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Home Range, Habitat Use, and Movements of Native Northern Map Turtles (Graptemys geographica), and Sympatric Invasive Red-Eared Slider Turtles (Trachemys scripta elegans), in the Upper Niagara River

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by

Brian Haas

An Abstract of a Thesis
in
Biology

Submitted in Partial Fulfillment
of the Requirements
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Buffalo State College
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ABSTRACT OF THESIS

Home range, habitat use, and movements of native northern map turtles (*Graptemys geographica*), and sympatric invasive red-eared slider turtles (*Trachemys scripta elegans*), in the Upper Niagara River

Turtle populations throughout the world are in decline due to the effects associated with anthropogenic disturbances. Northern map turtles in the Upper Niagara River are facing the same effects associated with shoreline development, pollution, and human induced mortality. A biotelemetric study was conducted to understand the population structure, habitat use, and behavior of northern map turtles in the Upper Niagara River. Turtles were trapped, outfitted with radio and sonic transmitters, and tracked from August 2013 until April 2015. Invasive red-eared sliders, which also inhabit the Niagara River were captured and tracked to allow for comparison. This invasive species is a habitat generalist and may have negative impacts on native turtle species. Red-eared sliders were only tagged and tracked when they were sympatric with the northern map turtles. The northern map turtle population is rare and diminishing in the Upper Niagara River. There was no evidence to support sympatric red-eared sliders were threatening the few resident northern map turtles with competition. Northern map turtles generally had larger home ranges and moved greater distances than red-eared sliders. The presence of both species was significantly predicted by surface cover and spent most of their time along developed shorelines. There was no evidence to support a common hibernacula for northern map turtles and one northern map turtle nest was located. Marinas were important components of all the tracked turtle's home ranges and may represent an ecological trap.

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Introduction

The understanding of habitat use and behavior is vital when studying the ecology of any animal. Often the most effective way to protect a species is through protection and /or restoration of their habitat (Carrier and Blouin-Demers 2010). Before these management actions can be considered, a thorough understanding of habitat use and behavior must be achieved. This information can vary between populations because of both natural and anthropogenic factors (Bennet et al. 2009). For these reasons, management implications for one population may not be suitable for another.

One of the most effective ways of obtaining behavioral and habitat use information is through the use of biotelemetry which offers the ability to record information from organisms for long undisturbed periods of time. This method can reduce the biases that can be associated with conventional approaches (Bridger et al. 2001). Biotelemetry enables organisms to be studied in a natural environment away from biases related to human interference that can occur in a lab or with mark recapture methods. Biotelemetry has been used for habitat use studies with the goal of habitat conservation for a wide range of aquatic species such as lake sturgeon (Caswell et al. 2001), manatees (Flamm et al. 2005), and Kemp's ridley sea turtles (Schmid et al. 2003). Similar approaches have been applied to birds (Boal et al. 2005) and mammals (Harveson et al. 2004).

It is important to note that biotelemetry is limited by the researcher's ability to match the technology to the questions that are being asked about the organism and its habitat (Cooke et al. 2004). For example, it is important to use the proper sampling rate when studying diving behavior or basking behavior. Sampling every second would be excessive, sampling every half hour could potentially miss critical behavior. In addition, the different temporal and spatial scales that are analyzed will have powerful effects on the patterns and conclusions that are drawn from the study. Broad scale studies often reveal general patterns, while finer scale studies normally will give more detail to the biological mechanisms that drive those patterns (Weins 1989).

The way in which habitat is used by an organism can be influenced by numerous factors such as habitat structure (Carriere et al. 2009), food availability and predation (Heithaus and Dill 2002), and seasonality (Pluto and Bellis 1988). Anthropogenic factors can also greatly influence the way in which an organism will interact with its environment (McLoughlin et al. 2011). Consequently, the movement and behavior of an organism will be driven by the cumulative effect of all factors acting upon it. Not all individuals of a species will respond to these factors in the same way. Different physical and behavioral characteristics of individuals can shape their response to the biotic and abiotic factors that make up their environment. For example, previous studies on map turtles suggest that differences in home ranges and movement patterns are influenced by one or more of the following factors: sex, body size, seasonality, and life-history stage. (Carriere et al. 2009, Lindeman 2003, Pluto and Bellis 1988, Pluto and Bellis 1986)

Turtles are especially sensitive to habitat destruction and disturbances because their life history requirements are associated with both aquatic and terrestrial habitats. These needs include sites for feeding, basking, mating, nesting, and overwintering. An array of habitat features are associated with these sites such as food availability, above water structures, substrate types, current, dissolved oxygen etc. These features provide the unique conditions that are needed to satisfy the life history needs of freshwater turtles living in temperate North America. The presence of habitat features that sustain these specific behaviors is required to support a viable population of turtles. This offers a challenge for the protection of a species and demands an understanding of how they use these features, as well as where these features are located.

Turtle habitat is commonly located on prime waterfront real estate, and as a result shoreline development can threaten turtle populations. In addition, roads bisect their habitat and increase mortality, especially of females looking for nesting sites (Wood and Herlands 1997). This can alter the population structure by skewing the sex ratio (Steen and Gibbs 2004). The natural flow of numerous bodies of water has also been manipulated leading to changes in turtle habitat and food web collapses (Gibbs et al. 2007). Even if habitats are not physically manipulated, the presence of humans can alter the way in which turtles use their environment. Moore and Seigel (2006) determined that yellow-blotched map turtles were affected by human disturbance. Recreational activities such as boating, picnicking, and camping, altered nesting and basking behaviors, specifically causing delays and/or abandonment of both behaviors. The energetic cost of nesting was likely increased and the disruption of nesting activities was leading to a reduction in the viability of the turtle population.

The many key habitat features that are required, and the overlap with anthropogenic disturbances leads to a complex problem for turtles. Understanding the habitat use and behavior gives insight into map turtle habitat requirements, which is the first step in their protection and management. With this in mind, I have outlined the goals and aims of my study.

Study Goals

Overall Goal: To define habitat use and behavior of the northern map turtle in the Upper Niagara River. Red-eared sliders were studied as a comparison and to determine any habitat overlap that may lead to competition. I examined if possible habitat limitations reduced the fitness of northern map turtles.

General questions and aims:

1) *How many northern map turtles are in the upper portion of the river and what is the structure of the population?*
2) *What are the home ranges for northern map turtles and red-eared sliders, are there differences between them and does seasonality alter the size of their home ranges?*
3) *How far do individuals of both species move per day and does this change with season?*
4) *Does each species occupy unique habitat and does their habitat use overlap? What is the best habitat predictor of presence for both species?*
5) *How do the individual turtles fulfill the requirements needed for basking, nesting, and brumating in the Upper Niagara River?*

I summarized and synthesized all of the above general questions, to reflect how northern map and red-eared slider turtles behave and use the river. Conservation and restoration implications were drawn that can help direct future actions aimed at protecting northern map turtles and their habitat in the Niagara River.

Materials and Methods

Study species

Graptemys geographica

The northern map turtle (*Graptemys geographica*), also called the common map turtle belongs to the family Emydidae. They have an olive green to gray brown carapace with patterned lines resembling topographic lines on a map, hence the name *geographica*. As individuals age, the lines fade and the carapace darkens. The carapace is smooth and has a keel running along the midline, and the rear edge of the carapace is serrated and flared. The plastron is yellow and will fade to a cream color as the turtle ages. Their skin is a shade of green with yellow, green, or orange lines on the head, neck, and limbs. Behind each eye there is a distinctive colored triangular patch (Gibbs et al. 2007).

Northern map turtles are widely distributed from Southern Quebec in Canada, to Northern Georgia and as far west as Kansas in the U.S. (Ernst et al. 1994). They are distributed farther north than any other *Graptemys* species (Nagle et al. 2004). In New York, populations are centered around the Great Lakes and in the Hudson River. Despite their large geographic range, their habitat is limited to large bodies of waters such as lakes and rivers. They prefer slow moving water and soft bottom substrates (Gibbs et al. 2007). They are active from April until early November, with a shorter active season in northern zones (Ernst et al. 1994). The northern map turtle is assumed to have been present historically in the Niagara River based on current and old species range maps, however anthropogenic disturbances most likely led to their decline in population numbers (personal communication Ken Roblee senior wildlife biologist region 9 NYDEC).

Sexual dimorphism is extreme in this species with females growing to nearly twice the size of males. The female carapace length ranges from18-27 cm, whereas male carapaces range from 9-16 cm. In addition, trophic (feeding) morphology is different between sexes, with females having larger heads and alveolar surfaces, the flat surfaces within the cutting margin of the jaw of a turtle (Lindeman 2000).

Basking

Northern map turtles exhibits very strong basking tendencies like other Emydid species. Basking maintains the health of a freshwater turtle through thermoregulation, epidermal care, and elimination of parasites. Basking is paramount in achieving the optimal temperature for physiological processes (Boyer 1965). Map turtles are very wary and will retreat to the water when disturbed. They may bask in large numbers, which only adds to their wariness; if one turtle retreats to the water usually the others will follow (Ernst et al. 1994). A two year study of northern map turtles (Bulte and Blouin-Demers 2010), concluded that they spent on average 46% of the daylight hours basking. Their study noted the effect of temperature on time spent basking, increasing in cooler periods by almost 10% over warmer periods.

Nesting/hatching

Mating occurs in both the spring and autumn seasons, and nesting peaks during the middle of June. Nests are flask shaped and contain approximately ten to twenty eggs (Ernst et al. 1994). White and Moll (1991) concluded that females in a Missouri stream lay on average ten eggs per clutch and lay at least two, and possibly three clutches a year. Prime nest sites receive full sunlight and are located in loose soil or sand (Ernst et al. 1994). Nagle et al. (2004) monitored 75 natural nests in central Pennsylvania. Some nests were made in disturbed sites such as areas near highways where fill material was stored. Substrates for nests included sand, coal slag, limestone gravel, clay, and various mixtures of these. Data compiled for nests in Ontario showed that nests were on average 35.7 meters from water with the minimum being 2 meters and the maximum being 252 meters (Steen et al. 2012).

Temperature dependent sex determination occurs in this species with mostly males being produced at 25°C and below, whereas mostly females are produced at 30.5°C and above (Bull and Vogt 1979). Once hatched, many northern map turtles display delayed nest emergence (Baker et al. 2003, Nagle et al. 2004). Nagle et al. (2004) found that hatchlings in 95% of their monitored nests overwintered in the nest and emerged the following spring. Emergence during the spring is spurred by increasing temperature and rainfall. This behavior may allow the turtles to enter into aquatic habitats when the environment is most favorable for dispersal, growth, and survival.

Feeding

Northern Map turtles are almost entirely carnivorous and specialize in foraging for mollusks. Mollusks made up 94.1% by volume of food eaten in a study conducted in the Niangua River, Missouri (White and Moll 1992) and 66% by volume of food eaten by females in a study conducted in the Mississippi River (Vogt 1981). The sexual dimorphism in trophic morphology and size may lead to differences in diets between sexes in some populations. Lindeman (2006) confirmed diet differences between northern map turtles in Presque Isle State Park in Lake Erie. This population fed almost exclusively on three taxa: zebra and quagga mussels, trichopteran larvae, and snails. The diets of juveniles and males consisted mostly of trichopteran larvae and snails. Mussels were of greater importance to small juvenile females than males. As females increased in size, the mussels became the main component of their diet (94.8% by volume in adult females).

Overwintering

Graptemys geographica requires a hibernaculum that has well oxygenated water. This allows the turtles to use aerobic respiration, which avoids lactic acid buildup. Metabolic depression, and extra pulmonary oxygen uptake are extremely important for overwintering. Despite very low levels of oxygen in the blood, the turtles are alert and can still respond quickly (Reese et al. 2001). A common hibernacula often occurs in this species and mating frequently takes place when individuals are together at these sites. Locations for hibernacula include the bottom of deep pools, under submerged logs, or in aquatic mammal burrows. (Gibbs et al. 2007).

Trachemys scripta elegans

The red-eared slider is also in the family Emydidae, with males reaching a length of 28cm and females 20cm. The slightly keeled carapace and skin are olive to brown in color and they have a distinct red postorbial stripe. *T. Scripta* is naturally distributed in the southeastern United States, but due to the pet trade they have established populations world-wide. Red-eared sliders can occupy most freshwater habitats, but prefer quiet waters with soft bottoms (Ernst et al. 1994). Moll and Moll (1990) note that Emydids, including sliders are often major components of river communities in North America. The presence of the red-slider has been studied in large rivers such as the Mississippi and the Illinois River systems. In the southern portion of the red-eared slider's natural range they can be active year round, but in northern zones they are generally active from April to November.

Due to their close phylogenetic distance, basking and nesting behaviors are very similar between red-eared sliders and those of the northern map turtle. Red-eared sliders have a high tolerance to anoxic conditions and can brumate in areas with low levels of dissolved oxygen (Milton and Prentice 2007). Red-eared sliders demonstrate temperature dependent sex determination similar to the northern map turtle. Delayed nest emergence and the laying of multiple clutches occurs as well. Red-eared sliders are opportunistic omnivores but are more carnivorous as juveniles and become more herbivorous as they mature (Ernst et al. 1994).

Aquatic turtles are important components of ecosystems because of their influence on trophic dynamics and their role as both consumer and as prey. They represent a strong link in the energy transfer between aquatic and terrestrial environments (Mitchell and Buhlmann 2009). In addition, the map turtle may play a role in the trophic transfer of contaminants due to predation of dreissenid mussels, which represent an important pathway for contaminants in aquatic food webs (Bruner et al. 1994). The study of these two turtle species offers further insight into the ecological health of the Upper Niagara River.

Study Site

The Niagara River connects Lake Erie and Lake Ontario, with the upper and lower river being separated by Niagara Falls. These international waters and their shorelines have been subject to intense development and environmental degradation for approximately two centuries. As a result, the biota inhabiting the Niagara River have been altered by habitat loss and a plethora of chemical pollutants such as PCBs, dioxin, mirex, chlordane, and pesticides. For example, reproductive issues and deformities have been documented in bird and fish of this river (Great Lakes area of concern www.epa.gov). During the 1980s the United States and Canada designated the river as an Area of Concern (AOC), with goals and management plans to improve the quality of habitats, wildlife, and the waters of the river (Great Lakes Area of Concern www.epa.gov, Niagara River: Great Lakes Area of Concern www.ec.gc.ca).

As the river flows north from Lake Erie it is split by Grand Island creating an east and west branch (Figure 1). This island contains two state parks, which have natural shorelines, Buckhorn at the northern end and Beaver Island that runs along the western shoreline to the southern end of the island. Strawberry Island is located to the south of Grand Island and has been the site of many habitat improvement projects. This island is designated a Critical Bird Nesting Area and a spawning site for many fish (Great Lakes Area of Concern www.epa.gov). Numerous marinas scatter the shorelines in this urbanized river. An important set of marinas for turtles, that I termed the Rich Marine Complex (RMC) is located near the headwaters and was a focus area during this study (Figure 2). A defining feature of this complex is a boat slip owned by the Army Corps of Engineers (ACE), which restricts boat traffic.

Figure 1. Map of the Upper Niagara River.

Figure 2. Map of the Rich Marine Complex (RMC), with the Army Corps of Engineers (ACE) slip bordered in red. The Black Rock Lock is outlined in yellow.

Research Techniques

Capture method

During preliminary research, baited hoop traps and trap nets (large underwater nets that have a leader and two wings that funnel aquatic animals into a cod end where they become trapped) were shown to be ineffective in capturing northern map turtles in the Upper Niagara River. As a result, I used basking traps, which were successful in capturing the map turtles. The only other effective trapping method for map turtles was using dip nets to actively capture individuals. Trapping was conducted from April through the end of June 2014 using basking traps and dip nets. Traps were checked every other day. Extensive shoreline surveys were conducted during prime basking time in early spring to look for basking turtles and potential areas to trap. In addition, map turtle locations from the preliminary field season were used to direct the placement of traps into known map turtle habitats.

Basking trap dimensions were 1.2 meters by 1.2 meters, with a 10.2 cm diameter pvc frame. Snow fencing was attached to the frame and had a depth of approximately 1.2 meters. On each side of the trap pieces of plywood were attached to serve as ramps. If ramps got waterlogged and began to sink, floats were added to keep the ramps at an appropriate angle. An additional piece of wood bisected the trap and served as a bridge (Figure 3).

Figure 3. Basking trap located in the waters of the Army Corps of Engineers (ACE).

Turtle processing/ transmitter outfitting

The length, width, and depth of captured turtles were measured using digital calipers. The condition of the turtle was assessed and any abnormalities or injuries were noted. A digital balance was used to measure the mass of each turtle. The sex of the turtle was recorded along with its age class (juvenile, adult). Size, tail length, and cloacal positioning were used to determine the sex, whereas annuli counts on the carapace along with size were used to determine age class.

Turtles were outfitted with one of two different radio transmitters, a larger Sir Track (two stage VHF harness temp transmitter,164 MHz, mass 18.5 g, length 30.5 mm, width 26.4 mm, depth 11.2 mm) or a smaller Holohil (SB-2F, 165 MHz, mass 6 g, length 20.5 mm, width 9.0 mm, depth 9.5 mm). I attached one of two different sized sonic transmitters, either the Sonotronic's smaller (IBT-96-5E, mass 7.8 g, length 36.5 mm, width 12.7 mm, depth 12.7 mm) or the larger (IBT-96-9E, mass 9.1 g, length 49.6 mm, width 11.4 mm, depth 11.4 mm) to each turtle. The two sizes of transmitters were needed so turtles of different dimensions and mass could have the more appropriate fitting. In conjunction with a concurrent study, turtles were also outfitted with a Star Oddi temperature/depth data logger (Milli DST-TD, mass 12 g, length 39 mm, width 13 mm, depth 13 mm). In addition to these attachments, mature females captured early in the season were outfitted with a Lotek Wireless GPSBUG (model SOB avian tag with turtle adapter, weight 16.3g, length 34.5mm, width 21.8mm, depth 14.7mm), which recorded GPS coordinates every 2 hours to aid in the locating of nesting sites. The weight of the equipment attached did not exceed 5% of the animal's body weight. In the few cases that it did, a float of syntactic material was glued to the shell to increase buoyancy and counteract the weight of the instrumentation, so as to not exceed the 5% limit.

Scutes were marked (Gibbons 1988) and strategically drilled using a high speed Dremel tool. Using steel leaders and crimps all equipment was attached through eye holes on the equipment and holes drilled in the scutes (2.8 mm). In addition, marine epoxy (PC-7 manufactured by PC-Products) was used to secure the equipment firmly against the shell. Prior to attachment, the shell was wiped down and cleaned with isopropyl alcohol. All algae were removed to ensure the equipment fit tightly against the shell. The turtles were held overnight to be sure the epoxy had cured prior to their release (Figure 4)

Figure 4. Female map turtle with attached instrumentation. Along keel of the carapace-radio transmitter, Posterior left-sonic transmitter, Posterior right-data logger.

Radio and sonic receivers

Two radio receiving base stations were set up at key bottlenecks for passive tracking. Each station consisted of a nine-element Yagi antenna (Arcadian Inc) and a Telonics TR-5 receiver. Active radio tracking was conducted using a handheld Telonics H antenna (RA-23k) and a Communications Specialists portable receiver (R-1000). In addition, the boat was equipped with a six-element Yagi antenna (Arcadian Inc) that could also be attached to the R-1000 receiver (Figure 5).

Passive sonic tracking was accomplished with the use of eight Sonotronic submersible underwater receiving stations (SUR-3). These were anchored to the river bottom with concrete weights and placed at key bottlenecks. On occasion, following large scale turtle movement, SURs were moved to an upstream and downstream location of the individual to aid in tracking. In some cases, SURs were moved to the headwaters of tributaries or canals if they were in the potential path of the moving turtle.

The SURs battery life was nine months. It stored 100,000 readings, and had a detection range of 80 meters. A sonic interrogation transponder (SIT-1) allowed for the SURs to be checked from the surface, to detect if any signals had been recorded. If there was a positive signal I would snorkel down to retrieve the SUR and proceed to download the data to a field laptop computer (Getac, model: B300). In most cases the water was too polluted to permit entry, so the SURs were often equipped with a looped rope that could be hooked, which allowed SUR retrieval using a boat hook (Figure 6). Active tracking was conducted using a Vemco VH110 hydrophone connected to a Vemco VR100 topside receiver (Figure 7). A Sonotronics underwater diver held receiver (UDR II) allowed me to swim, track, and recapture turtles.

The passive radio receivers aided in the location of turtles by recording when they passed through monitored segments of the river. This allowed for limiting areas to actively search for tagged turtles. Due to the more limited range of passive sonic receivers, they were often deployed in pairs, which allowed for the direction of movement to be noted by comparing the times they received signals.

Turtles were tracked, and when located the GPS coordinates were taken and a habitat index sheet was completed (Figure 8). Every two or three days individual tagged turtles were tracked. Periodically turtles were located multiple times during a day to gain insight into daily movement. A limited number of night tracks were also conducted to further the understanding of map turtle behavior. In addition, the GPSBUG allowed for turtle locations to be recorded in the absence of active tracking. During the winter, tracking was conducted from the land to ensure turtles were still located in their hibernacula. A triangulation technique utilizing two receiving locations was used from shore (Figure 9).

Figure 5. Active radio tracking using the boat mounted six-element Yagi antenna.

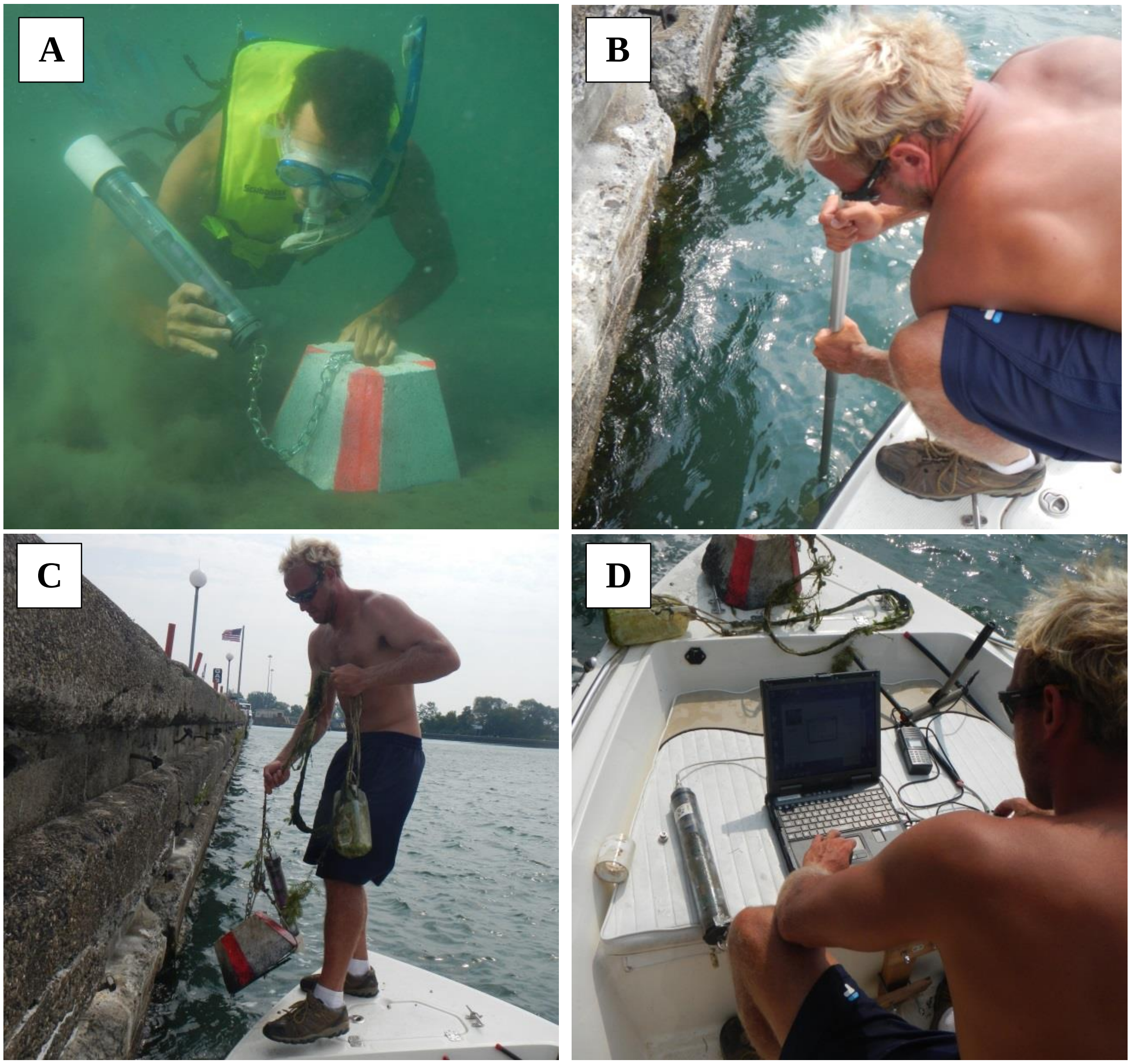


Figure 6. A. Underwater retrieval of the SUR unit. **B**. Initiating surface retrieval by using the boat hook to take hold of the retrieval loop located beneath the surface. The loop must be suspended deep enough below the surface to ensure it cannot get caught in boat propellers or be easily seen. **C.** Pulling the SUR unit and associated anchoring and retrieval components out of the water. The setup suspends the components vertically in the water column and consists of the anchor, the SUR, and a float attached to a rope loop. **D**. Downloading the data from the SUR unit using the field computer.

Figure 7. Active sonic tracking using the Vemco VH110 hydrophone connected to a Vemco VR100 topside receiver.

Broad Shoreline(B)- Will encompass the shoreline that spans 50 meters upstream and 50 meters downstream of where the turtle is located and 5 meters inland from the water's edge. If vertical bulk-heading is present then there will be no analysis of the area 5 meters inland, unless it extends out beyond the wall over the water.

Fine Shoreline(F)- Will encompass the shoreline 5 meters upstream and 5 meters downstream of where the turtle is located and 5 meters inland from the water's edge.

(B)Natural- Working in an urban river widens our definition of natural. Areas that have no visible sign of large scale anthropogenic substrates or alterations and have minimal to no anthropogenic relics/debris.

> **(F) Trees/shrubs-** woody plants are present, but do not extend beyond the water's edge
>
> **(F) Trees/shrubs with overhang-** woody plants are present, and they do extend beyond the water's edge.
>
> **(F) Reeds and aquatic grasses**

(B)Developed – Areas that are completely altered and or are intensively managed.

> **(F) Bulkhead-**any concrete or metal wall that is steep and vertical.
>
> **(F) Riprap-**loose stone amassed to form a barrier against erosion.
>
> **(F) Lawn-**maintained grasses.

(B)Mixed- Has both natural and developed fine shoreline qualities within the survey area.

Partially Submerged Structures- will encompass submerged structures within a 5 meter radius of the turtle. These will only encompass the listed structures that can be seen from the surface. It will not be quantified, only presence will be recorded.

> **Woody debris, Large Rocks, or Dock Pilings**

Surface Cover-Will encompass surface cover within a 5 meter radius of the turtle. Surface cover includes vegetation and debris. Surface cover will be quantified as 0%, 25%, 50%, 75%, or 100% coverage.

Depth-actual measurement

Current-actual measurement

Figure 8. Habitat index data sheet.

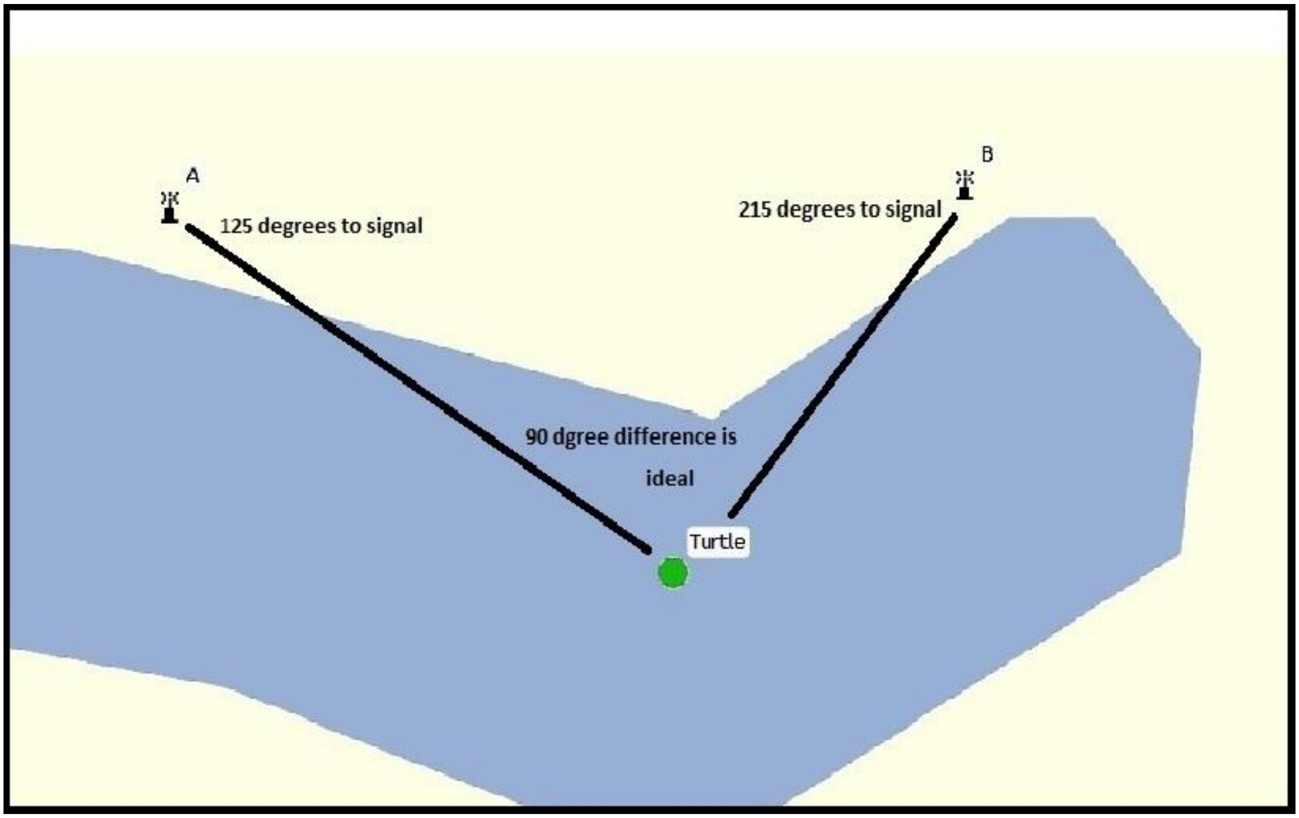


Figure 9. Image depicting the triangulation method employed from shore during the winter.

Environmental Monitoring

Environmental measurements which were recorded included air temperature, water temperature, wind speed, and water current velocity. Air temperature was recorded every minute using a Hobo data logger placed inside a solar radiation shield that was attached to the boat slip dock, at the marina that housed the research vessel (Anchor Marine, Ferry Rd, Grand Island, NY). Water temperature was recorded at each turtle location using a digital thermocouple thermometer (Fluke 52) with a type T thermocouple. Wind speed was measured with an anemometer (Professional touch screen weather center with PC interface, model TP1080WC), mounted at the boat slip dock. Water velocity was measured at every turtle location using a Global Water FP211 Flow Probe. An Aqua-Vu AVMicro underwater video recorder was used to help define the aquatic habitat features that turtles were using. River sampling was conducted every kilometer within the river home ranges of the map turtles. Sampling took place 10-15 meters from the shore. Substrate sampling was conducted using photographs from the Aqua-Vu, which was outfitted with a 0.25 m^2 pvc sampling frame (Figure 10). The same environmental measurements that were taken at each turtle location were also recorded at each sampling site. These data were used for turtle absences in presence versus absence habitat statistical analyses.

Figure 10. Underwater photos taken from the Aqua view camera showing the sampling frame and the silt substrate, which was the predominant substrate observed.

Data Analysis

Home range analysis

Turtle locations were entered into Arc Map 10.2. The ACE slip in the RMC had a barrier that prevented access. If a turtle's location was determined by telemetry to be behind the ACE barrier, the turtle was randomly assigned a coordinate that fell within the confines of the slip. Home range estimation was calculated using the complex linear home range method (CLHR) (Ouellette and Cardille 2011). Using this method, I created home ranges by generating the optimal route to reach all turtle location points in a constructed network. The network was constructed by taking numerous middle points between shorelines and creating centerlines that served as potential routes. To create a more realistic home range, I made the network cross the river in a biologically realistic way based upon observations and my knowledge of the river and the turtles that inhabit it. On a few occasions, I altered the route of the home range because it utilized backwaters that offered the optimal route, when in fact there was no sign of actual backwater use. Backwater routes were only included in the home range when observed location points were present. In addition, if a turtle had randomly generated points within the ACE slip it was assigned the entire length of the slip as part of its home range. Home ranges were created for each individual and each season.

The home range seasons were delineated by water temperature, which corresponded with seasonal map turtle movement patterns that were associated with travelling to brumation sites. Large scale movements (over two kilometers per day) did not occur excluding a female map turtle (MF3) when the water temperature rose above 22°C in the summer. Large scale movements only occurred again, once the water temperature dropped below 22°C in the fall. The water temperature had to measure above or below 22°C for at least three consecutive days that turtles were tracked to confirm the seasonal change. This seasonal division allowed for home range estimations to accurately reflect the three different seasonal home ranges. For the data analysis it was considered that spring migration began when turtles became active and ended June 27th (water temperature > 22°C). This time period consisted of the turtles moving back from their hibernacula. Summer site fidelity was considered to begin on June 28th and ended September 14th (water temperature < 22°C). This time period consisted of the turtles residing in a set of marinas and associated back waters. Fall migration was considered to begin September 15th and ended when the turtles began brumation (water temperature < 22°C). This time period consisted of the turtles moving back to their hibernacula.

Habitat selection

Upon locating an animal, a habitat index data sheet was filled out that described the habitat in which the turtle was located (Figure 8). This data sheet served as the main source of data for all habitat selection analyses. Absences also were recorded during the river sampling survey and were incorporated into a statistical model. Habitat index predictors of turtle presence were examined for collinearity (variance inflation) using the "car" package (Fox and Weisberg 2011) in R. Model selection was conducted using Akaike's Information Criterion (AIC) (Akaike 1973). AIC is a measure of model goodness-of-fit but includes an added penalty for model complexity (Burnham and Anderson 2002). Therefore, simple models that explain the data are scored lower and preferred more than complex models that equally explain the data. The lowest scores equate to the models that have the best goodness-of-fit. Using the best predictors from the AIC (Δ>2) model, I generated analysis of deviance (ANODEV) tables using a Chi square test, which is appropriate for binomial data. Statistics were completed using R version 3.0.2.

Turtle movement

Mean straight line distance moved per day was calculated by taking the straight line distances that were biologically realistic between locations and calculating movement for 24 hours. Straight line distances between locations were measured in Arc Map 10.2. Water temperature measurements (taken at each turtle location point) were averaged between locations, so an average value was coupled with the mean distance displaced per day. If location points were randomly generated in the ACE slip, the middle point of the slip was used to measure to the next actual point. If consecutive locations were randomly generated, then the distance moved per day was designated as half of the length of the ACE slip (60 meters). Figures plotting mean distance moved per day as a function of time with water temperature on the second Y-axis were created for each species Figures were created and performed using the R software package (3.0.2).

Basking

Every time a turtle was observed basking, the type of substrate that was being used was noted. Wood basking substrate was visually estimated as being small (0-10 cm diameter), medium (10-20 cm diameter) or large (>20 cm diameter). In addition, the distance from shore for basking behavior was measured in meters using a Bushnell range finder.

Nesting

Parameters for nests that were found were recorded. Parameters included distance from shore (m), nest depth (cm), nest substrate, and clutch size.

Brumation

Hibernacula sites were mapped for the 2013 and 2014 field seasons. Substrate, structure, dissolved oxygen (mg/l), current (m/s), and depth (m) were recorded for the 2014 hibernacula sites.

Results and Discussion

1) ***How many northern map turtles are in the Upper Niagara River and what is the structure of the population?***

Due to the small numbers of map turtle individuals, a mark recapture technique was not suitable for a population estimate, but trapping effort, shoreline surveys, and multiple recaptures of the same tagged individuals gave support to the hypothesis that the map turtle population is very small. In fact, the turtles captured may be the total number of individuals in the Upper Niagara River. Trapping efforts in the first field season (2013) consisted of 1439 trap nights and resulted in the capture of four map turtles (one adult male, two adult females, and one female on the verge of sexual maturity). The second field season (2014) had 518 trap nights during the peak basking time and season. This resulted in the recapture of all previously tagged individuals and only one new adult female map turtle. Shoreline surveys throughout the Upper Niagara River and its major tributaries add evidence to the scarcity of map turtles in this region. More than one hundred red-eared sliders, painted turtles, and snapping turtles were seen on these surveys, but no additional map turtles. Most observations of these turtles were in the tributaries and backwaters. These shorelines provided ample basking opportunities, which indicated competitive exclusion was improbable. As noted earlier, map turtles are prolific basking turtles, so their absence in the surveys likely indicates their absence in those areas.

Of the five map turtles originally tagged, one was killed and another could not be found. The turtle that disappeared was a gravid adult female, as determined by manual palpation. One hypothesis was that she was taken while on a nesting excursion. The urban surroundings and subsistence fishing that occurs in the area makes human removal very possible. The single turtle mortality occurred when a subadult female (MF3) went over Niagara Falls. She was last visually seen basking at the northern tip of Grand Island. Two hours later she was heading towards the Falls and her signal was coming from beyond the no boating zone. The next day I went out and received her signal coming from the bottom of the Horseshoe Falls. A later trip on the Maid of the Mist (a tourist boat in the Lower Niagara that brings you within 100 meters of the Falls) reaffirmed her presence at the bottom of the Falls. Her signal remained there for over a month, indicating she was probably caught in the churning waters. Her carcass was never recovered. Clearly, the map turtle population is dwindling and consists of only mature individuals, which may indicate lack of recruitment.

2) What are the home ranges for northern map turtles and red-eared sliders, are there differences between them and does seasonality alter the size of their home ranges?

Home ranges between species and individuals varied greatly, with most map turtles having larger home ranges than sliders regardless of season (Table 1). Seasonal home range size differences were greatest among the map turtles and were much less evident among the sliders. Every tagged turtle at one point was located in the RMC, and one individual from each species left this area and inhabited connecting tributaries. Map turtles and red-eared sliders spent much of their life in the RMC. During the 2014 field season, 67% of map turtle observations and 78% of slider observations were within the RMC based on 272 and 238 total observations, respectively. When the individual from each species that inhabited tributaries was excluded, 77% of map turtle observations and 97% of slider observations were within the RMC based on 238 and 185 total observations, respectively. Furthermore, the restricted ACE boat slip was occupied at some time by most individuals and is clearly important for the persistence of turtles within the RMC.

Two female map turtles had similar home ranges both spatially and temporally (Figure 11, Figure 12). Despite moving to different branches of the Niagara River to brumate, they each returned to the RMC. Map turtle female one (MF1) had a more direct route back to the RMC than map turtle female two (MF2), but both individuals utilized backwaters along the way. The part of MF2's home range that extends into the east branch was somewhat puzzling and may have been associated with a nesting excursion. The farthest point downstream was in front of a gravel beach that could have been a potential nesting site. Both of these females shared similar temporal trends consisting of a spring migration from hibernacula, a summer site, and a fall migration back to hibernacula.

Home ranges of four map turtles and one slider from the year 2013 were not divided by season due to the late capture and limited observations (Figure 13, Figure 14). They offer a baseline for understanding and comparing the 2014 home ranges. In addition, the 2013 home range for the female map turtle three (MF3) shows that her origin was from the RMC.

MF3 exhibited very different home ranges than any other turtles (Figure 15). Most of the differences are a result of MF3 leaving the RMC in 2013 and not returning in 2014. Her home range consisted of three distinct water channels, the river, a side channel with intermediate flow, and a creek. MF3 moved back and forth between these water channels with periods of sedentary behavior interspersed for the entire 2014 season. At one point she moved up river and entered a drainage pipe and crossed underneath a busy road where she remained for three days. Her extensive home range and varied movements resulted in her death, when she moved downriver and ended up going over the Canadian side of Niagara Falls. Her home ranges from 2013-2014 accounted for the entire length of the east branch of the River and numerous backwaters.

The vast home range and varied movement patterns of MF3 could be explained by a few hypotheses. First, this turtle was on the verge of sexual maturity and the lack of male map turtles may have spurred her to move and seek out mates. Second, it is well recognized that intraspecific differences occur in populations and that trait variation can alter behavior **(**Bolnick et al. 2011**)**. It may just be that this individual was genetically prone to a nomadic life or that she may have reacted differently to stressors and other factors that were experienced by the other map turtles.

The only male map turtle (MM1) had a much smaller home range than the females. For both years, he stayed within the RMC until the fall of 2014 (Figure 16). During the fall he left the marinas and moved downstream to brumate, which is puzzling since the home range from 2013 did not encompass this area. Despite the smaller scale, MM1 did have similar temporal trends as MF1 and MF2 consisting of movements in the spring and fall associated with brumation.

Tagged map turtles had much larger home ranges than the tagged slider turtles. Even in the summer, when brumation was not driving movement, map turtles utilized the entire RMC, while slider turtle home ranges were restricted to distinct sections.

		Complex Linear Home Range (km)			
Species	Individual	Spring 2014	Summer 2014	Fall 2014	2013
G. geographica	MF1	7.461	1.238	6.032	6.098
G. geographica	MF2	27.325	2.237	15.818	24.048
G. geographica	MF3	20.313	18.928	NA	25.451
G. geographica	MM1	1.059	1.008	2.443	0.133
T. scripta elegans	SF1	0.239	0.239	0.066	NA
T. scripta elegans	SM1	0.239	0.247	0.230	NA
T. scripta elegans	SM2	0.230	0.288	15.845	NA
T. scripta elegans	SM3	3.979	2.711	0.293	NA
T. scripta elegans	SM4	NA	NA	NA	0.218

Table 1. Complex linear home range lengths for each individual and each season tracked.

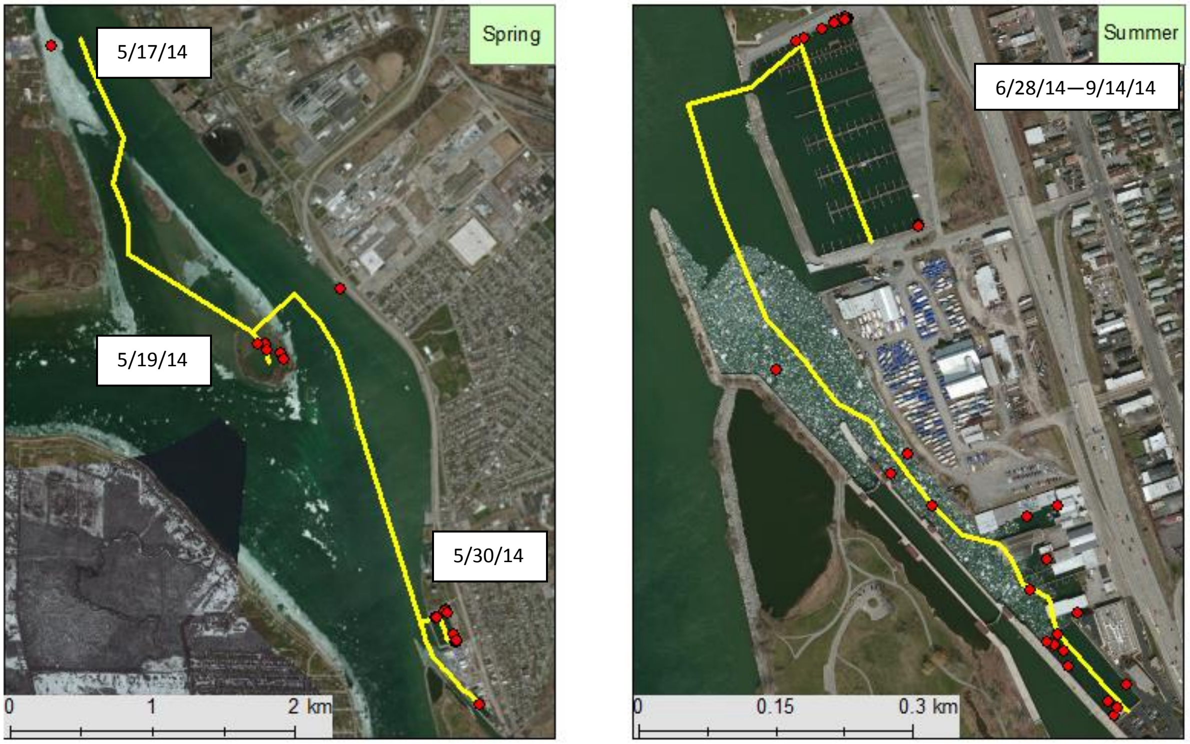
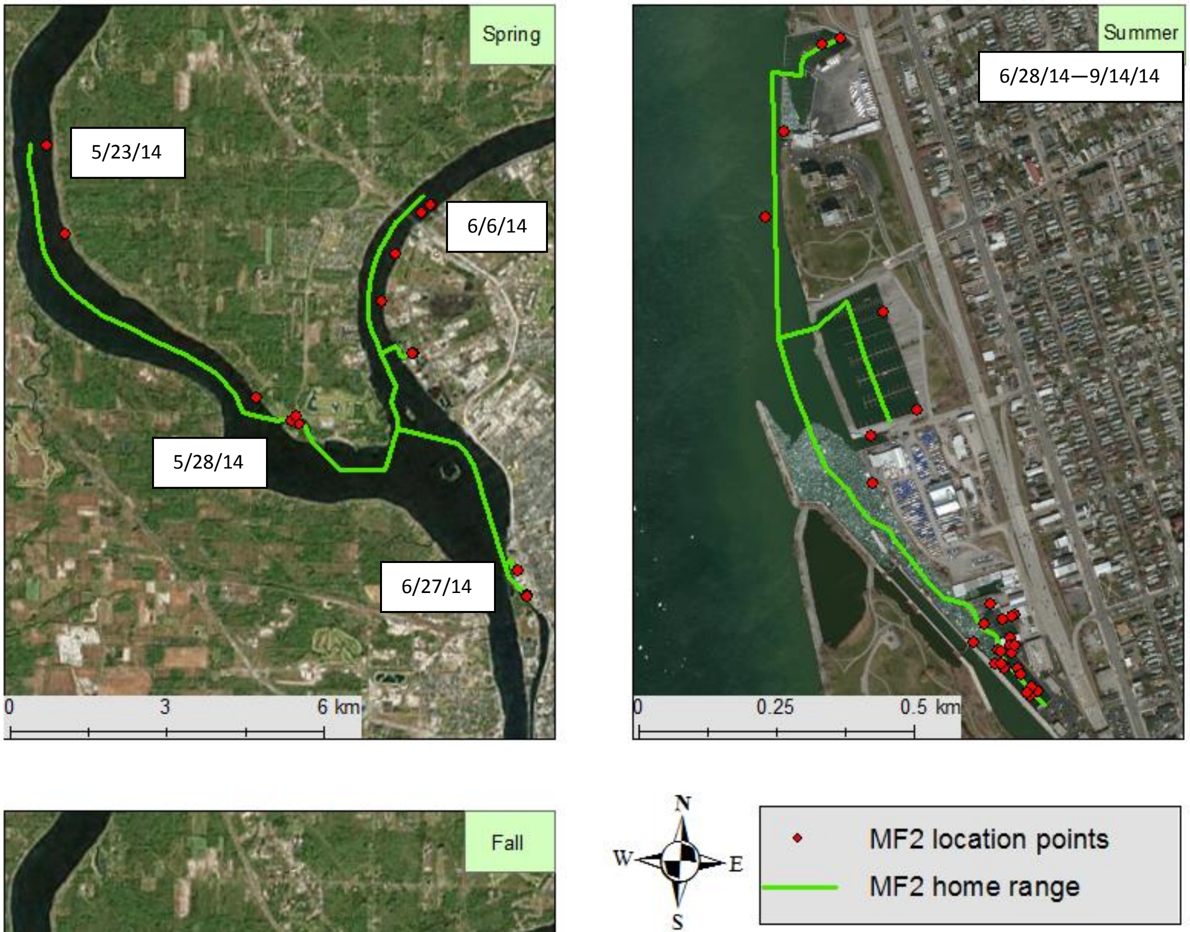


Figure 11. Complex linear home ranges of MF1 for each of the three defined seasons during 2014. Seasons were designated by water temperature (above or below 22°C), which fit cyclical movement patterns that were associated with map turtles finding brumation sites. Dates indicate the chronological path, when discernable.



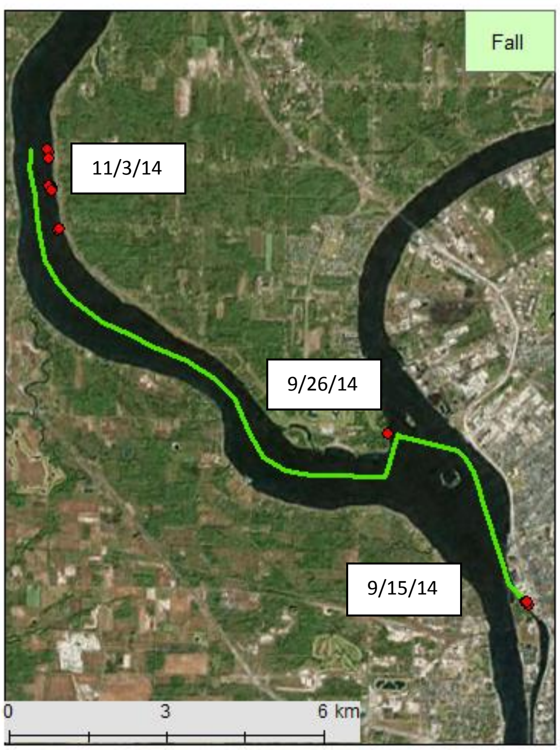
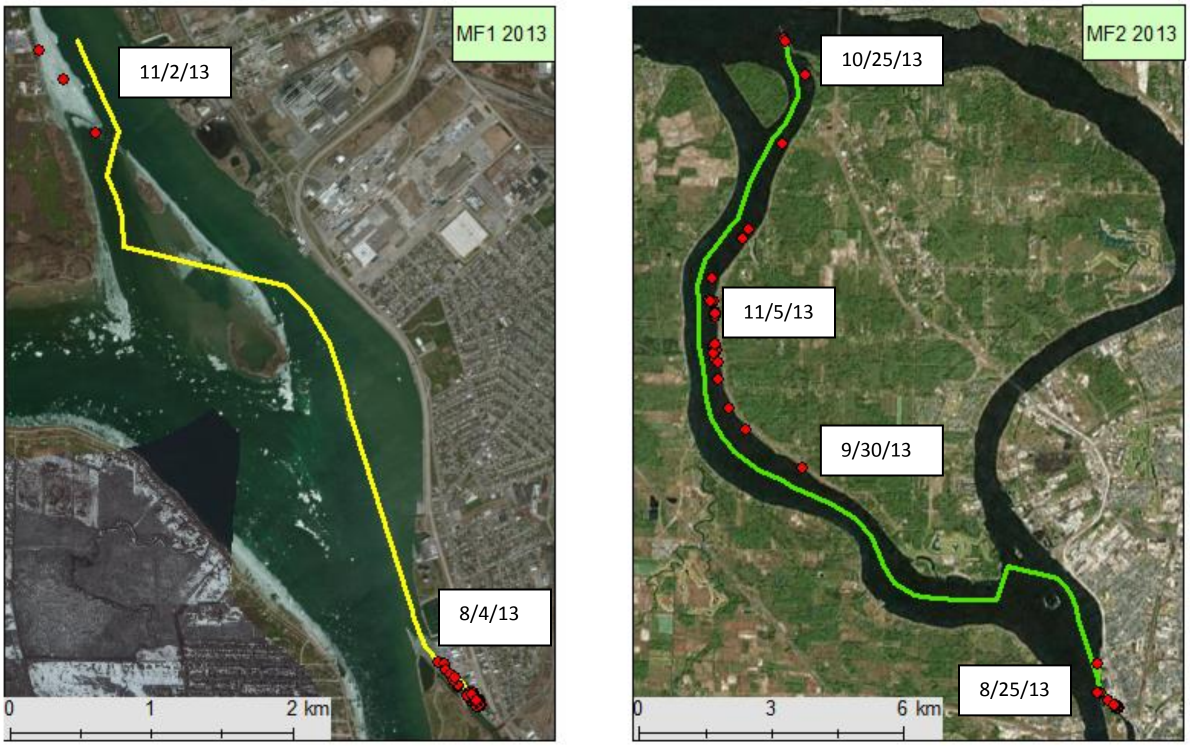
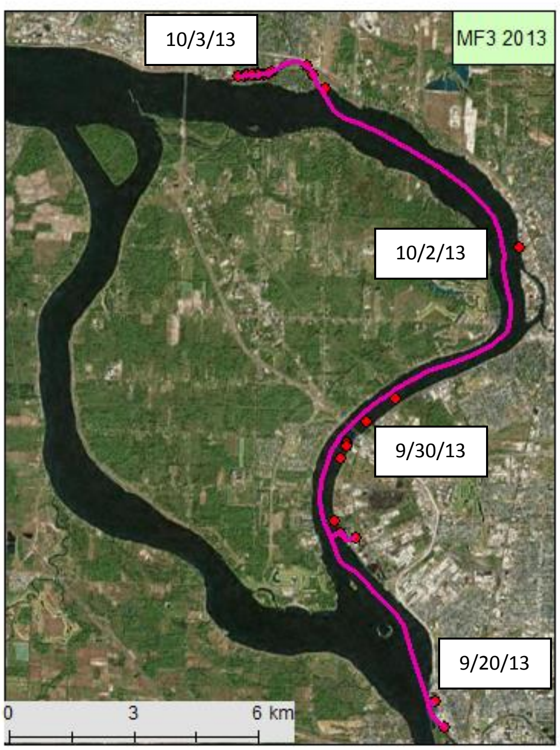


Figure 12. Complex linear home ranges of MF2 for each of the three defined seasons during 2014. Seasons were designated by water temperature (above or below 22°C), which fit cyclical movement patterns that were associated with map turtles finding brumation sites. Dates indicate the chronological path, when discernable.





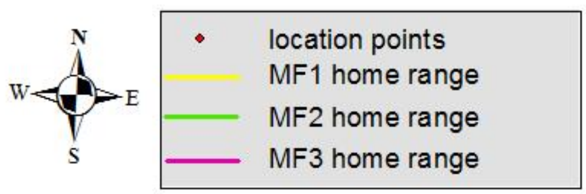


Figure 13. Complex linear home ranges of MF1, MF2, and MF3 for the 2013 field season. Dates indicate the chronological path. Earliest dates indicate when the turtle was released after being outfitted.

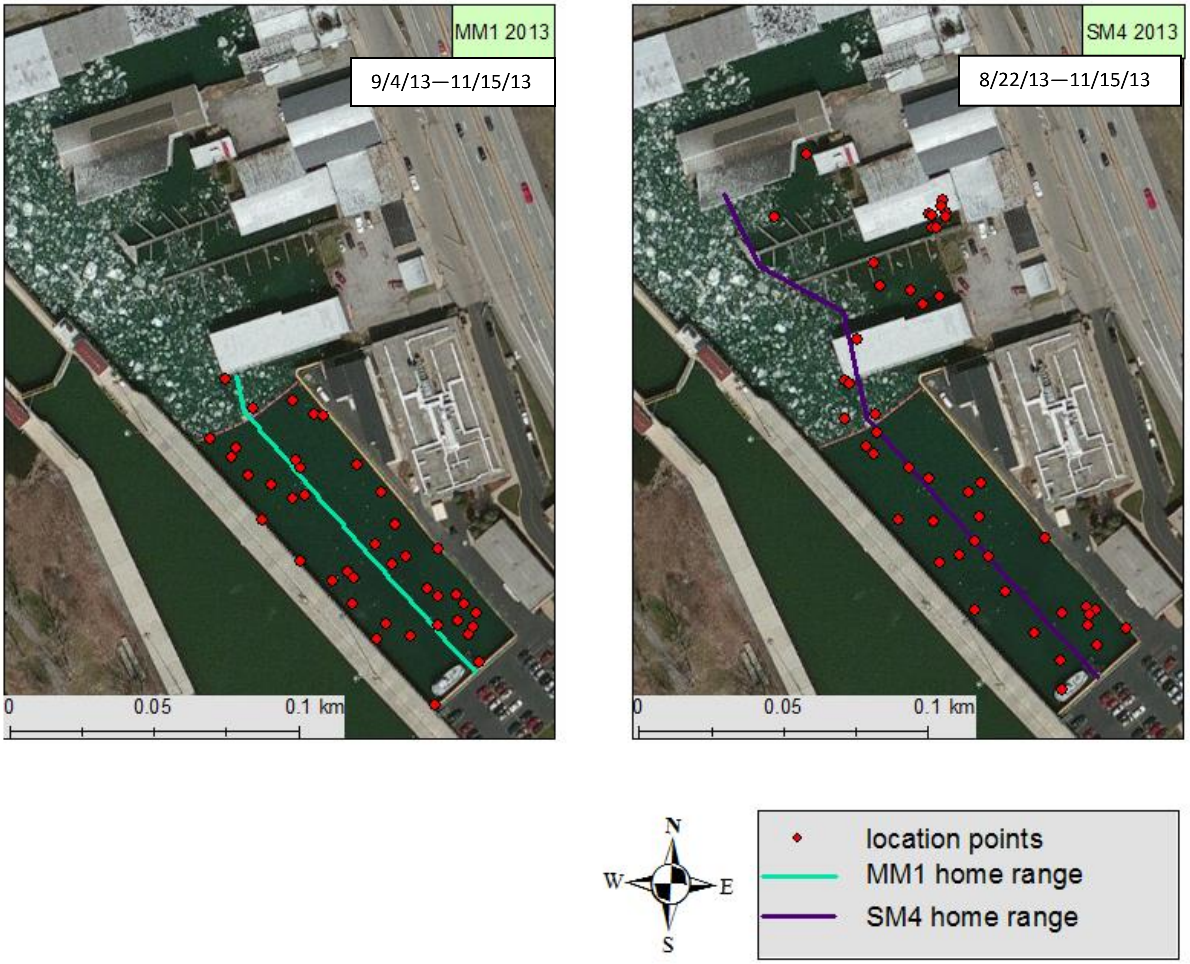


Figure 14. Complex linear home ranges of MM1 and SM4 for the 2013 field season. Dates indicate the duration of tracking.

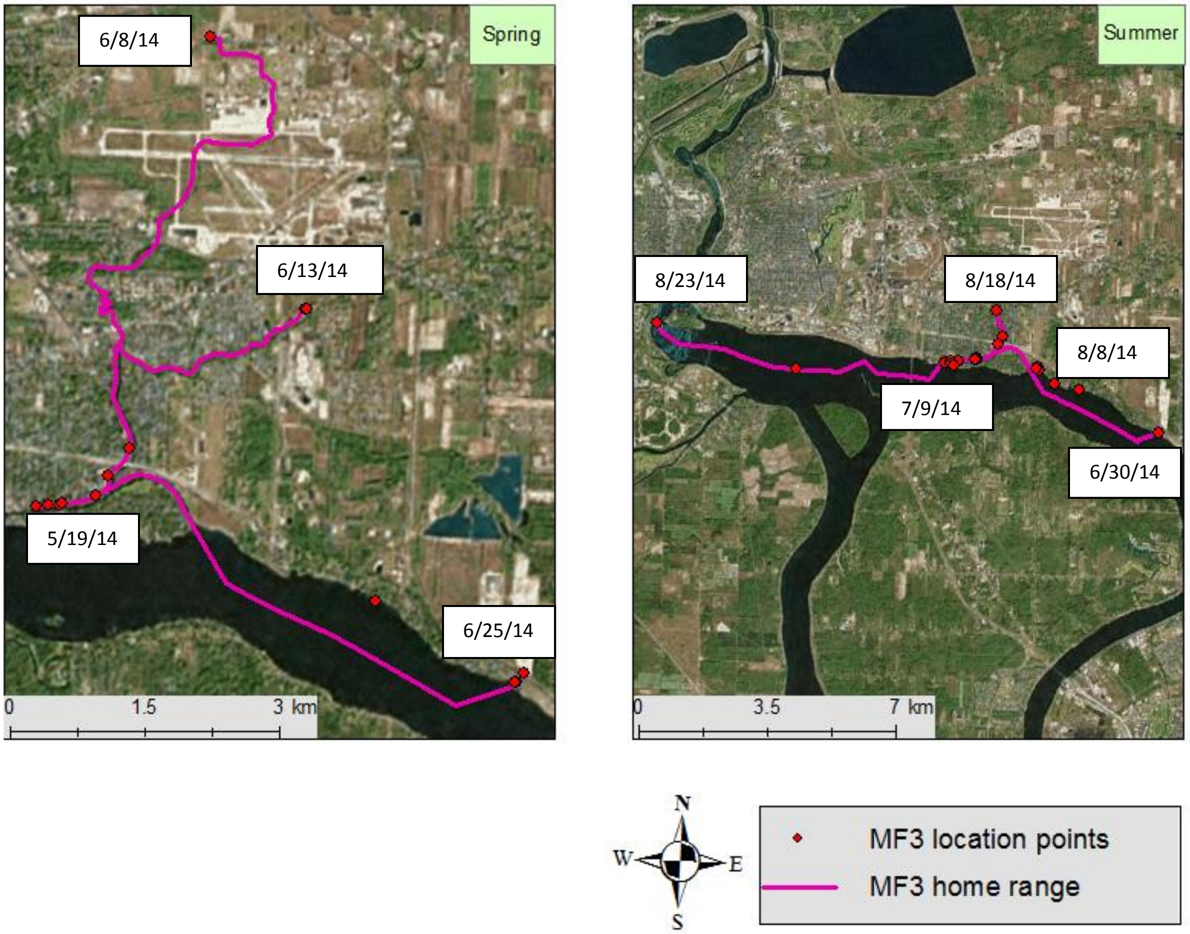


Figure 15. Complex linear home ranges of MF3 for each of the three defined seasons during 2014. Seasons were designated by water temperature (above or below 22°C), which fit cyclical movement patterns that were associated with map turtles finding brumation sites. Dates indicate the chronological path. At the point 6/8, the turtle was found walking in a road near a ditch by a local resident. The turtle was returned and released where she brumated, near the points associated with 5/19.

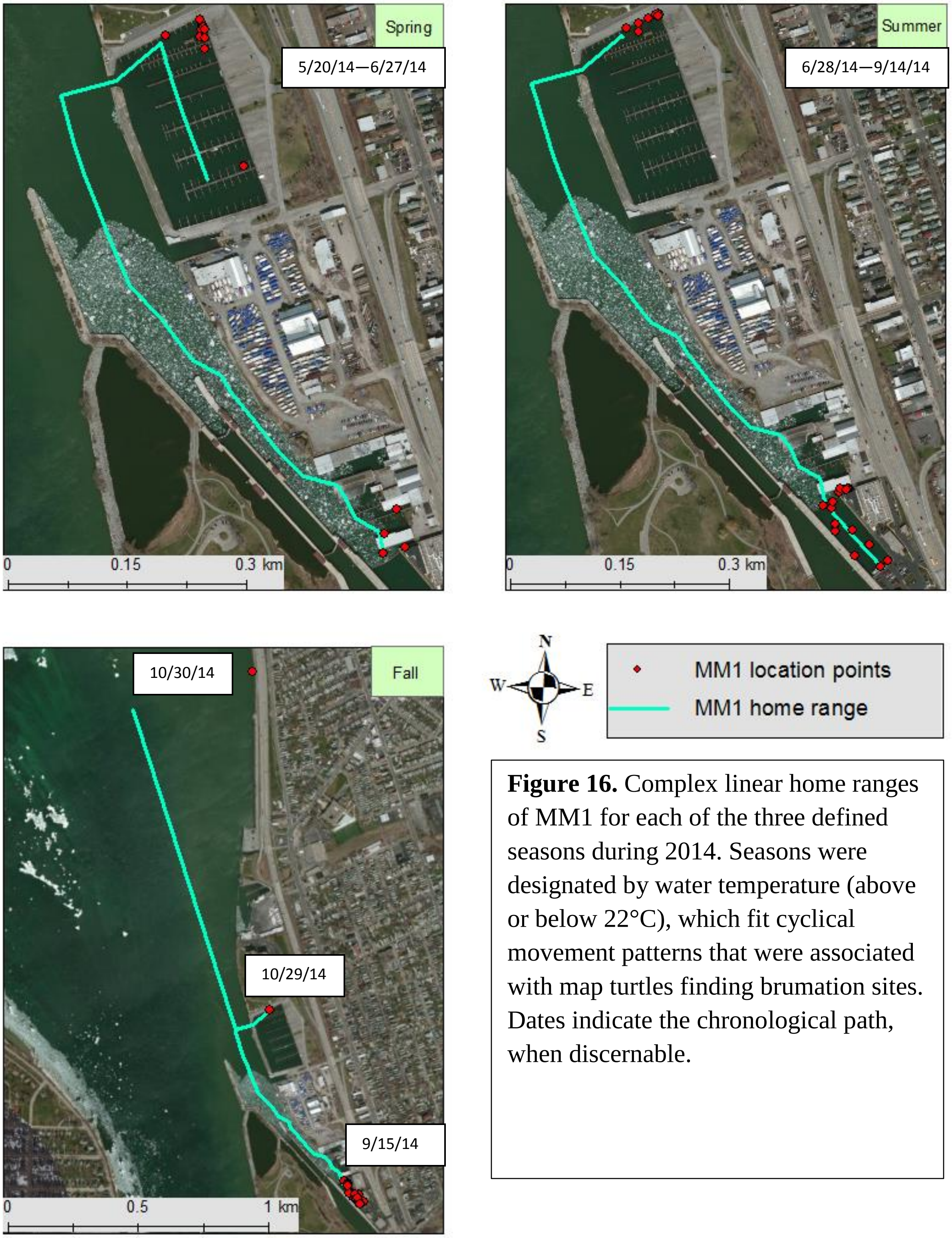
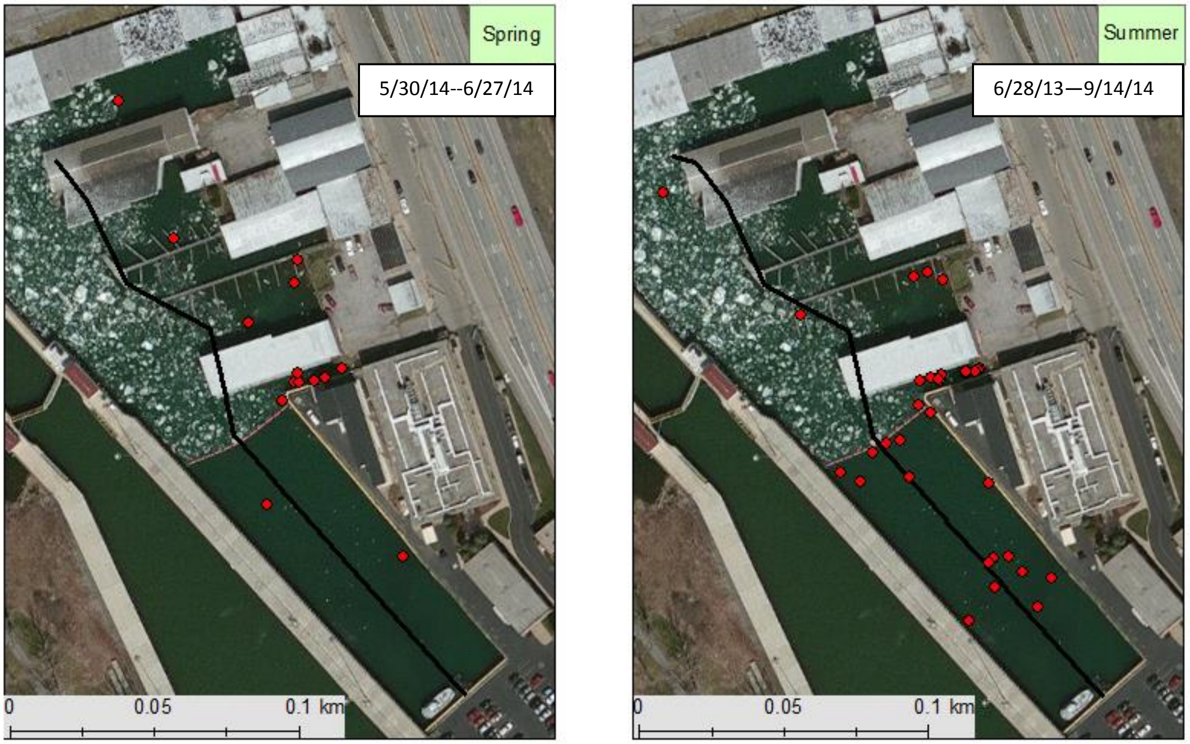


Figure 16. Complex linear home ranges of MM1 for each of the three defined seasons during 2014. Seasons were designated by water temperature (above or below 22°C), which fit cyclical movement patterns that were associated with map turtles finding brumation sites. Dates indicate the chronological path, when discernable.

Red-eared sliders that stayed in the RMC had home ranges similar to the summer ranges of the sympatric map turtles and utilized similar habitat features. The main difference is that the sliders stayed in distinct sections of the RMC, while the map turtles moved between the two main sections. Two red-eared sliders, one male (SM1) and one female (SF1) had very small home ranges concentrated in the south section of the RMC (Figure 17, Figure 18). A male slider (SM4) tracked in 2013 had very similar home ranges to these two individuals (Figure 14). Another male red-eared slider (SM2) had a home range that was confined to the north section of the RMC (Figure 19). SM2 never left the northern marina until the fall, which was a result of inadvertent displacement by a weed harvester. After not locating SM2, I spoke with the owner of Rich Marine. He said he cleaned out the vegetation a few days prior and that some of it went downriver. SM2 basked in vegetation more than any other turtle, and likely was picked up by the harvester and went downriver with the vegetation. As a result the turtle moved over 15 kilometers downstream to a different marina. Weed harvesting is common in the RMC and the owner often removes turtles from the conveyor belt and releases them back into the marina (Figure 20).

The final tagged slider (SM3) had a much different home range than the other sliders (Figure 21). SM3 was captured in the RMC, but soon after his release, he moved through the Black Rock Lock and ended up in the Black Rock Canal. From there he moved into Scajaquada Creek where he spent the rest of the field season. While this home range is very different than the other tagged turtles, it may be more common for other sliders in this area that occupy linear water systems. We tagged only sliders that were sympatric with the map turtles, but numerous other sliders were observed living in the canal and creeks and could have had home ranges that were similar to SM3.



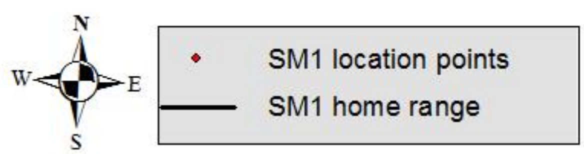


Figure 17. Complex linear home ranges of SM1 for each of the three defined seasons during 2014. Seasons were designated by water temperature (above or below 22°C), which fit cyclical movement patterns that were associated with map turtles finding brumation sites. Dates indicate time tracked.

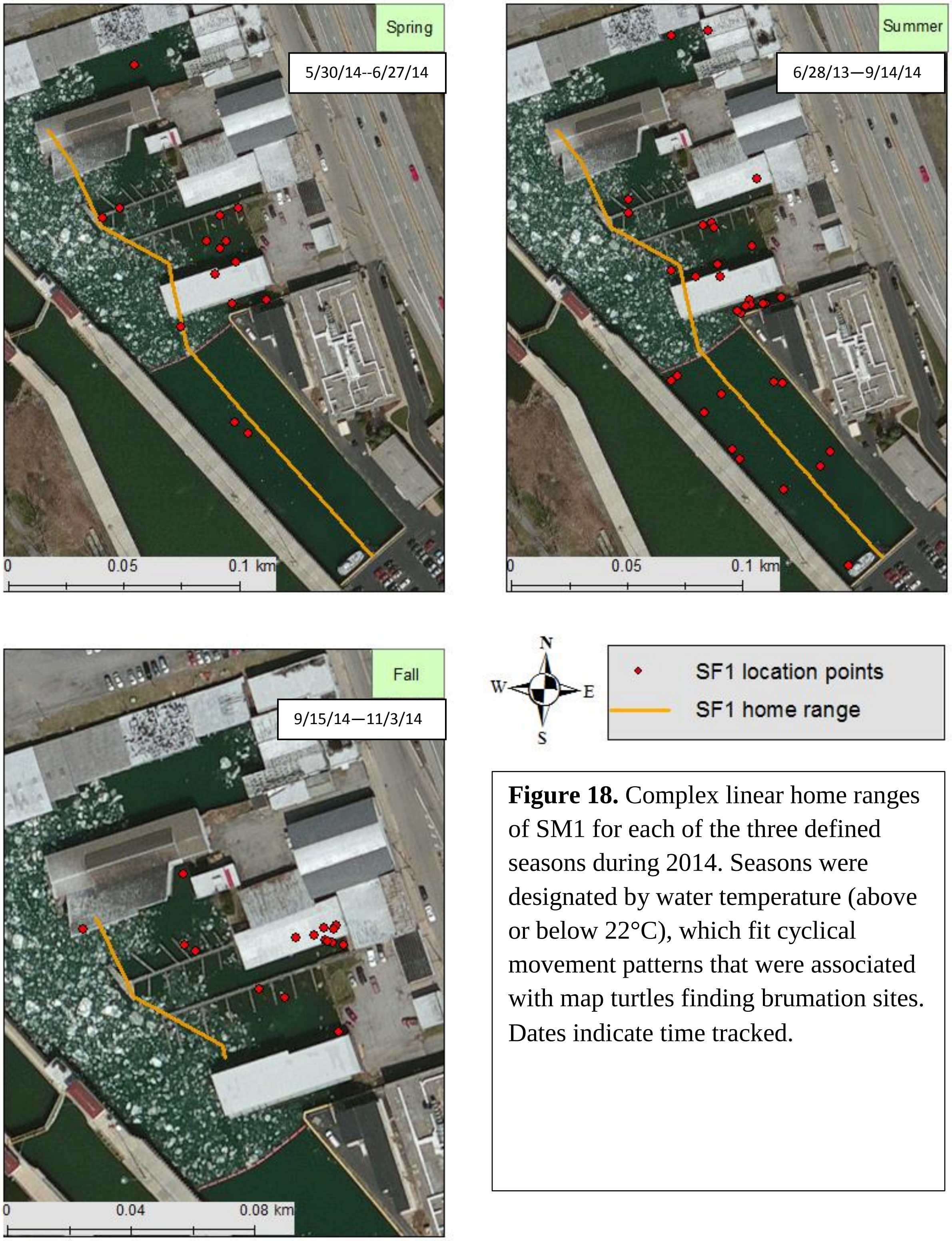
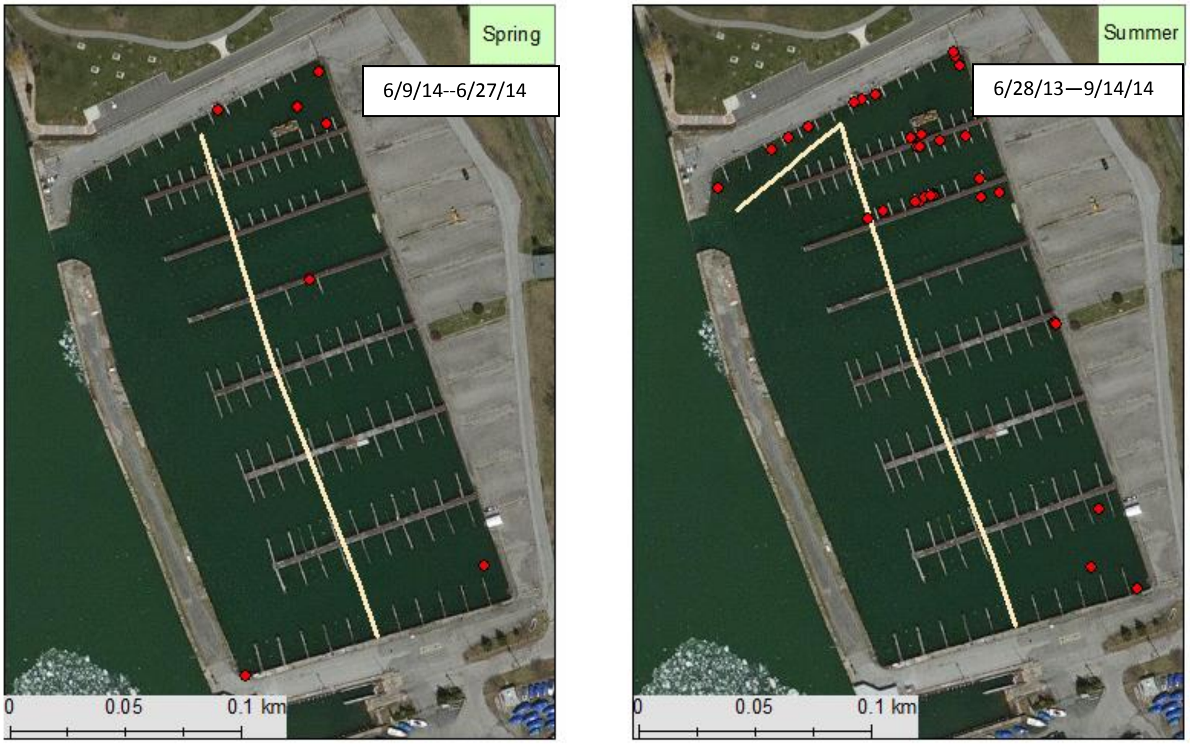


Figure 18. Complex linear home ranges of SM1 for each of the three defined seasons during 2014. Seasons were designated by water temperature (above or below 22°C), which fit cyclical movement patterns that were associated with map turtles finding brumation sites. Dates indicate time tracked.



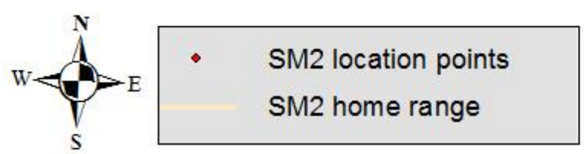


Figure 19. Complex linear home ranges of SM2 for each of the three defined seasons during 2014. Seasons were designated by water temperature (above or below 22°C), which fit cyclical movement patterns that were associated with map turtles finding brumation sites. Dates indicate the chronological path, when discernable.

Figure 20. Weed harvesting machine.

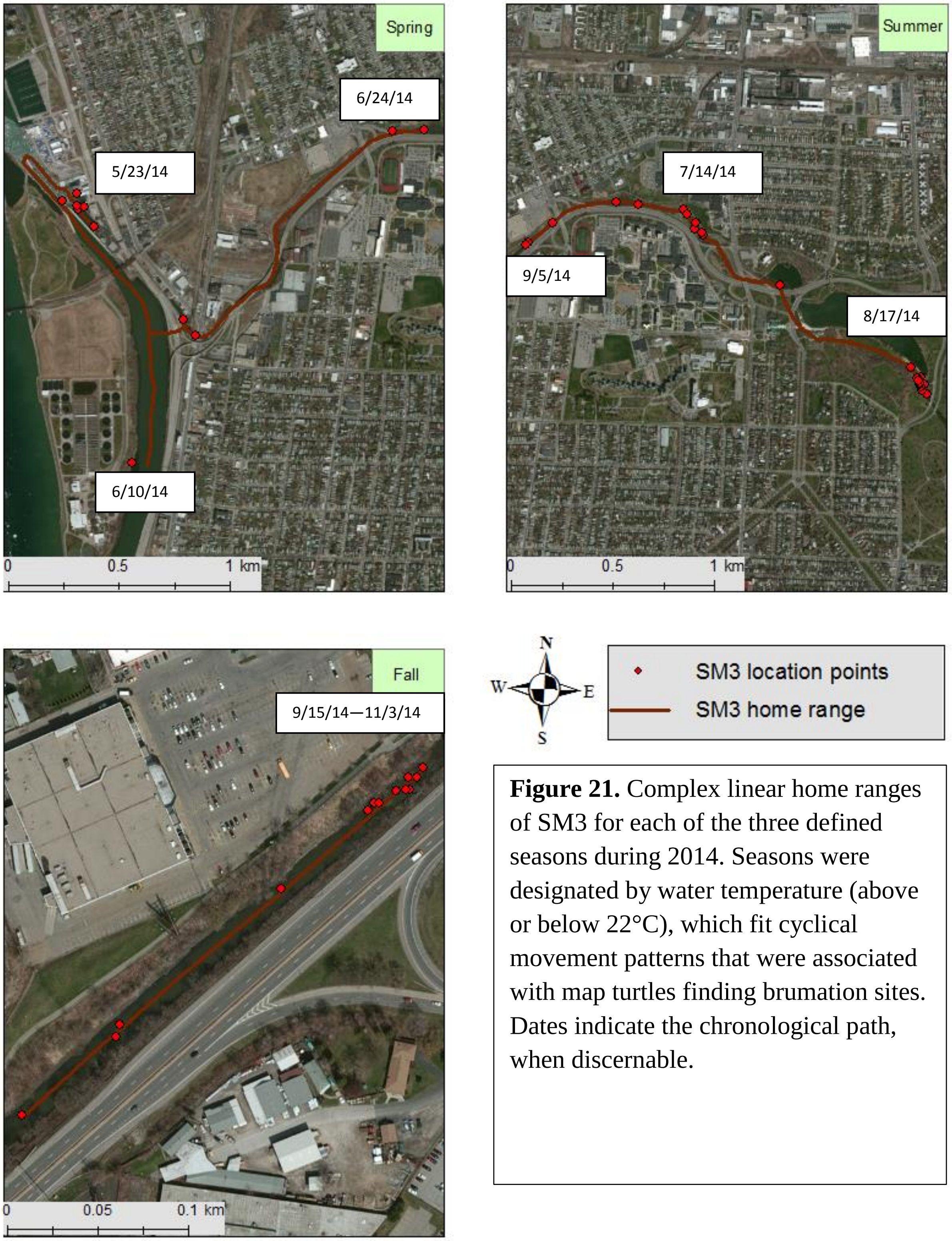


Figure 21. Complex linear home ranges of SM3 for each of the three defined seasons during 2014. Seasons were designated by water temperature (above or below 22°C), which fit cyclical movement patterns that were associated with map turtles finding brumation sites. Dates indicate the chronological path, when discernable.

3) How far do individuals of both species move per day and does this change with season?

Northern map turtles generally moved farther per day than red-eared sliders regardless of season (Table 2). Female map turtles moved considerably farther than all other turtles. Most large scale movements recorded for map turtles were in the spring or fall and were associated with returning from or heading to their hibernacula (Figure 22). Due to the high oxygen demands of map turtles (Reese et al. 2001), they must leave the marinas and find brumation sites in the river where there is more dissolved oxygen. Sliders did not move abnormal distances in the spring and fall associated with hibernacula sites. The high tolerance to anoxic conditions allowed the sliders to occupy areas that were low in dissolved oxygen like the marinas that they reside in (Milton and Prentice 2007). The abnormal movements in the spring and fall by sliders were likely related to anthropogenic disturbances. These disturbances were associated with displacement by a weed harvester and isolation from the RMC because of the Black Rock Lock.

		Mean distance moved per day(m)			
Species	Individual	Spring 2014	Summer 2014	Fall 2014	Total
G. geographica	MF1	397	145	225	238
G. geographica	MF2	993	133	581	468
G. geographica	MF3	801	934	NA	888
G. geographica	MM1	63	79	120	86
T. scripta elegans	SF1	39	47	22	38
T. scripta elegans	SM1	49	37	35	37
T. scripta elegans	SM2	91	36	662 (13)	137 (43)
T. scripta elegans	SM3	141	85	19	77

Table 2. Mean distance moved per day (m) for each individual and each season tracked. The total column gives the final mean of all the mean distance moved per day values during the spring, summer, and fall of 2014. The ( ) denotes the mean excluding the movements associated with the anthropogenic displacement.

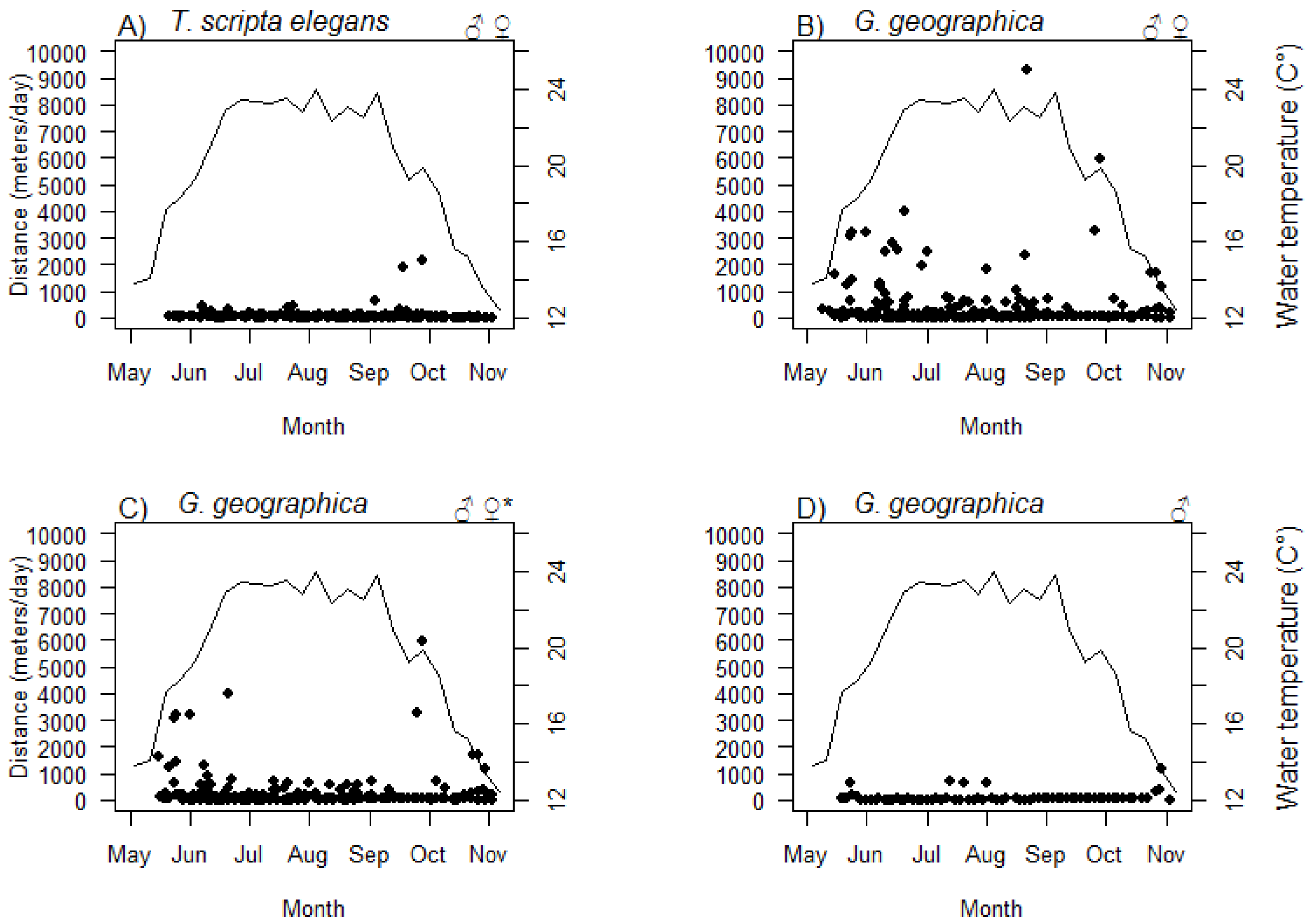


Figure 22. Mean straight line distance moved per day (m) and water temperature(C°) as a function of time. **A)** Three male and one female *T. scripta elegans* (231 mean distances). The two greatest distances are associated with a turtle that was inadvertently displaced from a marina and into the river by a weed harvester. **B)** One male and four female *G. geographica* (259 mean distances). **C)** One male and three female *G. geographica* (222 mean distances). *A female map turtle (FM3) that had highly variable movements that were different than all others was excluded. Once the water stayed above 22°C large scale movements ceased until the water temperature dropped below 22°C. **D)** One male *G. geographica* (71 mean distances). Distances moved were very similar for both of the male and female *T. scripta elegans.*

4) *Does each species occupy a unique habitat and does their habitat use overlap? What is the best habitat predictor of presence for both species?*

Habitat predictors (including surface cover, current, depth, broad shoreline, and fine shoreline seen in Figure 8) of turtle presence and absence (results from the river sampling) were examined for colinearity, but none was found. Variance inflation factors were < 1.75. Based on AIC, the best fit model retained both species and surface cover, however, only surface cover significantly predicted turtle presence (*df* = 4, *deviance* = 194.135, *residual df* = 840, *p-value* < 0.001) whereas there was no significant difference in presence by species (*df* = 1, *deviance* = .362, *residual df* = 844, *p-value* = 0.547). A species by surface cover interaction term was not significant (*df* = 4, *deviance* = 2.451, *residual df* = 836, *p-value* = 0.653), which indicated no significant effect of species on surface cover related presence.

Dense surface cover including both vegetation and debris was found almost exclusively in backwater areas of the river and was important to the presence of both species of turtles (Figure 23). In addition to surface cover, the backwaters also had minimal or no current. Red-eared sliders were never found were there was a current. The only exception was the slider that went up Scajaquada Creek where current measurements were not taken due to the poor water conditions and lack of access. Based on visual observation, current was minimal or nonexistent. The reason current did not predict slider presence based on the AIC best fit model was because many of the turtle absences were also associated with minimal to no current. Of the 265 times that map turtles were observed, they were found 42 times in currents greater than 0 (Figure 24). These occurrences were due to their seasonal movements to hibernacula. As noted earlier most individuals spent much of their time in the marinas. As a result, both species spent disproportionately more time along developed shorelines (Figure 25). Habitat occupancy was relatively similar between species based on the results of the AIC best fit model for all individuals and only movements associated with brumation sites altered habitat occupancy. While an individual from each species did not occupy the RMC, both individuals still inhabited habitats that exhibited slow moving waters and surface cover.

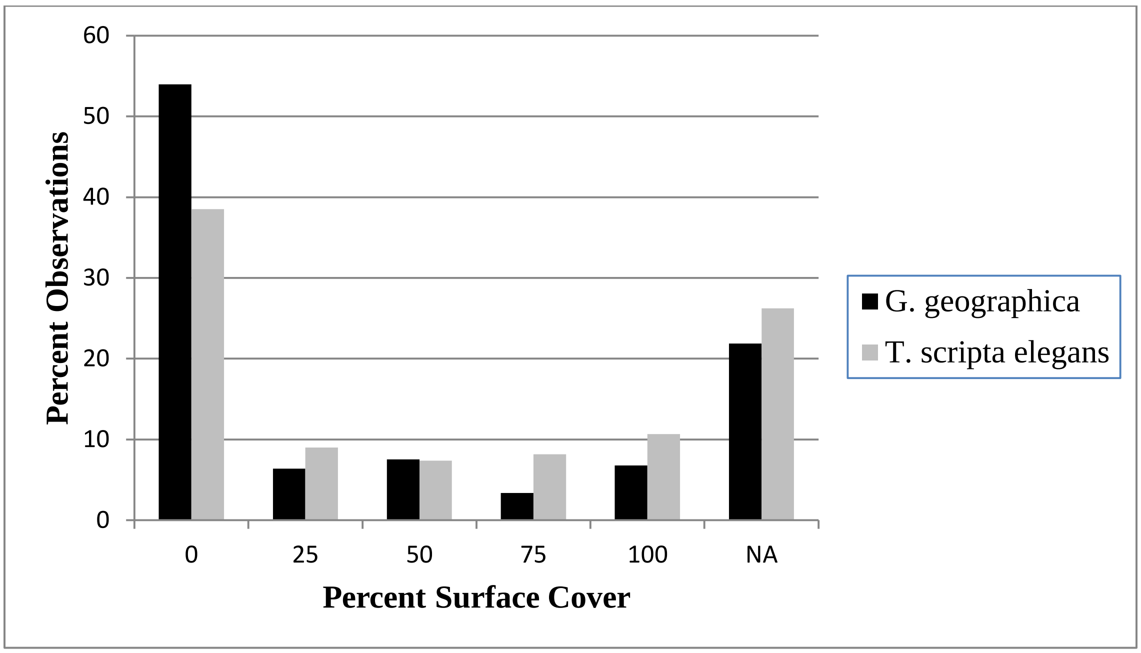


Figure 23. Percent observations as a function of percent of surface cover. Surface cover percent was designated by the amount of coverage within a five meter radius around the observed turtle.

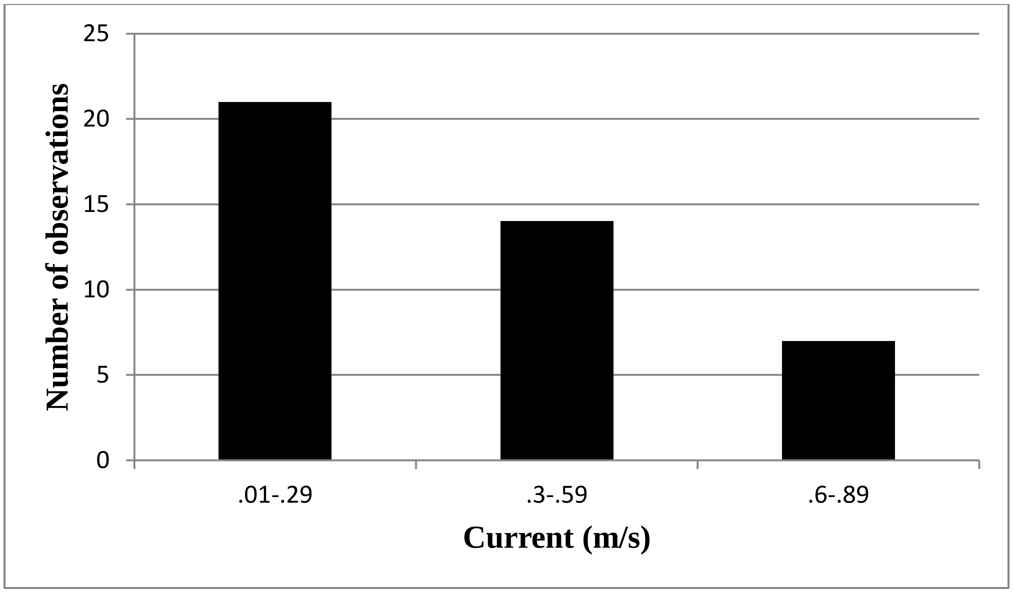


Figure 24. Number of map turtle observations divided between three current categories. Current velocity was measured one meter below the surface.

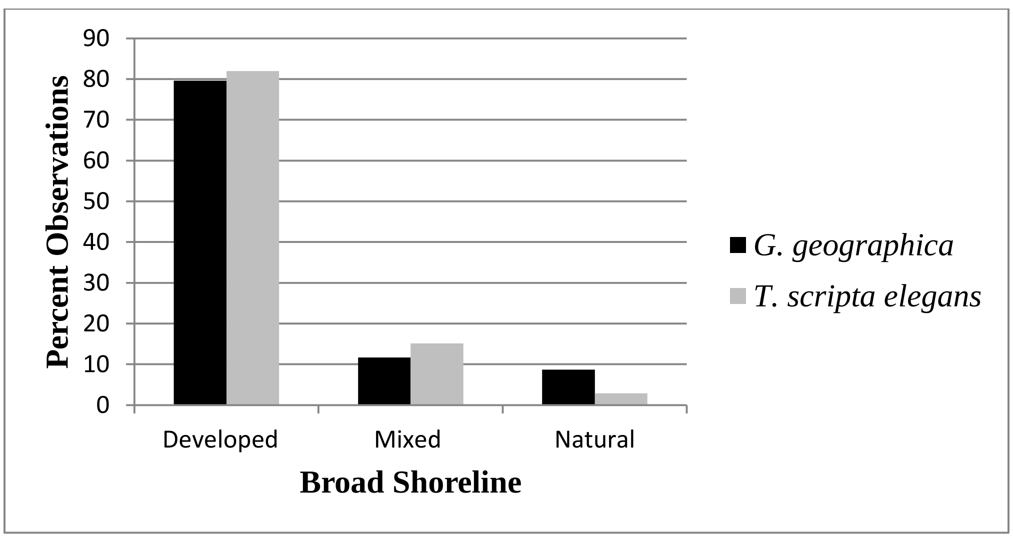


Figure 25. Percent observations as a function of broad shoreline for the entire tracking season (May-November). These data are from five *G. geographica* individuals for a total of 265 observations and five *T. scripta elegans* individuals for a total of 244 observations. Developed was defined as areas that are completely altered and or are intensively managed. Natural was defined as areas that have no visible sign of large scale anthropogenic substrates or alterations and that have no to minimal anthropogenic relics/debris. Mixed was defined as having both natural and developed fine shoreline qualities within the survey area.

5) ***How do the individual turtles fulfill the requirements needed for basking, nesting, and brumating in the Upper Niagara River?***

Life for both species in the Upper Niagara River is centered on important backwater locations, which are often in the form of marinas. These backwater environments offer ample refuge from the strong winds and currents of the river environment. These marinas provide most of the requirements needed for individual survival, but may also pose a threat to individual survival and offer limitations to the survival of the population.

Basking

Due to shifting winds and marina maintenance, basking substrate was transient, but basking materials generally were not limited. In addition, there were a few permanent basking sites in the marinas, which were in the form of old emergent pilings. Early in the active season (May and early June), the RMC had less basking materials because of the lack of vegetation compared to later in the season. By July basking opportunities were abundant and were comprised of various wood pieces and debris (plastics etc.). In addition, macrophyte growth began to accumulate along with mats of detached vegetation cover, which was used for basking and associated with presence. Wood was used more than any other substrate for both species (Figure 26). Of the turtle basking observations on wood, 87 percent occurred on the large wood class, which was defined as having a diameter > 20 cm (67 of 77 observations).

Wood, along with mats of vegetation and other debris in the corners of the marinas, served as central areas for basking (Figure 27). Basking most often occurred within 5 meters of shore for both species, which may be a function of the accumulation of debris near shore (Figure 28). Due to the limited number of turtles, competition over basking sites was not apparent and turtles were occasionally seen basking together on large long logs. It seemed that this marina complex offered enough basking opportunities for the individual survival of the limited number of turtles residing there.

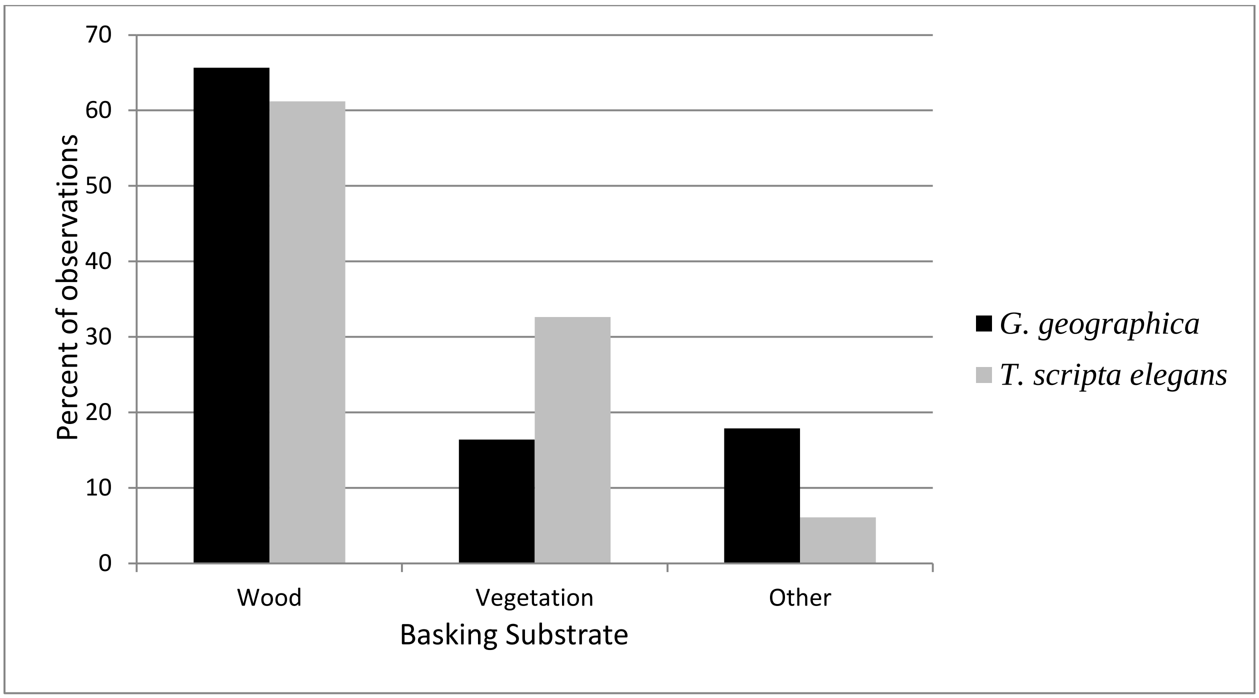


Figure 26. Percent of observations as a function of basking substrate for the entire tracking season (May-November). These data are from five *G. geographica* individuals for a total of 67 observations and five *T. scripta elegans* individuals for a total of 49 observations. The "Other" category included my basking traps and various types of anthropogenic debris, such as tires and pieces of plastic.

Figure 27. The northeast corner of Rich Marine, which was a central area for basking. The contents of this debris would change due to wind and marina maintenance. The red circle shows a map turtle basking.

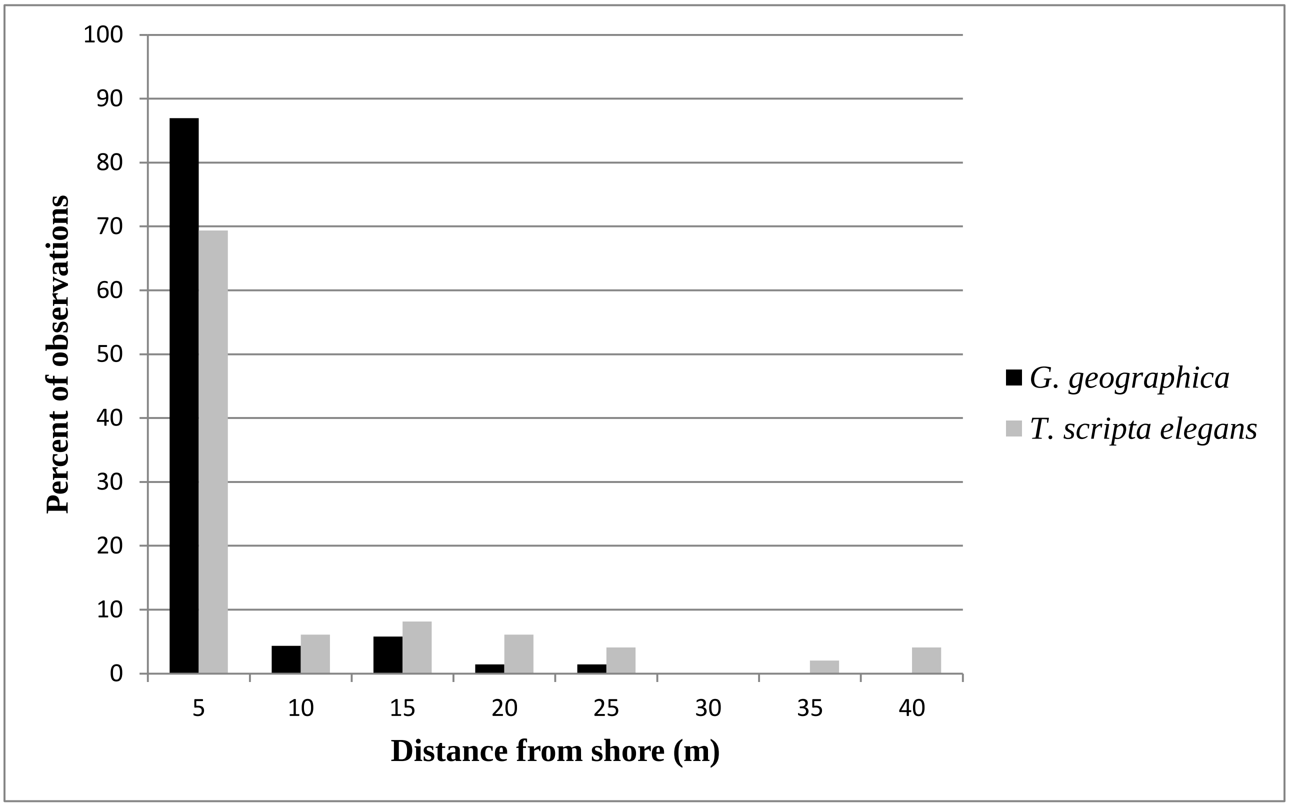


Figure 28. Percent of observations as a function of distance from shore (m) while basking during the entire tracking season (May-November). These data are from five *G. geographica* individuals for a total of 67 observations and five *T. scripta elegans* individuals for a total of 49 observations.

Nesting

Only one nest was found and it was from a map turtle (MF1). The nest was located next to a service road in a boat yard and contained 21 eggs (Figure 29). The substrate was mixed gravel and was 58 meters from the water. The nest depth was 7 cm to the top and 15 cm to the bottom, with a 9 cm width. The vertical bulkheads at this location limited shore access and resulted in only one area where turtles could gain access to land. This break in the bulkheading consisted of a concrete ramp that ran down to the water. It had a width of a meter or less at the access point depending on water levels. The eggs never hatched and contained partially developed embryos. The cause of hatching failure was not determined.

Regardless of the cause, this nesting site offers many potential threats to nesting turtles as well as hatchlings. Anthropogenic mortality from collection and car or boat collision pose dangers to both mature and hatchling turtles. In addition, the boat yard has many obstacles and barriers that could possibly prevent hatchlings from reaching the water through diversion or disorientation. The numerous bulkheads also could serve as an impediment to reaching the water. Hatchlings would have to walk over the edge and fall a few of meters to the water as opposed to walking down a sloping bank.

There are other potential nesting sites in the Upper Niagara River as well. A swimming beach at the southwest end of Grand Island has appropriate substrate and sunlight. This area is maintained and is used by people in the summer, which would offer similar threats as the boat yard. Another potential nesting area is on the east banks of the east branch of the river. The substrate is mixed gravel and is open to the sunlight. This location is where one of the mature females (MF2) temporarily moved to in the spring, but no nest was ever found. Two islands

(Strawberry Island and Motor Island) in close proximity to the summer refuge offer appropriate nesting substrate, but are highly vegetated and are not clear at the waterline, which would render them inadequate for nesting.

Figure 29. Nesting site. The circle indicates the area containing the nest and the "N" is the actual site of the nest. The square designates the break in the bulkhead that is the only access point in the vicinity of the nest.

Brumation

All three surviving map turtles brumated in different locations from each other, which suggests there is not a common hibernacula. Two individuals did migrate long distances to brumate very close to their overwintering sites from the previous year. The two red-eared sliders in the south section of the RMC both brumated within a few meters of each other in a vacant corner slip of the marina, while the one that inhabited Scajaquada Creek overwintered in the creek. The brumation site in the RMC is the same location where a tagged slider brumated the year before. This gives evidence that the specific site may be a common hibernacula for sliders that reside in the RMC. The locations of hibernacula sites for 2013 and 2014 can be seen in Figure 30 and Figure 31**.** Dissolved oxygen, depths, and distance from shore were recorded for all surviving turtles for 2014 (Table 3). The only similarity between species for brumation sites was the silt substrate, but this is also the predominant substrate in the river. Using the boat sonar, I observed that each of the map turtle's overwintering site was on the cusp of an underwater shelf. Two of the turtles were in areas of the river that had large dips and holes in the river floor that may serve as possible areas to wedge into.

Despite no evidence of common hibernacula, two of the adult female map turtles did show hibernacula site fidelity. This was evident in both space and time (Table 4). Both individuals had to move over five kilometers to return to these sites. The male map turtle did not have site fidelity and the difference between sites was puzzling. In 2013, the male map turtle did not leave the less oxygenated ACE slip, but in 2014 he made his farthest move in two years of tracking and moved over two kilometers downriver to an oxygenated site. Dissolved oxygen was not measured in 2013, but the basic dichotomy between marina oxygen levels and river oxygen levels would have been still present.

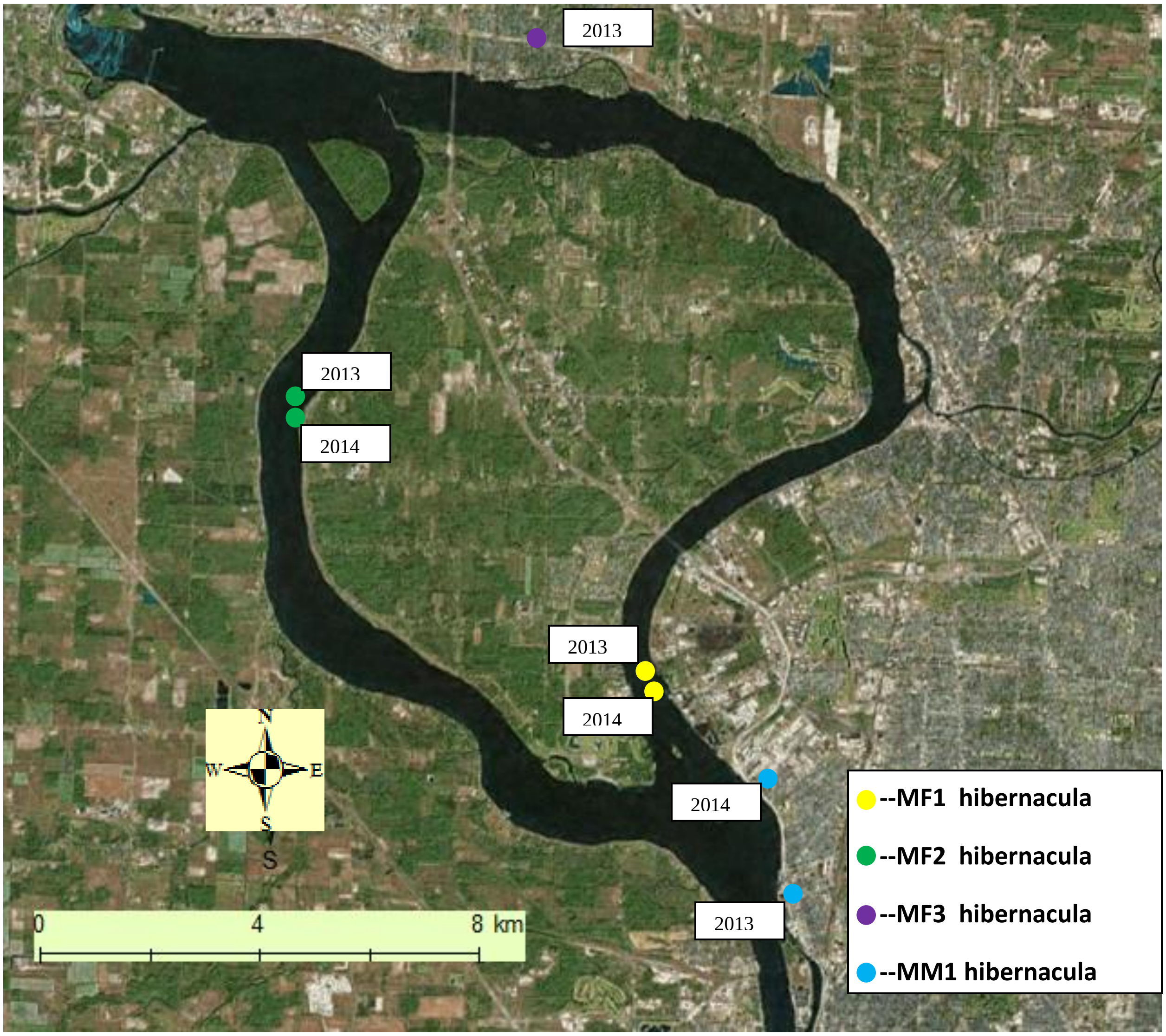


Figure 30. Hibernacula sites for all of the tagged map turtles.

Figure 31. Hibernacula sites for all of the tagged red-eared slider turtles. All sites are for 2014, except SM4 which was during 2013.

Turtle	MM1	MF1	MF2	SM1	SM2
Dissolved Oxygen (mg/l)	10.75	10.68	10.61	6.12	6.12
Current(m/s)	.1	.4	.8	0	0
Depth (m)	2	3	2	.75	.75
Distance from shore (m)	12	60	25	3	1
Substrate	silt	silt	silt	silt	silt

Table 3. Hibernacula measurements. All readings were taken between October 30th and November 3rd. Dissolved oxygen readings were taken at the bottom of the water column.

Turtle	MF1	MF2	MM1
Leaving Date (2013)	10/30	9/30	Never left
Leaving Date (2014)	10/24	9/26	10/29
Distance between brumation sites	300m	200m	2,220m

Table 4. Hibernacula fidelity. Leaving date refers to the first date the turtle was found outside of the summer refuge.

Conclusions

There are few map turtles occupying the Upper Niagara River and its tributaries. The resident map turtles spend most of their life along developed shorelines, specifically the RMC, an urbanized set of marinas. This area had deep still waters and ample surface cover for much of the year, which was the best predictor of turtle presence. Large scale movement patterns were associated with migrations to and from hibernacula sites. There was no evidence of communal hibernacula for map turtles, but it was evident for red-eared slider turtles residing in the RMC. Home ranges and daily movement patterns of map turtles varied by season and were generally larger than those of sympatric red-eared sliders. The relatively low numbers of map turtles and sympatric red-eared sliders likely limited both interspecific and intraspecific competition.

The findings from my study are consistent with many of the previous studies, however there were some notable differences. Ryan et al. (2008) conducted a telemetry study on map turtles and red-eared sliders in a highly urbanized canal system in Indianapolis. They concluded that whereas home ranges were larger for map turtles, daily movements were not different between species. Conversely, I found larger daily movement associated with map turtles. Similar to my findings, map turtles in Vermont moved distances up to eight kilometers to their hibernacula and then emigrated back to a summer home range (Graham et al. 2000). Adult female map turtles had larger home ranges than adult males in the St. Lawrence River, Canada (Carriere et al. 2009). This trend was consistent with my study. CLHR estimations for female map turtles in the Niagara were much larger than for map turtles in the Mille-Iles River in Canada using the same estimation criteria (Ouellette and Cardille 2011).

Peterman and Ryan (2009) analyzed basking substrates and contrary to my findings, they found that map turtles and red-eared sliders each appeared to prefer a specific basking substrate (rock and deadwood respectively). In the Niagara River, wood was the substrate most often basked on, but rock substrate was limited. Like the turtles in my study, they concluded that both species would bask in aquatic vegetation. In addition, adult male map turtles exhibited a strong preference for surface cover in Canadian waters (Carriere and Blouin-Demers 2010). Contrary to Carriere and Blouin-Demers (2010), my results indicate the prevalence of map turtles along developed shorelines. There has been some research indicating the potential negative impact that sliders could be having on native turtle populations (Cadi and Joly 2004, Nuria et al. 2010). No such impacts were observed. In fact, occasionally both species were seen basking simultaneously on the same substrate. The low number of turtles of both species and abundance of basking sites makes competition for basking sites improbable.

The northern map turtle population is undoubtedly small in the Upper Niagara River. It is important to note that the lack of detailed historic numbers make the discussion of this population difficult. It is unknown and only assumed based on historic range maps that there was a viable population of northern map turtles historically present in the Upper Niagara River. The remaining turtles could be a relic of a former population or an accumulation of immigrants from Lake Erie. The Niagara River may be a sink, where reproduction is insufficient to balance local mortality and is only maintained by immigration from a productive source population (Pulliam 1988). If this is the case, it may then be normal to have unstable numbers of individuals in the river. Genetic testing could possibly help resolve the source of these individuals. Regardless of their origin, these turtles are rare in the Upper Niagara River.

The Upper Niagara River is a difficult environment for turtles for a multitude of reasons. Hardened shorelines, urbanization, channelization, and river maintenance has led to increased water velocity and has removed snags and backwater marshes that could have served as refuges for turtles and other wildlife. As a result, marinas have become surrogate refuges for turtles. The river does contain a few natural backwaters and protected areas, but these areas were only temporarily occupied, passed by, or never reached by the tracked turtles. This leads to the question of why these turtles spend much of their lives in marinas?

Map turtles in the Upper Niagara utilize both marinas and natural backwaters as resting points going to and returning from hibernacula sites, but they leave these areas and return to the RMC. There is evidence of site fidelity in female map turtles (Carriere and Blouin-Demers 2010) and it has been shown that some species of turtles will maintain site fidelity in the face of habitat alteration and disturbance (Bernstein et al. 2007). The congregation of turtles in the RMC may be a result of site fidelity or there may be certain unique qualities that other marinas and backwaters do not have. If not site fidelity, there are a few potential and likely interacting factors that may attract the map turtles.

First, there is a high density of dressinid mussels attached to the bulkheads and other submerged structures in the RMC. The deep waters and ridged metal walls of the RMC increase surface area for dressinid attachment sites. This offers an ample supply of food, at least for mature females. The waters in the complex have no current and a silt substrate at the bottom. This matches the description of optimal map turtle habitat (Gibbs et al. 2007). Water depths range from one to five meters, giving turtles a wide selection of different depths. The accumulation of debris and surface cover offers adequate basking sites and cover for most of the year, while vertical walls help reduce winds from reaching a basking turtle. Finally, one of the most unique attracting qualities is the ACE boat slip (Figure 32). This is a 120 meter by 50 meter restricted boat slip that in two years has never been observed in use. This area offers a safe haven away from the boats and people in the surrounding area.

While there are many attractive qualities associated with the marinas, the potential negative effects give support to the RMC being a potential ecological trap. An ecological trap is a habitat that an organism finds equally or more attractive than other available habitats, despite experiencing reduced fitness while occupying it (Dwernychuk and Boag 1976). Numerous possible threats to individual mortality are present. Boat traffic is concentrated in these areas, and has been observed as a major threat to map turtle populations that can lead to rapid population extinctions (Bulte et al. 2010). In my study site, subsistence fishing is conducted and is concentrated in the vicinity of the RMC, which served as another threat. Evidently, nesting sites are limited due to factors such as bulkheading, and remaining locations are dangerous due to anthropogenic factors. As noted earlier, hatchling survival rate could be influenced by numerous factors associated with the RMC. I never observed a juvenile or hatchling despite thousands of trap nights and hundreds of days on the river, which gives support to the conclusion that this location may not have suitable nursery habitat. Furthermore, predators including mink, muskellunge, and birds of prey are abundant at times within the confines of the RMC. Both, unsuitable conditions for juvenile development (Severns. 2011) and altered distribution of predators have been found to reduce fitness and cause ecological traps (Weldon and Haddad. 2005). While these marinas offer certain attractive habitat characteristics, they undoubtedly offer threats to the survival of individuals as well as the population as a whole.

Figure 32. Army Corps of Engineers Slip (ACE) and the associated orange boat restriction barrier.

Management Implications

Management actions should be conservative in nature and all negative effects that could occur must be recognized and cost-benefit analysis should be examined. Sometimes in conservation ecology, management actions such as habitat alterations and species introductions can have potential adverse effects (Hedrick et al. 2000 (salmon), DePrenger-Levin et al. 2010 (thistle), Severns 2011 (butterfly), Ferronato et al. 2014 (reptiles)). Managers must carefully look at the broad ecological picture and take into account not only the target species, but all the flora and fauna, both native and non-native, that may be affected by actions. Furthermore, the potential successes and failures should be examined in light of the desired end goal of the project.

If the map turtle population of the Upper Niagara River is not a sink, and is in fact a relic of a former population, then the low number of individuals makes recovery unrealistic. The remaining resident individuals are far fewer than other minimum viable population sizes for vertebrates including turtles (Traill et al. 2007, Shoemaker et al. 2013). If a population of map turtles is desired in the river, then a reintroduction program would be an option along with elevating their protection status. Before a reintroduction program is initiated it would be important to determine whether the Niagara River offers appropriate habitat for a viable population and if the lack of appropriate habitat led to the downfall of the present population. If there is not enough suitable habitat, a reintroduction program would ultimately lead to the same situation as present. Dreitz (2006) notes that sometimes reintroductions are chosen without adequately addressing the factors that led to the species decline.

The effectiveness of reintroduction studies should be examined. Some studies have shown that relocation of reptiles (eastern box turtles and timber rattlesnake) are not an effective conservation strategy because of increased mortality and erratic behavior associated with the search for their original home range (Reinert and Rupert 1999, Hester et al. 2008). Furthermore, Dodd and Seigel (1991) conducted a review on reptile and amphibian relocation, repatriation, and translocation programs. They concluded that most of these programs did not demonstrate success as a conservation technique. To the contrary, Attum et al. (2013) found translocating musk turtles may be an effective conservation tool. The introduced musk turtles did not show increased mortality or erratic behavior in a wetland site, likely due to their inability to disperse from the introduction site. Considering the open nature of the Niagara River, dispersal from the reintroduction site would likely be an issue. However, dispersal upstream against strong currents would be difficult in certain locations, such as the headwaters of the Niagara River. Tuberville et al. (2005) found that penning translocated individuals significantly increased site fidelity, but this method would serve as a nearly impossible task in a riverine environment that is home to numerous other non-target species.

If reintroductions occur, the reintroduction stock should be extracted from populations in the same region and habitat type, so that local adaptions are maintained (Carr and Dodd 1983). In addition, the reintroductions should include hatchlings and juveniles. Since I have never observed a juvenile map turtle, it may be that the Niagara River does not contain suitable turtle nursery habitat. If juveniles cannot survive in this river, the reintroduction of only adults would be futile. If juvenile turtles are able to successfully grow to maturity, the next step is to secure, protect, or create appropriate nesting sites that are adjacent to turtle nursery habitat.

The placement of reintroduced individuals is a complex decision and should be thoroughly examined. If the habitat at the release site cannot support the species, the reintroduction will fail (Armstrong and Seddon. 2007). A few locations within the river could serve as potential reintroduction sites. The RMC is one possible site, since native turtles congregate there. The release of turtles in this location could help to understand if the RMC is the best map turtle habitat in the Niagara River, or if native turtles had site fidelity for this location. On the contrary, if this site is an ecological trap, it does not make sense to reintroduce individuals to an area that likely cannot support a viable population of map turtles.

Much has been done in recent years to improve the river through habitat restoration projects. These sites may be more appropriate release sites than the RMC, since they are protected and may offer more stability to the recovery of a viable population. There are two potential sites on Grand Island, Buckhorn State Park to the north and Beaver Island State Park to the south. The problem with Buckhorn State Park is that it is very close to Niagara Falls, which caused a mortality in the current population. In addition, it is far from the other potential sites, which would make monitoring difficult. Beaver Island State Park offers many advantages for reintroduction. It has numerous basking sites and has a large lagoon that restricts motorized boats. The nearby river shoreline is also part of the park and stretches around the tip of Grand Island to a protected backwater area called East Marsh. Since it is a state park, it would be easier to protect and create nesting sites if needed. Furthermore, release site input from researchers who have studied map turtles in natural settings could aid in site selection.

The number of individuals that can be secured for reintroduction should dictate the number of release sites. If reintroductions do occur, they should be focused in one or two sites. By doing this, individual numbers will be high in those areas, which may help reduce shock and limit spurious movements. In addition, more individuals at fewer sites will allow for a thorough and more statistically robust analysis of post reintroduction behavior.

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