Movements of Spotted Turtles *Clemmys Guttata* in Black Rock Forest

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Abstract

Wildlife tracking is a valuable tool to monitor movement for the purposes of species and habitat conservation, especially in response to manmade changes in habitat, and that is no different for rare turtles such as *Clemmys Guttata* otherwise known as the spotted turtle. Within Sphagnum Marsh in Black Rock Forest, there is an opportunity to evaluate the movement patterns of a spotted turtle population before the planned replacement of Sphagnum Pond dam which could result in habitat changes in water level. Through Very High Frequency (VHF) tracking of nine individuals and comparing collected GPS locations of six turtles to changes in water level, we are better able to understand the impacts of water level change on movement patterns of spotted turtles. Two major water events occurred throughout May to August 2023. One of these was a flooding event on July 9th and the other was a beaver dam breakage on August 5th. Both events gave great insight to the movement response of spotted turtles in Sphagnum Marsh to both flooding and draining within the area. Before the flooding event on July 9th, spotted turtles had a very localized population on the northern part of the western bank. After the flood, all but two turtles were located further south along the western bank. However, after the beaver dam break on August 5th, individuals continued to inhabit the southern part of the western bank until October when every turtle returned to the northern part of the bank to a shared hibernaculum. This information could be useful in predicting the response these spotted turtles might have to either flooding or draining within Sphagnum Marsh as a result of the potential work done to the nearby manmade dam as well as give insight on how best to manage this population when the area is faced with any change in habitat.

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Introduction

Wildlife Tracking and Conservation

Tracking efforts within a conservation scope aim to help guide species and habitat conservation and management by gathering information about species movement and what habitat conditions may affect that movement. These resulting management efforts can be realized as designation of protected zones for wildlife, highlight areas of competition between species, and can pave the way for ecosystem-based management strategies by combining tracking data of species to assessed habitat changes (Hays et., al. 2019).

Wildlife tracking also serves to evaluate a species ability to move and what might influence its movement (Nathan et., al. 2008). Focusing on these aspects of movement data is especially crucial since there are a wide array of things that influence an animal and how it moves. These could include availability of prey, temperature, health of the study individual, and conditions of the environment. Movement technology can allow researchers to gain a finer scale of understanding because of their flexibility in time and/or space within a research study (Allen & Singh, 2015). In addition to movement data, monitoring conditions such as weather and, in aquatic ecosystems, water level can be key to inferring behavioral conditions at a more precise scale (Katzner & Arlettaz, 2019).

Effects of Dam Construction and Removal on Wildlife

One of the most prominent impacts to wildlife movement is human constructions such as dams. Construction of dams can lead to altered waterflow, water quality, and can destroy habitat for wildlife (Liao et. al., 2009; Lewke 1978). But while the effects of building dams on wildlife have

been well researched but, in comparison, the effects of removing dams on wildlife has been largely neglected. In a study done by Shuman (1995), after evaluating the effects on various fish and other aquatic wildlife populations from historic dam removals, it was concluded that a thorough environmental assessment was crucial before the removal of dams. Erosion, diminished water quality, and habitat degradation are among the negative environmental effects caused by dam removal (Allen and Aggus, 1983). This created loss of habitat and, in some cases, caused populations of species to migrate elsewhere. However, the effects of dam removal and the subsequent environmental changes on various wildlife populations' movement remains relatively unexplored.

Sphagnum Marsh

A potential situation of wildlife being impacted can be found at the study site for this project, Sphagnum Marsh in Black Rock Forest. Black Rock Forest is a "living laboratory for field-based research and education" that boasts 3,920 acres with varied topography and high species and habitat diversity (Black Rock Forest, 2021). Sphagnum Marsh is a man-made marsh located near a stone dam connected to Sphagnum Pond. Sphagnum Pond is a reservoir maintained by the water department in Cornwall, NY within Orange County. The condition of the reservoir was last evaluated in 2017. During this assessment, the hazard potential classification was significant and the condition of the reservoir was determined to be poor (IndyStar, 2017). Recently, actions have been made to drain the reservoir to avoid total dam failure (Palmer, personal communication). Due to this expected change, we are motivated within this study to capture the "before" snapshot of the nearby Sphagnum Marsh before any potential habitat impacts are observed as well as evaluate current spotted turtle movements in response to habitat changes.

Spotted Turtle Movement and Habitat Selection

Sphagnum Pond is home to various wildlife within Black Rock Forest. Among these species is the *Clemmys guttata* or Spotted Turtle. The Spotted Turtle is a semi-aquatic species that has recently been put forth as a candidate for species reassessment with the intent for it to be listed as an endangered species on a federal level due to the species decline resulting from climate change and habitat fragmentation (U.S. Fish & Wildlife Service, 2022). With this potential new status comes the urgency to collect species data so conservation efforts can become more refined.

Spotted Turtle movement and growth is heavily influenced by habitat available as well as environmental conditions (Ernst 1975 & 1976; Coury 2022). Emergent wetland was heavily favored by the populations within this study and the individuals within that study did not travel far from those areas. Movement was also heavily influenced by environmental conditions such as precipitation and temperature with lower temperatures and high precipitation negatively influencing distance traveled. Similarly, in a study by Rasmussen and Litzgus (2010) and Yagi and Litzgus (2012), habitat selection evaluated at the second order (home range determined from population range) and third order (singular locations within or outside home range) was determined to be heavily influenced by environmental factors. Aspects such as seasonality had some effect on macrohabitat selection but microhabitat selection remained consistent. This indicated that while Spotted Turtle populations might move from one macrohabitat to another, the preference for microhabitats such as wetlands did not change.

Within the current conditions of Sphagnum Pond, there is an opportunity to record and evaluate Spotted Turtle movements before any major changes might take place. If Spotted Turtle populations shifted from one habitat to other nearby aquatic areas in response to habitat change,

those populations could be negatively impacted from the overlap in dietary niches with other species (Johnson, 1980). In a paper by Chaudhry (2023), an inverse relationship was found between the abundance of Spotted Turtles in a given region compared to other species given a dietary niche overlap. These other species included other semi-aquatic or aquatic species such as Painted Turtles (*Chrysemys picta*). Data regarding movement and habitat selection collected now can deepen our understanding of the potential future habitat selection of populations in the future, especially when competing species are in the newly selected habitat.

In this study, I aim to not only capture a sense of the spotted turtle population size and habitat occupied, but to understand how changes in water level can impact their movement using a combination of wildlife tracking technology and water level monitoring.

Methods

Trapping

Between the dates of June 1st and August 17th, 2023, ten Promar crayfish traps baited with sardines were used to trap Spotted Turtle individuals at Sphagnum Marsh. Traps were partially submerged in the wetland, ensuring a few inches of emergence at the top. Traps were checked and bait was replaced daily when weather permitted and pulled when severe weather was predicted to ensure safety as per suggestion of Bury et. al., (2012; 2013). Trapping locations were selected based on the presence of foliage and shaded areas for thermoregulation (Figure 1). Areas along both the western and eastern bank were selected to ensure trapping efforts were sampled throughout the marsh. Other areas along Sphagnum Marsh, especially along the southern bank, were densely vegetated and inaccessible for trapping.

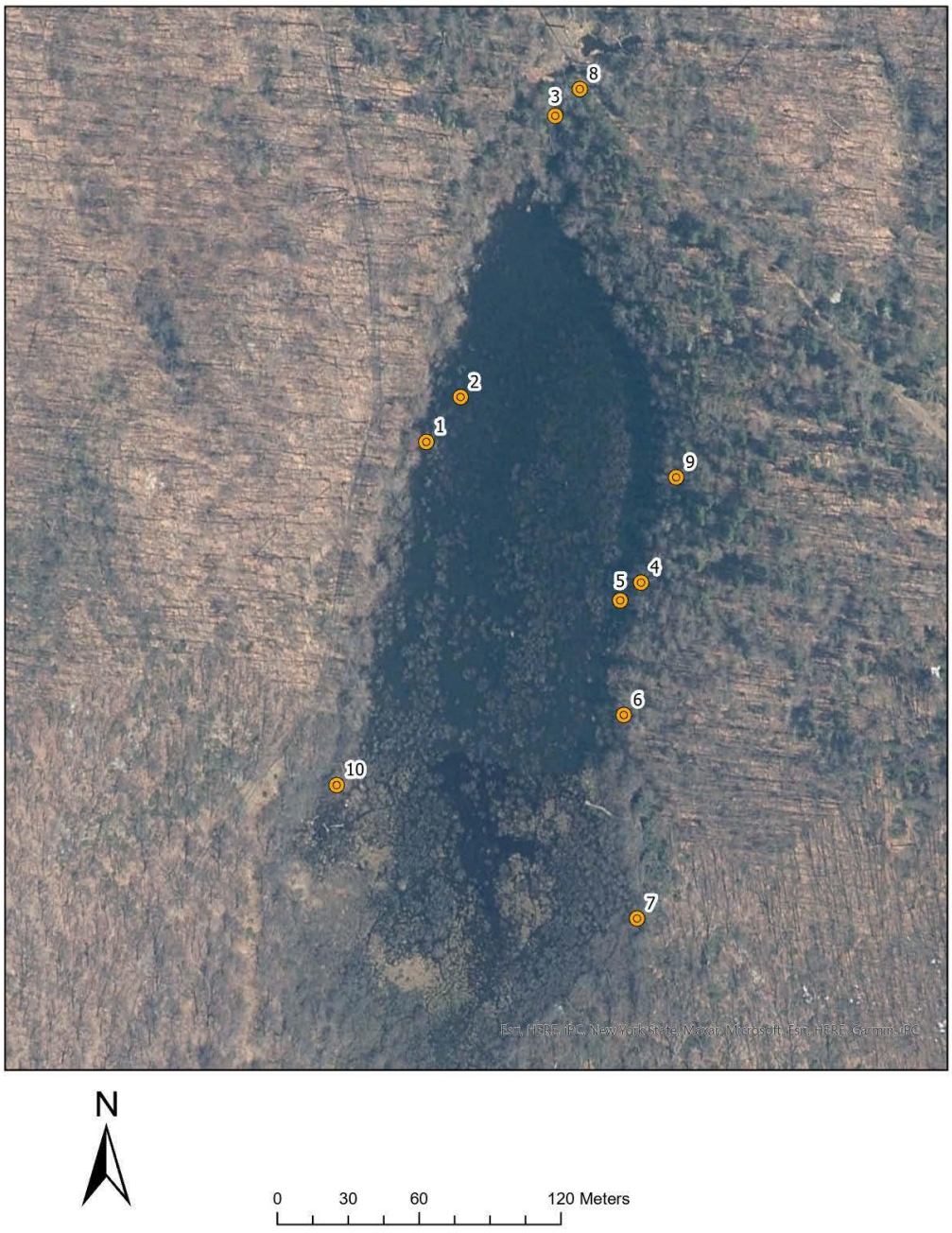


Figure 1: Ten trapping locations located in Sphagnum Marsh at Black Rock Forest.

Data Collection and Recording for Turtles

For individuals found, GPS location was recorded at the point of capture/release using a Bad Elf GPS Pro+ unit. Carapace (upper part of shell) and plastron (bottom part of shell) dimensions were recorded using a metric caliper, weight by using a kitchen or spring scale, sex was determined from shell and tail characteristics, and any injuries and abnormalities were noted. Unique identification codes provided by NY Department for Environmental Conservation (NYDEC) were notched in the marginal scutes (modified from Cagle, 1939).

Lotek Pinpoint-120 GPS units and Nanotag NFT-5-2 very high frequency (VHF) transmitters were attached with marine or gel epoxy to the individual in locations on the carapace that would not impede normal behaviors in a similar fashion to Eckler et. al., (1990). Considering the small size of spotted turtles and the requirement to keep attached equipment weight (<10% body weight as per NYSDEC), small sized Lotek devices were deployed. The smaller sized units have smaller batteries and reduced battery capacity, meaning there is a tradeoff for the frequency and span of time of which GPS locations are recorded. Lotek Pinpoint-120 GPS units have a three second burst rate and recorded on intervals of 2-12 hours. Originally, the Lotek units were scheduled to request a satellite location every twelve hours but this was switched in favor of a two-hour interval. Considering the equipment's inability to connect to satellites and record GPS coordinates while the device is submerged, the number of locations recorded for is heavily dependent on the turtle's activity during the scheduled collection periods so a more frequent interval burst was favorable to maximize the total amount of possible points collected.

VHF tracking was then conducted throughout the season. Because of the semi-aquatic nature of this species, tracking was done via kayak so as not to disrupt turtles and cause them to move to areas they would not normally occupy. This method also meant that is was not possible to

visually spot the turtles and so reliance on VHF signal strength was heavy. Locations were determined using a triangulation method which included picking three bearing points and confirming that the signal was coming from within those points. This location was then recorded using a Bad Elf GPS unit.

Changes in Water Level Data

Water level depths were recorded using a staff gauge and a trail camera every 2 hours which was placed in trapping location #1 (Figure 1). The gauge was deployed on July 19th and removed on August 16th. Water level data was compared to the movement patterns displayed by individuals this summer to evaluate the impact of those environmental changes on Spotted Turtle movement.

Data Analysis

With the exception of the Lotek data, all data was recorded using handwritten methods and Google Sheets. GPS data was inputted into Quantum Geographic Information System (QGIS) for mapping and visual analysis. Distance traveled was recorded and tracked, keeping seasonality in mind (e.g., nesting season) before being inputted in Microsoft Excel. Data regarding the latitude changes over time was then taken and formatted into a scatterplot (Figure 3). Additionally, water level data was input into Excel and a scatterplot was created showing the water levels over time with big water events being noted (Figure 3).

Between two major water events, VHF points were collected and data from six turtles within this study were mapped out using QGIS (Figure 2). These six individuals were selected because they

had 5+ points of useable data which was determined to be the minimum amount needed to observe a reliable movement pattern.

Results

Across the trapping days between June and the end of August, ten trapping locations were used (Figure 1). These traps were initially deployed on June 1st and trapping efforts did not cease until August 16th. Trapping days within this timeframe were weather-dependent with only June 13th-18th and July 20th-July 23rd being the only prolonged periods without trapping. However, only two trapping locations yielded any turtles (Table 1). Trap 1, which was located in the northern portion of the western bank, yielded eight of the nine turtles within this study, suggesting that a population of at least those eight turtles inhabited that region specifically of the marsh. One turtle was captured in trap 6, which was located in a southern part of the eastern bank, but the rest of the traps along the eastern side of the marsh yielded no spotted turtles and trap 6 only captured one. This could suggest that spotted turtles are not found in as large abundance along the eastern bank compared to the western bank.

Table1: Trap numbers and the total amount of spotted turtles caught in those traps across trapping efforts from June to the end of August.

Trap Number	Number of Spotted Turtles Caught
1	8
2	0
3	0
4	0
5	0
6	1
7	0
8	0
9	0
10	0

Three male and six female spotted turtles were captured between June and September 2023. Male weight ranged from 150-200 g while female weight ranged from 100-254 g (Table 2). This is well within expected healthy weights for these turtles, which is indicative of good population health.

Table 2: Morphological measurements of eight *Clemmys Guttata* individuals in captured in Sphagnum Marsh May-September of 2023.

Notch Code	Sex	Carapace Length	Carapace Width	Plastron Length	Plastron Width	Height	Weight
L1L2R1	Male	10.39 cm	7.61 cm	8.61 cm	5.12 cm	~	200 g
L1L2R2	Female	9.05 cm	6.72 cm	8.01 cm	4.97 cm	3.73 cm	120 g
L1L2R3	Female	7.55 cm	6.21 cm	7.52 cm	4.47 cm	3.00 cm	100 g
L1L2R9	Female	11.22 cm	7.90 cm	10.04 cm	5.85 cm	4.14 cm	168 g
L1L2R10	Female	12.58 cm	8.34 cm	10.72 cm	6.01 cm	4.35 cm	254 g
L1L2R11	Female	11.55 cm	8.23 cm	10.05 cm	6.15 cm	4.53 cm	224 g
L1L2R12	Male	11.01 cm	7.78 cm	8.86 cm	5.55 cm	4.01 cm	179 g
L3R11	Male	10.75 cm	7.47 cm	9.01 cm	5.04 cm	3.75 cm	150 g

Initially, there were plans to utilize both GPS data and VHF tracking to record locations of spotted turtle individuals. However, this proved to be an issue when two individuals, L1L2R9 and L1L2R10, were recaptured on June 21st. Data was pulled from the Lotek GPS units but only one location point was retrieved between the two turtles. Upon field testing further investigation,

it was determined that the Lotek units could not record location data while submerged underwater at any depth. Lotek units were reprogramed from attempting to receive location data every twelve hours to attempting to receive location data on a two-hour interval. This way there was an increased likelihood of data points being retrieved while the turtles were above water.

Despite consistent effort, recapture of the individuals outfitted with Lotek units in this study did not yield success and the data recorded on those units has not yet been retrieved. Therefore, there has been a shift in this study towards reliance on the GPS locations collected via VHF tracking data.

Two major water events occurred between July and August. On July 9th, there was a major flooding event that not only caused water levels to rise (Figure 3), but also had noticeable impact on habitat in the form of erosion of nearby roads and fallen trees. After that, on August 5th, a nearby beaver dam broke and the water level dropped considerably (Figure 3).

Throughout June to early July, spotted turtles were recorded to be occupying mostly the northern part of the western bank (Figure 2). However, after the flood that occurred on July 9th, there was a noticeable shift in location with L1L2R2, L1L2R3, L1L2R10 and L1L2R11 then occupying a space near the western bank further south (Figure 2). This could be normal seasonal shifts but with the location shift occurring in conjunction with the flood, it could also be because of the increase in water level. Individuals L1L2R1 and L1L2R9 remained closer to the northern part of the western bank which might suggest this is not seasonal since it would be expected for populations to move together.

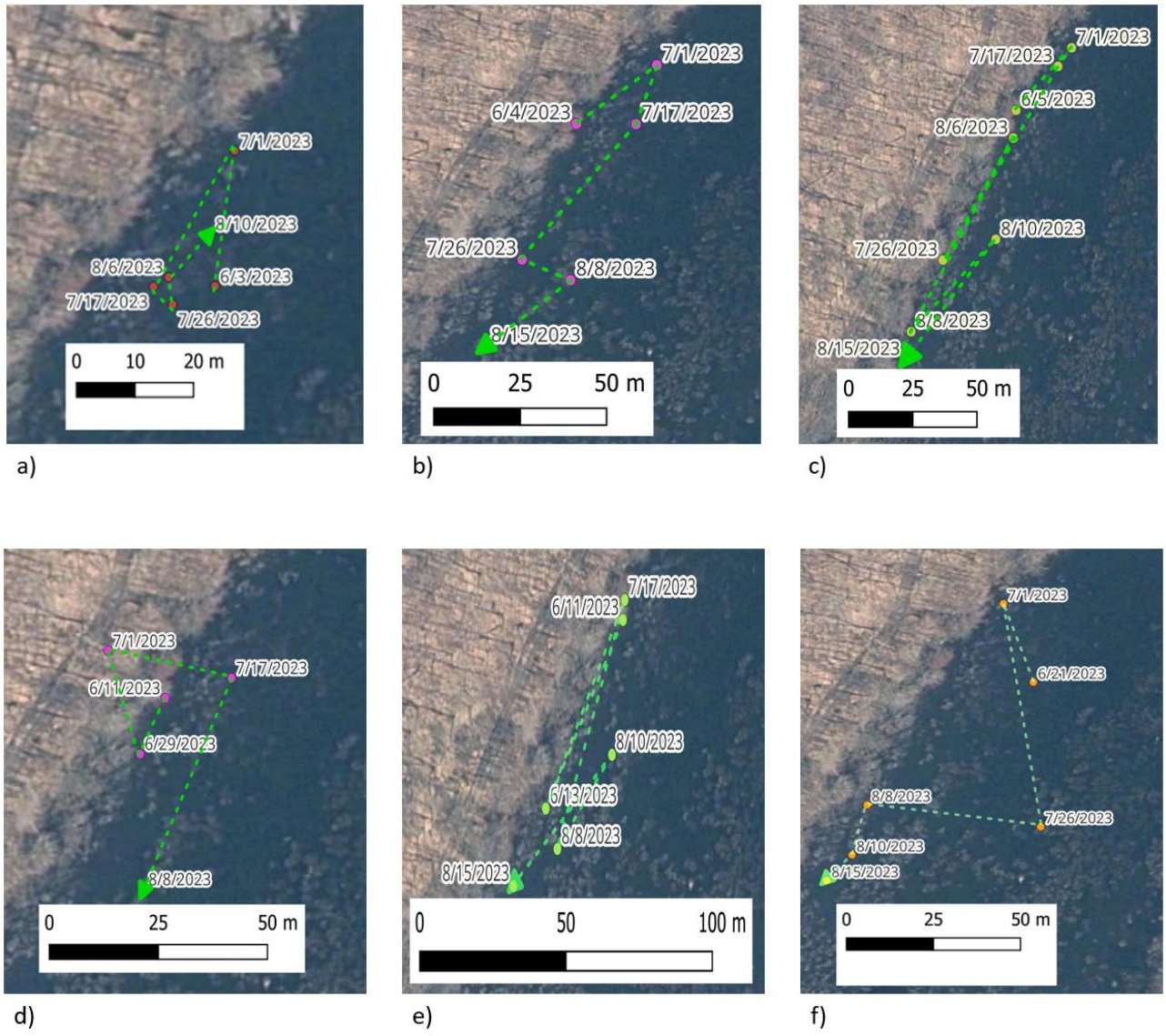
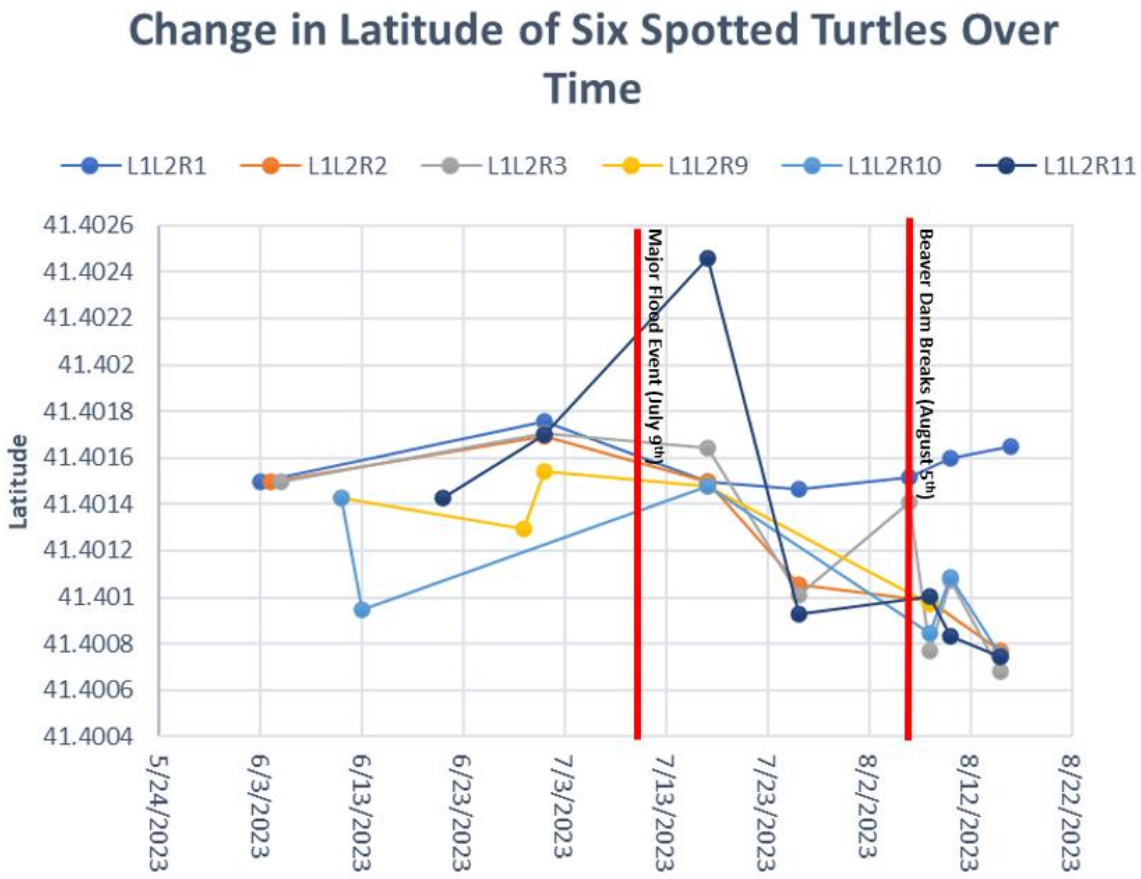


Figure 2: VHF points recorded and overview of movement path between tracking events for L1L2R1 (a), L1L2R2 (b), L1L2R3 (c), L1L2R9 (d), L1L2R10 (e), and L1L2R11 (f).

When comparing spotted turtle north and south movement throughout Sphagnum Marsh to hydrological changes, there appears to be more variance in latitude between spotted turtles when water levels are observed to be high, compared to after the August 5th beaver dam break where the water level is lower and individuals were more closely located (Figure 3).


Change in Latitude of Six Spotted Turtles Over Time
L1L2R1
L1L2R2
L1L2R3
L1L2R9
L1L2R10
L1L2R11
Latitude
41.4026
41.4024
41.4022
41.402
41.4018
41.4016
41.4014
41.4012
41.401
41.4008
41.4006
41.4004
Major Flood Event (July 9th)
Beaver Dam Breaks (August 5th)
5/24/2023
6/3/2023
6/13/2023
6/23/2023
7/3/2023
7/13/2023
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8/2/2023
8/12/2023
8/22/2023

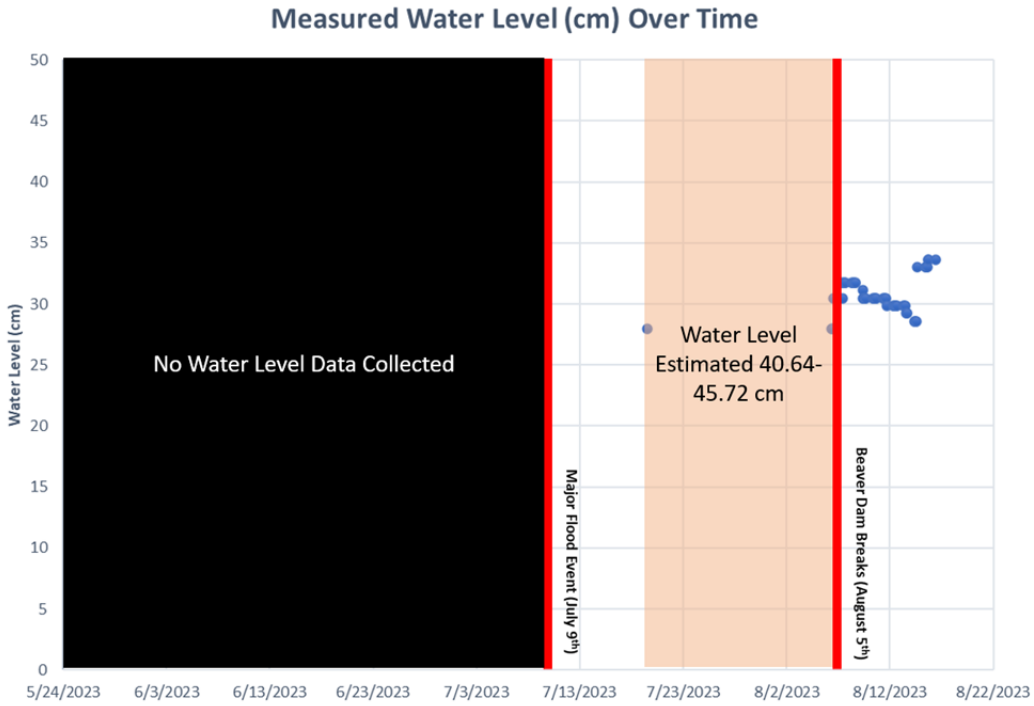

Measured Water Level (cm) Over Time
Water Level (cm)
50
45
40
35
30
25
20
15
10
5
0
No Water Level Data Collected
Water Level Estimated 40.64-45.72 cm
Major Flood Event (July 9th)
Beaver Dam Breaks (August 5th)
5/24/2023
6/3/2023
6/13/2023
6/23/2023
7/3/2023
7/13/2023
7/23/2023
8/2/2023
8/12/2023
8/22/2023

Figure 3: The change in latitude over time observed in six spotted turtle individuals (top) and the corresponding measured water level (cm) over time (bottom).

Individuals L1L2R1, L1L2R2, L1L2R3, and L1L2R11 occupy similar latitudes before the July 9th flood, with individuals L1L2R9 and L1L2R10 staying closer to each other and further from the main group (Figure 3). After the flood, all the individuals moved closer in latitude to one another except for L1L2R11 (Figure 3). After the beaver dam break on August 5th, only individual L1L2R1 was observed to be located further from the other individuals (Figure 3).

No water level data was collected prior to July 19th and between July 19th and August 6th, no water level data was reliably recorded on the trail cameras due to a misposition that made it so no pictures were taken of the actual water level. However, based on qualitative evidence of personal, unrecorded observations during this time and sediment deposition on the water gauge, the estimated water level range for this time period was between 40.64 and 45.72 cm. After the beaver dam break on August 5th, the water level dropped down to the 27.94 to 33.655 range.

After the field season ended on August 16th, spotted turtles outfitted with VHF and Lotek GPS devices were not recaptured. During September and October there were efforts to recapture these individuals but the only turtle that was recaptured from this study was L1L2R12 which did not have a Lotek GPS unit attached. Into October, the individuals in this study were tracked using VHF to a shared hibernation spot in Sphagnum Marsh, otherwise known as a hibernaculum (Figure 4). This hibernaculum was located near the northern area of the western bank, near where the turtles were originally trapped at the beginning of the season. This could point to a seasonal movement north along the bank for hibernation or it could signal that environmental conditions had returned to their state from the beginning of the season and the turtles moved back to occupy a preferred space.

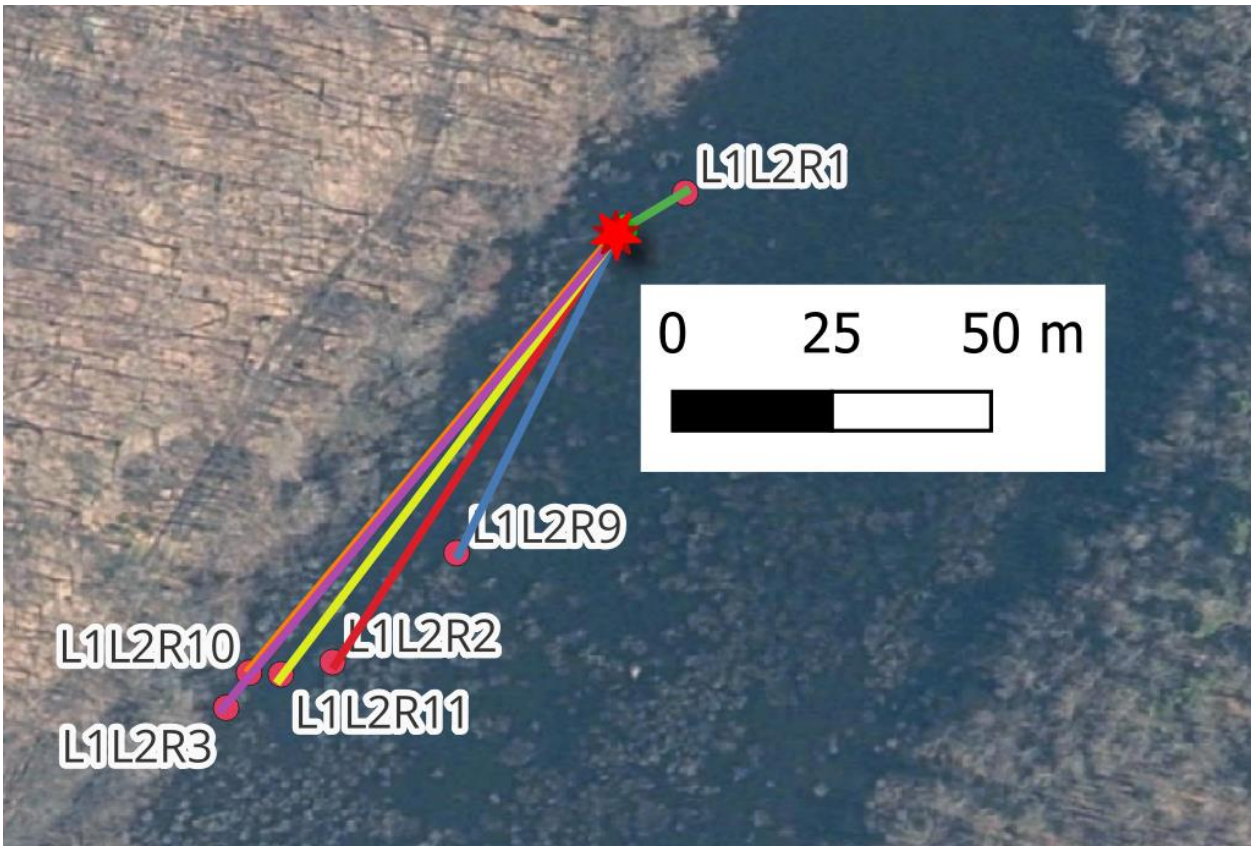


Figure 4: Line drawn from last recorded VHF location of six spotted turtle individuals to the shared hibernaculum found in October indicated with the red star icon. L1L2R1's path is the green line. L1L2R2's path is the red line. L1L2R3's path is the purple line. L1L2R9's path is the blue line. L1L2R10's path is the orange line. L1L2R11's path is the red line.

Discussion

Movement Data Interpretation

There is an observed pattern in movement within the population. In June and July, when VHF tracking began, many turtles were located further north. As the season progressed into late July –

early August, there was some movement south along the western bank, with a few turtles returning to the original northern area, before finally settling back into that southern area.

There are some interesting correlations between a July 9th storm that occurred in Cornwall and the movement patterns. The storm on July 9th caused flooding within the area as well as erosion of roadways in Black Rock Forest and damage to tree coverage. There was an inability to visit the site for about a week so no tracking was conducted until July 17th. However, when VHF tracking was resumed, there was a definite difference in location of the turtles. Most prominently, individual L1L2R1 traveled far south along the shore. Other individuals, such as L1L2R2 and L1L2R3, still traveled south but did not shift as far as L1L2L1.

Another event to note is the breakage of a nearby beaver dam on August 5th. However, despite the change in water level that resulted from this, only L1L2R3 moved back north (Figure 2). The other turtles remained in the southern area until October (Figure 4).

When regarding water table data in relation to changes in latitude, there is an observed pattern of location within the spotted turtle population at Sphagnum Marsh (Figure 3). There was more variance when water levels were observed to be high post-flooding. However, after the beaver dam break, there was less variance in latitude and turtles seemed to remain close to one another. Home ranges of spotted turtles have been recorded as being variable when extreme weather conditions are present. Rowe et. al., (2013) investigated the yearly home ranges of spotted turtles and found turtle movements to be substantially frequent in flooding or other high water level conditions but low when drought conditions are observed. This observed behavior could be applied to the July 9th flood, which was a weather condition that increased water level and during which turtle movements increased, and to the August 5th beaver dam break, which decreased the water level of the marsh and during which turtle movement was not as great.

This movement pattern could be because of seasonal movements. However, it is a correlation that is observed with most but not all of the turtles. L1L2R1 was distanced from the rest of the recorded population post-dam break. In fact, there was little location change from L1L2R1 compared to the rest of the population. This could be due to equipment malfunction, there is no way to be sure unless the turtle is recaptured and is missing the VHF receiver and the Lotek GPS unit successfully recorded data during this time period, but if the VHF equipment is still attached and functioning on this individual this might suggest some other reason for the little movement observed.

L1L2R11 also distanced itself heavily from the rest of the population after the flooding event on July 9th. But it soon rejoined the population in the further south region.

One reason this population might have moved further south along the bank post-flooding could be the observed density of foliage, which contained aquatic vegetation areas with shrubs and basking areas, which was more elevated than that of the northern region. If water level affected movement pattern, it could be inferred that areas with dense foliage and elevated basking areas that are not normally utilized would be preferable when dealing with higher water levels. In a study done by O'Dell et. al., (2021), the type of habitat selected by spotted turtles, freshwater marshes, and shrub swamps, was deemed to be preferred to areas with changing habitat conditions such as developed areas or salt marshes where there was once high-quality habitat. In another study by Beaudry et. al., (2009), spotted turtles were observed to prefer shrub and aquatic emergent vegetation cover when it was available. We can see this selection reflected in the areas where five of the six individuals chose to move after the habitat changes caused by the July 9th flood. As previously mentioned, this area was dense with foliage such as shrubs and

aquatic foliage that had not been covered by the elevated water level. It would make sense that it would be the more ideal habitat conditions chosen by these turtles in response to the flooding.

Water level has been observed to play a significant role in spotted turtle movements. This has been noticed both seasonally but also in conditions where water level changes dramatically. In a paper by Graham (1995) they note the variance in movement throughout the seasons but also in response to things such as water quality and depth which can impact abundance of food and ideal habitat.

In October, there was a shared hibernaculum between the nine individuals in this study within the original northern part of the western bank they were found in before the flood. This could just be a regular seasonal movement. In studies by Ernst et. al., (1989), Graham (1995) and Kaye et. al., (2001), hibernaculum were only around six meters apart from the previous year's spot.

But why would they return to the northern area after relocating south in response to the increased water levels from the flood if the conditions were no longer ideal? In a study done by Buchanan et, al., (2017) spotted turtles continued to return to previous years hibernaculum spaces despite nearby habitat disturbance. In another study performed by Enneson (2007), the construction of a beaver dam in 2000 caused spotted turtle populations to abandon the wetland they were occupying before eventually returning when the dam broke in 2005 and the water levels lowered. This suggests that spotted turtles are likely to relocate when water levels rise but return to their original habitat when original habitat conditions are present once more. With the beaver dam breaking in August the water level dropped significantly and that could have resulted in the original northern area becoming ideal habitat once more.

Setbacks and Study Limitations

There are several setbacks and limitations that inhibit the ability to make definitive conclusions about what factors affect Spotted Turtle movements. The biggest study limitation is the fact that only a single field season has been dedicated to this project and the turtles at this site. This makes it so aspects such as seasonal movements, especially during the nesting season, are not clearly defined.

However, this gives rise to opportunity for future studies to observe seasonal movement when there are less major water events. Fields seasons such as these could give a better idea of the seasonal movements of these turtles when there are no major environmental conditions changed.

As mentioned previously, there were also issues in experimental procedure with the water gauge which resulted in reliable data not to be recorded due to improper positioning of the trail camera.

Due to the nature of working with a small and semi-aquatic species, the ability to retrieve GPS and VHF units is lessened. The Lotek units may contain large amounts of location data from the 2023 summer field season. But beyond trapping attempts, which have been unsuccessful thus far, tracking turtles on foot or on a kayak to recapture them is seemingly impossible because of their speed and ability to sense disturbance in the water created by movement. Currently, the individuals in this study all seem to be hibernating together in the same location. In the best interest of turtle health, no efforts to retrieve the units will be made this winter to avoid stressing the turtles or disturbing this hibernation spot. These units will not be retrieved until Spring 2024 at the earliest so the data is not yet available.

Conclusions

Tracking and recording the movement of six spotted turtle individuals in this study to better understand their movement was the primary goal of this study. Additionally, seeing if there was a correlation between water level change and movement was an imperative aspect to understanding what might influence the movement of these rare turtles.

With the movement data that is currently assessed, along with comparisons to the timeline of certain events that altered water level of the study site such as the July 9th storm and the August 5th beaver dam breakage, there is some correlation between movement of spotted turtles and water level change. There was a movement pattern southward towards observed highly vegetated and elevated basking regions that occurred within the same time as rising water level changes. This did not also occur when the beaver dam broke seeing as most of the turtles remained in the same southern area until October when the population localized in a shared hibernaculum. This, at the very least, suggests that turtles might have migrated further south in response to rising water levels but water levels dropping had little to no effect on their movement until months later when environmental conditions seemingly returned to their pre-flood state.

Using this information, with additional field seasons, management strategies can be developed to mitigate the negative effects of any habitat change that should occur. With the potential for changes in habitat to result from the nearby dam removal and repair, it is important to develop strategies to ensure these rare turtles are not displaced from ideal habitat conditions. This information could also extend beyond Black Rock Forest and be used for conservation strategies for the spotted turtle in the face of various changes in habitat conditions.

Recommendations

By collecting data on Spotted Turtle movements when faced with changes in habitat conditions, such as the case with the possible dam removal and repair at Sphagnum Pond, we can determine how best to mitigate negative impacts on the populations within that region. Whether this is by relocating turtles to suitable habitats directly or monitoring populations in newly chosen habitats, we can use movement data such as that collected here to evaluate the impact these changes might have on certain populations and their movement behaviors.

Collecting data on movement could also have larger application for studies involving other turtle species experiencing changes in habitat due to dam removal or reservoir drainage. These applications could pertain to movement patterns during nesting season, which affect reproduction, or inform how turtles select habitat when conditions are affected by human impact.

In its entirety, determining the spatial ecology and habitat selection of Spotted Turtles is crucial to the development of future conservation and management efforts. With the current discussion surrounding whether to move the Spotted Turtle conservation status to endangered on a federal level, collecting data to use for future research is becoming a priority. Understanding the process by which Spotted Turtles select habitats is key to determining population distribution and abundance. It can also help to determine how Spotted Turtles select habitat and how conditions of certain habitats influence their movements.

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References

Allen, H., & Aggus, L. (1983). (rep.). Effects of Fluctuating Reservoir Water Levels on Fisheries, Wildlife, and Vegetation; Summary of a Workshop. *Defense Technical Information Center*.

Allen, A. M., & Singh, N. J. (2015, December 22). Linking movement ecology with wildlife management and conservation. *Frontiers*. https://www.frontiersin.org/articles/10.3389/fevo.2015.00155/full

Beaudry, F., deMaynadier, P. G., & Hunter, M. L. (2009). Seasonally Dynamic Habitat Use by Spotted (Clemmys guttata) and Blanding's Turtles (Emydoidea blandingii) in Maine. *Journal of Herpetology*, 43(4).

Black Rock Forest. (2021, July 23) About the forest. *Black Rock Forest.* https://www.blackrockforest.org/research/about-the-forest

Buchanan, S. W., Buffum, B., & Karraker, N. E. (2017). Responses of a Spotted Turtle (Clemmys guttata) Population to Creation of Early-successional Habitat. *Herpetological Conservation and Biology*, 12(3), 688-700. Retrieved from http://www.herpconbio.org/Volume_12/Issue_3/Buchanan_etal_2017.pdf

Bury, R.B., D.T. Ashton, D.J. Germano, N.E. Karraker, D.A. Reese, and K.E. Schlick. (2012). Sampling of turtles: trapping and snorkeling. Pp. 37–50 *In Western Pond Turtle: Biology, Sampling Techniques, Inventory and Monitoring, Conservation, and Management*.

Bury, R.B., H.H. Welsh Jr., D.J Germano, and D.T Ashton (Eds.) (2013) *Northwestern Fauna 7*, *The Society for Northwestern Vertebrate Biology*, Olympia, Washington, USA

Cagle, F. R. (1939). A system of marking turtles for future identification. *Copeia*, 1939(3), 170. https://doi.org/10.2307/1436818

Chaudhry, Eaqan A., et al. Habitat Usage, Dietary Niche Overlap, and Potential Partitioning between the Endangered Spotted Turtle (Clemmys Guttata) and Other Turtle Species. *Ichthyology & Herpetology*, vol. 111, no. 1, 24 Mar. 2023, https://doi.org/10.1643/h2021134.

Courey, M. (2022). The Spatial Ecology and Habitat Selection of a Spotted Turtle (Clemmys guttata) Population in Southwest Michigan (thesis). *ScholarWorks@GSVU*.

Eckler, J. T., A. R. Breisch, J. L. Behler. 1990. Radio telemetry techniques applied to the bog turtle (*Clemmys muhlenbergii* Schoepff 1801). Pages 69-70 in C. J. Sheviak, R. S. Mitch- ell, and D. J. Leopold, editors. Ecosystem management: rare species and significant habitats. *New York State Museum Bulletin* 471.

Enneson, J. (2007). Population viability analysis and response to habitat change in spotted turtles (Clemmys guttata). *Theses Canada*.

Ernst, C. (1975). Growth of the Spotted Turtle, Clemmys guttata. *Journal of Herpetology*. Retrieved November 30, 2023s from https://www.jstor.org/stable/1563197

Ernst, C. (1976). Ecology of the Spotted Turtle, Clemmys Guttata (Reptilia, Testudines ... *Journal of Herpetology*. Retrieved April 2, 2023, from https://www.jstor.org/stable/pdf/1562924.pdf

Ernst, C. H., Zappalorti, R. T., & Lovich, J. E. (1989). Overwintering sites and thermal relations of hibernating bog turtles, Clemmys muhlenbergii. *Copeia*, 1989(3), 761. https://doi.org/10.2307/1445511

Graham TE (1995) Habitat use and population parameters of the spotted turtle, Clemmys guttata, a species of special concern in Massachusetts. *Chelonian Conserv Biol* 1(3):207–214

Hays, G. et., al. (2019). Translating Marine Animal Tracking data into conservation ... - cell press. *Trends in Ecology & Evolution*. https://www.cell.com/trends/ecology-evolution/fulltext/S0169-5347(19)30024-2

IndyStar. (2017). Sphagnum pond dam in Orange County, NY. *Indianapolis Star.* Retrieved April 2, 2023, from https://data.indystar.com/dam/new-york/orange-county/sphagnum-pond-dam/ny00872/

Johnson, D. H. (1980). The competition of usage and availability measurements for evaluating resource preference. *Ecology*. 61:65-71.

Katzner, T. E., & Arlettaz, R. (2019, December 20). Evaluating contributions of recent tracking-based animal movement ecology to conservation management. *Frontiers.* https://www.frontiersin.org/articles/10.3389/fevo.2019.00519/full

Kaye, D. R, Walsh, K. M, & Ross, C. M. (2001). Seasonal movements and habitat preferences for the spotted turtle and eastern box turtle in Massachusetts. *UC Davis: Road Ecology Center.* Retrieved from https://escholarship.org/uc/item/4qx094rv

Lewke, R. (1978). Dams and Wildlife. *Passenger Pigeon*, 40(3).

Liao, W., Bhargava, D. S., & Das, J. (2009, August 24). Some effects of dams on wildlife: Environmental conservation. *Cambridge Core.* https://www.cambridge.org/core/journals/environmental-conservation/article/some-effects-of-dams-on-wildlife/B28DA02AC302DFB14056712458ED435F

Nathan, R., Spiegel, O., Fortmann-Roe, S., Harel, R., Wikelski, M., and Getz, W. M. (2012). Using tri-axial acceleration data to identify behavioral modes of free-ranging animals: general concepts and tools illustrated for griffon vultures. *J. Exper. Biol.* 215, 986–996. doi: 10.1242/jeb.058602

O Dell, D. I., Karberg, J. M., Beattie, K. C., Omand, K. A., & Buck, E. C. (2021, February 20). Changes to spotted turtle (Clemmys guttata) habitat selection in response to a salt marsh restoration - wetlands ecology and management. *SpringerLink*. https://link.springer.com/article/10.1007/s11273-021-09788-7

Rasmussen, Megan L., and Jacqueline D. Litzgus. Habitat Selection and Movement Patterns of Spotted Turtles (Clemmys Guttata): Effects of Spatial and Temporal Scales of Analyses. *Copeia*, vol. 2010, no. 1, 26 Feb. 2010, pp. 86–96., https://doi.org/10.1643/ce-09-141.

Rowe, J. W., Gradel, J. R., & Bunce, C. F. (2013). Effects of weather conditions and drought on activity of spotted turtles (Clemmys guttata) in a Southwestern Michigan wetland. *BioOne Complete*. https://bioone.org/journals/the-american-midland-naturalist/volume-169/issue-1/0003-0031-169.1.97/Effects-of-Weather-Conditions-and-Drought-on-Activity-of-Spotted/10.1674/0003-0031-169.1.97.full

Shuman, J. R. (1995). Environmental considerations for assessing dam removal alternatives for river restoration. Regulated Rivers: Research & Management, 11(3-4), 249–261. https://doi.org/10.1002/rrr.3450110302

U.S. Fish & Wildlife Service. (2022). (rep.). Status Assessment and Conservation Plan for the Spotted Turtle in the Eastern United States. *U.S. Fish & Wildlife Service*. Retrieved 2022, from https://www.northeastturtles.org/uploads/3/0/4/3/30433006/clgu_conservation_plan_10_13_22.pdf.

Yagi, K. T., & Litzgus, J. D. (2012). The effects of flooding on the spatial ecology of Spotted Turtles (Clemmys guttata) in a partially mined peatland. *Copeia*, 2012(2), 179–190. https://doi.org/10.1643/ce-11-106