, 8/17, 8/26, 9/2	60	8/11, 8/17, 8/26, 9/2	1	6/19
Interpretive Kiosk	7 (16)	7	8/7, 8/18, 8/25, 8/30	50	8/7, 8/18, 8/25, 8/30	2	6/14, 6/19
Hunt Club*	92 (226)	11	8/11, 8/18, 8/25, 9/5	100	8/11, 8/18, 8/25, 9/5	1	5/12
North Lagoons*	35 (86)	3	8/11, 8/18, 8/26, 9/5	30	8/11, 8/18, 8/26, 9/5	0	
Corps CDF*	39 (97)	4	8/7, 8/17, 8/26, 8/30	40	8/7, 8/17, 8/26, 8/30	1	6/19
Facilities*	122 (303)	14	8/7, 8/18, 8/21, 9/5	80	8/7, 8/18, 8/21, 9/5	1	6/19
Total		91		540		6	

*Denotes management units with significant portions that were inaccessible, developed, and/or did not contain suitable habitat for Eastern Fox Snakes.

microhabitat information (e.g., natural community type, dominant plant species) was recorded when possible.

Locations of Eastern Fox Snakes were recorded using a hand-held GPS unit. Observed fox snakes were captured, measured, weighed, and sexed, when possible. Total length, snout-vent length (SVL), and tail length were measured and recorded for all captured fox snakes. Total length was used to help determine age class designations with adult snakes ranging from about 90 – 170.5 cm (35-67 in), sub-adults or juveniles ranging from 32 – 89 cm (13- 35 in) and newly hatched or young snakes ranging from 26 – 31 cm (10-12 in) (Harding 1997). Adult and sub-adult or juvenile fox snakes were individually marked with PIT (passive integrated transponder) tags in the field or in the lab (i.e., for snakes that were also implanted with transmitters). The PIT tags were injected subcutaneously dorsal to the vent (i.e., cloacal opening) using a 10-gauge sterile syringe pre-loaded with the microchip. A tissue sample (i.e., scale clipping) also was collected from adult and sub-adult or juvenile fox snakes in the field or in the lab, when possible, and stored appropriately for future genetic analysis. A scale clipping was obtained from a ventral scale anterior to the vent using sterilized surgical scissors. In 2003 and 2004, a blood sample consisting of approximately 0.1-0.2 ml of blood was collected from the caudal (tail) vein of each captured fox snake using a sterile needle and syringe. However, blood samples were not collected in 2005. Photographs were taken of each captured fox snake for documentation. After all processing and data collection were completed, snakes were released at their respective capture sites. Michigan Natural Features Inventory's special animal survey forms were completed for surveys with fox snake observations (Appendix III).

Radio-telemetry

Three Eastern Fox Snakes were radio-tracked to their apparent hibernation sites in the fall of 2004, but only one of these snakes was radio-tracked in 2005. These snakes were first captured, implanted with radio-transmitters and radio-tracked during the spring and summer of 2004. Two of the snakes, an adult male and a sub-adult (sex unknown, possibly male), were captured during visual encounter surveys on 10 and 17 May 2004 and were radio-tracked through the spring, summer and early fall until 23 September 2004. One of these snakes, the adult male, was radio-tracked to a location underneath a large cottonwood tree on the east side of the dike or paved trail in the southeast corner of

the Hunt Club Unit in the fall of 2004, and the snake apparently overwintered at this location. The snake (or transmitter) was tracked to this location several times in the spring and early summer of 2005, and the snake was presumed to be dead because the transmitter signal never moved from this location in 2005. The sub-adult snake fox snake that was tracked in 2004 was relocated in April 2005 and was radio-tracked on a weekly or bi-weekly basis from 5–29 April and 2 July to 18 September 2005. The third snake, an adult male, was captured during time-constrained VES on 24 August 2004. It was implanted with a transmitter on 30 August and released back into the field at its capture site on 2 September 2004. The snake was radio-tracked several times until 23 September 2004 but had not moved from its initial capture site since its release. In April 2005, the transmitter was found on the ground at or near its initial capture site.

Four new fox snakes were found and captured during additional visual encounter surveys conducted on 14 and 19 June 2005 for the radio-telemetry study. These snakes were comprised of three adult females and one adult male (based on total lengths). One adult female and the adult male were found on 14 June in the Interpretive Kiosk Unit south of the parking lot at the north end of the unit (Figure 3). The other two adult females were found together in or around the entrance of a burrow located on the side of a paved trail that runs along the fence surrounding the Corps CDF Unit in the northeast corner of the Facilities Unit (Figure 3) on 19 June. Both snakes appeared to be ready to shed their skins.

The four snakes were transported to the laboratory of Dr. Bruce Kingsbury, Biology Department Chair at Indiana-Purdue University at Ft. Wayne, who surgically implanted radio-transmitters in the snakes using the following protocol. Each snake was anesthetized by placing it into a sealed chamber with a small container of isoflurane which vaporizes and permeates the chamber. The snake was measured, weighed, and sexed once it was anesthetized. Also, while the snake was anesthetized, the snake was PIT-tagged, and a scale clipping and/or blood sample were collected if necessary. Transmitters were implanted using a technique modified from Reinert and Cundall (1982). A small lateral incision was made on the ventral side of the body cavity approximately two-thirds of the way down the body. The incision was placed slightly above the surface that slides across the ground when the snake moves. Rather than cut through the body wall, the body wall was easily separated with little or no blunt dissection, and an incision was made in the peritoneum (body cavity membrane). A radio-transmitter was then inserted into the body cavity. Radio-transmitters weighing 9 grams (1 cm wide x 3 cm long cylinder, 20 cm whip antenna, 18-month life span, Holohil Systems Ltd.) were implanted in the three adult female snakes. A smaller transmitter weighing 5 grams (0.95 cm wide x 2 cm long cylinder, 12-month life span, Holohil Systems Ltd.) was used in the adult male snake because of its body mass or weight (i.e., only about 200 g). Although use of the 9-g transmitter in this snake would have been under the recommended limit of 5% transmitter mass to snake body mass ratio (Reinert 1992, Hardy and Greene 1999), the 5-g transmitter was used to be conservative. The antenna was placed subcutaneously along the body of the snake, anterior to the initial incision through a second, small incision. The primary incision was closed with PDS absorbable suture and surgical skin glue. The second incision was simply glued closed with skin glue.

After recovery from the anesthesia, the snakes were moved to a housing area. The housing area was kept at 80-82^{o}F, which is the temperature many snakes seek in the field during summer months based on previous studies. When the temperature fell below this level, a heat source (light bulb or heating pad) was placed near or under the terrarium in order to establish a thermal gradient. This allowed the snakes to behaviorally thermoregulate by moving towards or away from the heat source. The photo period of the room was 14:8 day:night. Each snake was held individually in a clean terrarium, away from other animals that might act as a source of pathogens. The snakes were inspected several times a day. Handling of the snakes during the recovery period was kept to a minimum. Water was provided, but food was not. The snakes were held for observation for 3-6 days (7 days maximum) after the surgery and then released at their respective capture sites in the park.

Once released, the snakes were radio-tracked on a weekly or bi-weekly basis throughout the field season from 22 June to 18 September 2005. The snakes were located during different times of the day between 9 am and 8:30 pm. The position of each location was recorded using a hand-held GPS unit and plotted on an aerial photo of the park using ArcView GIS (ESRI Inc.). At each location, the macro- and microhabitats in which the snake was found, the behavior of the snake, and weather conditions were recorded. The pulse interval of the radio-transmitter also was recorded and was used to estimate the body temperature of the snake. A visual confirmation of the radio-tracked snake was obtained when possible. The snakes were radio-tracked to their hibernation sites in the fall.

RESULTS

Surveys

In 2005, MNFI conducted about 91 hours of field surveys for the Eastern Fox Snake in Sterling State Park, with approximately 81 hours of line-transect and time-constrained visual encounter surveys (61 hours for line-transect, 20 for time-constrained) and about 10 hours of additional visual encounter surveys in May and June. Given that some surveys were conducted by multiple individuals, a total of about 171 person-hours of surveys were conducted, with about 121 person-hours of line-transect surveys, about 36 person-hours of time-constrained surveys, and about 14 person-hours of additional visual encounter surveys in May and June. Surveys were conducted by two primary individuals working with four different volunteers.

Overall, field surveys in 2005 resulted in a total of only six eastern fox snake observations, of which only five were captured (Table 2). Five of the six fox snake observations were documented during additional visual encounter surveys conducted on 14 and 19 June. The sixth fox snake observation was made incidentally while tracking a transmittered snake in September. No fox snakes were observed during line-transect and time-constrained surveys in 2005. The five captured snakes were all new snakes. One snake escaped capture when it was observed but may have been one of the snakes that was captured later that day at the same location. Two of the fox snakes were found in the Interpretive Kiosk Unit, and the other four fox snake observations were located along or near the fence surrounding the Corps CDF Unit in the northeast portion of the Facilities Unit. Figure 3 provides an aerial photograph of Sterling State Park with the locations of the fox snakes observed in 2005 as well as fox snakes found during surveys in 2003 and 2004 for comparison.

Of the five fox snakes that were captured in 2005, four were considered adults with total lengths ranging from about 96.5–109.5 cm (38-43 in) and weights ranging from 205 – 486 g (Table 2). The remaining fox snake was considered to be a young-of-the-year with a total length of 32.5 cm (12.8 in) and a weight of 10 g. The snake that escaped capture appeared to be an adult based on its body size. Three of the adult snakes were probed in the lab and were identified as females, and the other adult snake was a small male. The sex of the young snake is unknown because this is difficult to determine visually when the snake is so small and it was not probed in the field because of its size. Tissue samples (i.e., scale clippings) were collected from all four adult snakes but not from the young snake because of its small size. All four adult snakes were marked with a PIT tag and white liquid paper on the tips of their tails. All four adult snakes also were implanted with radio-transmitters and added to the radio-telemetry study. The young snake was not PIT-tagged because of its size and was only marked with white liquid paper on the tip of its tail.

Additional fox snake observations were reported by Sterling State Park and State Park Stewardship Program staff. A sub-adult fox snake was actually picked up by Sterling State Park staff on 16 June 2005. The snake was observed basking next to the paved trail along the fence surrounding the Corps CDF Unit in the northeast corner of the Facilities Unit at the same location at which MNFI staff found two fox snakes on 19 June 2005. The fox snake was given to MNFI staff and was measured, weighed, PIT-tagged and released at its capture site on 19 June.

The fox snakes observed during field surveys in 2005 were found in several different habitats and microhabitats (Table 2). One of the fox snakes found at the northern end of the Interpretive Kiosk Unit was found resting in herbaceous vegetation in a narrow band of palustrine scrub-shrub habitat dominated by willow along the lagoon about two meters from the water's edge. The other snake found in the Interpretive Kiosk Unit was basking in grass in open old field habitat adjacent to the scrub-shrub habitat in which the previous snake was found. The three fox snakes observed along the fence surrounding the Corps CDF Unit were found basking or resting in or near the entrance of a burrow along the side of a paved trail that runs along the fence surrounding the Corps CDF Unit. The habitat in the Corps CDF Unit immediately adjacent to the burrow was upland scrub-shrub with tall, dense shrubs but nearby habitats in the Corps CDF Unit and along the trail in the Facilities Unit were more open and consisted of old field, emergent marsh and palustrine scrub-shrub wetlands. Interestingly, the snake that was picked up by the Sterling State Park staff also was found basking in or near the same burrow along the paved trail under the Corps CDF fence. The last fox snake was observed in grassy old field habitat near the fence surrounding the Corps CDF Unit between the fence and the paved trail.

Fox snake detection frequencies or detection rates for the surveys can be calculated for the park as a whole based on the number of fox snakes observed and survey effort in terms of survey hours and/or person-hours. Only five fox snake observations were documented in about 91 hours for all visual encounter

Table 2. Summary of Eastern Fox Snake observations during visual encounter surveys conducted by Michigan Natural Features Inventory in Sterling State Park in Monroe County, Michigan in 2005.

Date	Management Unit	Survey Type[1] (LTS, TCS, AVS)	Capture (C)/ Recapture (R)	PIT tag ID #	Age class[2] (A, S/J, Y)	TL/SVL[3] (cm)	Weight (g)	Sex[4] (M, F, U)	Latitude	Longitude	Macrohabitat[5]	Microhabitat	Behavior	Radio-transmittered?
06/14/2005	Interpretive Kiosk	AVS	C	087 353 293	A	109.5/95	401	F	N 41 55.013'	W 83 20.373'	PSS/scrub-willow	herbaceous	resting	Y
06/14/2005	Interpretive Kiosk	AVS	C	087 293 539	A	97.75/81.5	205	M	N 41 55.018'	W 83 20.374'	OLD	grass	basking	Y
06/16/2005	Corps CDF	Sterling SP staff	C	087 310 521	S	82.5/71	175	M	N 41 54.819'	W 83 19.990'	paved walk	bare	basking	N
06/19/2005	Corps CDF	AVS	Escaped capture; may be snake 087 320 124 caught later that day	no pit tag	A	Unk	Unk	U	N 41 54.819'	W 83 19.990'	paved walk	burrow	resting	N
06/19/2005	Corps CDF	AVS	C	087 305 797	A	109/96.5	486	F	N 41 54.819'	W 83 19.990'	paved walk	bare	basking	Y
06/19/2005	Corps CDF	AVS	C	087 320 124	A	96.5/85.5	300	F	N 41 54.819'	W 83 19.990'	paved walk	bare	basking	Y
09/02/2005	Corps CDF/Facilities	AVS	C	no pit tag	Y	32.5/28	10	U	N 41 54.796'	W 83 20.068'	OLD	grass	unknown	N

[1]Survey type: LTS = line-transect visual encounter survey, TCS = time-constrained visual encounter survey, and AVS = additional visual encounter survey

[2]Age class: A = adult (~90-170 cm), S/J = sub-adult/juvenile (~32-89 cm), Y = young (~26-31 cm)

[3]TL/SVL: TL = total length, SVL = snout-vent length

[4]Sex: M = male, F = female, U =unknown

[5]Macrohabitat: OLD = old field, PEM = palustrine emergent wetland, PSS = palustrine scrub-shrub, PFO = palustrine forest, POW = palustrine open water, USS = upland scrub-shrub, UFO = upland forest.

Figure 3. Map of locations of Eastern Fox Snake observations during visual encounter surveys conducted by Michigan Natural Features Inventory at Sterling State Park in Monroe County, Michigan in 2005, as indicated by the red dots. Eastern Fox Snake observations documented during surveys in 2003, as indicated by the green triangles, and 2004, as indicated by the yellow triangles, also are shown on this map.

surveys combined in 2005, resulting in a detection frequency of about 0.05 fox snake observations/survey hour. For total person hours, five fox snake observations were documented in about 171 person-hours, resulting in a detection frequency of 0.03 fox snake observations/person-hour. However, detection frequencies based solely on additional visual encounter surveys conducted in May and June were much higher, with about 0.5 fox snake observations/survey hour (5 fox snake observations in a total of about 10 survey hours) and about 0.4 fox snake observations/person-hour (5 observations in about 14 person-hours). Only five fox snake observations instead of six were used in the detection frequency calculations because only five were observed during actual visual encounter surveys and one snake was observed incidentally during radio-telemetry.

In addition to Eastern Fox Snakes, a total of 15 observations of other snake species were documented during field surveys in 2005. These included 11 Eastern Garter Snake (*Thamnophis sirtalis sirtalis*) observations, 2 Butler's Garter Snake (*Thamnophis butleri*) observations, 1 Brown Snake (*Storeria dekayi*) observation, and 1 unidentified snake observation (Table 3). Of the total number of snakes observed, 6 observations were made during the line-transect and time-constrained visual encounter surveys, and 9 observations were made during additional visual encounter surveys. These observations were documented in only four management units which included the Corps CDF, Facilities, Hunt Club and Interpretive Kiosk units. It is important to note that these observations may not all represent separate individuals since repeated surveys of the same areas were conducted and observed animals were not marked.

Other amphibian and reptile species also were observed during field surveys in 2005. These included at least 12 Northern Leopard Frog (*Rana pipiens*) observations, 1 Bullfrog (*Rana catesbeiana*) observation, 2 Green Frog (*Rana clamitans melanota*) observations, 39 Painted Turtle (*Chrysemys picta*) observations, 5 Common Map Turtle (*Graptemys geographica*) observations, and 1 Common Snapping Turtle (*Chelydra serpentina serpentina*) observation. Most of the turtles were observed basking on logs in the water in the Hunt Club Unit.

Radio-telemetry

A total of four Eastern Fox Snakes were radio-tracked in 2005 on a weekly or bi-weekly basis from 5 April to 18 September (Figure 4). Of these, one was initially captured and radio-tracked in 2004, and the rest were new snakes that were captured and added to the study in June 2005. An additional fox snake was captured and implanted with a radio-transmitter in 2005, but we were never able to obtain a transmitter signal for this snake after it was released. This snake was an adult male that was captured on 14 June 2005 in the Interpretive Kiosk Unit. The snake was implanted with a 5-g transmitter instead of a 9-g transmitter which is the type of transmitter that was implanted in the other three snakes. The 5-g transmitter may have been faulty since other researchers have reported having problems with these transmitters.

The fox snake that was radio-tracked in 2004 (PIT tag#: 052 563 549, hereafter referred to as J54904) was initially captured in the Interpretive Kiosk Unit during additional visual encounter surveys on 17 May 2004. The snake was a juvenile or sub-adult (sex unknown, possibly male) that weighed 99 g and was approximately 77 cm (30 in) in total length (SVL = 64 cm/25 in, tail length = 13 cm/5 in) at the time of its capture. Because this snake was a juvenile, a 5-g radio-transmitter instead of a 9-g transmitter was surgically implanted into the snake. J54904 was radio-tracked to 11 locations from 17 June to 23 September 2004. During the radio-tracking period in 2004, J54904 was mostly located in the Interpretive Kiosk Unit in the vicinity of its initial capture site but was also located a few times on the other side of the lagoon in the Facilities Unit near the foot bridge (Figure 5). The snake hibernated underground along the raised dike or paved trail just north of the pavilion in the Interpretive Kiosk Unit about 2 m from the water's edge. The snake was radio-tracked to this location the following spring during three visits on 4, 17 and 29 April 2005. The snake was presumed to be dead because it had not moved from its overwintering site as of late April. However, the snake was tracked to a different location and was captured, weighed and measured on 2 July 2005. The snake appeared to be healthy. It weighed 235 g and was 96 cm (38 in) in total length (SVL – 82 cm/32 in, tail length = 14 cm/ 5.5 in), indicating a substantial increase in size from the previous year. The tail length and proportion of tail length to SVL or total length suggest that this snake is likely a male. During the radio-tracking period in 2005, J54904 was located exclusively in the Interpretive Kiosk Unit, moving north and south along the dike in this unit (Table 4 and Figure 5). On 2 September, the snake was located near its overwintering location from 2004. However, we were unable to get a signal and were not able to locate the

Table 3. Summary of Eastern Fox Snakes and other snakes observed during visual encounter surveys in Sterling State Park in Monroe County, Michigan in 2005.

Management Unit	Eastern Fox Snake	Eastern Garter Snake	Butler's Garter Snake	Northern Water Snake	Northern Ribbon Snake	Brown Snake	Unidentified snake	Total
Bean Field	0	0	0	0	0	0	0	0
Campground Restoration	0	0	0	0	0	0	0	0
Corps CDF	0	1	1	0	0	0	0	2
Corps Volcano	0	0	0	0	0	0	0	0
Facilities	0	1 (3)	0 (1)	0	0	0	0	1 (4)
Headquarters	0	0	0	0	0	0	0	0
Hunt Club	0	1 (3)	0	0	0	1	0	2 (3)
Interpretive Kiosk	0	0 (2)	0	0	0	0	1	1 (2)
North Lagoons	0	0	0	0	0	0	0	0
Total	**0**	**3 (8)**	**1 (1)**	**0**	**0**	**1**	**1**	**6 (9)**

Note: The numbers in parentheses indicate the number of snakes observed during additional visual encounter surveys.

snake on 8 and 18 September to determine its overwintering location for 2005. The snake's transmitter may have failed due to a dead battery.

J54904 was found primarily in open habitat types in 2005 as in 2004 (Table 4). J54904 was found primarily in herbaceous vegetation in old field habitats and also under rock in palustrine scrub-shrub habitats. Of the 10 active locations to which this snake was tracked in 2005, 7 were in old field habitats (70% of locations) and 3 were in palustrine scrub-shrub (30%). The snake was observed only twice during the radio-tracking period and was primarily either in or under vegetation or under rocks the rest of the time. The maximum distance between the two farthest documented locations for J54904 was approximately 470 m (0.3 mi) in 2005 and in 2004. This distance may be an underestimate of the maximum distance this snake can travel within its home range since this snake was only tracked on a weekly or bi-weekly basis and was not tracked or monitored continuously during the active season. It also was not tracked in May and June when fox snakes are believed to be most active.

The adult female that was initially captured in the Interpretive Kiosk Unit during additional visual encounter surveys on 14 June 2005 (PIT tag #: 087 353 293, hereafter referred to as F29305) spent most of the summer along the shore of the northern lagoon in the Facilities Unit just south of the main park road and boat lauch area (Table 5 and Figure 6). After its release on 22 June 2005, the snake remained in the Interpretive Kiosk Unit until mid-July when it slowly moved north to the Facilities Unit where it stayed from mid-July through early September. The snake then returned to the Interpretive Kiosk Unit in early September and overwintered about 150 m from its initial capture site.

Most of F29305's locations during the radio-tracking period in 2005 were underground or in rock or rock riprap along the shore of the lagoons in the Facilities Unit, with 10 of its 13 locations (77%) in this habitat type (Table 5). A few of the locations were in scrub-shrub habitat in or under dense shrubs. We were only able to get one visual observation of this snake during the radio-tracking period when it was found under the outdoor bathroom in the Interpretive Kiosk. The maximum distance between the two farthest documented locations (i.e., between the original capture site in the Interpretive Kiosk Unit and the easternmost location along the shore of the northern lagoon in the Facilities Unit) was about 570 m (0.35 mi) along the dike.

The two adult females that were captured together at a burrow along the paved trail and fence surrounding the Corps CDF Unit on 19 June 2005 utilized different parts of the park in 2005. The larger female (PIT tag #: 087 305 797, hereafter referred to as F79705) moved quite a bit during the radio-tracking period. The snake basically moved between the Corps CDF Unit and the old field habitats along the lagoons on the west side of the Facilities Unit (Table 6 and Figure 7). The snake was located once somewhere inside the Corps CDF Unit based on the radio signal but we did not have access into the unit and could not determine her exact location within the unit. We also were not able to get a signal and could not locate this snake on 23 and 31 July, but we were able to locate her again in the Facilities Unit on 7 August. This snake exhibited greater movement (i.e., distances moved between locations and frequency of movements) than any of the other snakes we have radio-tracked in the study to date. Some of the State Park Stewardship Program actually commented that they had seen a fairly large fox snake move across the Facilities Unit several times that summer. Interestingly, F79705 was located on 18 September back at the hole or burrow along the fence of the Corps CDF Unit at which she was initially captured, and this is where she overwintered.

F79705 was primarily found in herbaceous vegetation or grass in old field habitats, with 7 of 12 locations (58%) in these habitat types (Table 6). This snake did not spend as much time underground during the radio-tracking period as F29305, and we were able to get visual observations of this snake at most of the locations to which it was tracked during the summer. The maximum distance between the two farthest documented locations (i.e., between the snake's capture site along the fence of the Corps CDF Unit and the southernmost location near the bridge in the Facilities Unit) was about 600 m (0.37 mi). The perimeter or total distance among the documented locations was over 1,300 m (0.81 mi). This distance should still be considered an underestimate of the total distance this snake can travel within its home range though since this snake was only located weekly or bi-weekly during a portion of the snake's active season.

The other adult female initially found at the burrow along the fence of the Corps CDF Unit (PIT tag #: 087 320 124, hereafter referred to as F12405) was located mostly inside the Corps CDF Unit or in old field habitat just outside or near the Corps CDF Unit's fence during the radio-tracking period in 2005 (Table 7 and Figure 8). Because we did not have access to the Corps CDF Unit in 2005, we were not able to determine her exact locations, movements and habitats used for most of the summer. Interestingly, in September, she also returned to the same hole or burrow along the paved trail and fence surrounding the Corps CDF Unit where she was initially found with F79705.

Overall, a total of eight different fox snakes have been implanted with transmitters and radio-tracked from 2003 to 2005. Of these, one fox snake was radio-tracked in 2003, three in 2004 and four in 2005. Only two snakes have been radio-tracked over multiple active seasons, but none have been tracked or monitored over multiple winters. Almost all of the radio-telemetry locations to date have been along the dike in the southeast portion of the Hunt Club Unit, along the entire length of the Interpretive Kiosk Unit and along the lagoon in the northwestern portion of the Facilities Unit, with several locations in 2005 in or along the southern half of the Corps CDF Unit and the northeastern corner of the Facilities Unit (Figure 9).

Figure 4. Map of radio-telemetry locations for Fox Snakes J54904 (as indicated by the red dots), F29305 (purple dots), F79705 (yellow dots), and F12405 (blue dots) in Sterling State Park in 2005.

Table 4. Summary of radio-telemetry locations and habitats for Fox Snake J54904 in Sterling State Park in 2005.

Location	Date	Unit	Habitat[1]	Microhabitat	Visual?[2]	Behavior	Latitude[3]	Longitude[3]	GPS Waypt.	Weather	Comments
1	04/05/2005	Interpretive Kiosk	W. side of trail, N. of pavilion, old field near shoreline, by cottonwod, dogwood, reed canary grass	Underground	N	Unknown	41.91213333	-83.34273333	F26601	72-76F, 100% sun, 10mph	Overwintering site - pulse seems slow
2	04/17/2005	Interpretive Kiosk	W. side of trail, N. of pavilion, old field near shoreline, by cottonwod, dogwood, reed canary grass	Underground	N	Unknown	41.91215000	-83.34270000	F26602	78F, 50% sun, 5-10mph	Strong signal with cord but weak signal without cord, presumed still underground
3	04/29/2005	Interpretive Kiosk	PSS/ grass	Grass, same general area as 4/5 and 4/17	N	Unknown	41.91215000	-83.34270000		54F, overcast, 0-5mph	Suspect dead
4	07/02/2005	Interpretive Kiosk	PSS/OLD	Herbaceous	Y	Resting	41.91548333	-83.34040000	26603	80-82F, 75% sun, 3-5mph	Snake=235g, SVL=82cm, tail=14cm
5	07/08/2005	Interpretive Kiosk	OLD	Herbaceous	N	Unknown	41.90000000	-83.34003333		80F, light rain, 6-10mph	
6	07/14/2005	Interpretive Kiosk	OLD	Herbaceous	N	Unknown	41.90000000	-83.34003333		82F, overcast, 5-10mph	
7	07/23/2005	Interpretive Kiosk	OLD	Herbaceous/ underground	N	Unknown	41.91576667	-83.34033333	26604	82F, 90% sun, 3-5mph	Moving, then went underground
8	07/31/2005	Interpretive Kiosk	OLD	Herbaceous	Y	Unknown	41.91560000	-83.34048333		78F, clear, 3-5mph	Snake looked good
9	08/07/2005	Interpretive Kiosk	OLD	Herbaceous	N	Unknown	41.91201667	-83.34263333	F26605	82F, clear, 0mph	Underground in hole
10	08/15/2005	Interpretive Kiosk	OLD	Herbaceous	Y	Basking/ foraging	41.91361667	-83.34161667	F26606	78F, 20% sun, 5-10 mph	Snake looked good
11	08/21/2005	Interpretive Kiosk	PSS	Rock	N	Resting	41.91440000	-83.34146667	F26607	80F, 100% sun, 5-10 mph	In rock outcropping
12	08/26/2005	Interpretive Kiosk	PSS	Rock	N	Resting	41.91420000	-83.34153333	F26608	79F, 100% sun, 0-3mph	Hiding in rocks on edge of water
13	09/02/2005	Interpretive Kiosk	PSS/ dogwood	Rock	N	Resting	41.91223333	-83.34273333	F26609	74F, 100% sun, 5-8mph	Deep underground
14	09/08/2005	Unknown	Unknown	Unknown	N	Unknown	No GPS point			76F, 100% sun, 3-5mph	Could not find snake
15	09/18/2005	Unknown	Unknown	Unknown	N	Unknown	No GPS point			82F, 65% sun, 3-5mph	Battery may be dead

[1]Habitat: OLD = old field, PEM = palustrine emergent wetland, PSS = palustrine scrub-shrub, PFO = palustrine forest, POW = palustrine open water, USS = upland scrub-shrub, UFO = upland forest

[2]Visual?: This indicates whether visual observation of the snake was obtained (Yes/No)

[3]Latitude and Longitude: Expressed in decimal degrees

Figure 5. Map of radio-telemetry locations for Fox Snake J54904 in Sterling State Park in 2005 (as indicated by the red dots) and some of the radio-telemetry locations from 2004 (green dots).

Table 5. Summary of radio-telemetry locations for Fox Snake F29305 in Sterling State Park in 2005.

Location	Date	Unit	Habitat[1]	Microhabitat	Visual?[2]	Behavior	Latitude[3]	Longitude[3]	GPS Waypt.	Weather	Comments
1	06/14/2005	Interpretive Kiosk	PSS-scrub, willow	Herbaceous	Y	Resting	41.91688333	-83.33955000		77F, 100%sun, 5-8mph	Capture site - found with adult male fox snake PIT tag # 087 293 539; surgery on 6/16, released on 6/22
2	06/27/2005	Interpretive Kiosk	Rock riprap on shore adjacent to dogwood shrubs	Under rocks	N	Unknown	41.91866667	-83.33873333	F49901	85-90F, 100% sun, 0-5mph	In hole in rocks
3	07/02/2005	Interpretive Kiosk	Rock riprap on shore adjacent to dogwood shrubs	Under rocks	N	Unknown	41.91870000	-83.33868333	49902	80-82F, 100% sun, 0-5mph	Same spot as last time
4	07/08/2005	Interpretive Kiosk	Under bathroom	Underground	Y	Unknown	41.91913333	-83.33855000	F49903	82F, overcast, 0-5mph	
5	07/14/2005	Facilities	PSS - shrubs	Rock	N	Unknown	41.91878333	-83.33558333	F49904	82F, overcast/hazy, 5-10mph	
6	07/23/2005	Facilities	Rocks at shore	Riprap	N	Unknown	41.91876667	-83.33568333	F49905	82F, 90% sun, 3-5mph	Probably basking before we approached
7	07/31/2005	Facilities	Shoreline	Riprap/ underground	N	Unknown	41.91970000	-83.33766667	F49906	80F, 100% sun, 3-5mph	
8	08/07/2005	Facilities	Rocks at shore	Riprap/ shrub	N	Unknown	41.91915000	-83.33630000	F49907	80F, clear, 3-5mph	
9	08/15/2005	Facilities	Rocks at shore	Riprap/ underground	N	Unknown	41.91958333	-83.33743333	F49908	79F, 25% sun, 3-5 mph	
10	08/21/2005	Facilities	Rocks at shore	Riprap	N	Unknown	41.91953333	-83.33728333	F49909	82F, 100% sun, 5-10 mph	
11	08/26/2005	Facilities	Rocks at shore	Riprap	N	Unknown	41.91951667	-83.33703333	F49910	82F, 100% sun, 0-3 mph	Very close to last location
12	09/02/2005	Facilities	Rocks at shore	Riprap	N	Unknown	41.91963333	-83.33753333	F49911	75F, 100% sun, 8-12mph	Moved underground as we approached
13	09/08/2005	Interpretive Kiosk	PSS - ~150 ft from parking lot in Dogwood and grapevine	Scrub shrub	N	Unknown	41.91728333	-83.33915000	F44912	76F, 100% sun, 3-5mph	
14	09/18/2005	Interpretive Kiosk	PSS	Shrub	N	Unknown	41.91825000	-83.33918333	F44913	82F, 65% sun, 3-5mph	

[1]Habitat: OLD = old field, PEM = palustrine emergent wetland, PSS = palustrine scrub-shrub, PFO = palustrine forest, POW = palustrine open water, USS = upland scrub-shrub, UFO = upland forest

[2]Visual?: This indicates whether visual observation of the snake was obtained (Yes/No)

[3]Latitude and Longitude: Expressed in decimal degrees

Figure 6. Map of radio-telemetry locations for Fox Snake F29305 in Sterling State Park in 2005, as indicated by the purple dots.

Table 6. Summary of radio-telemetry locations for Fox Snake F79705 in Sterling State Park in 2005.

Location	Date	Unit	Habitat[1]	Microhabitat	Visual?[2]	Behavior	Latitude[3]	Longitude[3]	GPS Waypt.	Weather	Comments
1	06/19/2005	Corps CDF	USS/paved trail - where paved trail turns toward the east	Hole/burrow along paved asphalt trail	Y	Basking	41.91365000	-83.33316667		72-76F, 25-75% sun, 0-3mph	Capture site - at hole/burrow where two other fox snakes were also found this year; surgery 6/21; released 6/27; shed while held
2	07/02/2005	Facilities	OLD - old field, grasses and wildflowers	Herbaceous	Y	Traveling	41.91346667	-83.33621667	F47901	85-090F, 100% sun, 0-5mph	
3	07/08/2005	Corps CDF/ Facilities	USS - in hole where paved trail turns	Hole/burrow along paved asphalt trail	N	Unknown	41.91348333	-83.31978333	F49702	76F, overcast, 0-5mph	
4	07/14/2005	Facilities	OLD - near water by sidewalk	Herbaceous	Y	Basking/ traveling	41.91340000	-83.33733333	F49703	82F, overcast, 5-10mph	Appears to have recently eaten
5	07/23/2005	Unknown	Unknown	Unknown	N	Unknown	No GPS point			82F, 90% sun, 3-5mph	No signal, could not locate snake
6	07/31/2005	Unknown	Unknown	Unknown	N	Unknown	No GPS point			80F, 100% sun, 3-5mph	No signal, could not locate snake
7	08/07/2005	Facilities	OLD - near bridge on SE	Herbaceous	Y	Foraging/ basking	41.91115000	-83.33995000	F49704	82F, clear, 0-3mph	Snake looks good
8	08/15/2005	Facilities	OLD	Herbaceous/ grass	Y	Foraging/ basking	41.91400000	-83.33701667	F49705	78F, 20% sun, 5-10mph	Snake looks good, went into hole at base of pine tree
9	08/21/2005	Corps CDF	OLD	Grass	Y	Resting	41.91312075	-83.33399721	F49706	81F, 100% sun, 0-3mph	Ready to shed
10	08/26/2005	Corps CDF	Unknown - inside fence	Unknown	N	Unknown	No GPS point			82F, 100% sun, 0-3 mph	
11	09/02/2005	Corps CDF	OLD	Grass	Y	Basking/ foraging	41.91343333	-83.33466667	F49707	75F, 100% sun, 5-8 mph	Went into hole in ground
12	09/08/2005	Facilities	OLD	Grass	Y	Basking/ resting	41.91276667	-83.33323333	F49708	76F, 100% sun, 3-5mph	Looks good
13	09/18/2005	Corps CDF	OLD	Hole/burrow along paved asphalt trail	N	Unknown	41.91350000	-83.33313333	F49709	82F, 65% sun, 0-3mph	

[1]Habitat: OLD = old field, PEM = palustrine emergent wetland, PSS = palustrine scrub-shrub, PFO = palustrine forest, POW = palustrine open water, USS = upland scrub-shrub, UFO = upland forest

[2]Visual?: This indicates whether visual observation of the snake was obtained (Yes/No)

[3]Latitude and Longitude: Expressed in decimal degrees

Figure 7. Map of radio-telemetry locations for Fox Snake F79705 in Sterling State Park in 2005, as indicated by the yellow dots.

Table 7. Summary of radio-telemetry locations for Fox Snake F12405 in Sterling State Park in 2005.

Location	Date	Unit	Habitat[1]	Microhabitat	Visual?[2]	Behavior	Latitude[3]	Longitude[3]	GPS Waypt.	Weather	Comments
1	06/19/2005	Corps CDF	USS - where paved trail turns toward the east	Hole/burrow along paved asphalt trail	Y	Basking	41.91365000	-83.33316667		72-76F, 25-75% sun, 0-3mph	Capture site - at hole or burrow where two other fox snakes were also found this year; surgery 6/21; released 6/27; shed while held
2	07/02/2005	Corps CDF	USS - where paved trail turns toward the east	Same hole as on 6/19/ underground	N	Unknown	41.91350000	-83.33313333	F39901	80-82F, 100% sun, 0-5mph	
3	07/08/2005	Corps CDF	PSS/USS - scrub-shrub inside fence	Unknown	N	Unknown	No GPS point			72-74F, overcast, light rain, 0-5 mph	
4	07/14/2005	Corps CDF	PSS/USS - scrub-shrub inside fence	Unknown	N	Unknown	No GPS point			82F, overcast, 5-10 mph	
5	07/23/2005	Corps CDF	PSS/USS - scrub-shrub inside fence	Unknown	N	Unknown	No GPS point			83F, 95% sun, 0-3 mph	
6	07/31/2005	Corps CDF	PSS/USS - scrub-shrub inside fence	Unknown	N	Unknown	No GPS point			81F, 100% sun, 0-3 mph	
7	08/07/2005	Corps CDF	PSS/USS - scrub-shrub inside fence	Unknown	N	Unknown	No GPS point			82F, clear, 0-3 mph	
8	08/15/2005	Corps CDF	OLD	Herbaceous	Y	Basking/ foraging	41.91313333	-83.33408333	F39902	79F, 30% sun, 3-5 mph	Skin appears a bit loose, snake is slightly swollen- may have eaten a while ago or may be swollen near transmitter
9	08/21/2005	Corps CDF	PSS/USS - scrub-shrub inside fence	Unknown	N	Unknown	No GPS point			81F, 100% sun, 3-5 mph	
10	08/26/2005	Corps CDF	PSS/USS - scrub-shrub inside fence	Unknown	N	Unknown	No GPS point			82F, 100% sun, 0-3 mph	
11	09/02/2005	Corps CDF	OLD	Grass	N	Unknown	41.91321667	-83.33416667	F39903	75F, 100% sun , 5-8 mph	Snake moving under grass, could not find it
12	09/08/2005	Corps CDF	PSS/USS - scrub-shrub inside fence	Unknown	N	Unknown	No GPS point			76F, 100% sun, 3-5mph	
13	09/18/2005	Corps CDF	USS - where paved trail turns toward the east	Hole/burrow along paved asphalt trail / underground	N	Unknown	41.91350000	-83.33311667	F39904	82F, 65% sun, 305 mph	

[1]Habitat: OLD = old field, PEM = palustrine emergent wetland, PSS = palustrine scrub-shrub, PFO = palustrine forest, POW = palustrine open water, USS = upland scrub-shrub, UFO = upland forest

[2]Visual?: This indicates whether visual observation of the snake was obtained (Yes/No)

[3]Latitude and Longitude: Expressed in decimal degrees

Figure 8. Map of radio-telemetry locations for Fox Snake F12405 in Sterling State Park in 2005, as indicated by the blue dots.

Figure 9. Map of all Eastern Fox Snake locations based on visual encounter surveys (as indicated by the triangles) and radio-telelmetry (as indicated by the circles or dots) in Sterling State Park in Monroe County, Michigan from 2003-2005.

DISCUSSION

The total number of Eastern Fox Snake observations documented during visual encounter surveys in 2005 was very small, similar to survey results in 2003 and 2004. Only six observations of Eastern Fox Snakes were documented in over 90 hours and over 170 person-hours of surveys in 2005. Overall, surveys from 2003–2005 at Sterling State Park have documented a total of only 23 Eastern Fox Snake observations and 21 individual snakes in almost 500 hours and over 600 person-hours of surveys (Table 8). The number of fox snake observations documented during surveys in 2005 was lower than the number of fox snakes found in 2004 but similar to that found in 2003 (Table 8). In order to calibrate for different survey effort and to facilitate comparisons of results among years, detection frequencies based on numbers of fox snake observations per survey hour or per person-hour can be calculated. Detection frequencies for all surveys combined (i.e., line-transect, time-constrained and additional VES) in 2005 were 0.05 and 0.04 Eastern Fox Snake observations per survey hour and per person-hour, respectively. These detection frequencies are lower than those for surveys in 2004 (i.e., 0.09 and 0.07 observations per survey hour and per person- hour, respectively) but slightly higher or comparable to those for surveys in 2003 (0.02 observations per survey hour and per person-hour) (Table 8). Detection frequencies for just the line-transect and time-constrained VES combined were again highest for surveys conducted in 2004 and lowest for surveys in 2005 because no fox snakes were documented during these surveys in 2005 (Table 8). However, comparisons of detection frequencies should be viewed with caution as species detectability can be influenced by relative abundance as well as a number of other factors including habitat conditions, weather or survey conditions, behavior of individuals, age of individuals, and surveyor bias (Thompson et al. 1998). In general, overall detection frequencies were similar and very low across all three years of the study.

A number of factors may have contributed to the low number of Eastern Fox Snakes that have been documented during visual encounter surveys in Sterling State Park from 2003-2005. First, the Eastern Fox Snake population within Sterling State Park and/or individual management units may be fairly small. This is plausible given apparently limited and degraded habitat and the high level of human use and disturbance within the park. The fox snake population at Sterling also continues to be threatened by road mortality and intentional and unintentional killing by humans. Also, prior to initiation of recent habitat restoration efforts and this monitoring study, a significant amount of habitat disturbance and loss had already occurred in areas within the park in which fox snakes had occurred historically. Examples of this would include removal of the old campground from the Campground Restoration Unit and removal of the park headquarters from the Corps Volcano Unit. These actions and associated activities might have already adversely impacted the fox snake population within these units and the park in general. However, despite the small numbers of fox snakes that were located during surveys from 2003-2005, snakes of different age classes were found including young snakes, providing evidence that some reproduction or recruitment has occurred in the fox snake population in the park. We also keep finding new snakes during our surveys, and additional snake observations continue to be documented by the Sterling State Park and/or State Park Stewardship Program staff. The small number of fox snake captures and recaptures to date preclude determining fox snake relative abundance or population density within the park at this time.

Aspects of the fox snake's biology and ecology also may have contributed to the low number of fox snake observations documented during visual surveys at Sterling State Park from 2003-2005. Snakes are often cryptic in color and behavior and are also patchy in their distributions, both spatially and temporally (Ministry of Environment, Lands and Parks 1998). Both these factors can contribute to low detection rates during visual encounter surveys. Eastern Fox Snakes can be cryptic in color, behavior, and habitat use, and also may have a patchy distribution temporally and spatially given the distribution of available habitat within the park. Radio- telemetry data from fox snakes tracked at Sterling State Park from 2003-2005 indicate that fox snakes at Sterling can spend a great deal of time under cover or under ground during the active season in general and particularly during the hot summer months (i.e., July and August). Eastern Fox Snakes and other snakes at Sterling State Park also have been found quite frequently under large concrete slabs, many of which can not be lifted or checked due to their large size and weight. Radio-telemetry of fox snakes at Sterling State Park also has demonstrated how cryptic and difficult it can be to detect fox snakes even when they are above ground. Fox snakes, even large individuals, can be completely hidden from view

Table 8. Summary of results of Eastern Fox Snake surveys conducted by MNFI from 2003-2005 in Sterling State Park in Monroe County, Michigan.

	2003	2004	2005	Total
Total fox snake observations for all surveys	6	11	6	23
Total fox snake observations for LTS and TCS	4	7	0	11
Total fox snake observations for AVS	2	4	6	12
New fox snakes observed during all surveys	6	9	6	21
New fox snakes observed during LTS and TCS	4	5	0	9
New fox snakes observed during AVS	2	2	5	9
New fox snakes captured during all surveys	6	9	5	20
New fox snakes captured during LTS and TCS	4	5	0	9
New fox snakes captured during AVS	2	2	5	9
Fox snake recaptures during all surveys	0	2	0	2
Fox snake recaptures during LTS and TCS	0	2	0	2
Fox snake recaptures during AVS	0	0	0	0
Survey effort - all surveys (survey hours)	290	100	91	481
Survey effort - LTS & TCS (survey hours)	92	70	81	243
Survey effort - AVS (survey hours)	198	30	10	238
Survey effort - all surveys (person-hours)	290	159	171	620
Survey effort - LTS & TCS (person-hours)	92	96	157	345
Survey effort - AVS (person-hours)	198	64	14	276
Detection frequency - # fox snake observations/survey hour for all surveys	0.02	0.09	0.05	0.05
Detection frequency - # fox snake observations/survey hour for LTS & TCS	0.04	0.07	0.00	0.05
Detection frequency - # fox snake observations/survey hour for AVS	0.01	0.07	0.50	0.05
Detection frequency - # fox snake observations/person-hour for all surveys	0.02	0.07	0.03	0.04
Detection frequency - # fox snake observations/person-hour for LTS & TCS	0.04	0.07	0.00	0.03
Detection frequency - # fox snake observations/person-hour for AVS	0.01	0.06	0.36	0.04

Surveys:
LTS = line-transect visual encounter surveys
TCS = time-constrained visual encounter surveys
AVS = additional visual encounter surveys

Note: For 2006 detection frequencies, only used 5 fox snake observations because 1 fox snake observation was recorded while tracking a transmittered snake.

when they are under vegetation or thatch that is even only several inches deep. In 2006, surveyors did not detect and walked by several transmittered fox snakes during line-transect and time-constrained surveys.

Habitat changes or conditions in some of the management units may have contributed to the low number of fox snake observations documented during visual surveys at Sterling State Park from 2003-2005. Habitat conditions in some management units in the park during this study were either unsuitable for fox snakes or made it very difficult to detect fox snakes during visual surveys. For example, habitat restoration efforts in the Campground Restoration Unit removed all ground vegetation and topsoil during the fall/winter of 2003. Bare ground and very open habitat conditions, which did not provide suitable habitat for fox snakes, comprised a good portion of this unit during the surveys in 2004 and 2005. Additionally, the availability of artificial cover was greatly reduced in the Corps Volcano Unit after surveys in 2003 which may have contributed to lower numbers of fox snakes found in this unit in 2004 and 2005. Some of the management units including the Corps Volcano, Hunt Club and Facilities units also contained areas that had very tall, dense ground vegetation which made it very difficult to detect fox snakes during visual surveys in these areas.

Finally, survey conditions or methodology may have contributed to the low number of fox snake observations documented during visual surveys at Sterling State Park. For example, timing of the surveys may have been an important factor. The best time to survey for fox snakes is typically May and June when the snakes are most active and most visible since the vegetation is generally shorter and/or less dense (Harding 1997, Lee 2000). Also, Eastern Fox Snakes are generally active throughout the day, but during periods of intense heat, fox snakes may become more nocturnal (Evers 1994). Consequently, the line-transect and time-constrained surveys at Sterling may have documented such low numbers of fox snakes because they were conducted during late summer and early fall from late July or early August through mid-September when snakes were spending more time under cover or underground or perhaps were more active at night due to warm weather conditions during the day. Also, fox snake detection frequencies for additional visual encounter surveys conducted during the spring and early summer (i.e., May and June) in 2004 and 2005 were higher than those for line-transect and time-constrained surveys in 2004 and 2005 and additional VES in 2003 which were all conducted during late summer and fall (i.e., August and September), providing further evidence that timing of the surveys may have led to low numbers of fox snakes found. Surveys for fox snakes at Sterling State Park in 2006 as part of a continuing and expanded study also found more snakes during additional VES in June than during line-transect and time-constrained surveys in August and early September. Other researchers also have reported difficulty in seeing or finding fox snakes during late summer and early fall (Bekker pers. comm.). These results strongly suggest that spring surveys may be more productive than late summer or early fall surveys and should be considered in future monitoring efforts for this species.

In addition to timing of surveys within an active season, annual weather conditions immediately prior to and during surveys also can affect survey results. The weather during the summer of 2005 prior to and during fox snake surveys was characterized by very high air temperatures and little rain. These weather conditions may have contributed to 2005 survey results in which no fox snakes and very few other snakes were found during line-transect and time-constrained surveys since snakes and other herps are generally not as active or visible during hot, dry weather (Karns 1986). Other researchers in the region also reported finding reduced numbers or fewer snakes in general during the 2005 field season. Overall, the low numbers of Eastern Fox Snakes documented during surveys at Sterling State Park to date were likely a result of a combination of all the factors described earlier.

Although survey results from 2003-2005 may not be conclusive in determining potential impacts of habitat restoration efforts on the fox snake population in Sterling State Park in terms of relative abundance because of small sample sizes, survey and radio-telemetry results to date suggest that fox snake use of particular management units within the park may have been impacted to some degree. A majority of the radio-telemetry locations and locations at which fox snakes were found during surveys occurred along the dike in the southeast corner of the Hunt Club Unit and all along the Interpretive Kiosk Unit and along the lagoon in the northwest portion of the Facilities Unit (Figure 9). These locations were in areas that had undergone some habitat restoration but generally had not been dramatically altered. Prior to this study, Eastern Fox Snakes had been documented in these management units as well as other units in the park such as the Campground Restoration Unit. Surveys and radio-telemetry from 2003-2005 did not document any fox snakes in the Campground Restoration Unit. However, park staff and contractors reported seeing at least one

fox snake in this unit during the study. Restoration efforts in the Campground Unit removed a significant amount of the soil, vegetation and available cover in this unit in 2003 and dramatically changed habitat conditions in this unit which likely impacted fox snakes' use of this area. Another unit in which significant habitat restoration activities have been conducted is the Bean Field Unit. The northern third or half of this unit has been planted with several native prairie plant species to provide a local seed or plant source for habitat restoration efforts on-site. Suitable habitat appears to be available at least in portions of this management unit (e.g., the southern or southeastern portions of the unit), but no fox snakes were found in this unit during surveys from 2003-2005. In 2006, one of the transmittered fox snakes was located a few times in the Bean Field Unit but only in the southwestern portion of the unit that had not been planted or heavily disturbed during habitat restoration efforts. However, some fox snakes were found in areas that had been sprayed and burned for invasive species control, indicating they can certainly tolerate some habitat restoration activities.

The radio-telemetry portion of the study provided additional insights into Eastern Fox Snake ecology and distribution at Sterling State Park. Similar to telemetry results in 2003 and 2004, the fox snakes tracked in 2005 were all located primarily along the dike or along the edge of the lagoons and generally near the water or emergent wetland's edge (i.e., generally within 1-3 m but further away in some cases). Maximum distances between known or documented locations for the four snakes tracked in 2005 were very similar to those documented for radio-tracked snakes in 2003 and 2004. The radio-telemetry results from 2005 also indicate that fox snakes may exhibit some site fidelity and return to the same hibernation site from one winter to the next. The fox snakes returned to the same areas or in some cases the same burrows in the fall of 2005 at which they were initially captured in the spring. The fox snake that was radio-tracked in 2004 and 2005 utilized a similar area or home range within the park in 2004 and 2005 and returned to at least the same general area for overwintering. Fox snakes also may emerge from their overwintering sites a little later in the spring than other snakes, and may stay near their overwintering sites for some time after emergence. One of the fox snakes that was radio-tracked in 2004 was still located at its overwintering site at the end of April in 2005. Also, several of the snakes radio-tracked in 2005 overwintered in or near their initial capture sites at which they were first observed and captured in mid-June of 2005, indicating that fox snakes may stay at or near their overwintering sites until mid-June in the spring. Fox snakes also may enter their overwintering sites earlier than expected. During this study, most radio-tracked fox snakes were at their overwintering sites by mid-September (e.g., Sept. 18 in 2005). It is important to keep in mind though that emergence and ingress times can vary annually dependent upon local weather conditions.

Similar to survey and radio-telemetry results in 2003 and 2004, the Eastern Fox Snakes that were found during surveys or were radio-tracked in 2005 primarily utilized open upland and wetland habitats such as old field, palustrine emergent wetland and palustrine scrub-shrub habitats. Snakes were often found in or under open or thick grass, shrubs or dense emergent vegetation. Similar to snakes tracked in 2003 and 2004, fox snakes tracked in 2005 were primarily found on or along the side of paved trails, in or under concrete slabs or rock riprap along the shore of the open water lagoons, underground in tree root networks or burrows, or on the surface or underground along the embankment of the dike. Again, cover was very important for the fox snakes in the study. The most important habitat feature required by snakes is cover or shelter (Ministry of Environment, Lands and Parks 1998). The use of cover, dense vegetation and underground retreats by Eastern Fox Snakes may represent an important strategy or adaptation for coping with hot weather conditions, avoiding detection by predators and/or surviving in heavily used or disturbed habitats (Lee 2004). The use of natural and artificial cover by fox snakes at Sterling State Park suggests that placing cover boards in areas with suitable habitat may be an effective survey technique for this species (Lee 2004).

Most of the fox snakes that were tracked during the radio-telemetry study hibernated or overwintered underground along the dike or paved trail in the Hunt Club Unit. It was presumed that the snakes overwintered in some sort of burrow or tree root network but this could not be determined based on the snakes' signals. Two of the snakes in 2005 overwintered in a burrow along the paved trail along the fence of the Corps CDF Unit in the northeast corner of the Facilities Unit. All the hibernation sites documented to date were in areas elevated above the water or emergent wetlands although a few of the overwintering sites were located fairly low along the dike's embankment. Other snake species such as the eastern massasauga recently also have been documented as hibernating in uplands or transitional

areas between wetlands and uplands (Wildman pers. comm., Sage pers. comm.). Eastern Massasaugas also have been found to hibernate submerged or partially submerged in water in crayfish, small mammal or other burrows. It is unknown if Eastern Fox Snakes specifically use crayfish or other animal burrows or if they hibernate submerged in water. Protection of suitable hibernacula is critical for maintaining fox snake populations. Thus, known hibernacula within Sterling State Park (e.g., the dike in the Hunt Club Unit) should be maintained until more is known about fox snake overwintering ecology.

Although the numbers of fox snakes found during surveys from 2003-2005 have not changed dramatically, the number of observations of other snake species documented during visual surveys at Sterling State Park has drastically declined during this time period. Over 270 observations of other snake species were documented during surveys in 2003. Only 69 observations of other snake species were documented during surveys in 2004. In 2005, only 15 observations of other snake species were documented for all visual surveys combined. In particular, the number of eastern and Butler's garter snakes have decreased significantly, from 121 and 110 observations of these species, respectively, in 2003 to only 11 and 2 observations of these species, respectively, in 2005. The Facilities, Hunt Club, Corps Volcano and Corps CDF units contained the highest numbers of observations of other snake species in 2003. In 2004, 80-97% fewer observations of other snake species were documented in these four units, and 33-95% fewer in the other units. This may have been due to impacts from the restoration activities, climatic conditions during the spring and summer of 2004 (i.e., cool, wet spring followed by cool, dry summer) and/or different surveyors. Observations of other snake species should continue to be documented and monitored during future surveys.

Finally, although study results from Sterling State Park in 2003-2005 indicate that Eastern Fox Snakes can inhabit highly disturbed and actively managed sites, the long-term viability of this population remains unknown. The fox snake population within the park continues to face a number of threats including highly degraded and limited habitat (at least currently); population isolation; road mortality; intentional and unintentional killing, harassing or disturbance by people; incidental take or impacts due to park management activities (e.g., mowing of large areas reduce or minimize areas with sufficient cover for shelter, foraging, dispersal, and safe passage or protection from predators); and predation. The ongoing restoration efforts may create additional habitat for fox snakes in the future but also can pose threats to the park's fox snake population in the short term. Given that little is currently known about the status and structure (i.e., recruitment rate, sustainable mortality rate, etc.) of the fox snake population in Sterling State Park, efforts should continue to minimize threats to the population and the snake mortality rate within the park. Since fox snakes have been found primarily in the Hunt Club, Interpretive Kiosk and Facilities units during this study, consideration of management activities and ways to minimize potential adverse impacts of these activities on Eastern Fox Snakes is especially warranted in these units.

FUTURE WORK

Continued monitoring of Eastern Fox Snakes at Sterling State Park is needed to continue to assess and provide insight into potential impacts of recent habitat restoration efforts on the fox snake population in the park. A study funded by the Michigan DNR's Wildlife Division was initiated in 2006 to continue the fox snake monitoring and radio-telemetry study at Sterling State Park. Survey and monitoring efforts have basically utilized the same methodology as surveys from 2003-2005. Additional surveys have been conducted in the spring and early summer to compare with results from late summer surveys to evaluate timing and effectiveness of surveys and to try to increase the numbers of fox snake observations. Cover board surveys also were added to the study. The radio-telemetry portion of the study also has been expanded with more snakes added to the study. This study has been conducted in conjunction with a similar study of Eastern Fox Snakes at The Nature Conservancy's Erie Marsh Preserve, located about 10 miles south of Sterling State Park. Erie Marsh also has been undergoing habitat management and restoration in a similar but somewhat less disturbed, larger and more contiguous landscape context. Sharing and comparing results among the two study sites will provide additional insight into Eastern Fox Snake ecology and response to habitat management activities.

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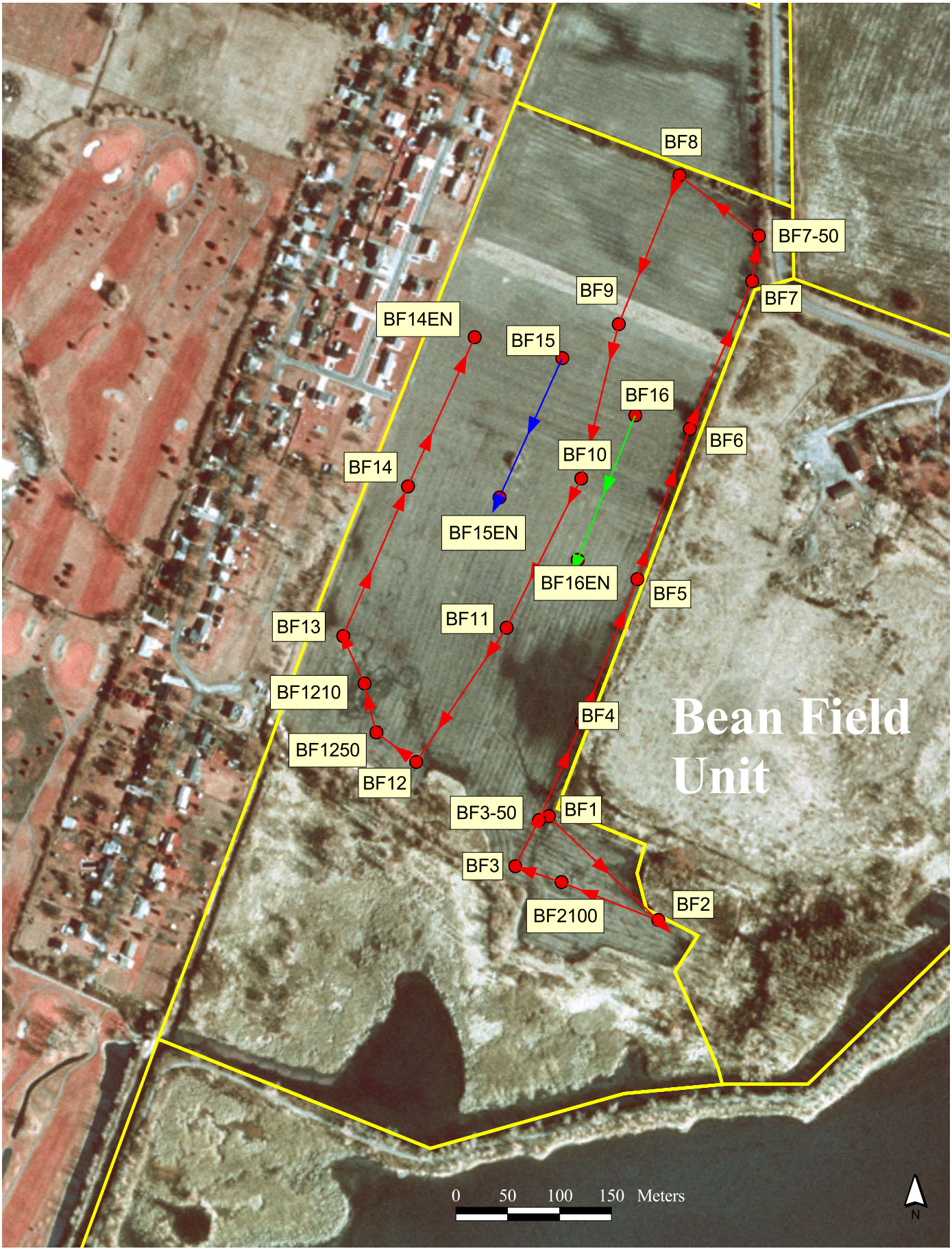
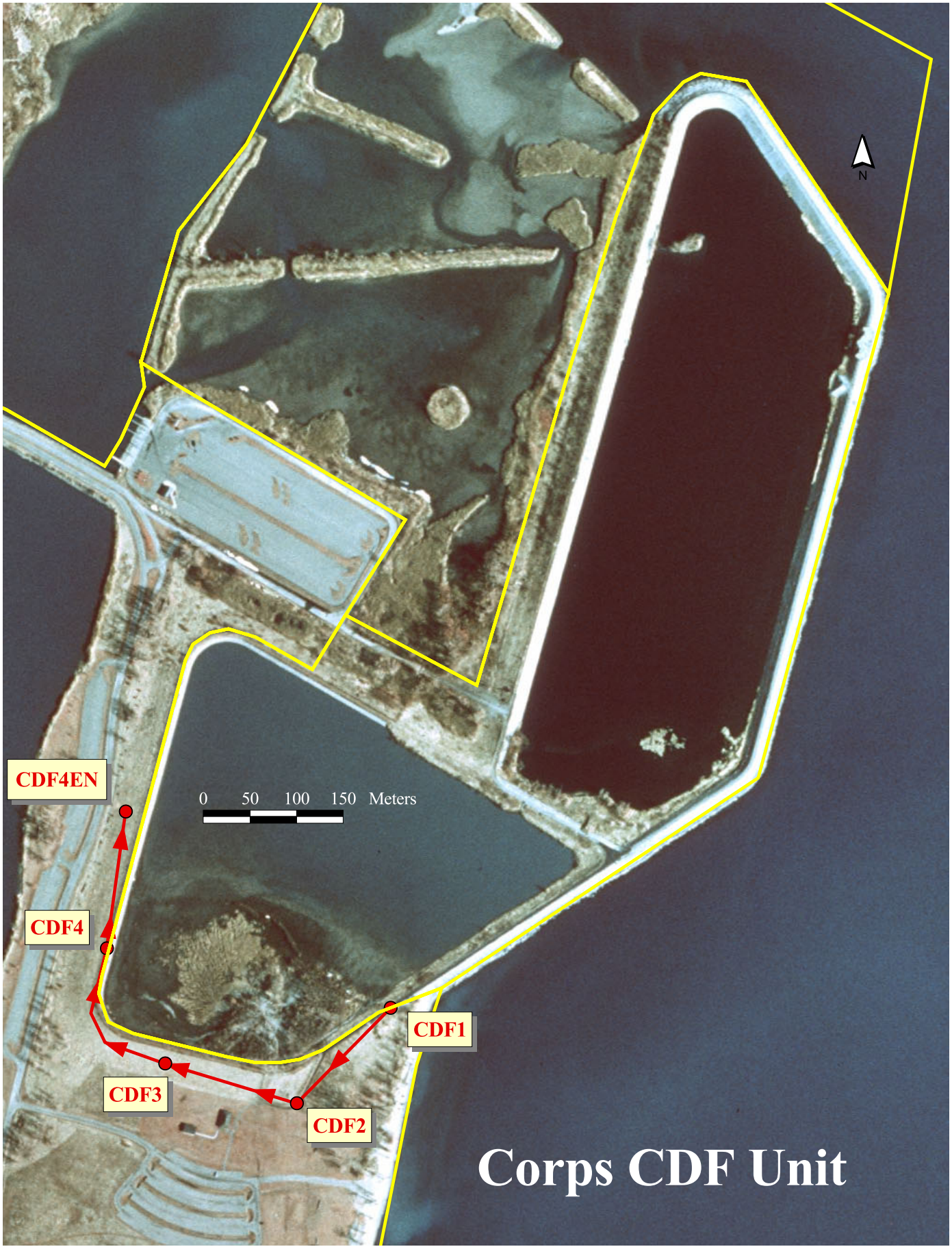
APPENDICES

Appendix I. Maps of the locations of the line transects for the visual encounter surveys conducted by Michigan Natural Features Inventory in all nine management units within Sterling State Park in Monroe County, Michigan.

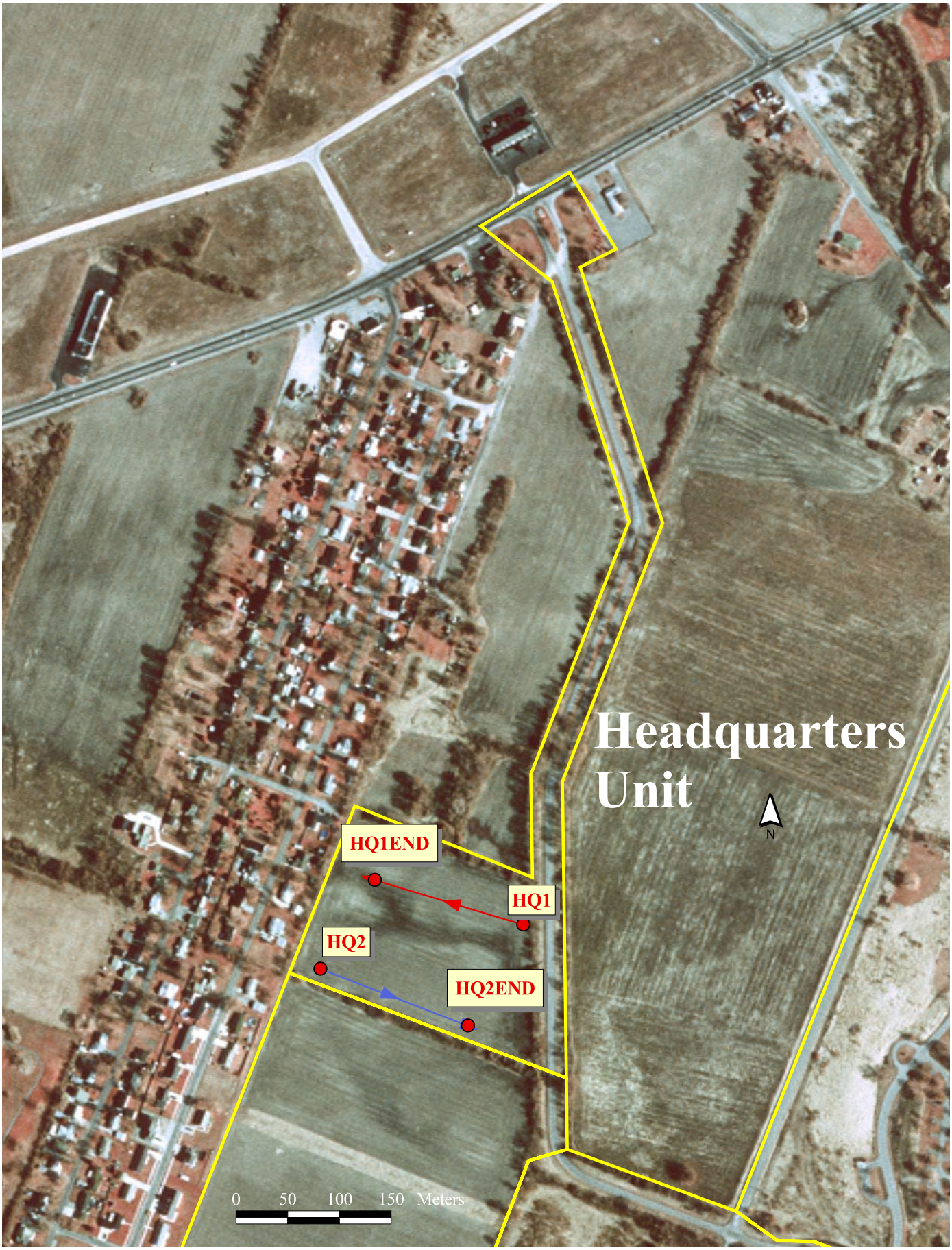

Headquarters Unit
Campground Restoration Unit
North Lagoons Unit
Beam Field Unit
Corps Volcano Unit
Corps CDF Unit
Interpretive Kiosk Unit
Hunt Club Unit
Facilities Unit
0 250 500 750 Meters
Sterling State Park
Management Units

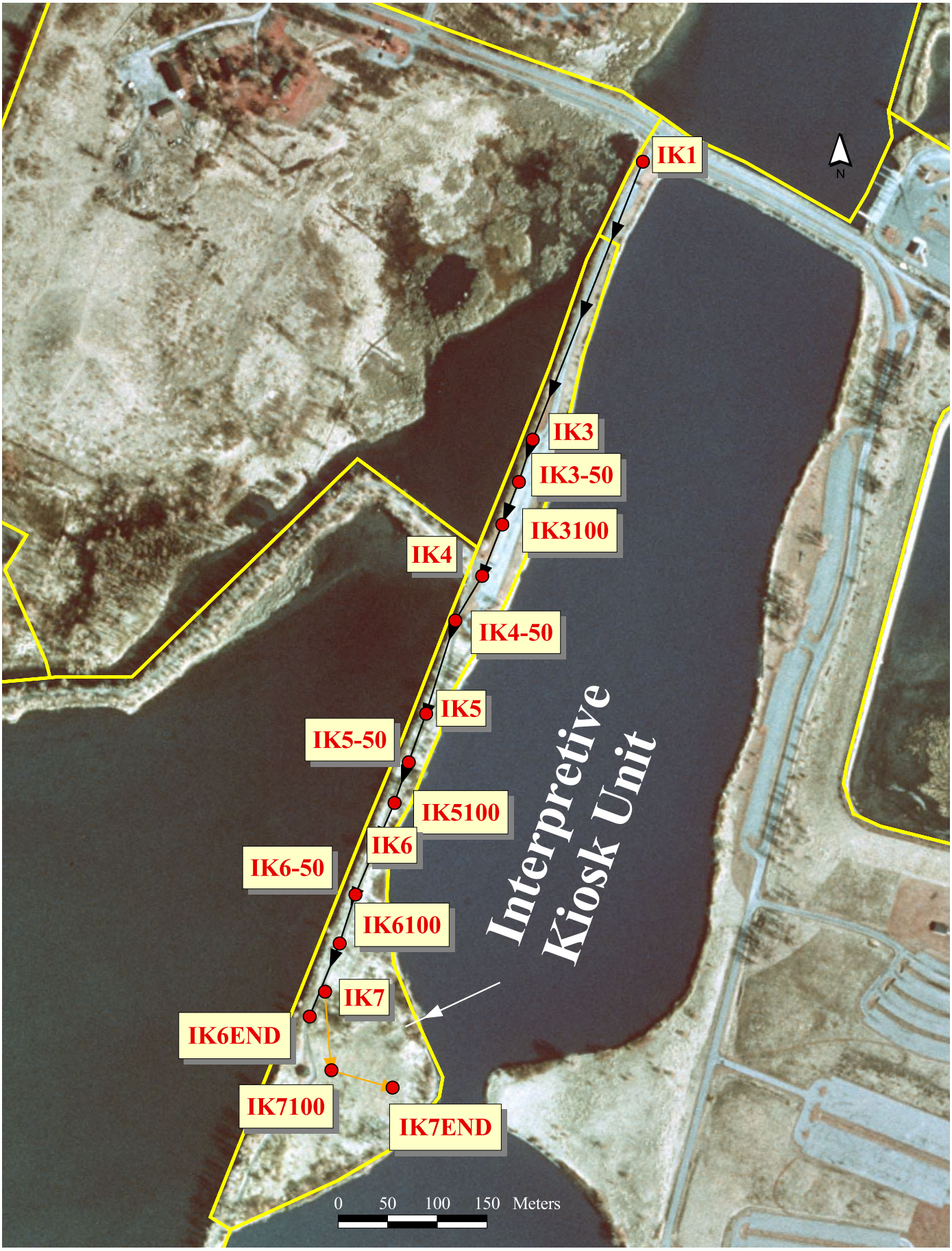

BF8
BF7-50
BF9
BF7
BF14EN
BF15
BF16
BF6
BF14
BF10
BF15EN
BF16EN
BF5
BF13
BF11
BF1210
BF4
BF1250
BF12
BF3-50
BF1
BF3
BF2
BF2100
Bean Field Unit
0 50 100 150 Meters
N


N
CDF4EN
0 50 100 150 Meters
CDF4
CDF1
CDF3
CDF2
Corps CDF Unit


C1
C1-CON
C2
C3
C4
C5
C6
C7
C8
C8-CON
C9
C9-CON
C10
C11
C11CON
C12
C12END
C12CON
C12-CT
C13
C14
C14END
Campground
Restoration
Unit
N
0
50
100
150
Meters


F1
F2
F3
F4
F5
F6
F7
F8
F9
F10
F10CON
F11
F12
F13
F14
F14EN
F14END
Facilities
Unit
0 80 160 240 Meters
N


Headquarters Unit
N
HQ1END
HQ1
HQ2
HQ2END
0 50 100 150 Meters


IK1
IK3
IK3-50
IK3100
IK4
IK4-50
IK5
IK5-50
IK5100
IK6
IK6-50
IK6100
IK7
IK6END
IK7100
IK7END
Interpretive Kiosk Unit
N
0 50 100 150 Meters


NL3END
NL3
NL2
NL1
0 50 100 150 Meters
North Lagoons Unit
N


V1
V11-50
V11
V2
V5-CON
V18END
V12
V8
V3
V6
V4
N
V10
V8100
V7
V18
V17
V13
V8END
V6-100
V17-50
V19
V20END
V17100
V13CON
V16-50
V14
V17END
V16
V19END
V14100
V20
V15100
V15
V14CON
V9STAR
V950
V9END
V9100
Corps Volcano Unit
0 40 80 120 Meters


Hunt Club Unit
0 70 140 210 Meters
N
HC9
HC9END
HC10
HC10EN
HC11
HC11EN
HC8EN
HC8STR
HC8
HC7END
HC7
HC7STR
2003 Points
HC6END
HC6100
HC6-50
HC6
HC6EN
HC6STR
HC5END
HC5
HC4END
HC4
HC3END
HC2
HC1
HC1-50
HC1100
HC1END
2004 Points

EASTERN FOX SNAKE MONITORING AT STERLING STATE PARK

Date:		County:		Unit:			Unit #:		Visit #:		
TimeBeg:		T, R, S:									
TimeEnd:		Surveyor(s):					Survey type:				
Duration:		Weather Summary:		Beg Tair:		Sun:	Wind:		Precip.:		
Transect/Area:				End Tair:		Sun:	Wind:		Precip.:		

SUMMARY: EFS: EGS: NWS: NRS: OTHER:

Time	Transect #	Habitat Description	Species	GPS	Behav	Microhab	Length	Age/Sex	Photo #	Comments

Macros: PFO, PSS, SDG, CAT, UFO, USS, OLD

EFS, NWS, EGS, NRS, UNK

B, R, C, M, F, T, U

Shrub, Sedge, Grass, Rock, Log, Herb, Bare, Island, Detritus, Other; incl. species

COMMENTS (Draw or attach site map showing macrohabitats and transects on back):

Appendix II. Continued.

Appendix III. Michigan Natural Features Inventory (MNFI) Special Animal Survey Form

MICHIGAN STATE UNIVERSITY EXTENSION

SPECIAL ANIMAL SURVEY FORM

Michigan Natural Features Inventory

SURVEYOR INFORMATION

Survey date: __ __ __ __ - __ __ - __ __	Time from: _____ to: _____ am or pm (circle)	Sourcecode: F __ __ __ __ __ __ __ __ M I U S

Surveyors (principal surveyor first, include first & last name): _____

_____

Weather conditions: _____

Revisit to this EO needed? ___yes ___no Why?: _____

ELEMENT INFORMATION

Scientific name: Data sensitive? Y N	EOID:	Occ.# (if known):

FILING

SURVEYSITE:	SITENAME:
QUADCODE:	QUADNAME:

LOCATIONAL INFORMATION

Was the Landowner contacted? Yes _____ No _____ Landowner Name:
_____

Owner Type: _____ Note: _____

DIRECTIONS: Provide detailed directions to the observation (rather than the survey site). Include landmarks, roads, towns, distances, compass directions.

_____

_____

_____

Township/Range/Section _____

County _____ Managed area _____

Was GPS used? Yes _____ No _____ Type of unit _____ Unit number _____

Waypoint name/# (when using Garmin) _____ File name (when using Trimble) _____

OPTIONAL: Latitude _____ Longitude _____

FEATURE INFORMATION (mandatory) Point: <12.5 m in both dimensions, Line: >12.5 m in one dimension, Polygon: >12.5m in both dimensions

Source Feature: Single Source EO _____ Multi-Source EO _____ Conceptual Feature Type: Point _____ Line _____ Polygon _____

TOPOGRAPHIC MAP (mandatory, the website topozone.com can be used as a source for these maps)

1. Attach a photocopy of the appropriate part of a USGS topographic map (1:24,000 scale if available) and write the map scale on the photocopy. Please do NOT enlarge or reduce the map.
2. Indicate on the map the exact location of the observation(s):
   a. When the observed area is ***no larger than a pen point*** on the map (i.e., only a small number of individuals or extremely small patches), place small points on the map indicating the location(s) of the individuals or patches, and label each point with an arrow so they are more easily seen.
   b. When the observed area is ***larger than a pen point*** on the map, (e.g., a population of plants, foraging birds):
      (1) Draw a thin solid boundary line showing the extent of the observed area occupied by the individuals.
      (2) Indicate disjunct patches (polygons) by drawing the boundary for each patch separately.
      (3) If the boundary follows the edge of a lake, stream, road, marsh or other feature, draw the boundary precisely on the edge of the feature.

(4) Where needed, add notes to the map with instructions on where the boundary line is located or if the boundary is shared with other observations.

3. A hand drawn sketch may be included for finer details.

LOCATIONAL CERTAINTY

Is your depiction of the observed area on the map within 6.25 **m (approximately 20ft)** of its actual location on the ground? Y N
If **N,** complete the following:

a. Estimate of uncertainty distance: based on landmarks, elevation, etc., the location of the observed area on the map is accurate to within
_____ meters kilometers feet miles of its actual location on the ground.

b. Is the observed area known to be located within some feature(s) on the map (e.g., wetland boundary, lake, road, trail, highway, contour lines)? Y N

If Y, indicate the boundary within which the observed area is known to be located on the map line, and if applicable, identify the feature (e.g., marsh).

Appendix III. Continued.

IDENTIFICATION
Photograph/slide taken? ___yes ___no If yes, will a copy be submitted to Heritage? ___yes ___no MNFI office: Added to collection?____ (check)

Specimen collected? ___yes ___no Collection # and repository: _____

Identification problems? ___yes ___no If necessary, describe the important animal characteristics you used for identification: _____

_____

SIZE OF ELEMENT OCCURRENCE
Size is a quantitative measure of the area and/or abundance of an occurrence. Components of this factor are 1) area of occupancy, 2) population abundance, 3) population density and 4) population fluctuation.

Type of observation: ___sight ___ song/vocalization ___ road kill ___ trapped ___ other (explain):_____

Abundance (number of pairs, chicks, nests, adults, juveniles, hatchlings, behavior, sex, size of each individual, etc.):

Actual number observed:_____

_____

_____

Number estimated and basis for estimate:_____

_____

_____

_____

Population density (if practical): number:_____ per area unit:_____ (i.e., meters^2, kilometers^2, miles^2, etc.)
Does population fluctuate? (May be particularly relevant to invertebrates):
___ yes ___ no ___ unknown. Explain: _____

Area of occupancy (fill in one):_____meters _____acres _____miles Type of measurement (check one): ___ Precise ___ Estimate

ASSOCIATED SPECIES
List other species observed at this site. Note especially listed species and potential competitors, predators, and prey. Mark appropiate columns.

Species	ID +	ID ?	Number Observed	Notes, observations, etc.

CONDITION:
Condition is an integrated measure of the quality of biotic and abiotic factors, structures and processes within the occurrence, and the degree to which they affect the continued existence of the occurrence. Components of condition for species are: 1) reproduction and health, 2) ecological processes, 3) species composition and biological structure, 4) abiotic physical/chemical factors. Factors to consider: evidence of regular successful reproduction, habitat degradation, disturbance, presence of exotic species, the degree to which ecological processes are sustaining the habitat. Where possible include a comparison to other occurrences.

EVIDENCE OF REPRODUCTION:_____

_____

_____

EVIDENCE OF DISEASE/PREDATION:_____

CONDITION (continued)

HABITAT DESCRIPTION: Describe the specific habitat or micro habitat where this animal occurs. Convey a mental image of the habitat and its features including: land forms, aquatic features, vegetation, slope, aspect, soils, associated plant and animal species, natural disturbances.

LANDSCAPE CONDITION: Describe the condition of the landscape surrounding the elements habitat (i.e., farmland, residential area, pristine forest)

CURRENT THREATS to this occurrence (i.e., grazing, logging, mining, plantations, ATVs, dumping, etc.) Discuss exotics in the next section.

POTENTIAL THREATS to this occurrence:

EXOTICS PRESENT? ___yes ___no. If yes, describe their impacts to the occurrence.

PAST IMPACTS to the occurrence (i.e., logging, , etc.):

TOPOGRAPHY	Aspect:	Slope:	Light:	Position:	Moisture:
Elevation:_____ft. If elevation is a range: Minimum: _____ft. Maximum:_____ft.	___N ___NE ___E ___NW ___S ___SE ___W ___SW	___flat ___0-10 ___10-35 ___35+ ___vertical	___open ___partial ___filtered ___shade	___crest ___upper slope ___mid slope ___lower slope ___bottom	___Inundated ___saturated (wet-mesic) ___moist (mesic) ___dry-mesic ___dry (xeric)

MANAGEMENT AND PROTECTION

MANAGEMENT, MONITORING AND RESEARCH NEEDS for this occurrence (e.g. burn periodically, open the canopy, ensure water quality, control exotics, keep out the ATV's, study effects of browsing)

AREAS IN NEED OF PROTECTION: (e.g. the entire marsh, the slope and crest of slope, the fen and upland, etc.)

If you have any questions regarding this form and its methodology please contact MNFI at (517) 373-1552.
P:\nfi\field forms\special_animal_form.doc
Rev. 10/2003