5-2019

A biotelemetric study comparing diving behavior and brumation sites of translocated and resident northern map turtles (Graptemys geographica) and their response to replica model turtles on artificial basking/nesting platforms in the Upper Niagara River

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An Abstract of a Thesis
in
Biology

by

Jesse Karcher

Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Masters of Arts

May 2019

ABSTRACT OF THESIS

A biotelemetric study comparing diving behavior and brumation sites of translocated and resident northern map turtles (*Graptemys geographica*) and their response to replica model turtles on artificial basking/nesting platforms in the Upper Niagara River

Anthropogenic shoreline development leading to a lack of access to terrestrial nesting sites is one of the causes for northern map turtle decline in the upper Niagara River. Translocation of adult map turtles and the development of floating basking/nesting platforms were proposed as possible remedies for this population decline. Biotelemetry along with aerial and underwater drones were used to assess habitat preferences between resident and translocated turtles. It was expected that the platforms would be used for basking and nesting and that a platform located in a natural location would be more successful than one in a developed area, due to its close resemblance to the translocated turtles' native habitat. The developed area platform received the most use. Map turtles did not use the platform for nesting. Comparisons were made between translocated and resident turtles' basking behavior, depth selection, and brumation site selection. The highest number of turtles seen basking was between noon and 4 p.m. An air temperature exceeding water temperature by 9 °C frequently initiated basking behavior. Model turtles did not significantly alter basking behavior. Brumation habitats of translocated turtles was similar to that of resident turtles, with most turtles selecting sites in the river. The depths selected for brumation were similar between translocated and resident turtles. GIS modeling was used to define the areas used by the turtles. This information is being applied to conservation efforts that are currently being undertaken along the Niagara River to incorporate turtle nesting habitats in appropriate areas.

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ACKNOWLEDGMENTS

This project was funded by the Fish and Wildlife Habitat Enhancement and Restoration Fund through the Ecological Standing Committee as part of the New York Power Authority's license commitments for the Niagara Power Project. Tim DePriest and Ken Roblee of the New York Department of Environmental Conservation were responsible for the initial concept of the project and brought to our attention the lack of information on turtles in the Niagara River.

I would like to thank Dr. Standora for giving me the opportunity to work on this project and for his knowledge and skill with the biotelemetric methods used for this project. He also instructed me in grant writing, applying for permits, and proper procedure for filing paper work with the SUNY Research Foundation. I would like to thank Dr. Noonan, Professor at Canisius College for introducing me to Dr. Standora. I won the lottery getting to work alongside my fellow graduate student Chelsea Moore, with whom I worked countless hours. The guidance and editorial comments of my thesis committee (Drs. Standora, Lindeman, Pennuto, and Warren) were greatly appreciated. A special thank you to Dr. Lindeman for his input on the initial design of the platforms, as well as for instructing me on the techniques for capturing and processing turtles and for providing turtles for the translocation. I would like to also thank Dr. Warren for his expertise and guidance with the R statistical program and statistical analysis. Dr. Mix's guidance and help with GIS in creating interpolations or potential trends in habitat use based on abiotic variables is greatly appreciated. I am grateful for the assistance given by Sue Chislett, the biology secretary. I would like to acknowledge those who aided in turtle tracking, Michelle May, Roger Karcher, Stephanie and Staci Czaja, Adam and Andrew Fron, Billy Moore, Adam Haines, Megan Kocker, Matt Lahue, and Susan Standora.

I would like to thank the Great Lakes Field Station staff, especially manager Mark Clapsadl and field and lab technician Brian Haas, for providing assistance and facility access. The cooperation by numerous private and governmental entities was imperative in effectively conducting the research. Specifically, Anchor Marine, Rich Marine, and the Army Corps of Engineers all willingly gave needed access to their facilities. I would also like to thank Beaver Island State Park managers Gregory Brown and Andrew Hillman for allowing part of this project to be conducted within the state park. In addition, many of their employees were friendly, helpful, and showed continued interest throughout the project.

Research was conducted under the Pennsylvania Fish and Boat Commission License #2016-01-0236, and New York Department of Environmental Conservation Scientific License #1446 issued to SUNY Buffalo State. The Institutional Animal Care Use Committee (IACUC) approved this study under application #37.

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Introduction

Population decline in semi-aquatic freshwater turtles has been linked to increases in shoreline development. Shoreline vertical erosion protection devices prevent semi-aquatic turtles from accessing terrestrial nesting sites. In addition to lack of nesting site access, factors such as the pet trade and human consumption have all contributed to a decline in semi-aquatic turtles across North America in recent years. (Gibbons et al. 2000, Buhlmann and Osborn 2011, Winters et al. 2015)

The northern map turtle (*Graptemys geographica*) is a species of concern in New York State, especially in the upper Niagara River (Haas 2015). It is a species that lives in swift-moving waters, such as large rivers with rapid currents, but also can be found in backwater areas with little current. To meet their needs for oxygen requirement during brumation, turtles will locate in areas where water is constantly moving to provide a continuous flow of oxygenated water (Haas 2015). The population of northern map turtles in the upper Niagara consisted of only five individuals, three females and two males, upon initiation of this study. Those minimal numbers made the map turtles in the upper Niagara River a proposed candidate for conservation efforts. Before significant attempts to conserve a species are undertaken, background information needs to be collected to determine the potential causes of population decline and which conservation attempts are likely to be effective (Dodd and Seigel 1991). Also, enough information about life-history characteristics needs to be gathered so the species is completely understood. If any management attempts are undertaken before the species is understood, the odds of helping it are reduced.

Studies at other locations have explained food preferences and habitat selection, which are key factors in understanding what affects the local turtle populations (Carrière and Blouin-Demers 2010, Richards-Dimitrie et al., 2013). Adult male and female map turtles exhibit little overlap in diet; males feed largely on aquatic insects and smaller mollusks and females almost exclusively feed on invasive mollusks which are larger than native species. These preferences also show geographic variation. In some areas turtles feed on the same prey and other areas provide multiple feeding options (Lindeman 2006, Bulté et al. 2008, Richards-Dimitrie et al. 2013). The lack of overlap comes from the sexual size dimorphism seen within the species and morphological adaptations for mollusk specialization (Lindeman 2000, Lindeman and Sharkey

2001, Collins and Lindeman 2006, Lindeman 2006). Any foraging overlap occurs between adult males and juvenile females because of their similar sizes, but even juvenile females prefer to feed on a mussel heavy diet due to the larger head size compared to males (Lindeman 2000). Zebra and quagga mussels are abundant in the upper Niagara River; thus, diet was not considered as a limiting factor for map turtle success.

In map turtles size plays an important role in habitat selection. Larger turtles swim more efficiently and against stronger currents. Because females are larger than males, they use areas with deeper water and stronger currents than males (Bulté et al. 2008, Carrière and Blouin-Demers 2010). Males, on the other hand, use shallower water that has surface cover (Carrière and Blouin-Demers 2010). Both sexes require access to shore. The Niagara River is mostly developed with bulkheads or erosion prevention devices. This causes problems for two reasons. First, turtles are ectotherms and use external sources to regulate their body temperature for efficient bodily function and parasite elimination (Boyer 1965). Thus, basking site access is important, as *G. geographica* spend on average 46% of the daylight hours basking (Bulté and Blouin-Demers 2010a). Map turtles can temporarily bask using floating debris that is washed into the river. The second problem that results from inaccessibility to shore is restricted access to nesting sites. This issue became the main focus for the conservation project that is described here. Creating artificial basking/nesting platforms was one of the major driving factors of the project.

Previous turtle conservation efforts in other areas have used artificial mounds to help in nesting efforts for turtles with declining populations (Buhlmann and Osborn 2011, Paterson et al. 2012, Wnek et al. 2013). Artificial mounds have been effective in helping turtles that do not have an area suitable for nesting. Turtles laying eggs in artificial mounds had higher numbers of developed eggs and hatchlings compared to natural nests (Paterson et al. 2012). Harold Avery (personal communication, 2017) has constructed an artificial beach at Magnolia Lake in Dennis, New Jersey, to provide a suitable nesting area for red-bellied turtles (*Pseudemys rubiventris*). At Magnolia Lake, approximately 30 nests were laid in the previous year, but more than half were depredated by foxes and other mammals. Thus, artificial nesting sites may increase eggs laid and number of hatchlings, but other events may hinder the success of artificial nesting sites.

Many species of turtles exhibit a homing behavior towards their natal nesting sites (Buhlmann and Osborn 2011, Paterson et al. 2012). It is difficult to create artificial nesting sites and have the turtles simply find them by chance. Many species of turtles elicit homing behavior when searching for nesting and brumation sites. One effort to discourage this behavior has been to physically put the turtles on the mounds so that the female will become familiar with their location and then have a greater chance to revisit the site (Buhlmann and Osborn 2011). Alternatively, floating basking/nesting platforms can be moved to locations that the turtles show a preference toward. Other studies have transported turtles to the artificial nesting site or placed permanent artificial mounds near known nest locations (Buhlmann and Osborn 2011, Paterson et al. 2012).

The turtles in the upper Niagara River are currently faced with heavily restricted access or no access to terrestrial nesting sites due to human development. I hypothesized that floating artificial basking/nesting platforms placed in the river at sites the turtles used would allow for successful nesting activity and produce hatchlings. If more eggs were laid and successfully hatched on the platform in the river, then the abundance of northern map turtles could, in theory, rebound on its own.

Since the local population contained only five turtles a translocation was undertaken. Translocation has been described as the process of moving individuals of one species to another area where the species currently resides, historically did reside, or has never resided before (Reinert 1991, Fischer and Lindenmayer 2000). Reptile translocations have been effective in repopulating areas where they have gone extinct or to aid struggling populations (Burke 1991). Prior to translocating any individuals from one population to another, researchers must ensure the source population can absorb the loss of population numbers (Reinert 1991). Also, Germano and Bishop (2008) suggest the number of translocated individuals needs to be enough to provide a self-sustaining population, as well as add substantial genetic diversity.

In recent years there have been other translocation studies examining freshwater turtle responses on the new environment. Bogosian (2010) studied the ability of alligator snapping turtles to find suitable habitats when they were released into an area that had few suitable habitats. The results from his study were promising because the snapping turtles were able to find locations within the translocation area that provided adequate resources for survival.

Another study examined the movement patterns of translocated and resident three-toed box turtles (Rittenhouse et al. 2007). Translocated box turtles were able to find suitable habitats within the translocation area. The type of habitat (connected or fragmented) the turtle was removed from played an important role in the movement behavior of the translocated turtles (Rittenhouse et al. 2007).

Homing behavior must be considered when translocating species because individuals may attempt to leave the study area and simply find their way home (Rittenhouse et al. 2007, Germano and Bishop 2008). A soft release involves individuals being placed within a confined space within an area, so the animals become comfortable with their new surroundings before complete release (Attum et al. 2013). Attum et al. (2013) used a hard-release technique for musk turtles, simply releasing them and assessing their survivorship and site fidelity. The researchers found that hard-released turtles exhibited similar movement, survivorship, and site fidelity as resident turtles due to natural barriers limiting dispersal of hard-released turtles (Attum et al. 2013). Musk turtles have limited overland movement, thus by releasing the translocated turtles into a patchy wetland habitat, dispersal was limited (Attum et al. 2013). The researchers were unclear if the hard released turtles would have responded to the environment similarly to the resident turtles if the release site allowed for long-distance dispersal. When deciding between release strategies it is important to consider the movement patterns of local animals as well as physical features that can limit movement. Resident turtles at sites within the upper Niagara River watershed have been observed moving up to a mean distance of 900 meters (Haas 2015). The natural barrier of Niagara Falls at the downstream end and the high-velocity current at the upstream end restrict dispersal and limit homing behavior. Nevertheless, the upper Niagara River is a large moving body of water with multiple tributaries allowing for many dispersal options.

It is important to understand the physiological requirements for a species that is being translocated for population enhancement. As an ectothermic species, the northern map turtle requires external heating for metabolic processes. The most frequently observed behavior displayed by this species for thermoregulation is aerial basking. Understanding the thermal history and thermal requirements of the animal is vital for successful translocation of reptile species. A simple ambient air temperature reading will not provide enough information to have predictive value for determining species' behavior. To get a better measure of the operative environmental temperature for ectothermic species, wind speed, shortwave radiation, total radiation, water temperature, and substrate temperature of basking material in addition to the air temperature are needed (Crawford et al. 1983). Crawford et al. (1983) found that for pond sliders, shortwave radiation, total radiation, and air temperature were positively correlated with operative environmental temperatures and whereas wind speed was negatively correlated with operative temperature. Most importantly Crawford et al. (1983) suggested that basking site substrate temperature was the best single predictor of operative environmental temperature.

The data collected by Crawford et al. (1983) were used to create a temperature profile for the environmental factors that predicted when turtles were most likely to initiate basking behavior. For northern map turtles, raising the body temperature is critical for food processing and nutrient uptake (Bulté and Blouin-Demers 2010b). The rate of map turtle heat assimilation is size dependent, forcing larger-sized females to spend more time basking than the smaller-sized males (Bulté and Blouin-Demers 2010b). Females have an added thermal requirement that males do not, as they produce and lay eggs (Bulté and Blouin-Demers 2010b). Having to produce eggs and find suitable locations for nesting puts added thermal constraints on females.

The ability to regulate temperature more effectively has been linked with the movement patterns seen in adults (Ben-Ezra et al. 2008). Map turtles have a restricted active season and time constraints are important to note when a species needs to both forage and reproduce before brumation. Bulté and Blouin-Demers (2010b) only examined water temperature in their study of basking behavior. This variable is often below optimum body temperatures for metabolic rates for digestion, but there were no other abiotic factors recorded to elaborate on basking preference.

A major requirement for map turtles for overwinter survival is a continuous supply of oxygenated water (Reese at al. 2001). When map turtles are kept in anoxic water conditions, they are unable to survive for more than 50 days. Turtles that were kept in the anoxic conditions had a shift in ion concentrations which lead to lethal pH levels in the blood (Reese et al. 2001). Map turtles have been observed to brumate in large and small groups and have high brumation site fidelity, often returning to within 200 meters of previous brumation site (Graham et al. 2000, Haas 2015). Selection for areas that receive constant water flow throughout winter is essential for survival.

One of the key factors which needs to be addressed when translocating a species is the location of release. If the new environment is too dissimilar from the native, individuals may exhaust all their energy in attempting to find suitable habitat, thus increasing mortality (Rittenhouse et al. 2007). I hypothesized that the translocated turtles would show a different pattern of habitat selection, diving behavior, and brumation site selection than resident turtles. I expected that translocated turtles would spend more time near the surface visually searching for favorable basking locations and potential nesting sites.

In the upper Niagara River I observed snapping turtles (*Chelydra serpentina*), red-eared sliders (*Trachemys scripta elegans*), eastern spiny softshell turtles (*Apalone spinifera spinifera*), and painted turtles (*Chrysemys picta*) basking along the river. Turtles were seen basking together or separately. The red-eared slider is an invasive species in the Niagara River. It has been implicated in the displacement/decline of Spanish terrapins (*Mauremys leprosa*) and red-bellied turtles (*Pseudemys rubriventris*) in their native ranges, respectfully (Polo-Cavia et al. 2010, Pearson et al. 2015).

Study goals

Overall goal: to assess the success of translocating turtles from Presque Isle Sate Park into the upper Niagara River and to evaluate the frequency of nesting and basking activity on the artificial platforms. Floating platforms were used to provide basking opportunities for map turtles and help determine the environmental conditions predicting aerial basking. Biotelemetry was used to monitor the turtles' behavior in the natural setting and helped inform where to place floating platforms.

General questions and aims:

1. ***Do translocated turtles have similar body conditions (mass/length ratios) compared to the resident turtles?***
    - *How do body conditions of the translocated turtles compare to turtles from the source population?*
2. ***Do translocated turtles show a habitat preference different from resident turtles?***

- *Will the habitat preference shift with changing water temperature, air temperature, or photoperiod?*

3. ***Do translocated turtles use the water column differently from resident turtles?***
   - *Is there a difference in where in the water column the translocated map turtles spend most of their time during the first week post brumation than the resident map turtles?*
   - *How will the diving behavior of the translocated turtles differ between the first and second week after release? Do they spend more time at the surface?*
   - *How do the diving behaviors differ between translocated and resident map turtles for entering and exiting brumation?*
4. ***Do translocated turtles exhibit movement patterns different from resident turtles?***
   - *Does the temperature of the water affect distance traveled by translocated and resident turtle differently?*
5. ***Will resident and translocated turtles select brumation habitats with similar oxygen concentrations?***
6. ***Will turtles bask on the platforms? Will the time of day affect the observed basking events on the platform?***
   - *Will the turtles use one portion of the platform more than another portion? (Detachable ramps, base portion, ramp to sand, top of sand)*
7. ***Will model turtles affect the basking behavior of turtles?***
   - *Will the presence of turtles on one ramp of the platform attract turtles to that ramp, or will turtles select the ramp without the models?*
   - *Will model turtles placed near the sand substrate attract turtles to the nesting area?*
8. ***What abiotic factor is the best predictor for basking behavior (air temperature, water temperature, substrate temperature, solar radiation, wind speed, relative humidity)?***
   - *Is there an air temperature threshold where map turtles begin to bask? Does this threshold shift with wind speed or relative humidity?*

- *Is there a temperature difference between the water and the air required for the turtles to initiate basking?*
- *How does cloud cover/solar radiation affect basking behavior?*

9. ***Do turtles nest on the basking/nesting platform?***
   - *Will there be a difference in frequency of nesting between resident and translocated turtles?*
   - *Will the location of the platform affect the frequency of nesting?*

By the end of the project there was only a single egg laid by a red-eared slider on any of the platforms. There were only two documented attempts of females laying eggs. If the time spent on the sand portion of the platform was 30 minutes or longer, it was considered a nesting attempt.

Materials and methods

Study species

Northern map turtles (*Graptemys geographica*), also known as common map turtles, belong to the Emydidae, a large family of fresh water turtles native to North America. Within this family are also pond turtles, painted turtles and terrapins to name only a few. Northern map turtles have a geographic range from southern Ontario and Wisconsin to northern Georgia and Arkansas (Figure 1). These turtles are found in water ranging from slow backwaters to streams to large lakes. They are observed most frequently in areas that have a high abundance of fallen trees which they use for aerial basking (Ernst et al., 1994, Lindeman 2013).

This species of map turtles has a low central ridge that runs along the carapace. The carapace is greenish with thin yellow-orange rings, giving it a resemblance to a topographical map. A distinct marking on the northern map turtle is the yellow spot behind the eye (often triangular) (Gibbs et al., 2007, Bulté et al. 2013).

Most jurisdictions of the United States and Canada list the northern map turtle as a species of special concern. Although it is native to the upper Niagara River region, the current population has been considered on the decline in recent years and at risk for local extinction (Haas 2015). This species displays extreme sexual size dimorphism, females grow to about twice

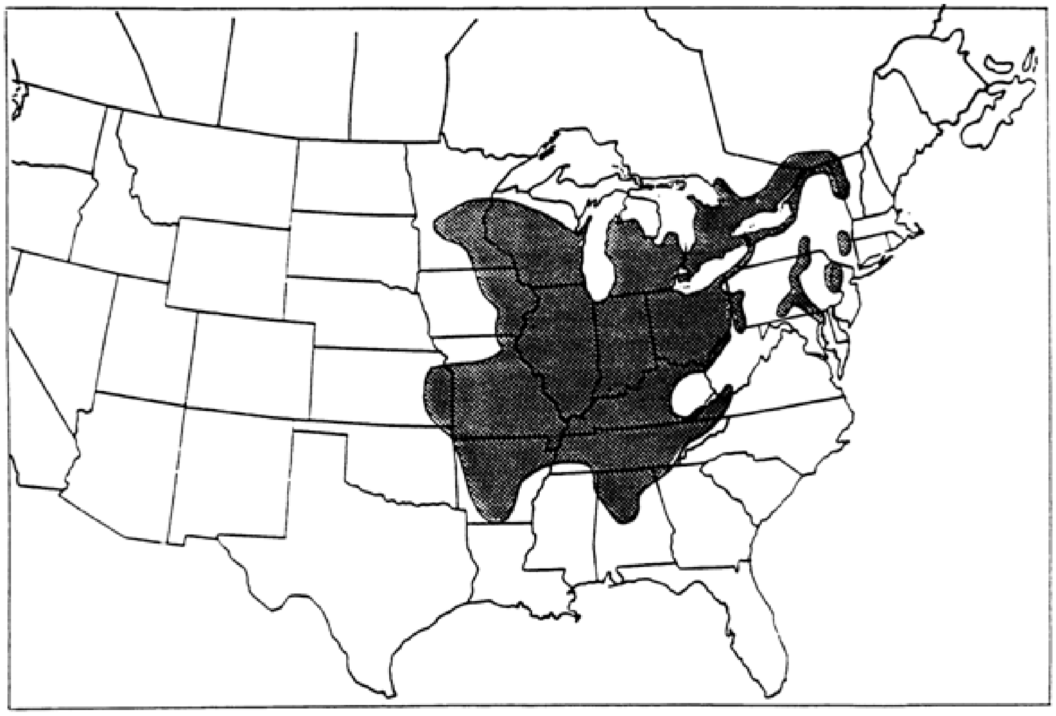


Figure 1. Distribution of northern map turtles in North America and Canada (Ernst et al., 1994).

Figure 2. From left to right, an adult male and an adult female northern map turtle.

as wide in carapace and plastron length and twice as high in shell height as the males, and 8-10 times as large by mass (Figure 2, Lindeman 2000, Bulté and Blouin-Demers 2010b) They also display sexual dichromatism in the distinct triangular mark behind the eye, with males having brighter and more saturated spots than females (Bulté et al., 2013). The degree of sexual size dimorphism has significant effects on the basking requirements for the sexes (Bulté and Blouin-Demers 2010b). This species has been seen in both swift-moving water and in still water along Lake Ontario and the St. Lawrence seaway (Carrière et al. 2009). They have been found in areas with waters as deep as 25 meters (Carrière et al. 2009). They use basking behavior to help regulate body temperature. They can be observed out of the water for long periods of time warming their bodies before returning to the water.

Study site

My study took place in the upper portion of the Niagara River, from its connection to Lake Erie to Niagara Falls, along with its tributaries. The Niagara River is listed as an area of concern (AOC) by the United States Environmental Protection Agency (EPA) (Great Lakes area of concern www.epa.gov). These are areas with significant impairment of benefits due to human activity and are in the process of being restored by local and federal agencies.

Two areas were used for placement of the artificial basking/nesting platforms: Beaver Island State Park lagoon (BIL) and the Army Corps of Engineers' (ACE) off-limits area near the Black Rock Lock (Figures 3 and 4). These two areas contrast greatly, which allowed for behavior to be measured in natural and developed areas. The Beaver Island State Park lagoon is a protected area where motorized boat traffic is not allowed and there is very little developed shoreline. The only watercraft that are allowed are canoes or kayaks, effectively rendering the risk of death via boat strike to zero, at least when the turtles are in the lagoon. In the lagoon, turtles have easy access to dry land for basking and nesting. On the other hand, the Army Corps of Engineers area is completely developed with bulk heads which severely limit terrestrial access. This area is at the dead end of a channelized waterway. To get to this area, turtles must swim past two marinas, Harbor Palace Marina and Rich Marine Marina. This site may have a high incident of disturbance because of its proximity to people. The current resident turtles however have often been observed at this location during the summer months (Haas 2015).

Figure 3. Recently renovated habitat at Beaver Island State Park. There are multiple tethered downed trees that are important for basking, as well as contiguous shorelines throughout the lagoon allowing for potential terrestrial nesting. Sand from the platforms located here has been placed on the island pictured to begin the construction of a permanent suitable nesting mound.

Figure 4. Army Corps of Engineers' (ACE) unused boat slip. The Orange barrier restricts boat traffic to only approved vessels. This area is completely bulk-headed with no access to nesting habitats.

Artificial Basking and Nesting Platforms

Artificial basking/nesting platforms were constructed on top of EZ-Dock floating dock units. The nesting area itself was composed of sand on top of a wooden box. Map turtles nest on shore to ensure that the eggs will remain out of the water. Therefore, we constructed a ramp to get to the nesting area, which was approximately one meter above water level. There were two ramps to get out of the water and onto the platform. The ramp and wooden box structures where constructed out of lumber (Figure 5). Once assembly was completed, the wood was painted brown with non-toxic wood stain to reduce the risk of the wood rotting. For the prototype design, the ramp from the EZ-Dock unit to the nesting sand was divided into two sides. One half was sand and the other half was carpet to allow for the turtle to have something to grip onto. To minimize any balancing problems, this design was changed for the second two platforms, which were constructed with three ramp section, to more evenly distribute the weight of the sand. The center section held sand and the two sections on either side were wood covered with carpeting. The top portion of the box structure was filled with a minimum of 15 cm of masonry sand. The three sides of the nesting portion of the platform were also covered with camouflage netting to better conceal the platform and give a more natural look (Figure 6). The EZ-Dock portion of the platform had four cleats to tie off four Danforth anchors to secure the platform to its position but also allow for easy removal and transport to a different location. In the Army Corps area, the platform was attached to a ladder that is set into the bulkhead. This platform was attached to the ladder with two stainless steel chains through PVC tubes and a piston to keep the platform away from the wall but to allow for water level fluctuations.

Each platform was equipped with a wireless surveillance camera that had the ability to send images to cell phones to ensure up-to-date images of the basking/nesting area. To deter avian species from access to the nesting site, monofilament line was strung between support dowels. Also, to reduce the risk of predation by land animals, the platforms in Beaver Island were kept away from shore so that potential predators would have had to swim to the platform.

Each basking platform that was deployed in the river was also equipped with four HOBO data loggers for collecting temperature and solar radiation data (Figure 7). These data loggers were located on each ramp leading from the water to the platform, as well as at the surface of the water and half a meter deep. Readings in the water were taken every 15 minutes and the two data

Figure 5. Construction of the basking/nesting platforms. A) Initial construction of platforms. EZ dock base with ramps and wheels. B) Near complete nesting box structure, hard ramps on either side of the center compartment for a sand ramp.

Figure 6. First completed platform with attached surveillance camera. This prototype was then modified to more evenly distribute the weight and had three ramps leading to the sand.

Figure 7. Left) HOBO data logger which recorded light intensity and temperature. Four were placed at each platform. Right) iButton data loggers recorded temperature, three of which were placed in the sand of each platform.

Figure 8. Red-eared slider toy replica used to test if the presence of other turtles on the platforms influences live turtles' basking behavior.

loggers on the platform recorded measurements every 5 minutes. The iButton data loggers recorded temperature values of the sand at three different depths, as well as on the surface of the platform (Figure 7). In the sand, the loggers were at 15 cm deep, 7 cm deep, and just below the surface. They collected readings every 15 minutes. The iButton on the surface of the platform collected reading every 5 minutes to help capture rapid weather changes.

To determine if the presence of other turtles on the platforms would affect live turtle basking, replica model red-eared sliders were placed onto the platforms (Figure 8). For the BIL and ACE platforms, the models were placed for approximately three days on each platform followed by three days without models.

Research techniques

Translocation

Ten map turtles from Graveyard Pond, Presque Isle State Park, Erie, Pennsylvania, were translocated into the upper Niagara River (Figure 9). Presque Isle is an area with connected aquatic and terrestrial habitats while the Niagara River has severely limited connections to suitable terrestrial nesting sites. Developed areas are not favorable for nesting activity because of severely limited terrestrial access, but there is an abundance of mussels on the bulkhead walls, which are a preferred food source for adult female map turtles (Bulté and Blouin-Demers 2008, Richards-Dimitrie et al. 2013). The Presque Isle population has a substantial numbers of map turtles, therefore the removal of ten individuals would not impact the population in any significant way (Figure 10). This number was agreed upon between two well-known turtle biologists (Drs. Ed Standora and Peter Lindeman), as well as the conservation authorities, The Pennsylvania Department of Conservation and Natural Resources and the local New York State Department of Environmental Conservation. Twelve turtles were initially captured in Graveyard Pond by Dr. Peter Lindeman with the assistance of myself and research partner Chelsea Moore. The turtles were then held in quarantine from May of 2015 until August 2015 in multiple aquariums at Buffalo State College. During this period, turtles were tested for possible pathogens (FV3 Ranavirus, Mycoplasma sp., Herpes Consensus PCR, and Adenovirus Consensus PCR). Following testing, they were moved to a single holding tank at the Great Lakes Field Station. The animals were held until being released on October 18th and 28th. The 10 individuals that

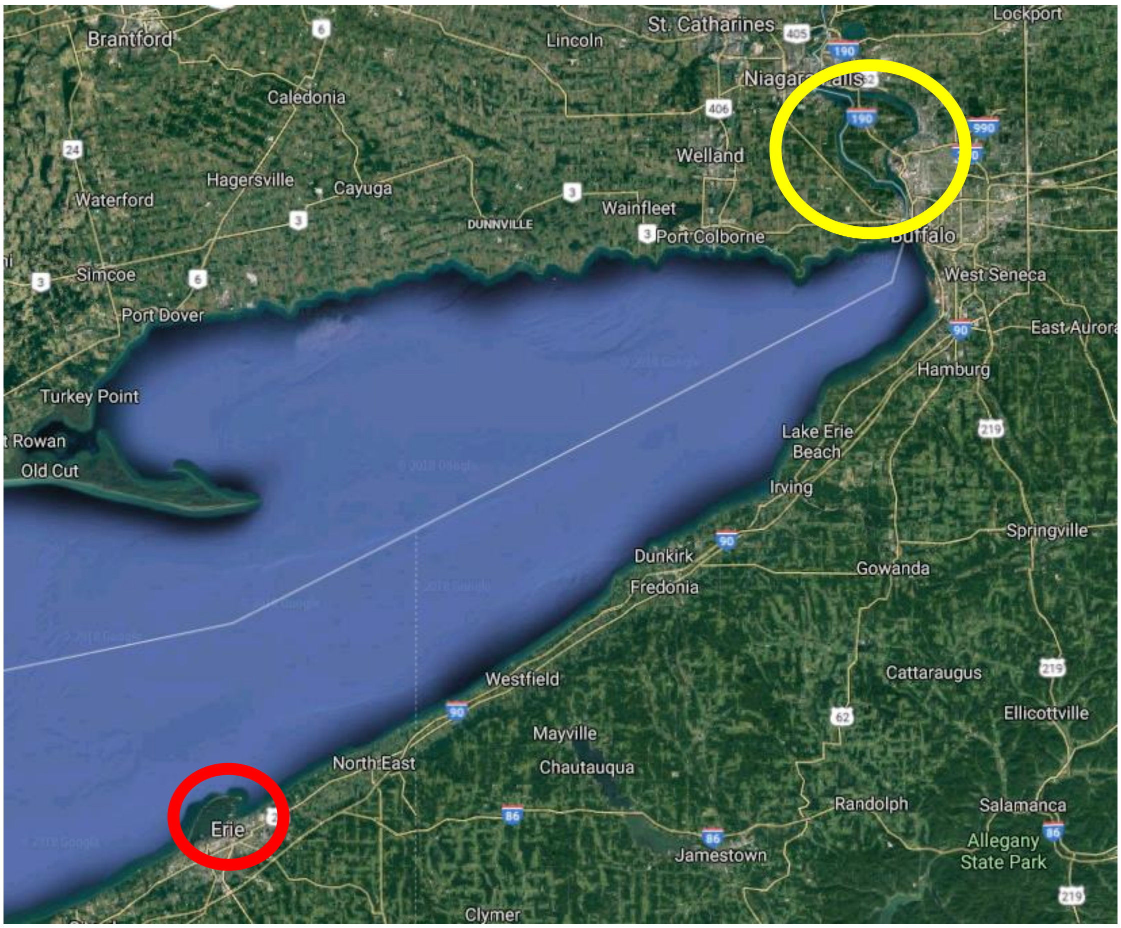


Figure 9. A Google Maps image of western New York and the northwestern portion of Pennsylvania. The red circle is Presque Isle State Park in Erie, Pennsylvania from which the translocated turtles were collected. The yellow circle is the upper Niagara River where the turtles were released.

Figure 10. Numerous basking northern map turtles at Presque Isle State Park, Erie, Pennsylvania

were released in the Niagara River had negative results for these pathogens. Turtles were outfitted with sonic transmitters, radio transmitters, and data loggers.

When individual box turtles were placed into new habitats that were similar to old habitats, they exhibited less movement than individuals that were placed in to new habitats that were dissimilar (Rittenhouse et al. 2007). For my project, turtles were taken from Graveyard Pond in Presque Isle State Park, Erie, Pennsylvania. As a state park, Presque Isle is a very natural location where turtles have plenty of access to shore and other basking locations, such as logs. The floating platforms that I have constructed were placed in two different environments with very different habitats. The first location was in Beaver Island State Park Lagoon which is very comparable to Presque Isle, while the second habitat was the Army Corps of Engineers' restricted backwater boat slip. It is completely bulk headed and situated directly next to a marina. By placing the basking/nesting platforms in two different environments, turtle behavior was compared between habitats. The developed area is not favorable for nesting activity because it has severely limited terrestrial access, but there in an abundance of mussels on the bulkhead walls, which are a preferred food source for adult female map turtles (Bulté and Blouin-Demers 2008, Richards-Dimitrie et al., 2013). Selection along an urban gradient has shown that some species of turtle prefer basking habitats that are in more developed areas with moderate to low human disturbance (Hill and Vodopich 2013). Platform locations were used to provide data about northern map turtle habitat preference between natural and developed sites.

Due to an extended quarantine period, translocated turtles were not released until October when temperatures were cool and basking time was limited. Because it was late in the active season for these turtles, a hard release was favored for the turtles' safety. Also, a hard-release was favored to allow for turtle behavior to be assessed with limited human contact. A soft-release may increase the possibility of a behavioral modification due to release site selection. Part of my study was to observe the translocated turtles' habitat selection. Using a hard-release allowed for a more accurate habitat selection assessment.

<u>Radio/sonic transmitters and data loggers</u>

Each turtle was outfitted with a radio transmitter, a sonic transmitter, and a data logger (Figure 11) which allowed for biotelemetric tracking (Cooke et al., 2004). When using live animals in the wild, the mass of all attached equipment should be no more than 5% of the animal’s mass. This is important when working with species that are sexually dimorphic. When new turtles were captured they were brought back to the lab at Buffalo State for processing. The turtle was first weighted and measured (minimum straight carapace and plastron lengths). They were then cleaned to remove any growths that may have been present on the carapace. A cotton pad soaked in ethanol was then rubbed on the carapace to remove any bacteria or oil from handling. Identification marks (3 mm diameter holes) were drilled in the marginal scutes, always avoiding using the bridge marginal scutes. This project always used two letters to designate each turtle, e.g., CQ, IA, IC. following the code established by Cagle (1939) and Gibbons (1988). Each transmitter was attached in two ways. The first was with nylon coated 1X7 stainless steel leader line and size three wire leader connector sleeves. The wire was strung through the transmitters and then a sleeve was used to create a loop. The other end of the line was then passed through an ID hole, if in a functional location, or through a new 2 mm hole in the marginal scutes, again closed off by a sleeve. All lines were as tight as possible to restrict the transmitter’s movement to ensure they would not accidently detach. The second method was by using PC7 epoxy. The epoxy provided a secondary method to secure the transmitters to the turtles as well as limiting the number of sharp edges and ends of wire. The epoxy also allowed for decreased drag produced by the attached transmitters. It created a smooth surface transition from carapace to transmitter for the water to flow over the carapace making the turtle as hydrodynamic as possible with the equipment attached.

Radio and sonic transmitters allowed for turtles to be located so movement patterns could be determined. Radio transmitters that were used were from either Lotek Wireless Incorporated or Holohil Systems Ltd. The only difference was the size. Lotek Wireless transmitters were the larger transmitters with a weight of 19.35 g while the Holohil transmitters were 6.0 g. Sonic transmitters were purchased from Sonotronic, also in two different sizes. The smaller IBT-96-5E had a mass of 7.8 g and the larger IBT-96-9E had a mass of 9.1 g. The need for two different sizes of transmitters was to ensure that they did not inhibit swimming. Data loggers from Star Oddi were used to gather information about the depth and temperature of the water. These transmitters have only one size that was suitable for this project. The model used was the DST milli- L-F temp-depth archival tag (50 m max depth) weighing 12 g with memory of 699,000 measurements taken before data needed to be downloaded. When the turtles were recaptured, all equipment was removed and replaced.

Figure 11. Female map turtle with a radio transmitter attached to the center of the carapace, a sonic transmitter attached to the left posterior marginal scutes, and temperature and depth data logger on the right posterior marginal scutes.

Tracking Seasons

Northern map turtles in the upper Niagara are active between April and November (Haas 2015). Nesting behavior begins in early spring (Geller 2012). Therefore, tracking and nest site monitoring were conducted daily or every other day depending on how many turtles were located and the distance that they moved from the previous location. For tracking the turtles, a six-element Yagi antenna was mounted to a research boat. Starting from the dock, scanning for turtles allowed for close approximation of the turtle location as the boat was driven along the shores of the river. When the boat got close to a turtle's location, a Telonics H-antenna gave a more precise location (Figure 12). Then the Sonotronic sonic receiver was used to pinpoint an exact location. This receiver is more directional, making it possible to pinpoint the turtle's exact location. Once a turtle was located, water temperature, depth, distance from shore, GPS location, wind speed, and current were recorded. This process was completed for each turtle when it was located. Water temperature was recorded using a digital thermocouple thermometer (Fluke 52). Depth was taken with the boats Lowrance fish-finder and chart plotter. This device uses a sonic signal to calculate the depth of the water. My study examined whether there are abiotic factors that are predictive of basking behavior in northern map turtles and whether there was a difference in basking preferences between native and translocated turtles.

Turtles were located until late fall (October-November) from the boat to ensure that the brumation location was accurately recorded. There are differences between the sexes and between lotic and lentic species for distances traveled to and from brumation sites (Carrière et al. 2009). In this study translocated turtles came from a population which is native to a more lentic system and may have a different level of oxygen requirement. Here I looked to see if there was a difference between resident and translocated turtle brumation sites and if so, whether that difference was correlated with dissolved oxygen levels in the water.

Basking Traps

Basking traps were used to capture turtles throughout the tracking season. Basking traps were constructed with large PVC tubes in a rectangular shape approximately 1.5 m x 1.0 m with snow fence netting attached to the PVC, creating a net in the water catching turtles (MacCulloch and Gordon 1978, Haas 2015). Wooden planks were cut to lay across the top and over the sides of the PVC so that the turtles could use the wood to bask. When they jumped off the edge of the

Figure 12. Active tracking using the six-element Yagi antenna, an H-antenna, and the Sonotronic sonic receiver.

Figure 13. Basking trap used to capture tracked turtles for measurement and equipment retrieval and replacement, as well as any new individuals that entered the system.

wood the turtles were trapped in the snow fencing until they were physically removed (Figure 13). The basking traps served two purposes. First, the traps allowed for passive capture of turtles so that measurements (carapace length, plastron length, and mass) could be collected for tracked turtles and compared between resident and translocated turtles, and between translocated and source population turtle growth rates. There have been differences observed between growth rates in other populations of map turtles (Bennett et al., 2009). Second, the basking traps allowed for recapture of tracked turtles so their transmitters and data logger could be replaced.

Surveillance Cameras and Drones

The surveillance cameras were mounted on the platforms to monitor nesting and basking activity. The camera was a HCO Spartan GoCam powered by Verizon (Figure 14). This model allows the camera to send images to an email address for real-time updates. There was also an application for phones that connects directly to the camera. The camera took pictures every three minutes.

The cameras were mounted on PVC poles approximately 3 m above the platform to view most of the basking and nesting area. The presence of a stationary camera trap did not affect the behavior of Ouachita map turtles in Wisconsin (Geller 2012), so I expected that the behavior of northern map turtles was also not affected. If the images displayed a turtle moving up the ramp to the sand to potentially lay eggs, that camera was switched to video mode to record the event. Translocated and resident northern map turtle basking behaviors were compared to determine if differences existed. To determine if there was an influence of the presence of conspecific or other species on turtle basking behavior I placed replica model red-eared sliders on the platforms. This provided data to determine if the presence of red-eared sliders in the upper Niagara River influenced native turtle behavior.

Also, drone surveillance was used in the immediate vicinity of the platforms so that the turtles would be minimally affected by human contact. In the Beaver Island lagoon where water traffic is restricted to hand-powered crafts (kayaks, canoes, etc.), a drone allowed for quick surveillance of the area with minimal invasion into the habitat. The drone was a Splash Drone Waterproof with a mounted GoPro HERO4 silver attached on the underside (Figure 15). The camera recorded video of the flight that the drone took over the lagoon to search for turtles which may be in the water, on the shore, or near the platform. For underwater surveillance, an

Figure 14. Surveillance camera used to capture real time images of turtles on the basking/nesting platforms.

Figure 15. Left) Arial Splash Drone Waterproof with a mounted GoPro HERO4 silver. Right) OpenROV Trident underwater drone

OpenROV Trident underwater drone was used to capture video of brumation behavior, as well as some swimming and feeding behavior (Figure 15). This drone was controlled with a Singularity S192K remote control unit that allowed for real time visual observation of drone dives.

Data analysis

1. **Do translocated turtles have similar body conditions (mass/length ratios) compared to the resident turtles?**

By taking measurements every time a turtle was captured by basking traps or other means (hands, nets, etc.), the growth rates and body condition for resident turtles and translocated turtles were compared. Turtle masses were averaged to provide one data point for each individual turtle. To account for different patterns of weight loss and gain only measurements that were taken in June and July were considered. The translocated turtles were also compared to the source population of map turtles to see if the Niagara River turtles had different or similar growth rates. Source population data were provided by Dr. Lindeman who has been collecting data on the map turtle population in Presque Isle for many years. He provided a large data set of turtle measurements from which six male and six female adult turtles were randomly selected. Translocated turtle numbers consisted of six male and six females, and resident turtle numbers were two males and three females. To calculate a body condition index (BCI), a turtle's mass was divided by its carapace length. An analysis of variance (ANOVA) was used to determine if there were significant differences in the body conditions among the three groups of turtles. BCI was analyzed as a function of group (n=3), sex (n=2), and their interaction, and then a Tukey HSD was performed.

2. **Do translocated turtles show a habitat preference different from resident turtles?**

Turtle location data recorded throughout the tracking season was used to assess habitat preference. GPS locations were collected for every turtle every day to every other day. The points were then transposed onto a map using GIS. The field season was divided into four segments to see if habitat preference shifted in response to water temperature. The separated seasons were winter, intermediate (spring and fall) and summer. These separations were created based on water temperatures, winter 3-13 °C, spring (January-June) and fall (July-December) 13-

23 °C, and summer 23-33 °C. Kernel densities were calculated for each of the seasons. Kernel density calculates the density of the point or line features. GIS creates output layers that are easily interpreted to see areas with high numbers of points or lines (Worton 1989). In GIS, the points could show trends based on water temperature, air temperature, or photoperiod (seasonality) (Micheli-Campbell et al., 2013).

3. **Do translocated turtles use the water column differently than resident turtles?**

The data collected for the first week after translocation were compared to the second week of translocation to see how the behavior differed following release. Then data collected from the time before entering brumation were compared to see if there was a difference in how the resident and translocated turtles entered brumation.

4. **Do translocated turtles exhibit movement patterns different from resident turtles?**

The water temperature was divided into four categories, winter 3-13 °C, spring (January-June) and fall (July-December) 13-23 °C, and summer 23-33 °C. Distances moved were calculated using GPS points and creating straight lines between them, only incorporating aquatic travel. These distances were then divided by the number of days between the observations. GPS points that were within 10 meters of each other were considered to have remained in the same place. All other distances were considered to have moved.

5. **Will resident and translocated turtles select brumation habitats with similar oxygen concentrations?**

Once the turtles were in their brumation locations, oxygen concentrations were taken using a Hydrolab Quanta Multi-Probe meter to compare between resident and translocated turtle selected locations.

6. **Will turtles bask on the platforms? Will the time of day affect the observed basking events on the platform?**

For this question, use was defined as turtles on the platform for basking or nesting. The surveillance camera took pictures every three minutes, allowing enumeration of turtles on the platform throughout the day. The days were separated into six equal parts (early, mid, late a.m., and early, mid, late p.m.) to determine if there was a difference in time of day for basking. Then the data were compared between platform location sites (n=3) to see if there was a difference in the time of day that the turtles used the platforms for basking. Different species that were not outfitted with transmitters were also examined to see if there were any trends in map turtle basking behavior in response to other individuals. The time to the emergence after the first turtle left the water was also calculated to see if there was a difference in time going from one to two turtles, then two to three turtles and so on.

7. **Will model turtles affect the basking behavior of turtles?**

Model turtles were placed onto the platforms for a period of approximately three days and then removed for the same length of time. Each platform was its own control when the models were not on the platform. In Beaver Island, platforms were located across from one another, one facing east and the other facing west. An ANOVA was used to see if there was a significant effect of the model's presence on the platforms on initiating live turtles basking. The number of minutes that turtles were seen basking was analyzed as a function of platform, the presence/absence of the model and their interaction, then a Tukey HSD was performed.

8. **What abiotic factor is the best predictor for basking behavior (air temperature, water temperature, substrate temperature, solar radiation, wind speed, relative humidity)?**

This question used all the abiotic data that were collected at each platform along with the surveillance camera photos. The camera photos showed when an individual turtle began a basking event. Using the time stamp that was provided on every picture I determined the solar radiation, air temperature, water temperature and substrate temperature at the platform at that time. These data allowed me to determine a temperature threshold that the substrate needed to be, or air temperature needed to be for a turtle to initiate basking. If the temperature was cool for the time of year but the solar radiation was high, basking might have been observed. An Akaike's Information Criterion (AIC) was run to determine the best indicator for basking behavior. AIC compares multiple competing variables to determine how much that variable is responsible for a particular outcome or behavior (Akaike 1973, Symonds and Moussalli 2011).

Results and discussion

Body Condition

With any translocation study it is important to collect data about the animals' growth rates following release in their new habitats. The extreme sexual size dimorphism is clear when comparing mass to SCL (Figure 16). Adult female turtles can have a wide range of masses and lengths, while the males are confined to a narrower range for both. Throughout the duration of the study the translocated females did grow, indicating that they were able to find a suitable food source in the upper Niagara River (Table 1). Map turtles show such an extreme sexual dimorphism that differences within each sex were tested separately when comparing body condition index (BCI). An ANOVA (Table 2) and a Tukey HSD *post hoc* were run for all the map turtles. There was an interaction effect of group and sex at the $p = 0.059$ level. All male map turtle groups showed no significant differences in BCI: resident vs. translocated $p = 0.999$, resident vs. source $p = 0.999$, and translocated vs. source $p = 0.999$ (Figure 17). Resident female turtles showed a significantly greater BCI than both translocated and source turtles ($p = 0.005$ and 0.024, respectively, Figure 18). Translocated and source turtle BCIs were not statistically different ($p = 0.961$, Figure 18). In the Niagara River, translocated female turtles showed an average mass increase of 0.40 g/day from the 2017 to 2018 seasons, while resident females only averaged 0.12 g/day of mass increase (Table 1). Consumed energy can be converted to growth or to egg production, which depending on the age of the individual will differ between individual turtles (Harms et al., 2005). Resident female map turtles had a significantly greater BCI than both source and translocated turtles. This difference could be an indication of more food abundance or genetic differences between the Presque Isle and the Niagara River populations.

Habitat Selection and Movement Behavior

Using ArcGIS 10.6 translocated turtle habitat use was determined. The data were separated seasonally, (winter, fall, summer, and spring), using water temperatures as the criterion as described earlier. During the summer, turtle locations were more spread out geographically than during the winter, but still clustered in certain areas (Figure 19). The translocated turtles displayed a preference for the west river during their first-year post release due to the late time of release. Two turtles traveled down to the northern point of Grand Island, approximately 14 km as the river flows, while the remaining eight stayed slightly downriver from Beaver Island Lagoon

Table 1. Sample of resident and translocated female turtle measurement data.

Resident Turtles	Capture Date	SCL (mm)	Mass (g)	BCI	Translocated Turtles	Capture Date	SCL (mm)	Mass (g)	BCI
CQ	8/9/2017	267	2168.1	8.12	XH	6/7/2017	196	746.6	3.81
CQ	6/3/2018	269	2214.4	8.23	XH	6/8/2018	195	915.7	4.70
IA	8/30/2017	221	1482.6	6.71	XI	5/24/2017	221	1017.7	4.60
IA	6/6/2018	235	1506.3	6.41	XI	6/16/2018	222	1219.7	5.49
					XJ	5/24/2017	221	1242	5.62
					XJ	6/25/2018	221	1326.6	6.00

Table 2. ANOVA for body condition index as a function of group, sex and the interaction of group and sex.

	Df	Sum Sq.	Mean Sq.	F-value	Significance
Group	2	9.88	4.94	10.489	0.001
Sex	1	118.20	118.20	250.900	0.001
Group:Sex	2	3.03	1.51	3.211	0.059
Residuals	23	10.84	0.47		

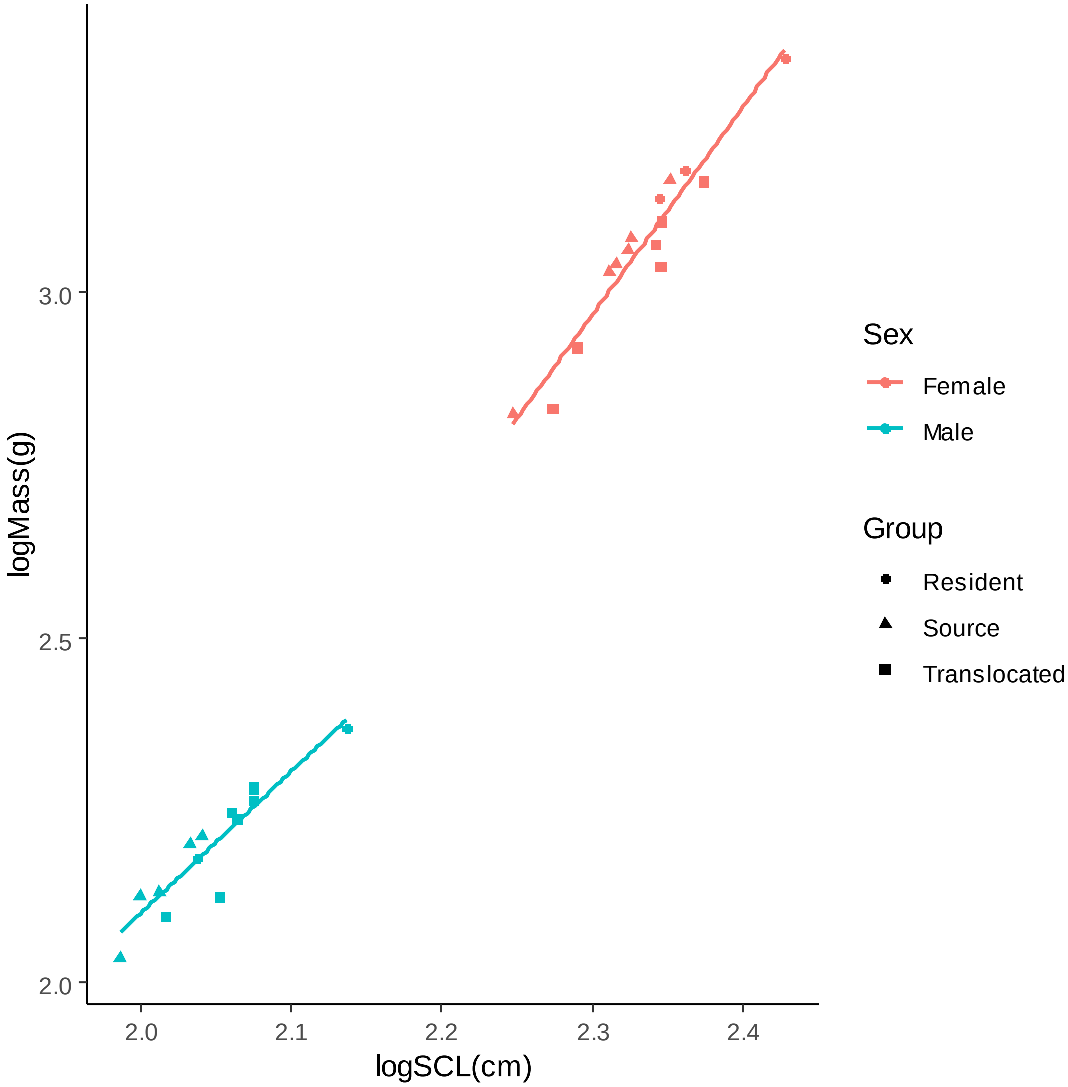


Figure 16. The log(Mass) as a function of log(SCL). Linear regressions were created for each sex independently.

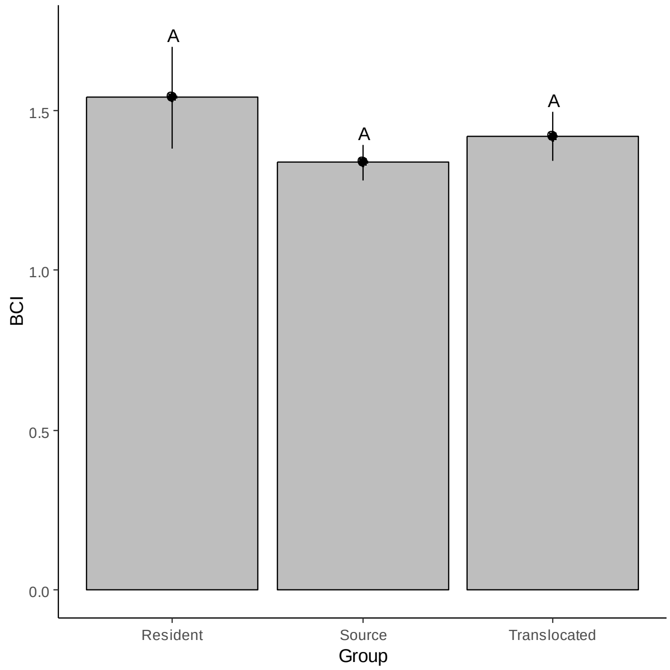


Figure 17. The mean body condition index (BCI) of male map turtles. Columns with the same letter are not significantly different. Error bars are ± one standard error.

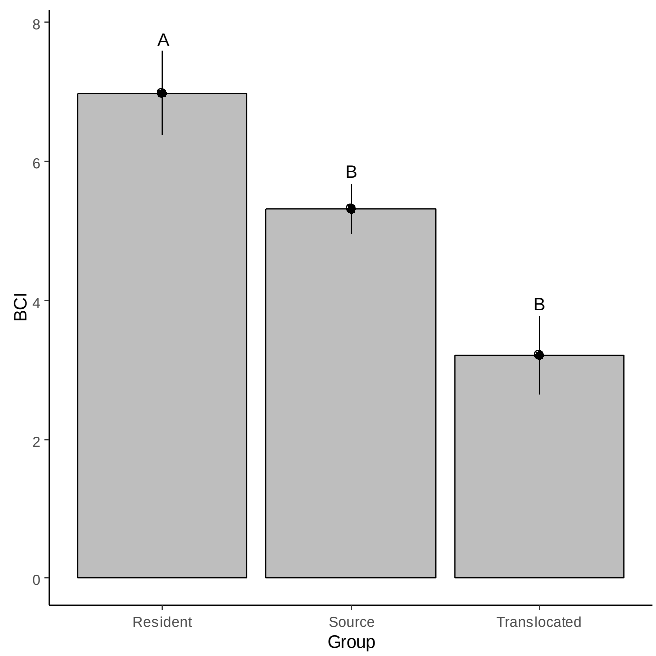


Figure 18. The mean BCI of female map turtles. Columns with the same letter are not significantly different. Error bars are ± one standard error.

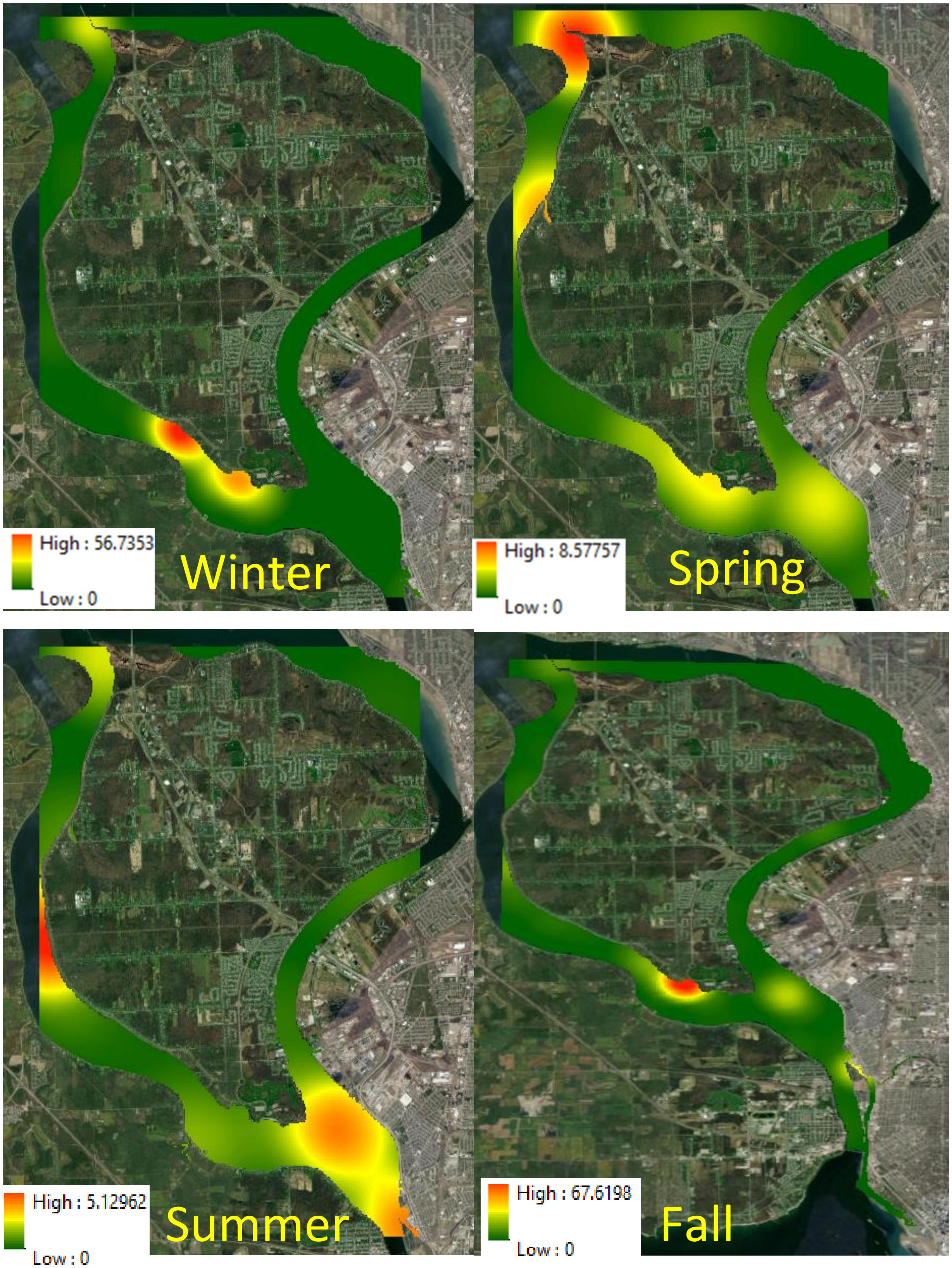


Figure 19. Calculated seasonal kernel densities for translocated map turtles.

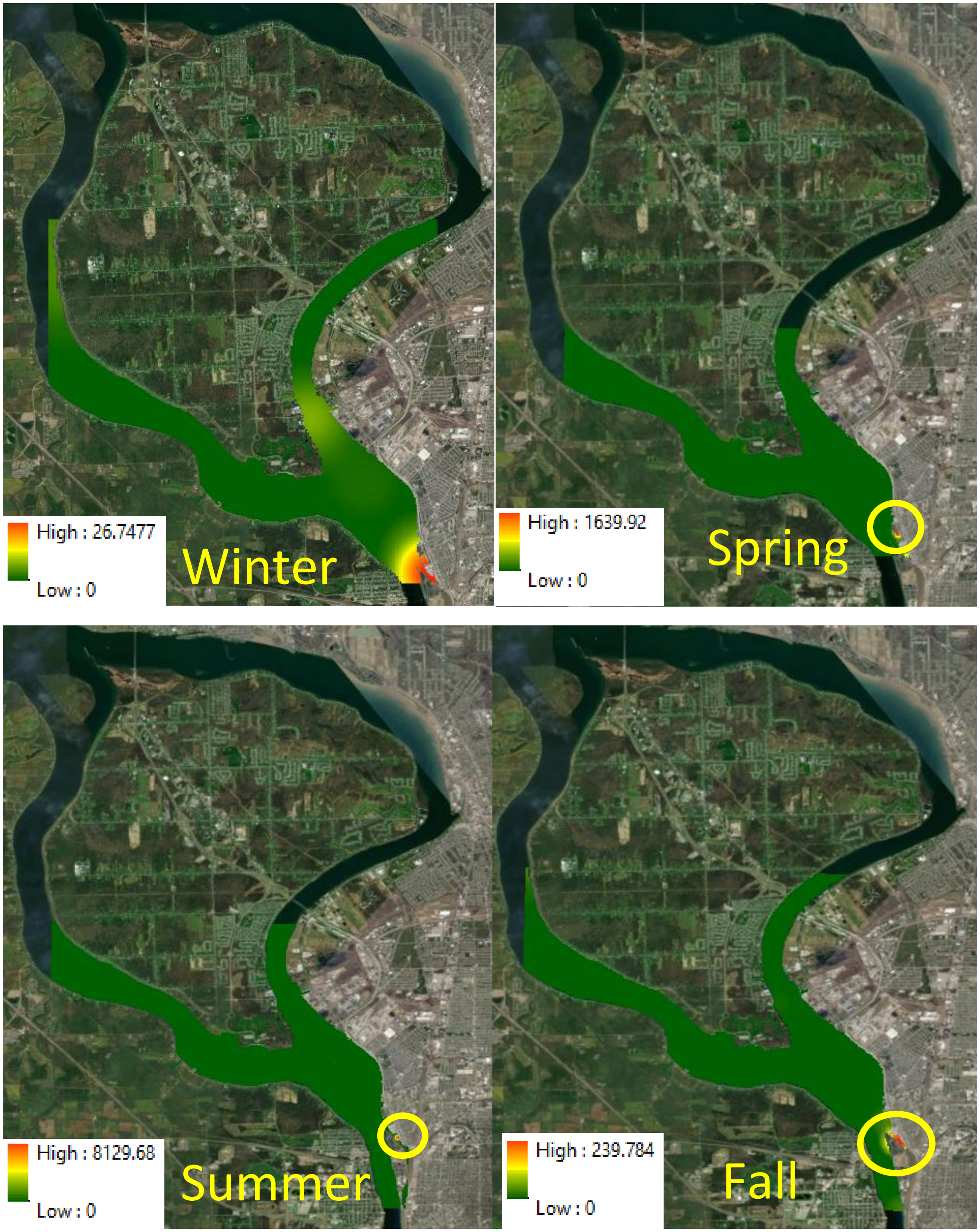


Figure 20. Calculated seasonal kernel densities for resident map turtles. Yellow circles indicate the areas with the highest densities.

(Figure 19). During summer the translocated turtles used the ACE and Rich marina, as well as Strawberry Island and the river at the western most point of Grand Island (Figure 19). The summer habitats displayed slow water currents and the potential for high water temperatures due to shallow water. Fall and spring kernel density analyses showed the greatest dispersal of turtle locations. Greatest densities of occurrence were near Beaver Island Lagoon, Big Six Marina, Strawberry Island lagoon, and the point at Buckhorn State Park, Grand Island (Figure 19). Winter habitat usage was limited mostly to river habitats. The densest winter cluster of turtle locations was in the west river offshore from West Oakfield Rd, GI, slightly downriver from Beaver Island Park. I suggest that this area was the most heavily used by the translocated turtles due to their late release in the season which did not allow for dispersal prior to brumation. The resident turtles have a smaller distribution than translocated turtles for all the seasons (Figure 20). The greatest density is centered around Rich Marina/ACE for spring, summer and fall. The difference in distribution could be indicating an exploratory behavior of the translocated turtles in their new habitat and selection of different seasonal habitats.

Unfortunately, due to the limitation of data storage of the temperature/depth data loggers all post brumation questions were unable to be answered. The loggers were set to take a reading every 15 seconds to capture minute movements of translocated turtles entering brumation. This caused the data registers to become full before the turtles were active again. Another unforeseen problem also arose with the data loggers. They malfunctioned at times and would only record temperatures and not depths. Of the translocated turtles that were recaptured, only three of the five loggers recorded depths. These data loggers showed that during the first week post release the turtles remained near the surface, which corresponds with their selection for Beaver Island lagoon (Figures 21 and 22). After three days, one turtle moved out of the lagoon and down the river but stayed close to the surface, potentially indicating visual orientation while moving down the river. During the second week one turtle continued to select deeper depths reaching a maximum depth of 8 m (Figure 21), while the other turtle continued to remain near the surface (Figure 22). When there were overlapping data, one resident turtle and three translocated turtles were compared (Figure 23). There was one translocated turtle that selected deeper depths throughout the time period, while the other translocated turtles and the resident turtle selected similar depths. A yearly comparison was graphed for one resident and one translocated turtle entering brumation. The resident turtle displayed similar selection of depths leading to brumation

Table 3. Percentage of observations that turtles were calculated to have stayed within 100 square meters or moved distances of greater than 10 meters.

	Stayed		Moved	
Winter	Resident	Translocated	Resident	Translocated
Male	98.41%	46.89%	1.59%	53.11%
Female	56.64%	36.63%	43.36%	66.88%
Spring				
Male	92.00%	100.00%	8.00%	0.00%
Female	57.75%	42.34%	42.25%	57.66%
Summer				
Male	93.75%	NA	6.25%	NA
Female	71.30%	22.91%	28.70%	77.09%
Fall				
Male	97.10%	42.12%	2.90%	57.88%
Female	83.87%	21.77%	16.13%	78.23%

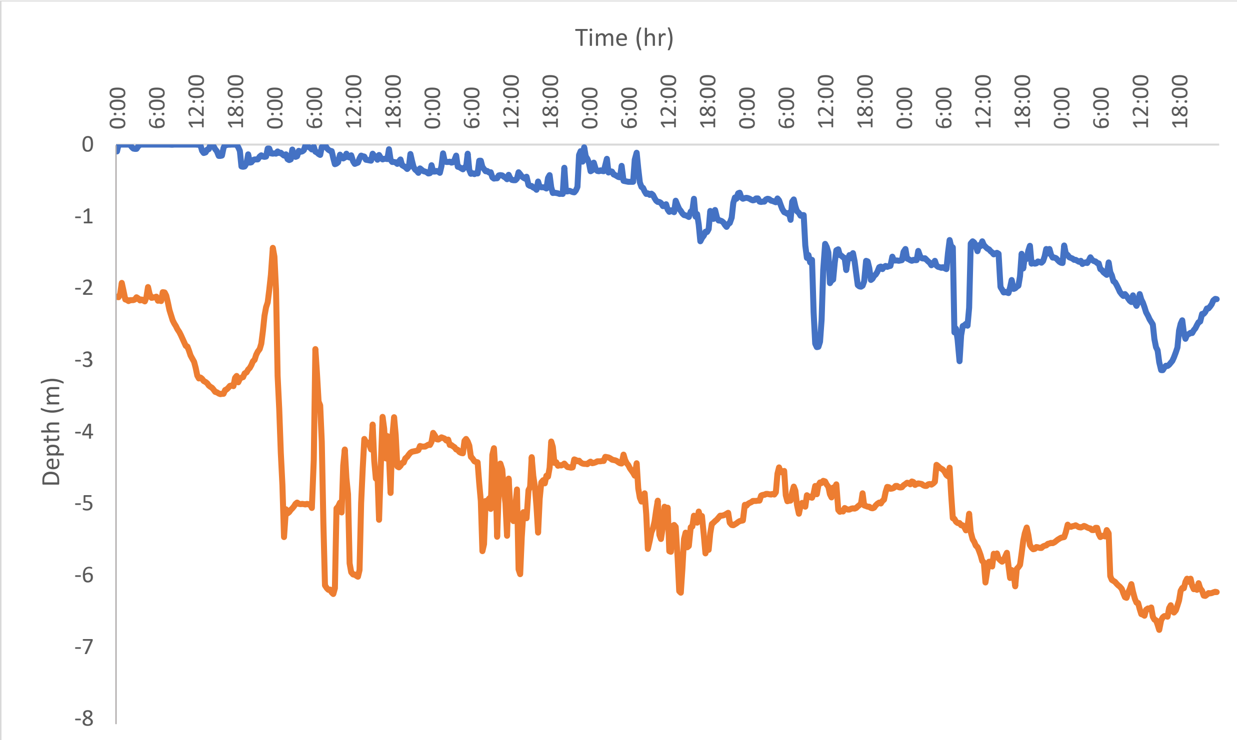


Figure 21. Diving profile for a female translocated turtle (XI) the first two weeks post release. Blue is the first week, orange is the second week.

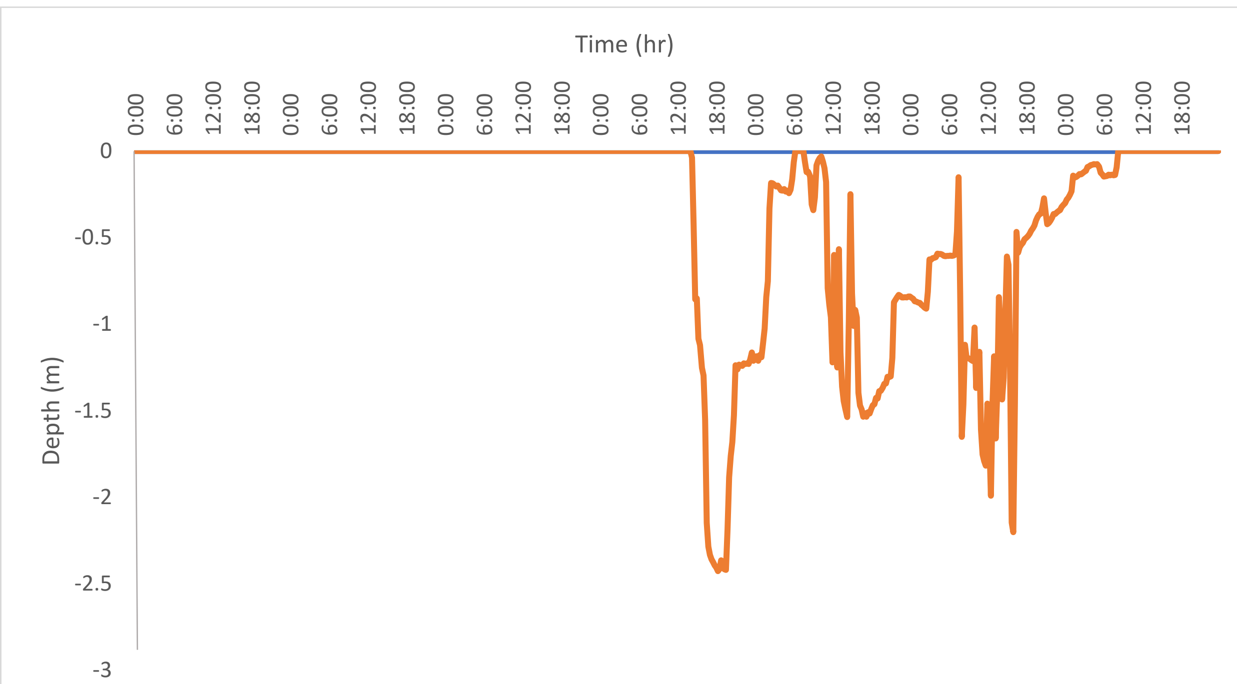


Figure 22. Diving profile for a female translocated turtle (XH) the first two weeks post release. Blue is the first week, orange is the second week. Areas where there is only one color displayed are over lapping depths.

Table 4. Oxygen concentrations recorded from brumation sites for resident and translocated turtles.

Turtle	Group	Water Temp (°C)	DO (mg/L)
CQ	Resident	7.9	11.49
XJ	Translocated	7.6	13.85
XI	Translocated	8	14.49
XH	Translocated	6.7	13.00

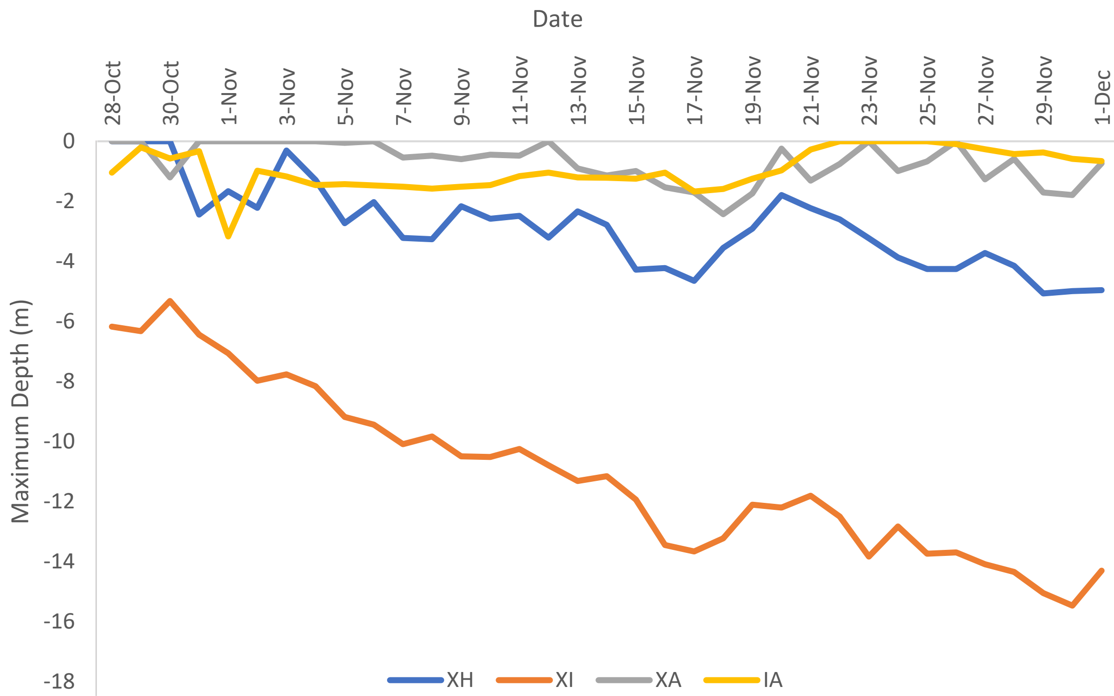
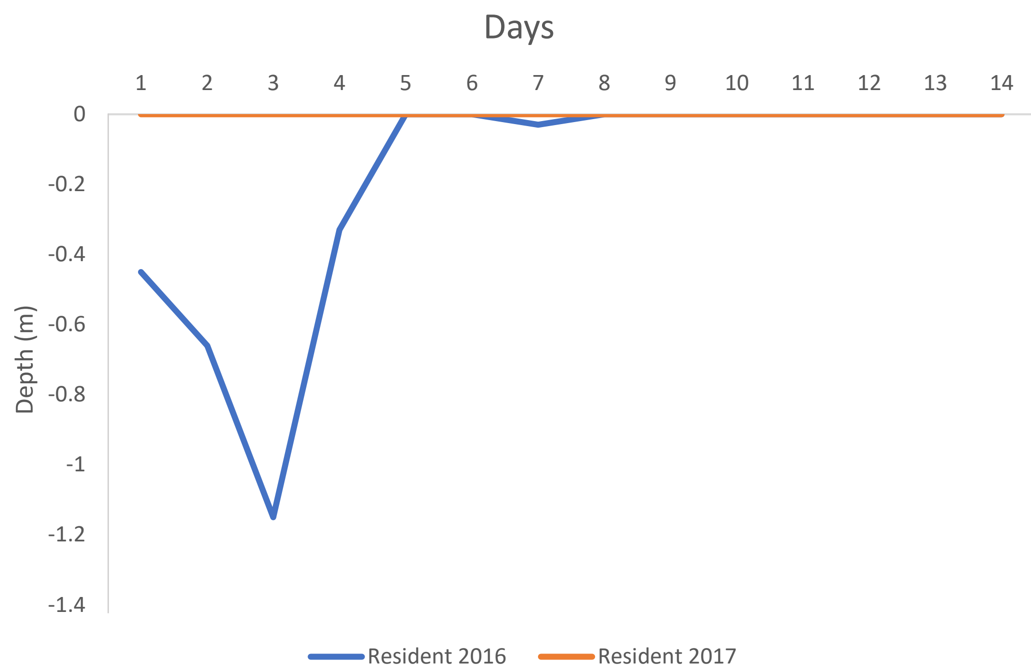


Figure 23. Maximum depth recorded for resident (IA) and translocated (XA, XH, XI) turtles from October 28th, 2016 to December 1st, 2016.



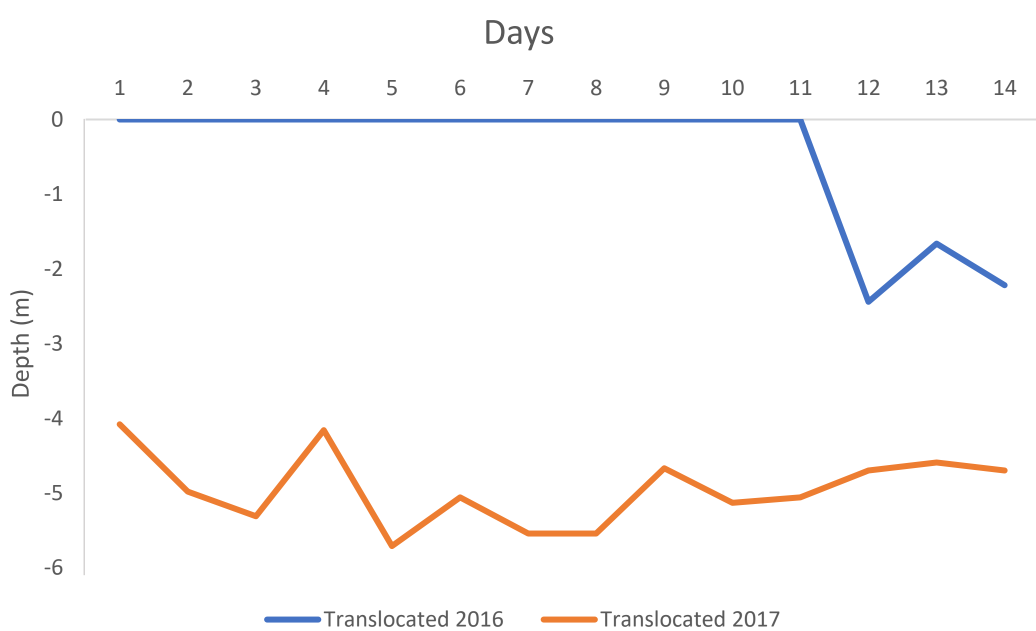


Figure 24. Top) A resident turtle's maximum depth two weeks prior to brumation in 2016 and 2017. Bottom) A translocated turtle's maximum depth two weeks prior to brumation in 2016 and 2017.

in 2016 and 2017 having overlapping depth selection, while the translocated turtled showed a greater depth selection variation between the two years (Figure 24). In 2016 the translocated turtles were released very late in the field season due to an extended quarantine, which resulted in selection of the first suitable habitat. The increased depth selected by the individual translocated turtle may be a more realistic depth selection for brumation in 2017.

There were only a few samples taken for dissolved oxygen. It was difficult to determine exactly when a turtle finally stopped moving for the season. Comparing the limited number of samples that were taken, indicates translocated turtles are in areas that have a slightly higher dissolved oxygen concentration, which may be an indicator of differences between lotic and lentic populations of turtles.

Translocated turtles on average moved more than the resident in almost all seasons (Table 3). The translocated turtles did begin brumation very shortly after being released, but not before making some exploratory movements. Perhaps explaining the similarities between winter percentages moved for translocated and resident females. There was no comparison for males in the summer season due to transmitter battery expiration before they could be recaptured.

Artificial Platform Usage

Basking

The artificial basking/nesting platforms were successful in providing a location for aerial basking in the upper Niagara River. The most basking activity was seen on the ACE platform, which had the highest number of individuals basking at the same time (7), but also had the greatest number of species visit the platform (4; 1 map turtle, 1 spiny softshell turtle, 3 red-eared sliders, and 2 snapping turtles) (Figure 25).

The 2017 field season had the greatest number of basking turtles seen at once for all the basking platforms throughout the three seasons of actively tracking the turtles. In 2016, the platforms were not deployed until early June (ACE and Beaver 1) and mid-August (Beaver 2), due to construction and time required for deployment. During 2016, low numbers of basking turtles were observed, while 2017 saw sporadic basking events but in higher numbers. The average numbers of turtles observed at the ACE platform was approximately the same between

Figure 25. Multiple species (northern map turtles, snapping turtles, red-eared sliders and a spiny softshell turtle) used the basking/nesting platform simultaneously.

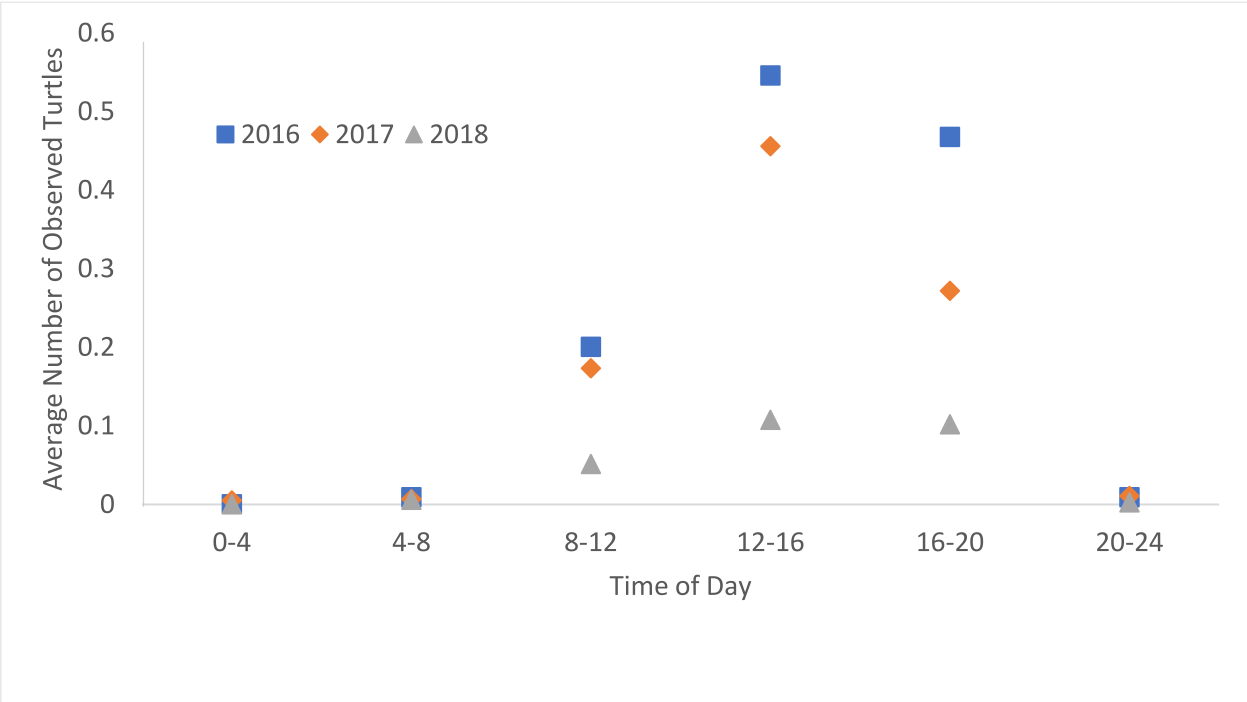


Figure 26. The average number of turtles seen basking on the ACE platforms throughout the 2016, 2017 and 2018 active seasons.

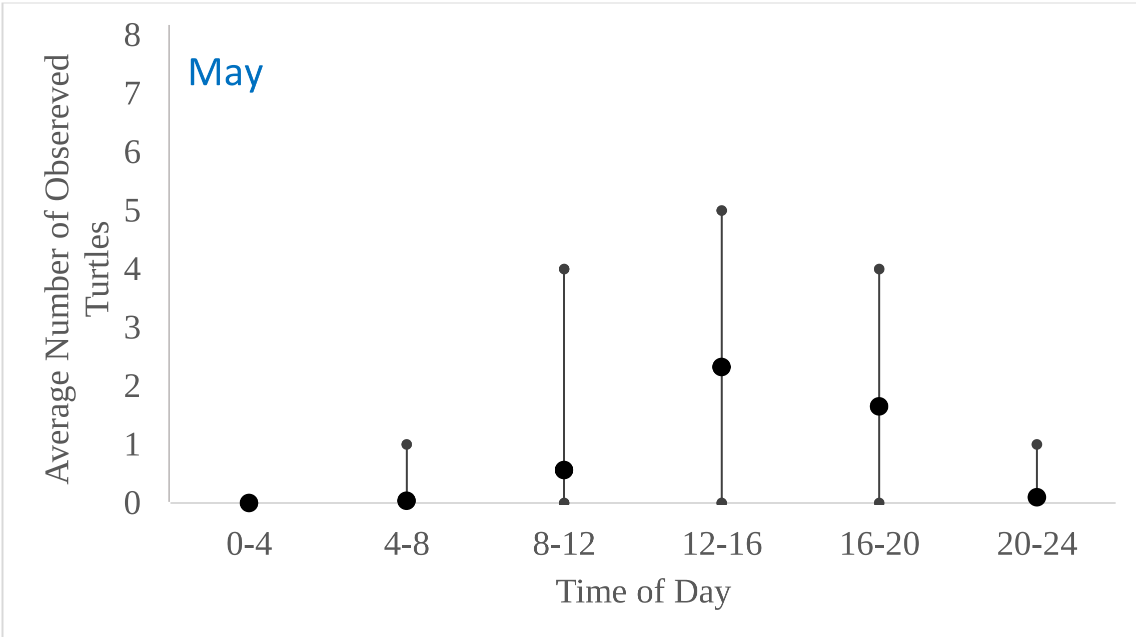


Figure 27. Large circles indicate the mean number of turtles of all species seen basking on the ACE platform during 2017. The upper and lower limits are the maximum and minimum number of turtles seen basking together at one time. Air temperatures were not available as HOBO data loggers were not yet deployed.

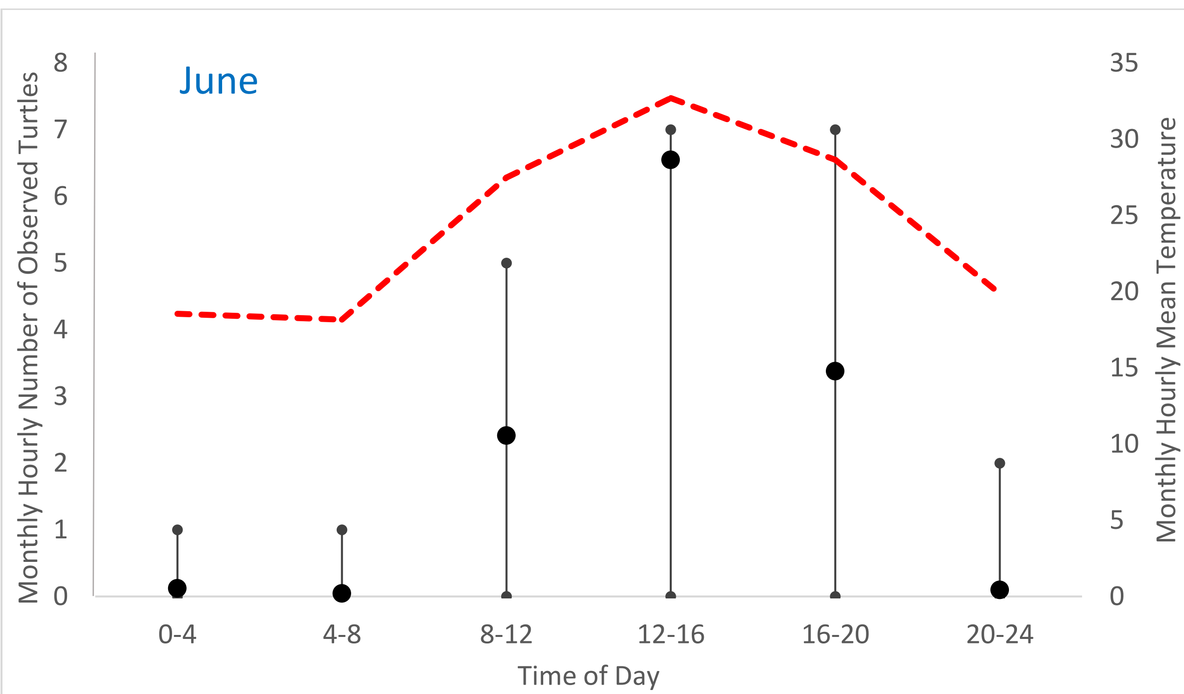


Figure 28. Large circles indicate the mean number of turtles of all species seen basking on the ACE platform during 2017. The upper and lower limits are the maximum and minimum number of turtles seen basking together at one time. The red line denotes the average air temperature that was experienced during the four-hour time period.

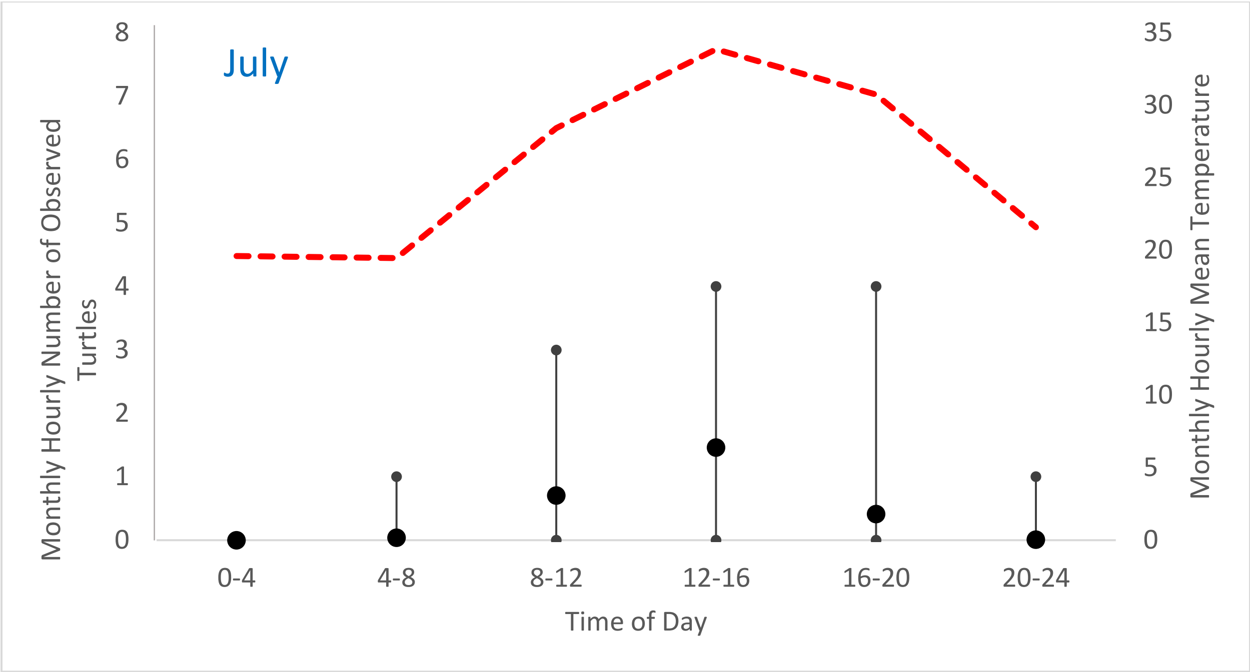


Figure 29. Large circles indicate the mean number of turtles of all species seen basking on the ACE platform during 2017. The upper and lower limits are the maximum and minimum number of turtles seen basking together at one time. The red line denotes the average air temperature that was experienced during the four-hour time period.

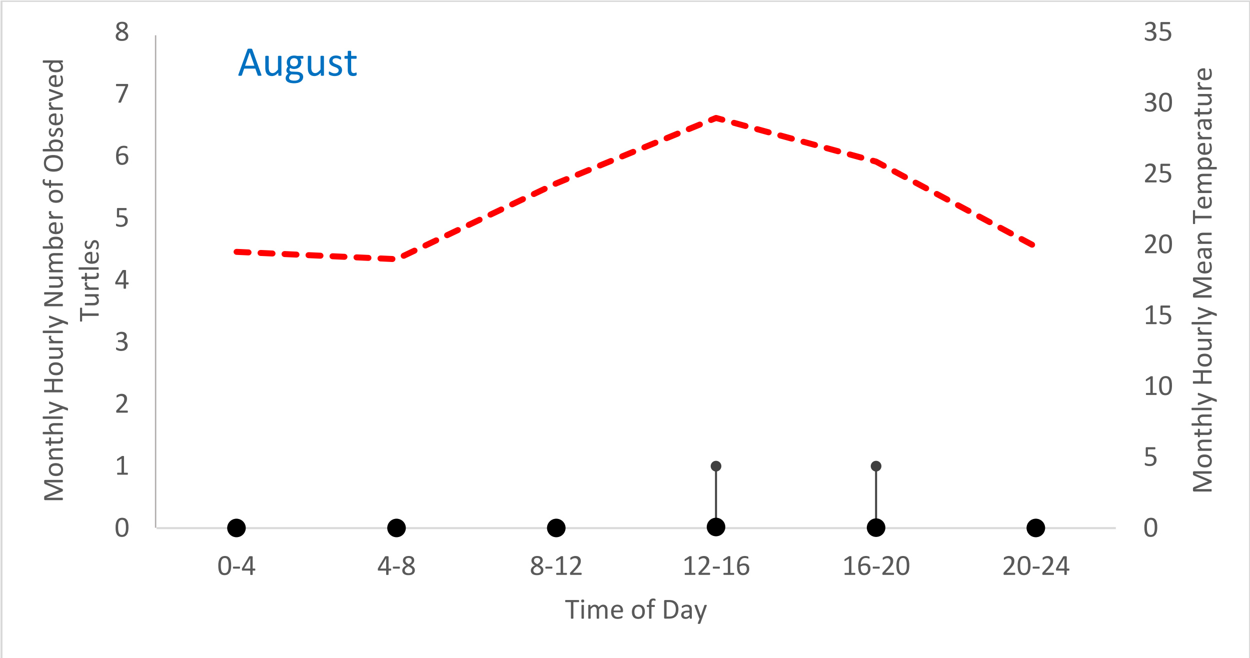


Figure 30. Large circles indicate the mean number of turtles of all species seen basking on the ACE platform during 2017. The upper and lower limits are the maximum and minimum number of turtles seen basking together at one time. The red line denotes the average air temperature that was experienced during the four-hour time period.

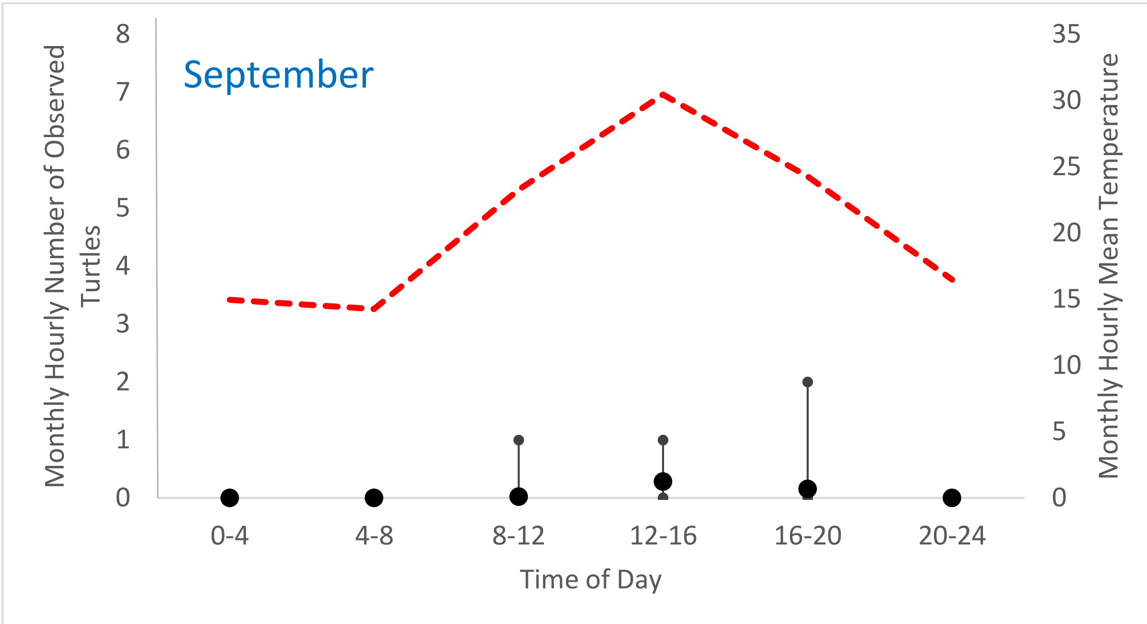


Figure 31. Large circles indicate the mean number of turtles of all species seen basking on the ACE platform during 2017. The upper and lower limits are the maximum and minimum number of turtles seen basking together at one time. The red line denotes the average air temperature that was experienced during the four-hour time period.

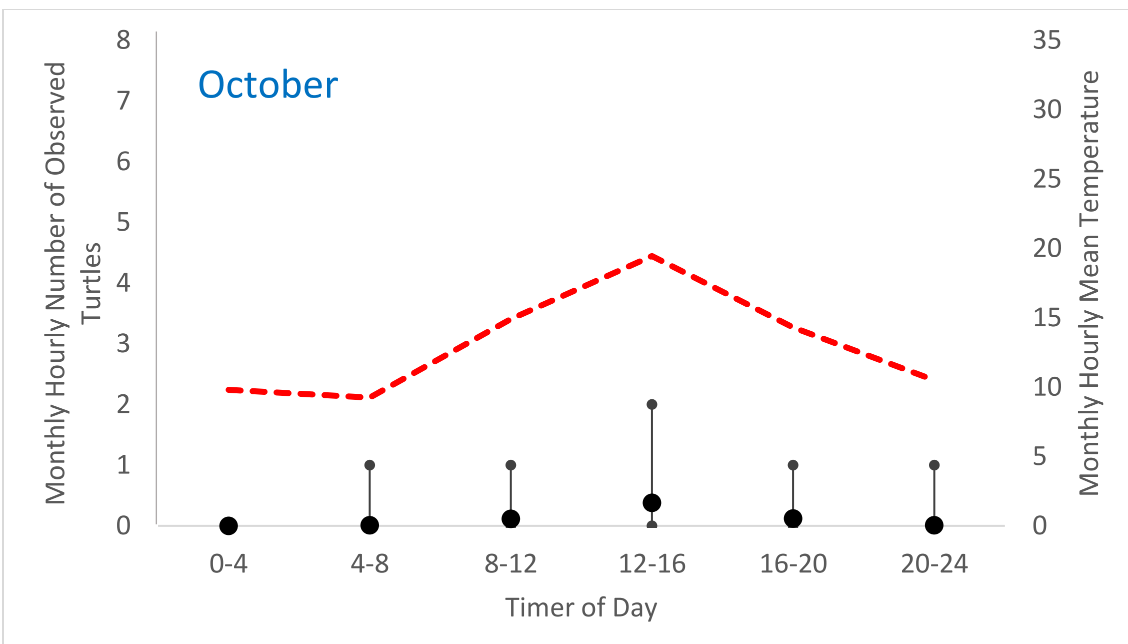


Figure 32. Large circles indicate the mean number of turtles of all species seen basking on the ACE platform during 2017. The upper and lower limits are the maximum and minimum number of turtles seen basking together at one time. The red line denotes the average air temperature that was experienced during the four-hour time period.

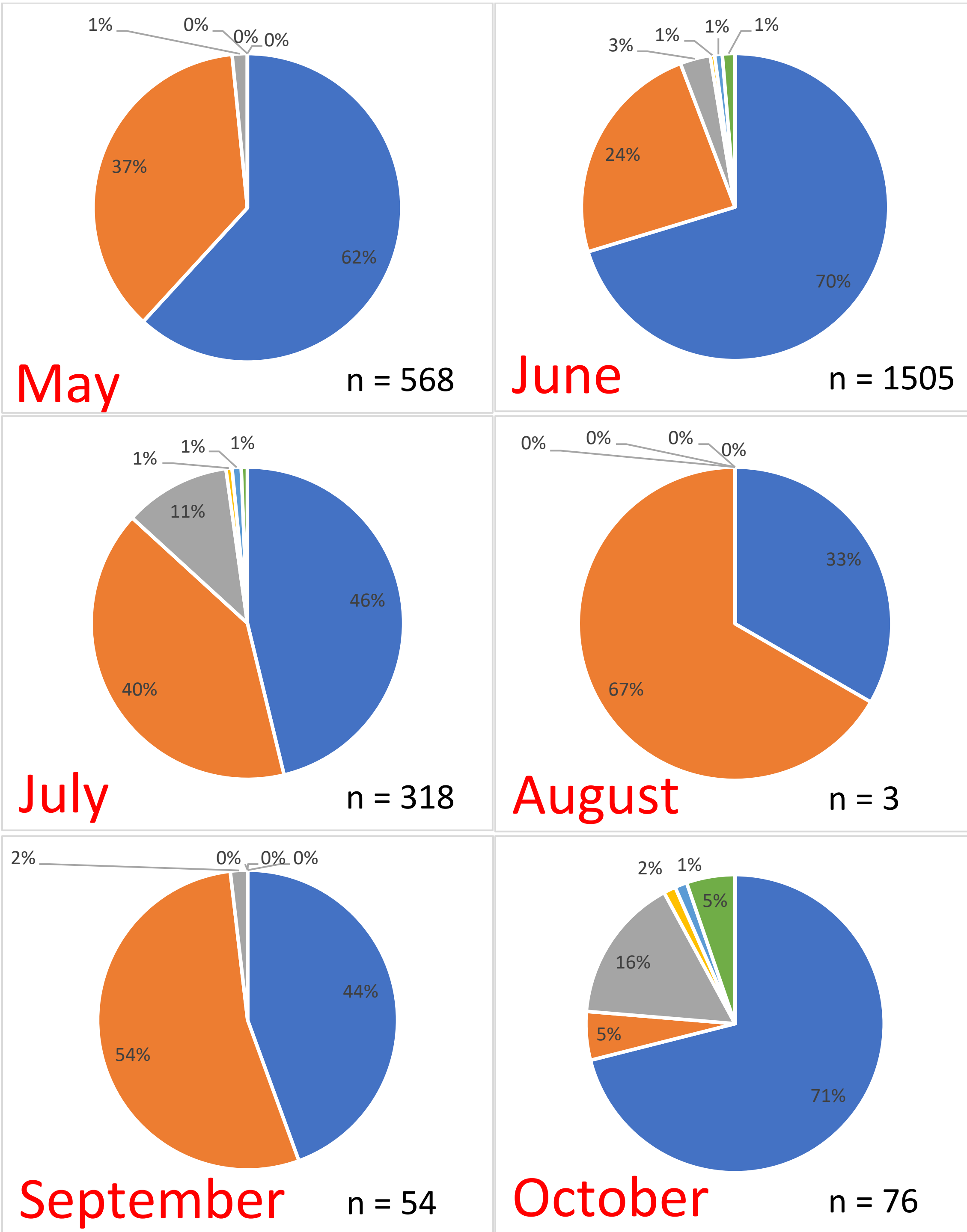


Figure 33. Monthly platform usage for the ACE platform during 2017. N is the total count of turtles observed (unique and repeat individuals) basking in each month. Dark blue is the front ramp, orange is the side ramp, gray is the platform, yellow is the sand ramp, light blue is the carpet ramp, and green is the sand.

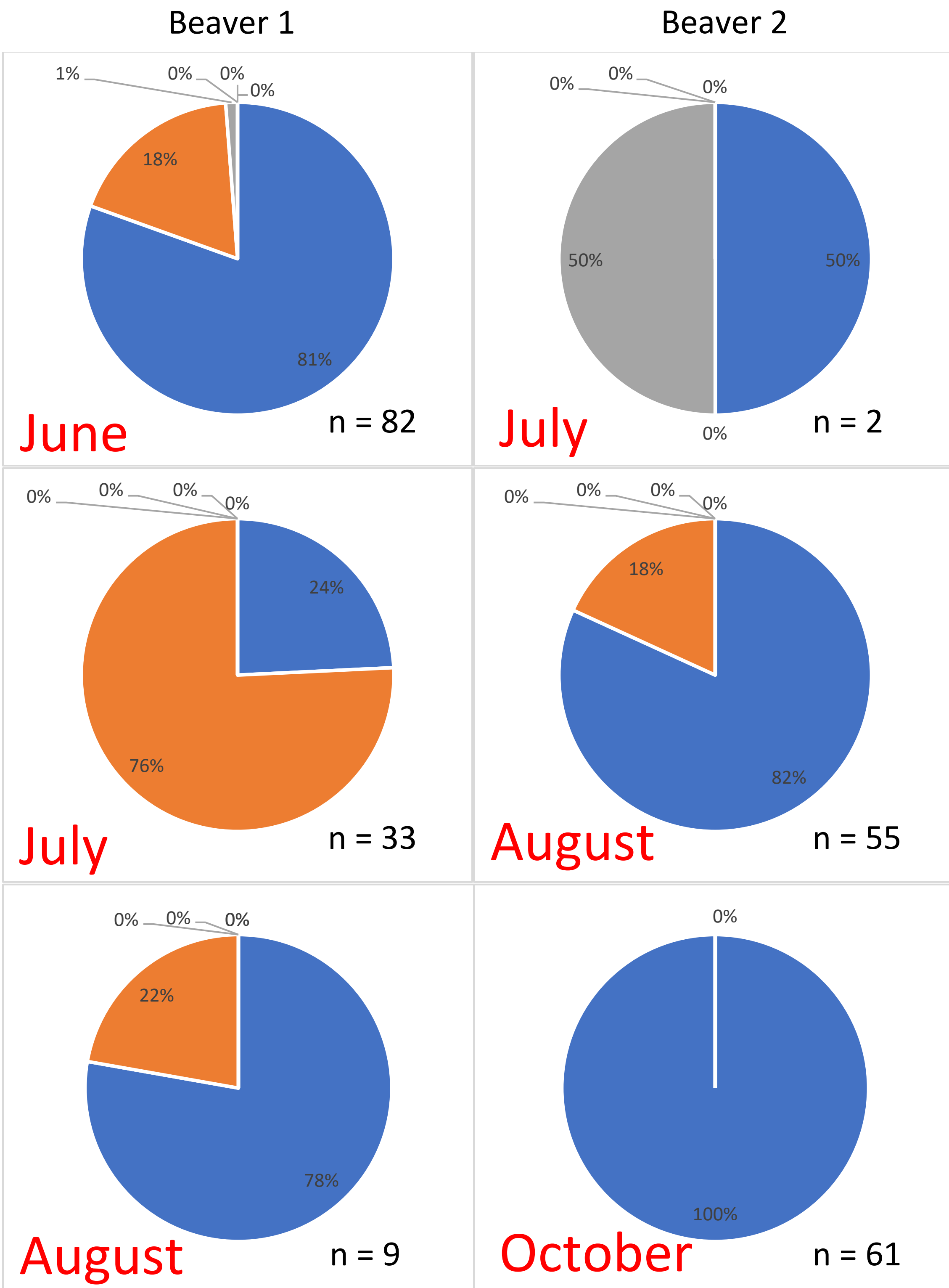


Figure 34. Monthly usage during 2017 for Beaver Island 1 on the left and monthly usage during 2017 for Beaver Island 2 on the right. N is the total count of turtles observed (unique and repeat individuals) basking in each month. Dark blue is the front ramp, orange is the side ramp, gray is the platform, yellow is the sand ramp, light blue is the carpet ramp, and green is sand.

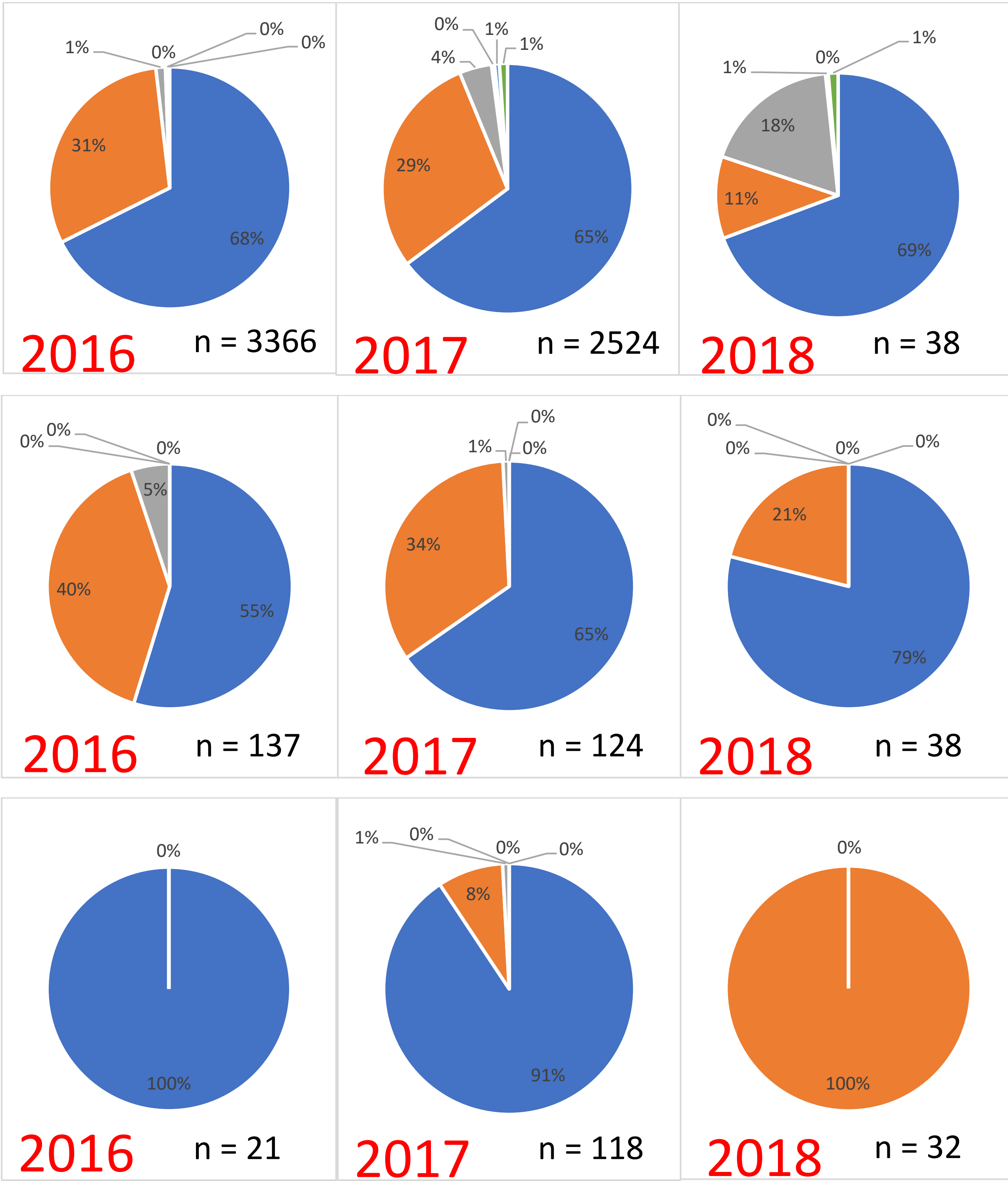


Figure 35. Yearly usage of each platform top) ACE, middle) Beaver 1, and bottom) Beaver 2. N is the total count of turtles observed (unique and repeat individuals) basking in each month. Dark blue is the front ramp, orange is the side ramp, gray is the platform, yellow is the sand ramp, light blue is the carpet ramp, and green is the sand.

2016 and 2017 (Figure 26). Initial investigation of the platform would be by one turtle for short periods of time but then a second or possibly a third would be basking at the same time during the first year of deployment, and only at the ACE platform. In the 2017 field season, platforms were all deployed by early May, as soon as the ice boom was removed from Lake Erie. Basking occurred primarily between the hours of 8 a.m. and 8 p.m., with the greatest numbers between 12 noon and 8 p.m. (Figures 27-32). The platform was categorized into six different sections; front ramp, side ramp, platform, carpet ramps, sand ramps, and sand. When a turtle was seen basking its location was recorded. An analysis of where the turtles spent their time on the platform was created to identify which areas of the platforms were used most frequently. A monthly breakdown of one platform showed that there was variation in which portion of the platform the turtles used, but primarily they used one of the two ramps more than the rest of the platform (Figures 33 and 34). Throughout the study the primary usage was seen on the front ramp across all three platforms (Figure 35). The turtles favored locations on the platform that were adjacent to the water. When I approached the platforms I frequently observed turtles jumping off the platform and swimming directly down. This selection for areas adjacent to the water could be a behavioral response to potential predators.

Turtles require aerial basking for thermoregulation and parasite desiccation (Boyer 1965). Abiotic variables were collected in two different manners, manually when each turtle was located and automatically at the platforms. The three variables that were collected automatically were air and water temperatures (°C) and light intensity/solar radiation (Lux). Measurements were taken at three separate locations, on the front ramp (Ramp1), the side ramp (Ramp2), and at the surface of the water (Surface). Using the AIC, a tool for predicting the single variable that accounts for the greatest amount of variation within the data for a certain outcome, the amount of abiotic variable variation was calculated to determine the best predictor for when basking would occur (Symonds and Moussalli 2011). The best light variable predictor for basking was light data from Ramp2, and the best temperature variable predictive of basking was the difference between the water and air. Light and temperature have a logarithmic relationship where temperature will (Figure 36). A generalized linear mixed-effects model made it clear that the temperature difference between the water and the air was the best indicator for when turtles would be present basking ($p < 0.001$). There is a wide range of temperatures observed for a single turtle basking

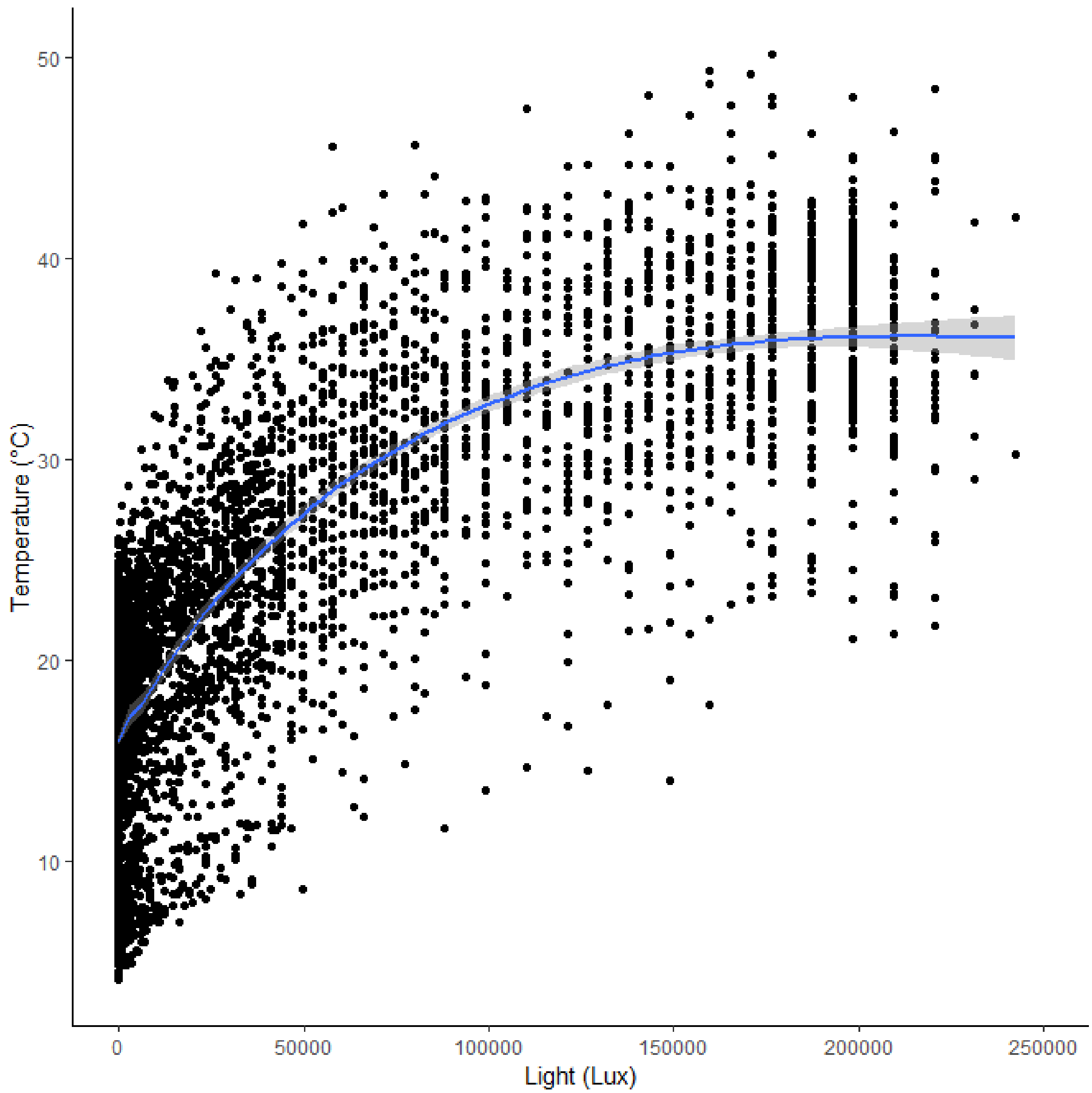


Figure 36. Relationship between light intensity (Lux) and air temperature (°C) from the front ramp HOBO data logger with fitted line in blue. The experienced light intensity changes with latitude, time of the day, and time of the year.

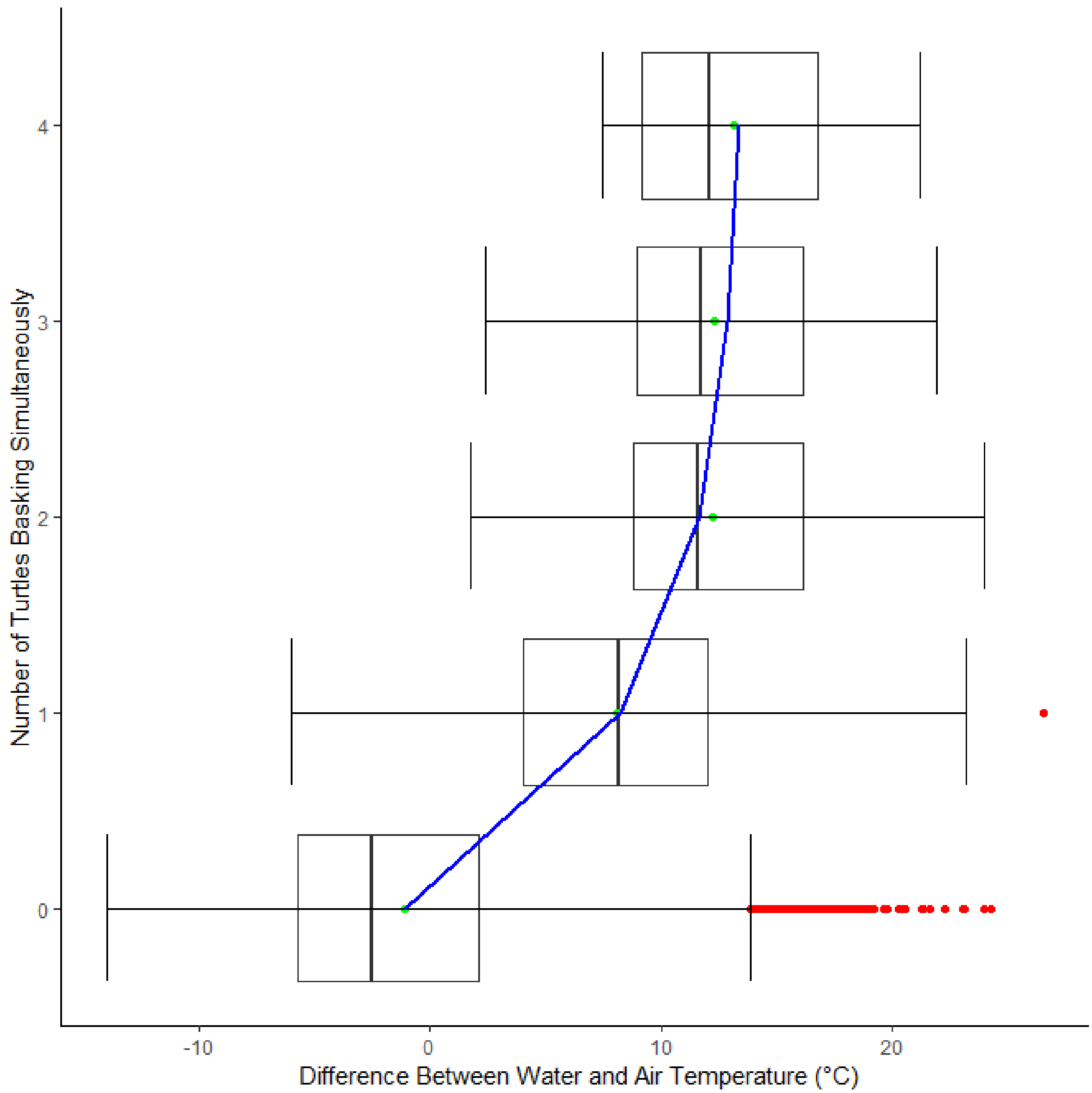


Figure 37. Number of turtles basking simultaneously on a single ramp in response to the temperature difference between water and air. Minimum and maximum values are the end whisker, red points are outliers, the center line in the box is the median while the green dots are mean values and the blue line is an exponential regression.

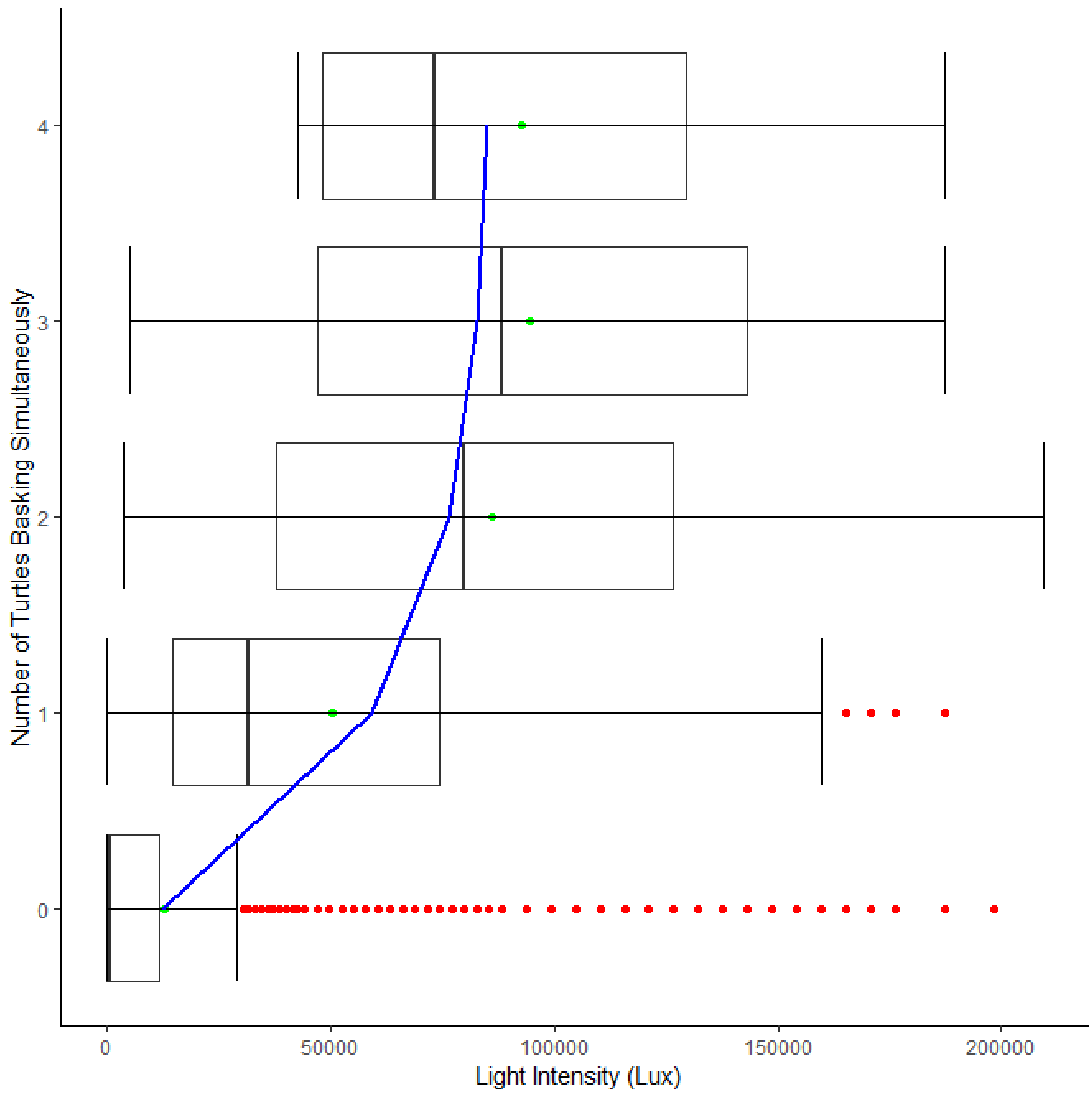


Figure 38. Box and whisker plots, showing the number of turtles simultaneously on a single ramp in response to light intensity for ramp 2. Minimum and maximum values are the end whisker, red points are outliers, the center line in the box is the median while the green dots are mean values and the blue line is an exponential regression.

on the platform, indicating that there are other variables that are important to initiate basking. The average temperature for when a single turtle was basking was when the difference between the water and air was approximately 9°C (Figure 37). The number of turtles basking on the platform increased as the difference between water and air increased, but with a saturating effect around 12°C (Figure 37). The same trend occurred with solar radiation (Figure 38). Looking at figures 37 and 38 it became clear that there were potentially other variables influencing basking behavior, due to the large variability.

The effect of an invasive species is often detrimental to the native fauna. In the upper Niagara River, the red-eared slider is an invasive species. Basking is an essential behavior exhibited by turtles. Other studies have shown that the presence of an invasive species shifted the basking locations and habits of native turtle species, generally in a negative manner (Polo-Cavia et al 2010. 2012). Placing replica toy red-eared sliders on the platforms had no significant effect on basking times for live turtles (Figure 39, $df = 1$, $F_{1,1}$=1.688, $p = 0.212$). There was even an instance when a painted turtle was seen basking between two of the models (Figure 40). This grouping behavior could potentially be a defense against potential predator attacks. In the future, further investigations could test to see if higher numbers of models would increase the number of live turtles seen basking.

There may not have been a significant effect of replica turtles on live turtle basking behavior, but it made me consider whether the number of turtles on the platform might influence the time it took for another turtle to emerge from the water and use the platform. Photos were used from the ACE platform surveillance camera. The calculation only considered turtles that were on the same ramp to be influencing the time for another turtle to emerge from the water. The maximum number of turtles that were seen basking at one time on a single ramp was five, but this only occurred a single time. The amount of time that it took for the next turtle to emerge and begin basking decreased as the number of turtles on the platform increased (Figure 41), from approximately 25 minutes going from one to two turtles to approximately 7 minutes going from four to five turtles.

<u>Nesting</u>

Unfortunately, during the duration of the study no clutches of eggs were laid on any of the platforms. A painted turtle laid a single egg on sand that was covering a portion of the

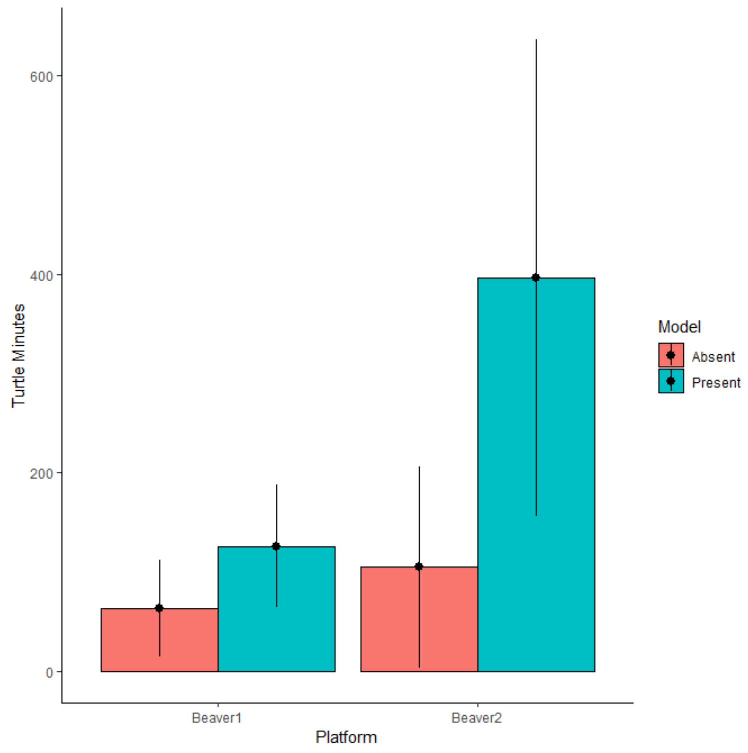


Figure 39. The effect of replica toy red-eared sliders models on turtle basking behavior. Turtle minutes (number of minutes a turtle was observed in the presence/absent of the replica model multiplied by number of turtles) for both BIL platforms. Error bars are ± one standard error.

Figure 40. A live painted turtle basking between two replica red-eared slider turtle models and a HOBO light/temperature data logger.

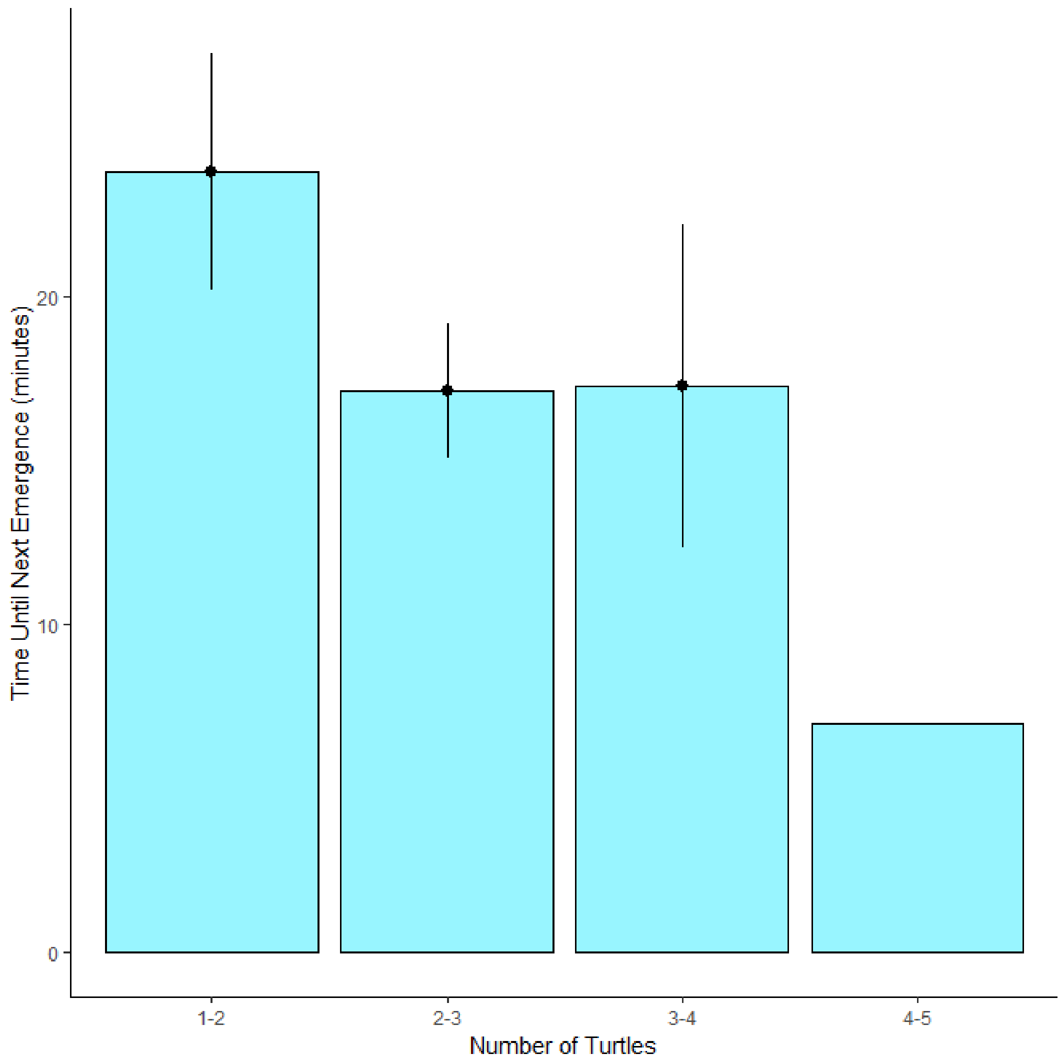


Figure 41. Bar plot for time to the emergence of the next turtle in minutes. Mean values ± one standard error.

platform section of the basking/nesting platform. This egg was not in any sort of depression, which might have indicated that the females was attempting to dig a nest hole, nor was there an attempt to cover the egg with sand (Figure 42). She laid this egg during the day. It is very possible that during her attempt to approach the sand portion of the platform, a person walked near the edge of the Army Corps property causing this individual to abandon the nesting attempt and leave this single egg exposed. Immediately upon discovery of the egg through the surveillance camera app the egg was transported to the incubator in the lab at Buffalo State. The egg was kept at an average temperature of 28°C, a lower cut off at 26 °C and an upper cut off at 30°C, with a moisture content in the incubator of approximately 81%. The egg never developed and apparently had not been fertilized.

On another occasion a female snapping turtle made a night visit to the sand portion of the ACE platform, potentially attempting to nest (Figure 43). Upon investigation of the sand substrate in the days that followed no eggs were found. This individual may have been attempting to lay eggs in the sand due to the prolonged time she spent on the platform but was disturbed by noises either due to passing vehicles on the nearby highway, or late-night works at the Army Corps buildings. There is also the possibility that this individual turtle was trying to prolong its thermoregulation by using residual heat provided by the sand substrate. The surface temperature of the sand substrate remained warmer than the water throughout the night (Figure 44).

Temperature data were collected from the sand substrate. The pivotal temperature for northern map turtles is 29 °C (Bull et al. 1982). Below this temperature males will be produced and above it females. Map turtles have been recorded to lay eggs up to twice a year, once in early spring and then again in late summer (Ernst et al. 1994). If eggs would have been laid on the platforms during the spring, then more males would have hatched than females (Figure 45).

The lack of nesting that was exhibited on all the platforms could potentially be due to the timing of the deployment in the spring time. The research vessel which was needed to deploy the platforms was not launched until the boom that restrains the large amount of ice built up on the lake had been removed. This limited how early the platforms could be placed on site.

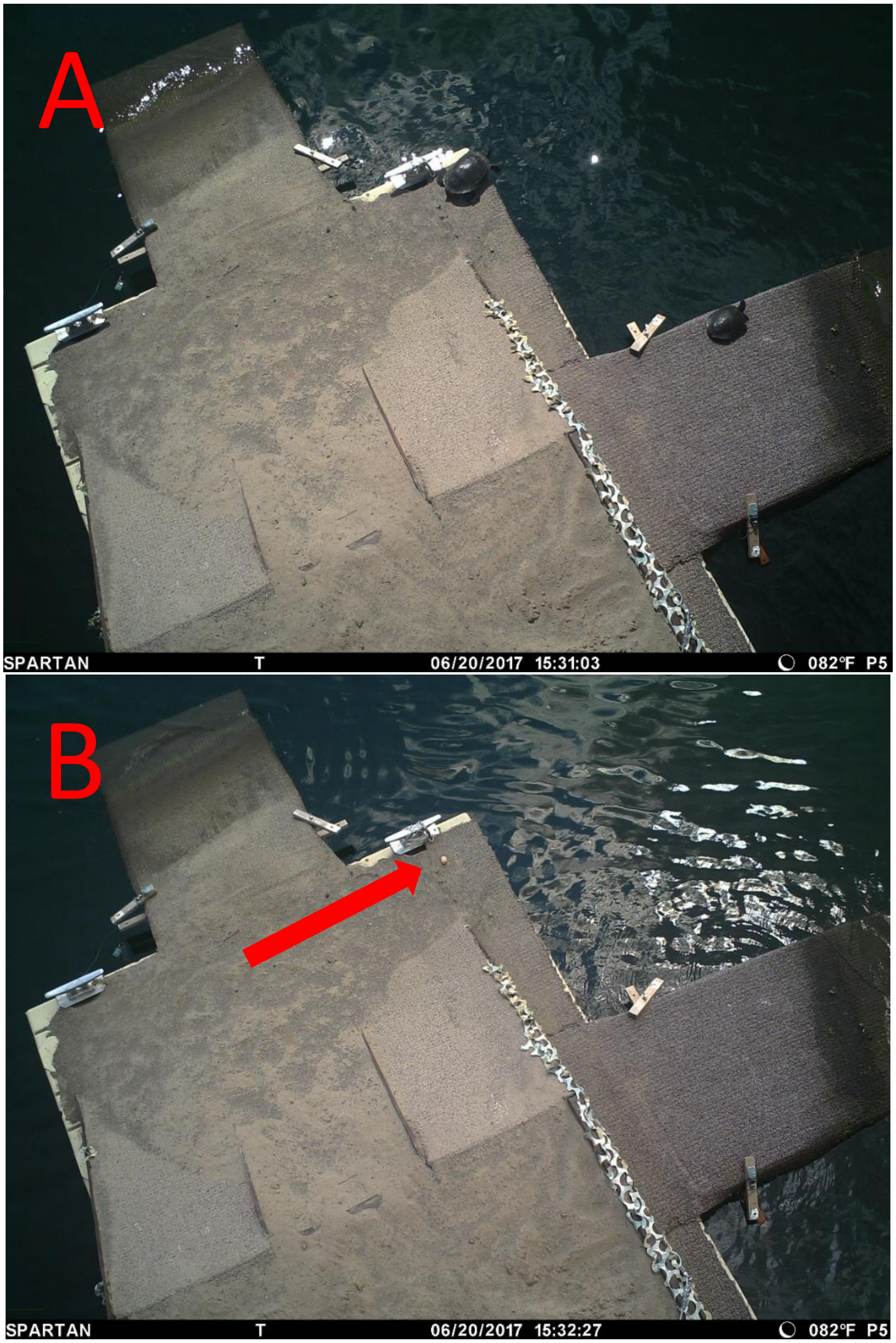


Figure 42. A) Female painted turtle basking on the platform. B) Egg siting on the sand directly where the turtle was previously located. Both images are taken from the surveillance camera attached to the platform. Images were taken about a minute apart. The red arrow is indicating the egg she laid.

Figure 43. Snapping turtle seen potentially attempting to nest. Image was taken by the surveillance camera that is attached to the platform.

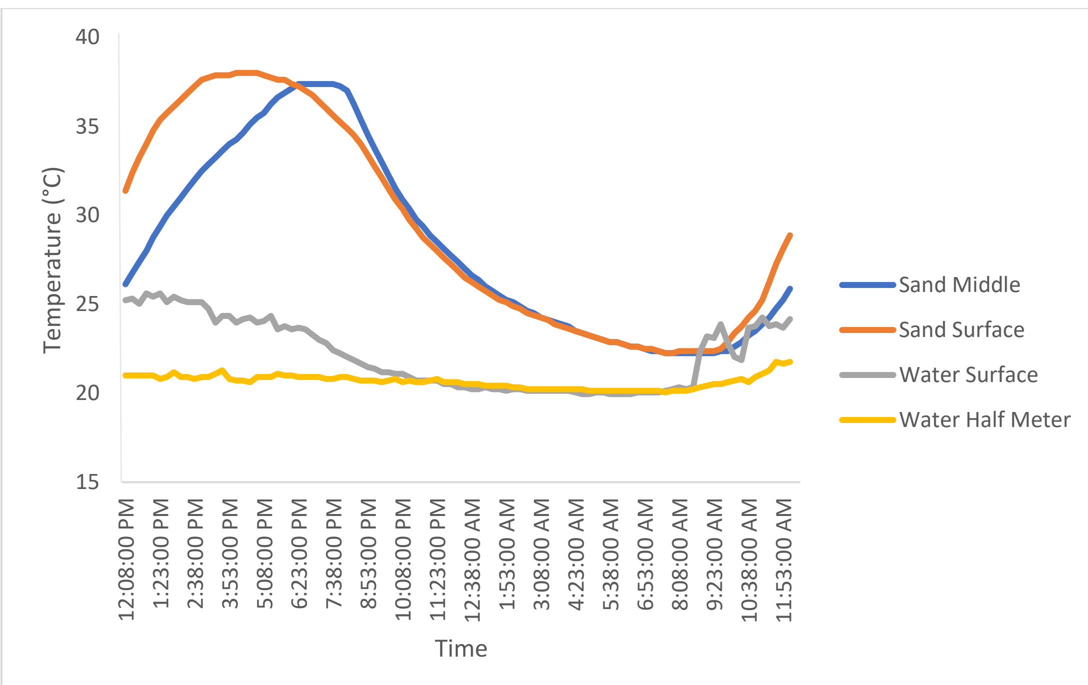


Figure 44. Thermal profile for the basking platform sand and surrounding water from noon on June 16th, 2017 to noon on June 17th, 2017. The graph is for the time period when the snapping turtle spent the evening on the platform.

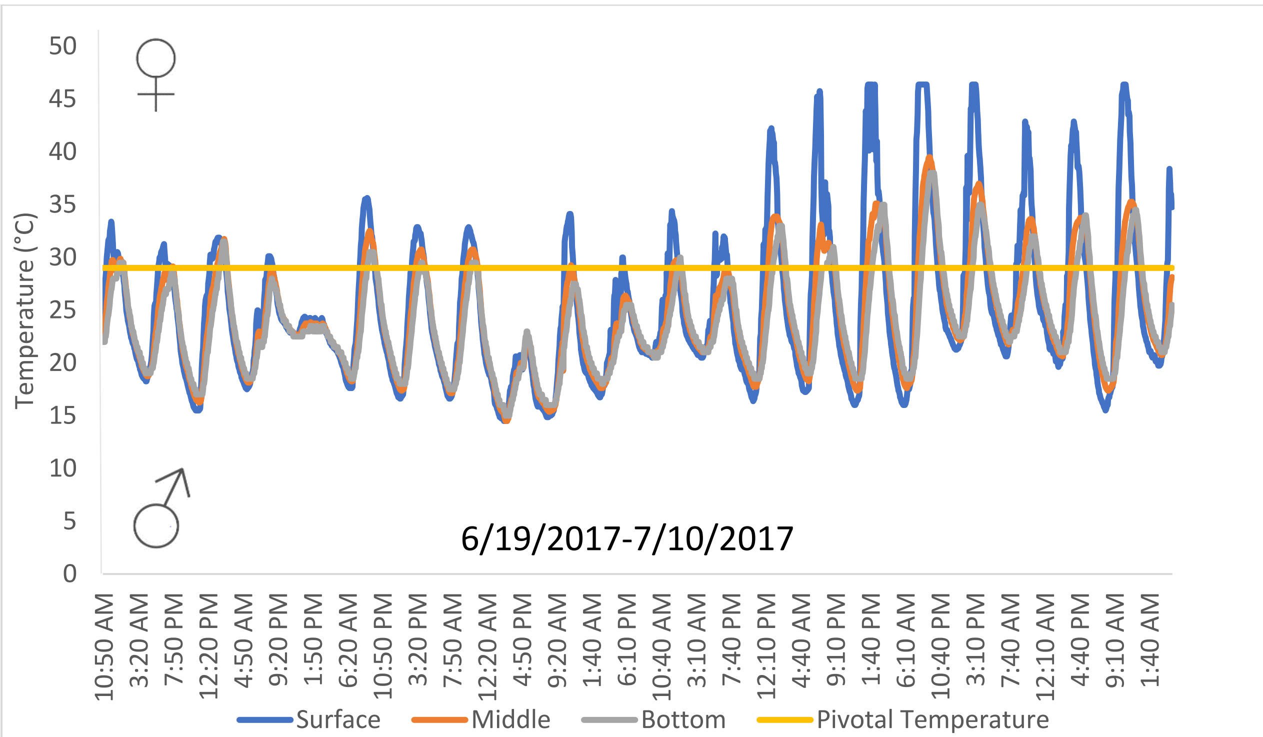


Figure 45. Thermal profile of temperatures obtained from the three iButton data loggers placed in the sand substrate for the ACE platform. The pivotal temperature which determines male or female hatchlings is 29 °C.

The argument then moves to prior knowledge of the platform's existence by the turtles. As previously stated, these animals display very habitual behavior in movement patterns and brumation selection (Haas 2015). Therefore, upon initial deployment of the platforms limited usage by turtles was potentially indicating that the animals had no knowledge that the platforms were available. Both the snapping turtle's potential attempt to lay a clutch of eggs and the painted turtle's egg were not observed until the 2017 season. This favors the argument of prior knowledge assisting the two attempts to nest.

If there were attempts to nest by other species on the platform, why didn't any of the map turtles seen on any of the platforms make any attempts to nest? To answer this question, one must look to the sex ratio of the population. In the upper Niagara River during the study period the population was heavily skewed toward females. Prior to the translocated turtles being released the ratio was 3:1 (F:M), and after the females were released that ratio shifted to 5:3. Upon completion of the 2018 field season there were no males being tracked due to the transmitter batteries having expired.

Conclusions

The artificial basking/nesting platforms were successful in providing suitable basking substrate in ACE, which is completely devoid of terrestrial access. The ACE platform was used by not only northern map turtles but also soft-shelled turtles, snapping turtles, and painted turtles. In this area (ACE) high numbers of turtles are present due to its lack of boat traffic and its abundant hard surface structure which is ideal for zebra mussels, an ideal food source. The platforms were primarily used on the portions directly adjacent to the water, which would allow for the turtles to quickly escape into the water if they felt threatened. The times that turtles were seen using the ramps to access the sand and the sand portions of the platform was far less than the amount of time turtles were observed basking on the ramps which led into the water or on the platform base. This basking preference may have limited the likelihood of nesting on the platforms.

Adult female northern map turtles were successfully translocated during this study. Of the six translocated females, four were successfully located alive in the following season. One individual had transmitter failure during the first month post release and was not found again.

Another turtle had its carapace recovered in a culvert in Beaver Island lagoon. She did not survive the winter. None of the adult male map turtles were recovered during the 2017 season. These turtles were not recovered from the river before their transmitter batteries expired. Turtles for this study were released the last week of October and the first week of November in 2016. The following year the surviving tracked individuals were all brumating by late September. That late release due to a required extended quarantine limited the success of turtles surviving to the following year. The annual comparison of a single female individual translocated turtle showed a selection of significantly deeper water in the second-year post release. An increased recapture rate could have been achieved for the males if the turtles had been released into the system during the summer and allowed to find suitable brumating locations. Also, due to the timing of release the boat was only used for two weeks post release, which forced terrestrial triangulations therefore limiting the accuracy of translocated turtle locations their first winter.

The northern map turtles in the upper Niagara River exhibited similar behaviors of seasonal movements, preferring to brumate on the edges of the main river and then spending their summer months in slow to no current areas such as Big Six Marina, Strawberry Island Lagoon, Rich Marina, and the ACE.

The turtles' hesitance to use the sand portion of the platform may indicate that a larger permanent area for nesting would be more successful due to its stable, non-shifting structure. The average distance that map turtles have been documented to nest from the water is 35.7 meters. The closest observed nest was 2 meters from the water. (Steen et al., 2012) This selection for areas farther away from the water may indicate why the map turtles did not nest on the platforms.

Management implications

Niagara River is listed as an area of concern by the United States Environmental Protection Agency (EPA). The establishment of a self-sustaining population of northern map turtles would add to the efforts attempting to remove the Niagara River from that list.

The Niagara River can be thought of as a fragmented habitat to aquatic species that do not have the ability to swim against swift currents which are flowing at the mouth of the river under the Peace Bridge. Also, Niagara Falls acts as a second barrier downstream. Any turtles that go over would most probably die. Habitats that are fragmented in one way or another need to be approached differently in regard to conservation than habitats which are continuous because animals may not be eliciting normal behaviors (Bennett et al. 2010). The reconstruction of the Unity Island Park lagoon and the creation of a fish passage into the Black Rock Canal are the beginning steps in creating a linked system for many aquatic species.

The data collected from this project have multiple real-life management implications that are already being implemented. This study provided information on habitat utilization and how these habitat selections shift temporally. Areas like Beaver Island State Park and Buckhorn State Park, both on Grand Island, have habitat enhancement projects that include turtle nesting habitats. Contractors have approached our research team for inputs for proper dimensions and substrate materials, as well as the most beneficial place for the construction for the nesting habitat.

The floating platforms have been seen to be very effective tools for sampling. The surveillance cameras allow for real-time observations without animal behavior being altered by human presence. These platforms can be deployed into areas of concern or habitats that have unknown species diversity and will allow researchers to collect quality data with minimal maintenance.

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