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Activity Patterns and Spatial Resource Selection of the Eastern Garter Snake (*Thamnophis sirtalis sirtalis*)

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LOYOLA UNIVERSITY CHICAGO

ACTIVITY PATTERNS AND SPATIAL RESOURCE SELECTION OF THE
EASTERN GARTER SNAKE (*THAMNOPHIS SIRTALIS SIRTALIS*)

A THESIS SUBMITTED TO
THE FACULTY OF THE GRADUATE SCHOOL
IN CANDIDACY FOR THE DEGREE OF
MASTER OF SCIENCE

PROGRAM IN BIOLOGY

BY

MATTHEW G. MOST

CHICAGO, IL

MAY 2013

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CHAPTER ONE

INTRODUCTION

The global decline of reptiles and amphibians has been identified as a problem of immediate concern for conservationists and wildlife managers (Roe et al., 2003). Of particular concern for many aquatic and semi-aquatic reptiles is loss of wetlands (Buhlmann and Gibbons, 1997). The United States has lost an estimated 53% of its wetlands in the last 200 years due to habitat destruction (Dahl, 1990). Many wetlands in the mid-western United States have fared even worse. For example, Indiana and Ohio have lost 87% and 90% of their wetlands, respectively (Dahl and Johnson, 1991). Recent trends among conservation organizations and wildlife agencies urge for protection of unique habitat, restoration of degraded habitats and establishment of connective corridors. Yet, the efficacy of these strategies has been difficult to evaluate without knowledge of the physiological and environmental requirements of targeted species (Hilty et al., 2006). If mitigation strategies and policies are to be effective, strategies to maintain viable populations should depend on knowing how species interact with their habitat (Gibbons, 1986; Dodd 1992, Buhlmann and Gibbons 2001). Further, understanding a species' microhabitat can provide important information necessary to improve habitat and create programs for species at risk (Rasmussen and Litzgus 2010). This lack of understanding may be a reason why many snakes are currently threatened by man-made habitat changes

(Mittermeier et al., 1992; Dodd 1993), and why it is difficult to predict how species will respond to habitat alterations.

The field of spatial ecology has proven to be an important tool in understanding species' habitat selection. For instance, many snakes actively search and select habitat patches within their home range (Burger and Zappalorti, 1988; Theodoratus and Chiszar, 2000; Blouin-Demers and Weatherhead, 2001). Habitat selection may be based on abiotic and biotic factors, such as water or moisture (Whitaker and Shine, 2002), biotic chemical cues (Theodoratus and Chiszar, 2000), or structural cues, such as the physical arrangement of objects in space (Plummer, 1981; Burger and Zappalorti, 1988; McCoy and Bell, 1991). Within a species, differing physiological requirements between sexes may result in differing patterns of spatial arrangement by gender, unraveling the mechanisms producing these patterns is complicated by variation imposed by age-specific, sex-specific, and temporal factors (Gibbons and Semlitsch, 1987; Gregory et al., 1987) which are seldom studied or analyzed simultaneously (Roth, 2005). Moreover, because the observer may misinterpret the scale(s) at which habitat selection may be occurring, it is important to investigate selection at multiple scales (i.e. temporal, physiognomy, prey availability) in order to accurately describe or identify factors of habitat selection (Wiens, 1989).

An individuals' mobility will limit available habitat, and movement patterns may differ based on season or sex (Morreale et al., 1984). Measuring movement patterns and the relationship to resources and habitat use can provide additional insight to a species'

niche (Wastell and Mackessy, 2011). Movement increases an animal's risk of predation and incurs energetic costs and should occur primarily in response to seeking suitable habitat, mating or foraging (Gregory, et al., 1987; Bonnet et al., 1999). In some instances, these necessities may drive directional migrations (Dingle 1996). In snakes, daily movement is usually a straight-line path in search of potential mates, prey (Duvall et al., 1985, 1990) or moving between hibernacula and summer activity ranges (Landreth, 1973; Gregory and Stewart, 1975).

Despite high relative abundances and a wide geographic distribution, studies of North American garter snakes (*Thamnophis*) are not geographically equally represented (Rossman et al., 1996). For the Eastern garter snake (*Thamnophis sirtalis sirtalis*), significant studies of its ecology and natural history have occurred in Alberta (Macartney et al., 1989) and Michigan (Carpenter, 1952; Costanzo, 1985; Gillingham and Rowe, 1984). Fitch (1965) ranked the habitat preference as follows: margins of ponds with low vegetation, a silt flat with willows and trees, woodland edges and trees in pastures, native prairie, meadows with introduced grasses, a fallow field in a bottomland, hardwood woodlands, upland fallow fields with weedy vegetation, and finally, disturbed and barren roads and yards. A more thorough understanding of *T. s. sirtalis* distribution is critical for effective conservation and management on a regional level. This information has the potential to elucidate site-specific information concerning habitat selection.

Research Goals

The main objective of this study was to determine environmental factors that best explained habitat selection for Eastern garter snakes (*Thamnophis sirtalis sirtalis*) from

northeastern Illinois. Specifically, I focused on the relationship between seasonal movement and home range size of male and female garter snakes. I analyzed habitat preferences of Eastern garter snakes during 2011 to measure preferred or avoided habitats. This research tested: 1) if the Eastern garter snakes were moving, and if they were moving, was there a difference in movement between males and females or season; 2) what the home ranges are for males and females; 3) do physical or spatial variables play a role in the selection of habitat for Eastern garter snakes, and if they do, do these variables change with season.

I hypothesized that males would be more active and would move more during the spring season than females as a result of seeking potential mates for reproduction. In addition I predicted that both males and females movements would decrease during the summer, as a result of a decrease in the availability of prey and an increase in temperature (Shine, 1979). I also hypothesized that the snake's ectothermic behavior explained habitat selection, as individuals would seek basking sources that achieved a higher temperature in the spring and seek shelter and/or higher coverage in avoidance of higher temperatures in the summer (Brown and Weatherhead, 2000). Findings from this study will contribute to a greater understanding of movement and habitat selection by *Thamnophis sirtalis sirtalis*, and will be valuable in future snake conservation efforts.

CHAPTER TWO

MATERIALS AND METHODS

Study Species

Thamnophis sirtalis has the greatest geographical distribution of any *Thamnophis* species, with populations extending from the Atlantic to the Pacific coasts and further north than any other species of snake in the western hemisphere. Due to great phenotypic and geographic variability, the common garter snake, *Thamnophis sirtalis*, has a confusing taxonomic history. From 1835 to 1853, five western forms of *T. sirtalis*, currently recognized as subspecies (*infernalis*, *parietalis*, *concinus*, *pickeringii*, *dorsalis*), were described as distinct species. A widespread subspecies of garter snake, the Eastern garter snake, *T. sirtalis sirtalis*, exhibits high variation in appearance, including vertebral lateral stripe patterns and color, size and patterns of dorsolateral spots, and darkness of ground color. *T. s. sirtalis* is one of the larger *Thamnophis* subspecies, having the potential to reach a maximum total length of 137.2 cm (Froom, 1972).

Thamnophis spp. have the longest active season and coldest temperature tolerance of any snake in North America (Fitch, 1965). In northern Alberta, males have been observed on the surface as early as the 2nd week of April (Macartney et al., 1989). In Michigan, *T. sirtalis* was the first species of snake active in spring and last to enter hibernation in fall (Carpenter, 1952). Garter snakes can travel long distances, for example *T. s. parietalis* from Manitoba and Alberta can move 4.3 - 17.7 km between hibernation

sites and summer feeding grounds (Gregory and Stewart, 1975; Lawson, 1989).

Thamnophis sirtalis sirtalis is a generalist, and feeds on a wide variety of prey items, including terrestrial and aquatic invertebrates, fish, amphibians, mammals, and birds. Fecundity in *Thamnophis spp.* is highly plastic being affected by body size, diet, and other environmental factors (Gregory and Larsen, 1993).

Currently, the Illinois Department of Natural Resources (IL DNR) does not recognize the Eastern garter snake (*T. s. sirtalis*) as a subspecies of concern and therefore offers no protection. However, IL DNR recognizes a population decline in other reptiles and amphibians.

Study Area

Fieldwork was conducted from March to November 2011, at the Elawa Farm site (Figure 1) on the property of the Lake Forest Open Lands Association (LFOLA) in conjunction with a on going herptofauna survey by the Wildlife Discovery Center (Figure 2). The LFOLA is a private not-for-profit corporation and land trust that supports land preservation and conservation through educational and community programs. The Lake Forest Open Lands Association maintains over 800 acres of open space in eight nature preserves, and oversees more than 350 acres of pristine and restored prairies, wetlands and woodlands. During the late 1980's, the Lake County Forest Preserve and the City of Lake Forest purchased the 450-acre Middlefork Savanna Forest Preserve, and acquired an additional 195-acre block of land in 1998, including the 16-acre Elawa Farm site. The original farm, built by the A. Watson Armour family in 1917, was 128 acres and included

the gatehouses, superintendent's house, and numerous other outbuildings, some of which are still standing.

Located 9.6 km west of Lake Michigan, Elawa Farm consists of a mosaic of oak savanna and woodlands, wet and mesic prairies, sedge meadows and marshes (Table 1). Chicago Wilderness has identified Middlefork Savanna as one of the most important sites for biodiversity in northeastern Illinois (<http://www.lcfpd.org>). However, potential threats to the site include invasion by herbaceous exotic flora (especially garlic mustard, *Alliaria petiolata*, and alder buckthorn, *Rhamnus frangula*). Active management of vegetation, concurrent with this study, included manual removal of invasive shrubs, herbicide application, and annual rotations of prescriptive burning.

Table 1. Available habitats (% extent) at Elawa Farms (Lake Forest, IL). See Figure 1 for outlined surveyed area

Habitat Type	Description	% Extent
Field/Meadow	A low-lying piece of grassland covered with coarse grass, often boggy and near a river.	21.2%
Forest	A dense growth of trees and underbrush covering a large area.	64.8%
Freshwater Wetland	An area of land covered intermittently with shallow water or has soil saturated with moisture.	6.8%
Marsh	A tract of soft wetlands characterized by monocotyledons.	4.9%
Urban	A disturbed area of land that has been cleared for settlement, grazing or cultivation.	2.3%

Snake Presence and Absence Data Collection

As a volunteer of the Wildlife Discovery Center and under its auspices, I cataloged native reptiles and amphibians found on Elawa Farms (Lake Forest, IL) (IDNR Permit Nos. NH11.5458). This entailed meandering surveys and identification of native reptiles and amphibians. Location of native species was documented by GPS, and these data coordinates were mapped. Data generated from this project were analyzed as part of my Master's thesis work at Loyola University Chicago. Subsequently on October 19, 2011, I received Loyola IACUC approval (ACTS No. 161) to collect data and handle snakes (see methods section). Data generated after October 19, 2011 was collected as a Biology M.S. student.

Meandering surveys were conducted from 0600 to 1600 hours, three days a week, twice a day in the morning and mid-afternoon, weather permitting, in an attempt to find Eastern garter snakes. Surveys included point of interest markers that were repeatedly visited as a result of GPS coordinates. Meandering surveys were supplemented with turning rocks and logs, peeling bark, and digging through leaf litter. Attempts were made to record both the snakes' body and basking site temperature before capture.

Temperatures were recorded using a MT 4 mini temp non-contact thermometer with laser sighting (Rayteck Corporation, Santa Cruz, CA). Snakes were captured by hand after temperature measurements, and for each snake the date, the time, and the location of capture were measured using a handheld GPS unit (Garmin eTrex Venture HC GPS Receiver, Garmin Ltd.©). When snakes were not present, data was collected using a

handheld GPS unit (Garmin eTrex Venture HC GPS Receiver, Garmin Ltd.©) and an assessment of physical habitat features surrounding the location were measured.

Figure 1. Aerial photograph of study site outlined in orange at Elawa Farms (Lake Forest, IL)

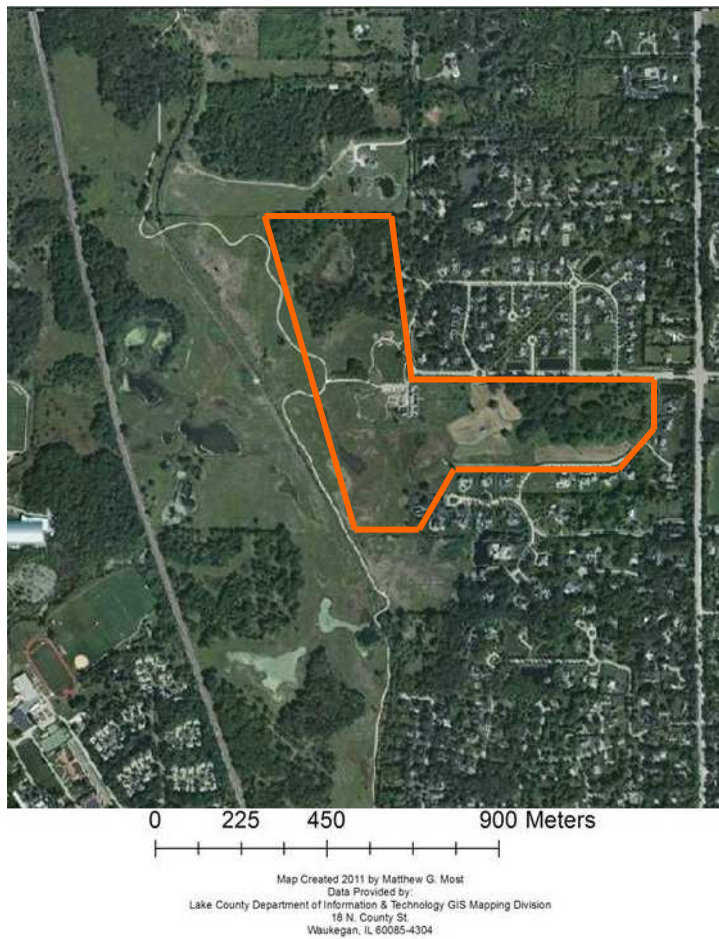
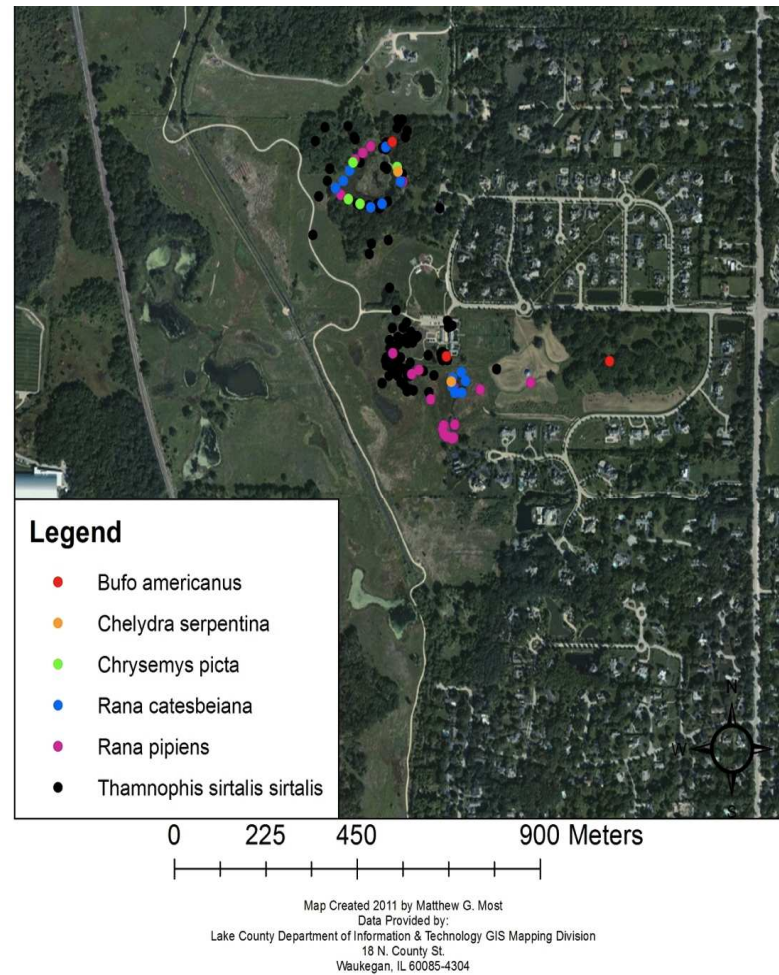


Figure 2. Reptile and amphibian species identified for a 2011 Lake Forest Open Lands Association herpetofauna survey



For each snake captured, a visual inspection for good motor skills, muscle tone, and dermal wounds was conducted as an indication of good health. Each individual was scanned with a reader to check for the presence of a passive integrated transponder (PIT) tag (1 x 12mm, Model 2028, EZid, LLC). If an individual was previously captured and recorded to have a PIT tag I recorded the tag number. I placed each snake into a ventilated snake bag while assessing the habitat features at the capture site (Table 2). The landscape features I recorded were specific to a 0.3 m x 0.3 m square plot around the capture site. All parameters were visually assessed, and the MT 4 mini temp non-contact thermometer with laser sighting measured the substrate temperature.

Table 2. Physical variables measured at each Eastern garter snake (*Thamnophis sirtalis sirtalis*) capture location

Variable	Definition
Basking type	Type of structures available and utilized for basking including: bare ground, coarse woody debris, herbaceous vegetation, leaf litter, woody vegetation, or concrete
Cover %	Area within location available for individual to hide. Must allow individual to conceal at least $\frac{3}{4}$ of body
Cover type	Types of cover available for thermoregulation including: bare, coarse woody debris, herbaceous vegetation, leaf litter, or woody vegetation
Vegetation type	Vegetation at site of capture including: bare, aquatic, low or tall graminoid, reed, or woody vegetation.
Substrate temperature	Temperature of exposed substrate/basking source, not shaded (°C)

Captured snakes were transported to the Wildlife Discovery Center. I measured each snake's mass (Salter Brecknell Model 311 digital scale, Brecknell USA, Fairmont, MN), snout-vent length (SVL), total length, and tail length. SVL is the distance from the

tip of the snout to the posterior edge of the anal plate. Total length is the distance from the tip of the snout to the posterior edge of the tail's tip or nipped portion of the tail.

To verify the gender, I inserted a lubricated surgical probe into the vent on either side of the snake's mid-line, and gently pushed towards the tail until the probe met resistance. The inserted probe's distance was marked on the probe and placed on the subcaudal scales found on the ventral surface of the snake's tail. For females, the length of the insertion equaled 1-3 subcaudal scale lengths, and in males the distance was 9-15 subcaudal scales in length.

Individuals not previously tagged and in good health were prepped for PIT tagging. Individuals were blotted dry and the skin between the first and second lateral scale rows (2nd scale row from the ventral surface) located mid-body on the right side were cleaned with a topical antiseptic (chlorhexidine) using a 0.1 x 0.1 m gauze pad. A single use, sterile, disposable syringe with preloaded tag (1 x 12 mm, Model 2028, EZid, LLC) delivered the tag. The injection site was cleaned with chlorhexidine using a gauze pad, re-dried, and sealed with loctite super glue (Rowe and Kelly, 2005). Each tag was uniquely numbered. Following PIT tagging, the snake was observed for 5 minutes for any abnormalities such as bleeding at the injection site or a reduction in movement. Snakes were returned to their capture site, and observed again for 5 minutes. No PIT tagged snakes were found dead during the study. No gravid or neonate snakes were used in the PIT tagging procedure.

GPS coordinates were converted to universal transverse mercator (UTM) coordinates (grid based method of specifying locations) and used to create shapefiles

within ArcView (Version 10.0, ESRI, Redlands, CA) for *T. s. sirtalis* on two scales: 1.) season and 2.) gender. To minimize redundancy, snakes captured more than once were included once per day at their initial capture location of the sampling day.

Calculation of Movement

To calculate movement for both male and female *Thamnophis sirtalis sirtalis*, the shapefiles created for gender and season were used in ArcView (Version 10.0, ESRI, Redlands, CA). The database was sorted by RFID's to identify successive captures for individual snakes during a season (i.e. spring and summer). I measured straight-line distances of > 2 m between successive captures with the measure tool for ArcView (Version 10.0, ESRI, Redlands, CA). These measurements were made each season (Turchin, 1998).

Calculation of Home Range

To calculate home range for individual *Thamnophis sirtalis sirtalis*, the shapefiles created for gender and season were used within ArcView (Version 10.0, ESRI, Redlands, CA). The shapefiles allowed for individual captures to be plotted on a geographically-referenced aerial photograph of the study site. The home range was calculated by 100% minimum convex polygons (MCP) using the Hawth's Tools extension (Beyer, 2004) for ArcView (Version 10.0, ESRI, Redlands, CA). The MCP method describes the area used by enclosing all observations within a polygon linking all peripheral points with no concavities in its form (Jennrich and Turner, 1969). The benefits of this approach are its simple and straight-forward nature, comparability to other studies, and inclusion of interior areas likely to act as corridors (Kingsbury, et al., 2003). The limitations of this

approach is that a polygon cannot be created with less than three unique input points.

Home ranges were only calculated for individuals who had been captured three or more times for 2011.

Landscape (Physical) Data Collection

Emergence from hibernation occurred around mid-March. *T. s. sirtalis* were observed moving to basking areas immediately outside of hibernacula, identified as crayfish burrows and a crack within the foundation of a building. The burrows were created by the Devil Crayfish, *Cambarus diogenes* (Taylor and Anton, 1999). *C. diogenes* is a burrowing crayfish that spends most of its life cycle in individually excavated underground chambers (Grow and Merchant, 1980). The burrows have chimneys ranging in height from a low mound to 30 cm (Grow and Merchant, 1980). *C. diogenes* tends to inhabit wetlands and moist woodlands and are one of the primary burrowing species in the central United States (Taylor and Anton, 1999). Crayfish burrows and other hibernacula were identified due to both observation of snakes entering and exiting structures, presence of silty clay like soil on freshly emerged snakes, and the high density of individuals surrounding location(s). Hibernacula locations were marked using a handheld GPS unit (Garmin eTrex Venture HC GPS Receiver, Garmin Ltd.©).

Locations of hibernacula in 2011 were converted into UTM coordinates from the obtained GPS coordinates to project data on an established coordinate system within ArcView. The data set with calculated UTM coordinates was then used to create shapefiles within ArcView (Version 10.0, ESRI, Redlands, CA). Shapefiles created for hibernacula were specific to the category of hibernacula (i.e. crayfish burrow or crack in

the foundation of a house). Landscape data for hydrology and elevation were collected by the Lake County Department of Information and Technology GIS/Mapping Division.

Spatial Data Collection

I calculated the distance from each snake to other members of the population, potential prey items (i.e. *Rana catesbeiana*, *Rana pippiens*, *Bufo americanus*, *Microtus pennsylvanicus*), and landscape features (i.e. nearest water feature and 2011 hibernacula). These measurements allowed for an analysis of spatial factors that may contribute to habitat selection.

Population Estimate

The number of individuals initially tagged during spring and recaptured in summer was used to estimate population size. The corrected model (unbiased model) used in the calculation was $N = [(M+1)(C+1)/(R+1)] - 1$, where N = the total population size, M = total number of individuals marked, R = recaptured individuals, and C = total number of individuals marked/unmarked second time (Chapman, 1951).

Movement and Home Range Analysis

I compared distanced moved in a season and home ranges of males and females in 2011 using a Mann Whitney U-Test (R Statistical Package).

Habitat Selection Analysis

The collected data were used to create several categorical classification trees (R Statistical Package). The creation of classification trees allowed for an analysis of the physical and spatial variables that best predicted the presence (habitat selection) of *T. s. sirtalis*. Classification and regression trees (Breiman et al. 1984, Clark and Pregibon

1992, Ripley 1996) are modern statistical techniques that are ideally suited for modeling unbalanced ecological data. These trees explain variation in a single response variable by one or more explanatory variable(s). Starting with all data represented by a single node at the top of the tree; the tree is grown by repeated binary splitting of data. At each split data are partitioned into two mutually exclusive groups, each of which is as homogeneous as possible. The splitting procedure is then applied to each group separately (De'ath and Fabricius, 2000).

The terminal or unsplit node(s) represent groups of data formed by the tree, otherwise termed "leaves" of the tree. The splitting procedure is continued until an overlarge tree is grown, which is then pruned back to the desired size. This tree is the "best predictive tree" because it provides the most accurate predictions (De'ath, 2002). Trees are summarized by their size, number of leaves, and overall fit, otherwise known as relative error (De'ath and Fabricius, 2000). To find the best predictive tree, cross-validation was used to obtain an honest estimate or true (prediction) error for all trees (Breiman et al, 1984).

CHAPTER THREE

RESULTS

Population Estimate

A total of 97 *Thamnophis sirtalis sirtalis* were captured and tagged during the study period (Figure 3). Individuals marked and recaptured were used to estimate population size. 69 snakes were marked in spring, and 13 were recaptured in summer. Estimated population size was 209 snakes for Elawa Farms (Lake Forest, IL).

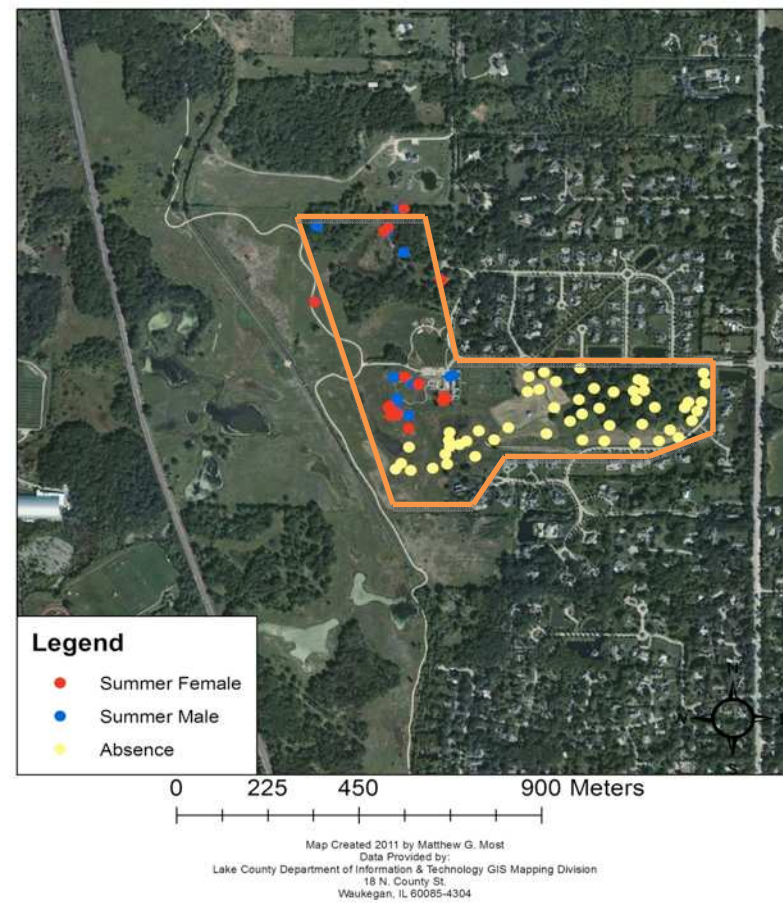
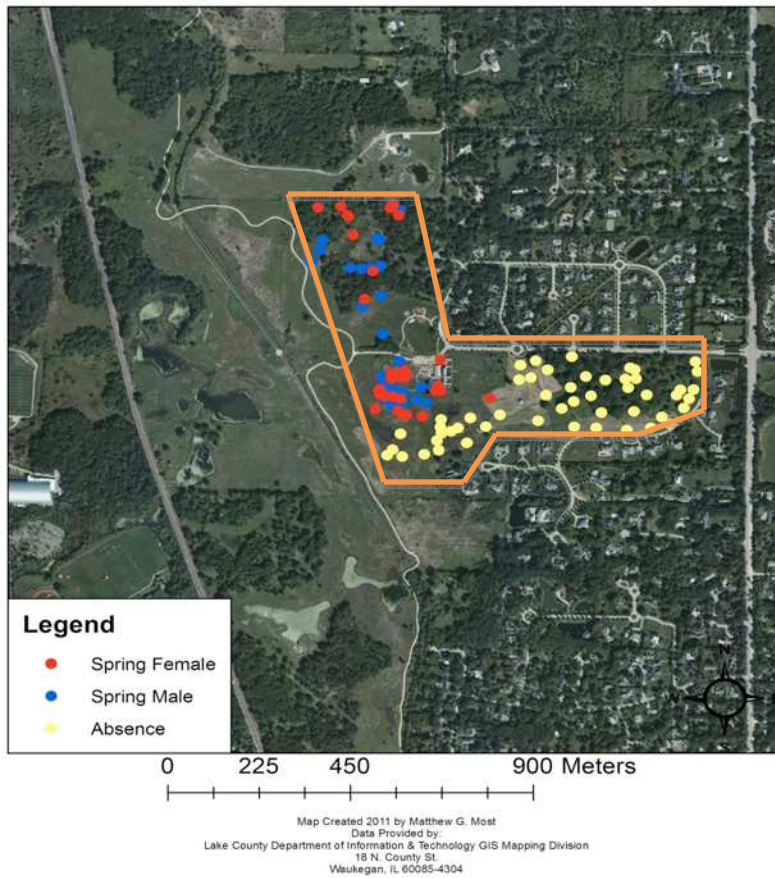
Movement

Unfortunately, individuals tagged during one season were not always recaptured during that season. 35 females and 33 males were recaptured in spring, and 27 females and 19 males were recaptured in summer. During spring, males averaged 16.42 ± 36.86 m (S.D.), while females averaged 11.74 ± 33.29 m (S.D.) ($W=1258$, $p=0.3367$, no significant difference). Summer movement was lower for males and higher for females, males averaged 1.16 ± 5.20 m (S.D.) and females averaged 18.67 ± 37.71 m (S.D.) ($W=414.5$, $p=0.0087$, a significant difference) (Figure 4).

Home Range

Unfortunately, individuals tagged were not always recaptured three or more times during 2011. Home ranges were calculated for 2 males and 5 females. For 2011, males' home range averaged 60.48 ± 62.73 m² (S.D.), while females averaged 549.2 ± 125.16 m² (S.D.) ($W=0$, $p=0.095$, no significant difference) (Figure 5).

Figure 3. Aerial view of Elawa Farms (Lake Forest, IL) identifying all captured male, female and absence locations for *Thamnophis sirtalis sirtalis* A) spring B) summer



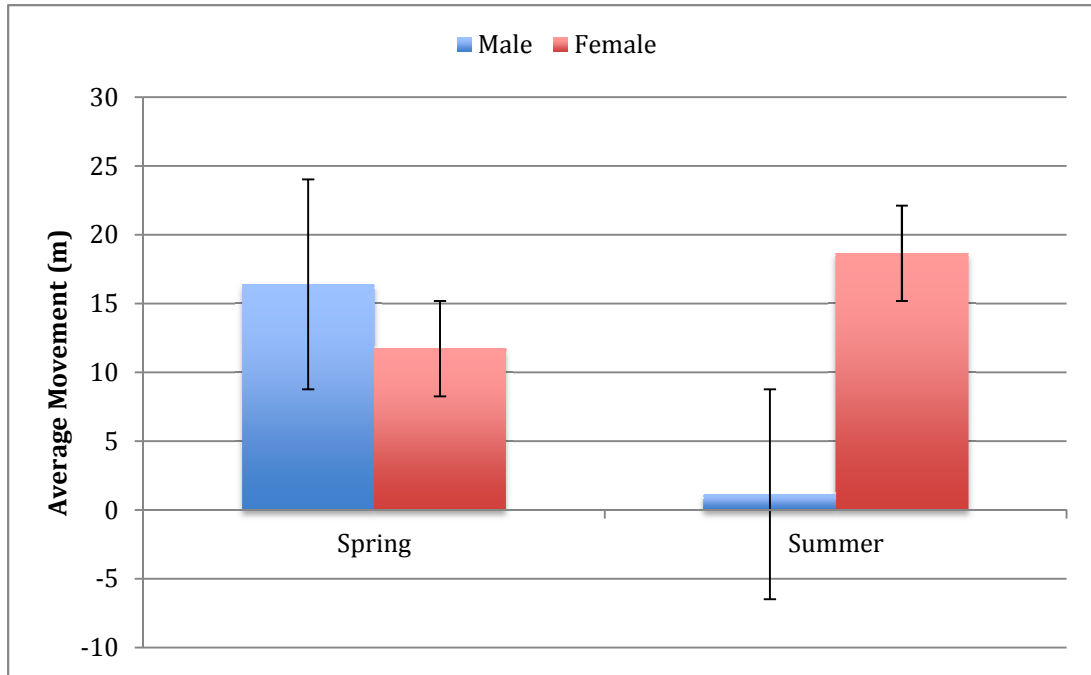


Figure 4. 2011 average seasonal movement for *Thamnophis sirtalis sirtalis* at Elawa Farms (Lake Forest, IL)

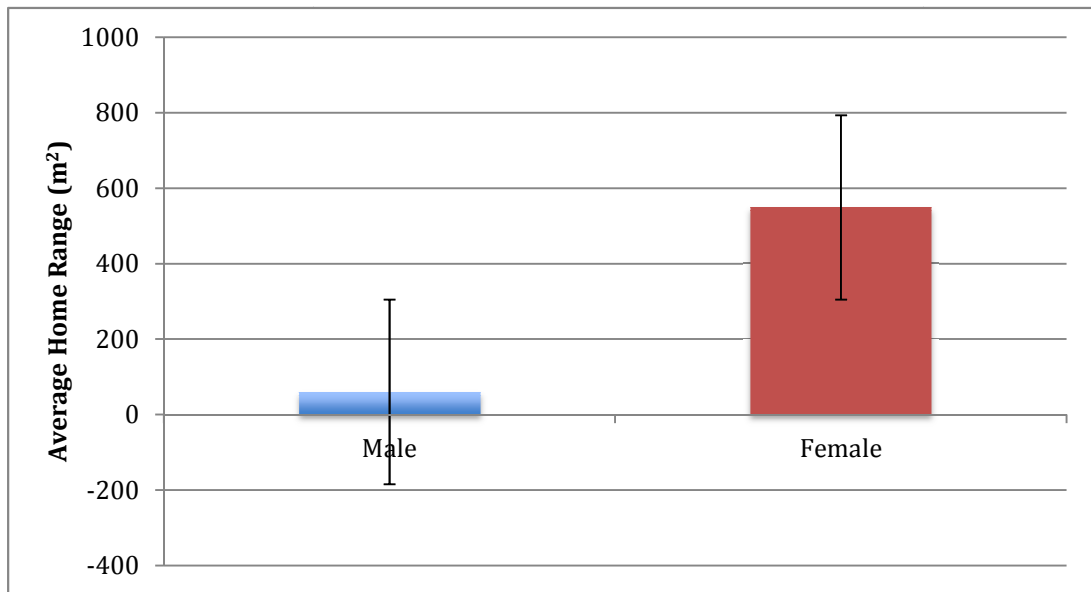


Figure 5. 2011 average home range for *Thamnophis sirtalis sirtalis* at Elawa Farms (Lake Forest, IL)

Habitat Selection

Nine classification trees, by season and gender, were constructed using physical predictors (P), spatial predictors (S), or physical and spatial predictors (P+S) (Table 3). From these analyses, twenty-seven models were produced. Physical predictors used in the model are basking source, cover source, elevation, habitat, percent of cover, and vegetation type. Spatial predictors are distance to *Bufo americanus*, furthest prey item, house hibernacula, *Microtus pennsylvanicus*, nearest crayfish burrow, nearest female, nearest male, nearest prey item, nearest water source, *Rana catesbeiana*, and *Rana pippiens*.

T. s. sirtalis' presence for 2011 was best predicted by spatial factors, which was location of nearest crayfish burrows ($R^2 = 94 - 98\%$) (Table 4) (Figure 6). Reviewing physical predictors, solely, presence is best explained by elevation < 687 ft and vegetation type being aquatic, and low or tall graminoid ($R^2 = 86\%$). To examine other physical and spatial variables the best predictor was removed from the analysis and alternative splits were examined. For instance, removal of distance to nearest crayfish burrows results in presence of *T. s. sirtalis* being best explained by distance to nearest male < 89.75 m ($R^2 = 91\%$), for 2011. Exclusion of elevation in analyses of physical predictors results in *T. s. sirtalis*' presence being best predicted by vegetation type ($R^2 = 79\%$). Other physical predictors include category of basking, habitat, substrate temperature ($^{\circ}\text{C}$), and percent of cover.

Figure 6. Aerial view of Elawa Farms (Lake Forest, IL) identifying 2011 hibernacula



0 225 450 900 Meters

Map Created 2011 by Matthew G. Most
Data Provided by:
Lake County Department of Information & Technology GIS Mapping Division
18 N. County St.
Waukegan, IL 60085-4304

Table 3. Variables used in the study at Elawa Farms (Lake Forest, IL). Variable character denoted by P = Physical, or S = Spatial; and type by N = Numeric or C = Categorical

Variable	Character	Type	Values
Basking source	P	C	Bare, coarse woody debris, concrete, herbaceous vegetation, leaf litter, woody vegetation
Cover source	P	C	Bare, coarse woody debris, herbaceous vegetation, leaf litter, woody vegetation
Distance to <i>Bufo americanus</i>	S	N	0 - 249.7 m
Distance to furthest prey item	S	N	30.3 - 442.5 m
Distance to house hibernacula	S	N	0 - 647.7 m
Distance to <i>Microtus pennsylvanicus</i>	S	N	0 - 203.3 m
Distance to nearest crayfish burrow	S	N	0 - 693.6 m
Distance to nearest female	S	N	0 - 642.6 m
Distance to nearest male	S	N	0 - 650.8 m
Distance to nearest prey Item	S	N	0 - 131.6 m
Distance to nearest water source	S	N	0 - 182.9 m
Distance to <i>Rana catesbeiana</i>	S	N	7.8 - 314.8 m
Distance to <i>Rana pippiens</i>	S	N	3.6 - 442.5 m
Elevation	P	N	202.4-212.1 m
Habitat	P	C	Field/meadow, forest, freshwater wetland, marsh, urban
Percent of cover	P	C	0, 3, 10.5, 20.5, 38, 63, 88 %
Vegetation type	P	C	Aquatic, low or tall graminoid, reed, woody
Substrate temperature	P	N	-17.8 – 34.1° C

Table 4. Regression tree analyses of *T. s. sirtalis* using physical and spatial predictors (P+S), only physical predictors (P), or only spatial predictors (S). All P+S and S regression trees had an equal Error, Size, and R^2 and are both represented by P+S below. The best predictor of presence for *T. s. sirtalis* is indicated

Sampling Period	Gender	Predictors	Size of Tree	Predictor	Error	R^2
2011	Male & Female	P+S	2	Crayfish burrow distance < 89.96 m	0.05	0.95
		P	4	Elevation < 209.39 m	0.14	0.86
	Male	P+S	2	Crayfish burrow distance < 89.96 m	0.05	0.95
		P	3	Elevation < 206.96 m	0.14	0.86
	Female	P+S	2	Crayfish burrow distance < 89.57 m	0.05	0.95
		P	3	Elevation < 207.57 m	0.16	0.84
Spring	Male & Female	P+S	2	Crayfish burrow distance < 99.9 m	0.06	0.94
		P	3	Elevation < 208.79 m	0.20	0.80
	Male	P+S	2	Distance to another male < 55.96 m	0.02	0.98
		P	3	Elevation < 206.96 m	0.14	0.86
	Female	P+S	2	Crayfish burrow distance < 82.14 m	0.06	0.94
		P	3	Elevation < 207.57	0.12	0.88
Summer	Male & Female	P+S	2	Crayfish burrow distance < 89.57 m	0.02	0.98
		P	3	Elevation < 206.96	0.18	0.82
	Male	P+S	2	Crayfish burrow distance < 86.36 m	0.05	0.95
		P	3	Elevation < 86.36 m	0.25	0.75
	Female	P+S	2	Crayfish burrow distance < 89.57 m	0.03	0.97
		P	3	Elevation < 86.36 m	0.19	0.81

CHAPTER FOUR

DISCUSSION

Movement

In snakes, movement usually follows a straight-line path in search of patchily distributed potential mates or prey animals (Duvall et al., 1985, 1990). Results of this study indicated males moved a larger distance in spring than summer. The seasonal movements by males may be the result of mate searching (Secor, 1994; Rivera et al., 2006; Todd et al., 2008). Previous research has indicated that this species is polygynous (Rivas and Burghardt, 2005) and that mating may occur with congregation, where adult male dispersal is a mate-seeking strategy.

Female movement increased during summer. This increase may be a result of social behavior whereby gravid females aggregate in midsummer prior to parturition (Gregory, 1975; Gordon and Cook, 1980). Viviparous gravid snakes spend a large portion of gestation basking to optimize thermal conditions of developing offspring (Shine, 1993; Brown and Weatherhed, 2000). As a result, an increase in movement may be due to females seeking potential cover (i.e. hibernacula) or basking and foraging sites (Winker et al., 1995; Perrin and Goudet, 2001) that have been previously used. Females used in an analysis of movement were often found in areas with a higher abundance of potential prey items, and may be seeking areas of higher temperature (Gibson et al., 1989).

Home Range

Variation in home range size is often attributed to the availability of resources (i.e. prey availability) and energetics (Duvall et al., 1985; Madsen and Shine, 1996; Whitaker and Shine, 2003). In nature, resources are often patchy and distribution affects both population and communities (Chesson, 2000). In all species, mobile animals select and exploit resource points from an array of possible resource points. Consistent with many other studies, individual variation in movement and seasonal activity patterns were observed (Plummer and Congdon, 1994; Secor, 1994). Larger individuals should travel larger areas than smaller individuals to satisfy a greater energy requirement (Shine, 1987).

Females had a larger home range than males, but this difference was not found to be significant. In the case of ectotherms home ranges can be largely affected by characteristics of the habitat type enhancing thermoregulation (Ward et al., 1976; Blouin-Demers and Weatherhead, 2001; Row and Blouin-Demers, 2006). Structural features, including coverage strongly influence a snake's habitat use (Reinert, 1993) due to thermoregulation, and as a result the relative availability of preferred habitat may contribute to a snake's home range.

Influence of Physical and Spatial Variables

Clustering occurred at distances of < 11.46 m in spring and < 15.33 m in summer. Clustering is often a result of selection for habitats containing spatially or temporally limited resources including food, basking sites, hibernacula or mates (Gregory et al., 1987). Many snakes actively select certain fragments of their habitat (Burger and

Zappalorti, 1988; Theodoratus and Chiszar, 2000; Blouin-Demers and Weatherhead, 2001). This process of habitat selection is due to temperature requirements, sensory adaptations, and limblessness of snakes that may require them to select very specific microhabitats and microclimates (Moore and Gillingham, 2006).

Spatial variables best predicted *T. s. sirtalis*' presence and included distance to nearest crayfish burrow and males. Physical predictors included elevation, basking site, habitat, substrate temperature, and percent of coverage. Alternative predictors for *T. s. sirtalis*' presence had a lower R^2 value. The initial tree for predicting *T. s. sirtalis*' presence used distance to nearest crayfish burrow, and when this variable was dropped, the resulting tree was weaker in its explanation (95.1 vs. 91.2 %). The analyses additionally predicted presence of females in field/meadow and urban habitats. The analyses also displayed how alternative predictors may lead to a weaker understanding of competing explanatory variables, when variables are dropped from the model. Spatial variables predicted *T. s. sirtalis*' presence considerably better than physical variables.

Meandering surveys solely indicate relationships, not causality, and follow-up experiments are necessary to determine reasons for the observed distribution of this species. The availability of potential hibernacula may be coincidental with the size of home range. This may be suggestive in an analysis of results, especially since females had a significantly higher movement in summer and larger home range than males, and may be a result of seeking shelter in nearby hibernacula, as individuals occupied a distinct core area during the sampled seasons.

The suite of gender specific variables examined within this study is not-all inclusive, and potentially important behavioral or habitat variables may have been omitted. A complete description of spatial patterns is complicated by variation in age-specific, sex-specific, and environmental factors. These factors are further complication by seasonal activity and spatial phenomena (i.e. patchiness of vegetation, slope, soil parameters, and plant species) (Gibbons and Semlitsche, 1987; Gregory et al., 1987).

Future Directions

This study dealt with a subspecies of garter snake monitored during 2011. An examination of this species' movement and activity allowed for an analysis of independent variables that best described habitat selection. The area selected for this research is located within an urban area and can be used in further investigations of corridors and habitat fragmentation in the Midwest. Human-induced disturbances have fragmented many habitats (Diamond et al., 1987; Saunders et al., 1991; Hobbs et al., 1992; Askins, 1993), which is seen as one of the greatest threats to biological diversity (Wilcove et al., 1986). Previous research on snakes has indicated that dispersion may be influenced by selective use of habitats and movements between habitats (Gregory et al., 1987). A future study examining other native species to Lake Forest, IL would benefit ecological modelers. This is particularly important, as the presence of other community members may be affecting habitat use of the study species. Data collected from additional studies could be used to monitor the community and assist in the continued recovery of species (i.e. Blandings Turtle) that were once common in the area.

CHAPTER FIVE

CONCLUSIONS

The goals of this study included obtaining accurate locations of *Thamnophis sirtalis sirtalis* to build a database that allowed for an analysis of spatial habitat use. These showed both seasonal movement and home ranges of individual *T. s. sirtalis*. The use of ArcView increased overall potential of data to integrate both spatial and physical factors in an analysis of habitat selection. While landscape features have been identified in the success of microhabitats for many reptilia species, the spatial role of these landscape variables may influence the success of a species.

The study identified females as having a significantly larger movement in summer than males and distance to crayfish burrows as the best predictor of *T. s. sirtalis*' presence. Further, the study species was observed moving in and out of these identified structures (termed hibernacula) during spring and late fall. The relative abundance of these structures may assist in the thermoregulative function of this subspecies, especially in area of unfamiliarity. However, a variety of factors could have also contributed to the success of this subspecies, including abundance of crayfish burrows, availability of *ranid* prey, and low elevation of land promoting flooded areas to exist with crayfish. Various community factors were not sampled (i.e. abundance of prey items and predators) but could have a strong effect on habitat selection of *T. s. sirtalis*, and future work should include a large suite of community variables. Although results of this study are valuable

in land management strategies in Lake Forest, IL the number of community variables that were omitted suggests that long term work is necessary to understand physical and spatial factors causing movement and home range of this subspecies. Such studies have the ability to identify key factors that can be imperative to the long-term success of a subspecies and the re-establishment of other native herptofauna.

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