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Tracking Box Turtles and Promoting Turtle Citizen Science

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Abstract

Eastern box turtles (*Terrapene carolina carolina*) often have a small range in terrestrial habitats and wetlands. Once a box turtle hatches, it makes a mental map of its home territory and will likely stay in this area for the rest of its life. To understand how the eastern box turtles utilize the North Carolina Arboretum gardens, thread-trailing was used to monitor movement patterns. Radio telemetry and GPS tracker loggers were also used to understand habitat preferences and to determine home ranges. For this research, five turtles were monitored and equipped with transmitters for tracking. Furthermore, to support the North Carolina Arboretum's box turtle research, data collected from 2018 and 2019 were analyzed and organized into GIS maps to understand habitat range and home range.

Keywords: Eastern box turtle, radio telemetry, GPS logger device, thread trailing, vegetation, movement

1. Introduction

Eastern box turtles geographically are found throughout the southeast from Maine to Florida.[1] Box turtles are a terrestrial and generalist species; therefore, they thrive well in different habits such as shrubby grasslands, meadows, wetlands, open woodlands, and field forest edges.[1] Eastern box turtles prefer habitat conditions that provide cool air temperatures, plant coverage, and moist environments[2]. Although Eastern box turtles are terrestrial, they do use aquatic resources for thermoregulation. It is hypothesized that ponds, streams, and wetlands increase the habitat quality for eastern box turtles, especially during the hot summer seasons[2]. For many years, box turtles were a common wildlife species.[1] But, unfortunately, across eastern North America, box turtles are disappearing. The eastern box turtle populations have declined in many locations in North Carolina.[1] Eastern box turtles are a vulnerable species vanishing due to habitat loss, fragmentation caused by human impact, and pet trade.[3] Wildlife conservationists worry that the eastern box turtle may disappear from North Carolina[1]. To help preserve the box turtle population's knowledge of their habitats is pivotal for conservation efforts to protect and increase populations.[3] Reptiles, like eastern box turtles, play an essential role in ecosystems such as seed dispersal. Monitoring their movement patterns will help researchers gain information to find the best methods of protecting them.[1] Furthermore, the thread trailing to study and observe eastern box turtles movements and plant preferences will help the North Carolina Arboretum with their conservation efforts and citizen science program.

The North Carolina Arboretum has partnered with the Box Turtle Connection, a statewide research initiative that began in 2007[1].The mission of the box turtle project is to promote citizen science and conservation for eastern box turtles. Environmental education through citizen science is an essential component of North Carolina Arboretum's community goals. Because environmental education is an integral part of the organization's initiatives Eco Explore, a citizen science initiative for kids from grades K-8, was created. In the twenty-first century, children are spending less time outdoors, which has adverse side effects on children's cognitive, physical, and psychological development [4]. Changing behavior begins with reconnection to nature and education. The purpose of this program is to connect children in the Asheville community to nature and science to inspire future generations to be active participants in

conservation. Eco Explore promotes nature engagement opportunities to children with merit badges like herpetology, botany, entomology, and ornithology. Each badge gives children opportunities to participate in challenges and games that provide them with identification skills and knowledge on how to foster wildlife in their community.

This project's original goal was to couple the box turtle tracking with the art badge and herpetology badge for EcoExplore by creating art activities in the classroom. Art can be an excellent tool for influencing a change in environmental values [5]. Studies have shown that drawing-to-learn is an intuitive process that can create a significant conceptual change for young learners [6]. Ideas for these activities included representational drawings and sculptures of box turtles in determining whether or not such activities enhanced learning experiences for the campers. However, due to Covid-19, in-person camp activities were canceled and prohibited due to social distancing concerns. To adjust to these changes, EcoExplore spent the summer creating educational videos for children online which I assisted with by making several videos on nature photography, nature journaling, and box turtles. In my videos, I focused not only on educating children about box turtles but also on engaging with nature in their backyard through photography and nature journaling such as observing a flower and drawing it. My goal for creating these videos was to give children an understanding of what they are seeing and a meaningful connection to nature by making art about animals and plants.

1.1 Study Site

The North Carolina Arboretum was designed by one of the most famous landscape architects, Frederick Law Olmstead. In 1986, his designs were used to create the North Carolina Arboretum [7]. The area is 176 ha within the Pisgah National forest. Every year the Arboretum attracts over 500,000 annual visitors from across the state, nation, and abroad [7]. The study area has different habitats such as hardwood forests, wetlands, pine forests, meadows, and cultivated gardens. An essential mission of the North Carolina Arboretum is to promote conservation efforts. One way the Arboretum strives to achieve this goal is through its citizen science program initiatives. One of these programs collaborates with the NC Box Turtle Connection, a 100-year study of box turtles[1]. Not only do volunteers from the Arboretum track the turtles, but also the Arboretum's environmental education program, EcoExplorer, involves campers to participate in the research. For this research project, EcoExplorer and the NC Box Turtle Connection methods of tracking box turtles were used.

2. Methods

I researched the following questions:

1. How can Radio telemetry techniques be used to determine eastern box turtle (*Terrapene carolina carolina*) movements and use of different habitat types? -movements, home range and different habitat types
2. How can thread-trailing techniques be used to determine eastern box turtle (*Terrapene carolina carolina*) use of different habitat types?
3. How can thread-trailing techniques be used to determine plant associations of the eastern box turtle (*Terrapene carolina carolina*)?
4. How can my research at the North Carolina Arboretum on box turtles be relayed to children in a way that promotes citizen science?

2.1 Radio Telemetry

I partnered with the North Carolina Arboretum to participate in their citizen science project, the Box Turtle Connection project, and conducted my research from June 14th to September 20th. Due to Covid-19, volunteer citizen science projects were canceled, and because of this circumstance, an essential part of my research was using telemetry. Four turtles are currently being tracked in the NC Arboretum system equipped with a radio telemetry transmitter and a unique set of 3 notches carved into their shells' rim. The marked groves act as a code to allow researchers to identify the turtles[1].

Radio telemetry is the primary method the North Carolina Arboretum uses to monitor the turtles. Radio telemetry allows researchers to locate the animal and track their movements[1]. Attached to the carapace is a transmitter that is affixed with epoxy. The transmitter emits a signal which can be detected with the receiver held by researchers in the field. Once the turtle is found, the coordinates are logged with a GPS and then recorded. The habitat the turtle was

found is also noted and categorized as: field/forest, field/meadow, pine forest, hardwood forest, stream, mixed pine/hardwood forest, core gardens, and other. Additional information about the percentage of clouds from 0%, 25%, 50%, 75% and 100% was recorded as well. Radio telemetry has been groundbreaking for wildlife biologists studying animal behavior and movement patterns[1]; however, it does come with drawbacks like human interference on animal behavior.

2.2 GPS Logger Device

The GPS device used in this research was created by two engineers who created open-source hardware for wildlife scientists.[8] The devices used were an Arduino based, open-source data logging system, as described in the article.[8] The logger provided a sequence of time-stamped GPS coordinates. The goal of using the GPS logger is to understand the turtles' spatial movements better.[8] The GPS device is a low powered GPS transceiver attached to the turtle's shell, which will allow remote data collection in large amounts over equivalent amounts of time[7]. For more isolated and distant turtles, like IMO, this tracking method was an excellent resource. The GPS logger device must be used with the radio telemetry equipment. The device continues to track information on the turtle's movements without human interference.

2.3 Thread trailing

Thread-trailing is a tracking technique that can reveal the details of exactly where and how far animals travel [9]. In comparison to radio telemetry and GPS logging, thread trailing is more accurate in determining a box turtle's movement patterns.[10]The thread used to measure distance is fixed carefully onto the carapace to ensure it does not affect the turtle's ability to move or mate. [11] Each day when the turtles were found, the threading device was attached to the carapace and tied off to a plant. As the turtle moves, the movement patterns will be measured with the thread trail. GPS locations from the beginning location and ending location were recorded along with the time. The objective of recording the GPS points is to compare straight-line distances between telemetry locations and the actual distances traveled between those locations using thread[12].

Thread trailing also provides information on the plant species the turtles interacted with throughout the study. Information like this cannot be ascertained by either radio telemetry or GPS logging[13]. Due to the variety of habitats and movements of the turtles, using a standard quadrat grid-based method was not feasible. Instead, the plants that the turtle directly made contact with while being thread-trailed were counted.

2.4 GPS Data Collection-Summarizing Habitat Preferences and Estimations of Home Range

GPS data collection from both the telemetry and GPS logger observations were recorded and analyzed. Data collected from the 2018 and 2019 box turtle volunteers' was reorganized, analyzed, and compiled to determine habitat preferences. GPS coordinates were also used to create GIS maps and to determine the home range of each turtle. Home range maps can help volunteers relocate turtles that have been lost from the system. Furthermore, home range maps help create a more comprehensive understanding of a turtle's behavior and preferred habitats[14]. Home ranges were made using minimum convex polygons in MATLAB. Minimum Convex Polygons is the standard way wildlife scientists define homeranges[14]; they are the smallest convex polygon that encloses all data points.

2.5 Environmental Educational Videos

In response to the Covid-19 pandemic, EcoExplore focused on providing environmental education following "social distancing" guidelines at home, in their backyard, or other outdoor areas. I created video content to be uploaded on the EcoExplore page and the audience ranged from kindergarten to third grade. I researched Jean Piaget's development theory on early childhood development to ensure my videos featured content on symbols, language, and imagination which are essential components of the preoperational stage[15]. I created four videos covering scientific photography, nature journaling, the differences between aquatic and terrestrial tortoises, and how scientists track box turtles. My videos were created using a software called PearDeck, an interactive presentation tool designed to engage students in individual learning experiences.

3. Results

3.1 Home Range -- Using Radio Telemetry and the GPS Logger Device

Data collected from the GPS logger and radio telemetry data from 2018 to 2020 was analyzed to create home range maps for each of the four turtles that I studied. By using this data, the spatial patterns of the box turtles were assessed, and ranges were distinguished. The home range area varied significantly between the turtles. For the four turtles, the average home range was 4.29 hectares, with a standard deviation of 2.44. The amount of area that a turtle occupies varies significantly by the turtle (Figure 1).

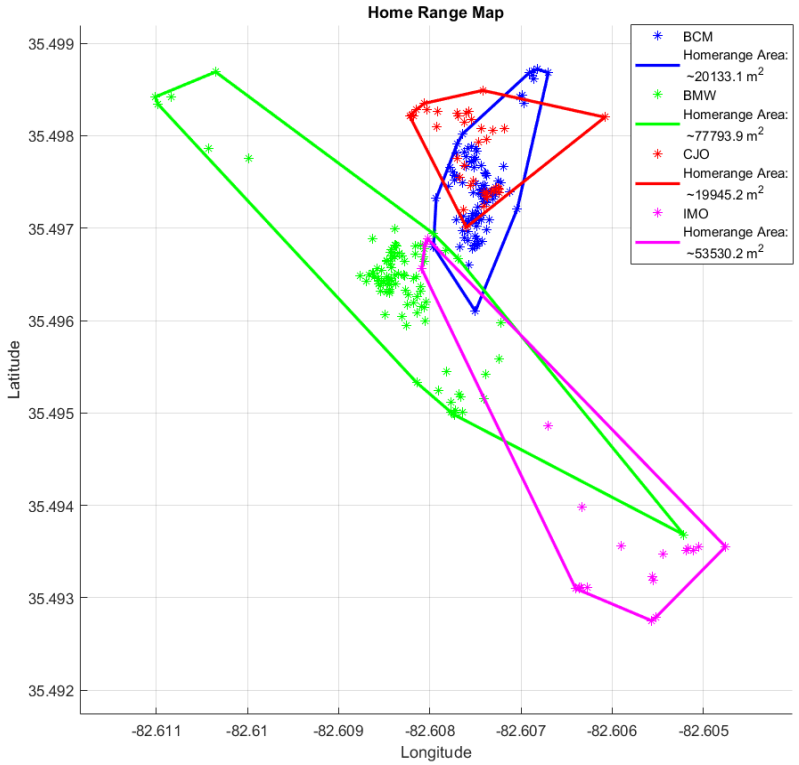

Figure 1. Map depicting habitat types and home ranges (minimum convex polygons; MCPs) of turtles at the North Carolina Arboretum.

3.2 Habitat Use- Using Radio Telemetry and the GPS Logger Device

Data analyzed from the radio telemetry and GPS logger show evidence that the turtles living in the arboretum utilize different habitat types such as the core gardens, field forest edges, forest, forest edge, and meadow (Figure 2). It is interesting to note how each of these habitat types is distributed closely, and the lowest used habitat was stream habitats, because box turtles are known to prefer habitats close to swamps, ponds or streams[1].

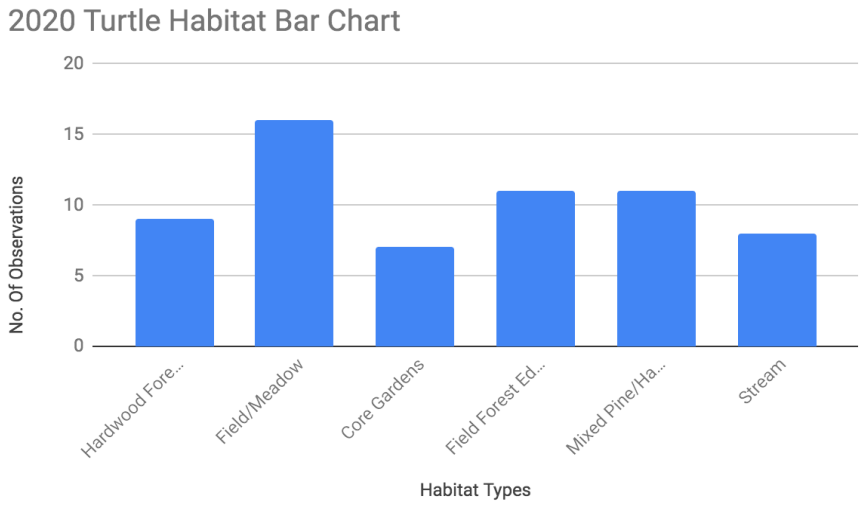

Figure 2. Habitats used by Eastern box turtles at the North Carolina Arboretum.

Habitats where turtles most frequently visited were upland or lowland mixed pine/hardwood forests. The stream habitat exhibited wetland characteristics, but only one turtle (IMO) consistently showed a preference for this environment, which contrasts with research showing turtles preferring wetland habitats[12]. Data for habitat preferences were collected from GPS locations and field accounts from 2019 to 2020. The overall turtle population used various habitats; however, each turtle utilized a specific habitat (Figure 3).

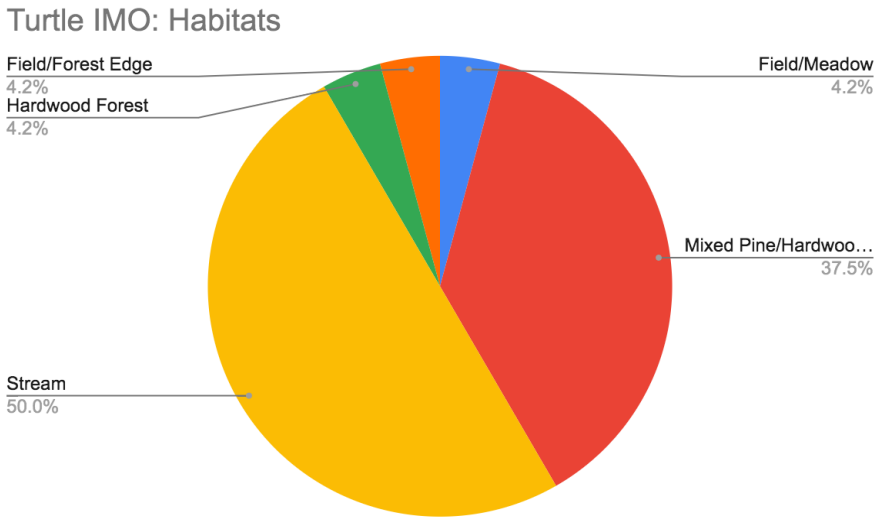

Figure. 3 Turtle IMO Habitat Preferences from 2019 to 2020

Data collected on habitat and GPS locations showed that Turtle IMO from 2020 to 2019 predominantly resided in stream habitats along the Bent Creek Trails of the North Carolina Arboretum. Turtle IMO was the only turtle that exhibited frequent preferences for habitats with water (Figure 3), whereas turtle CJO showed different habitat preferences (Figure 4).

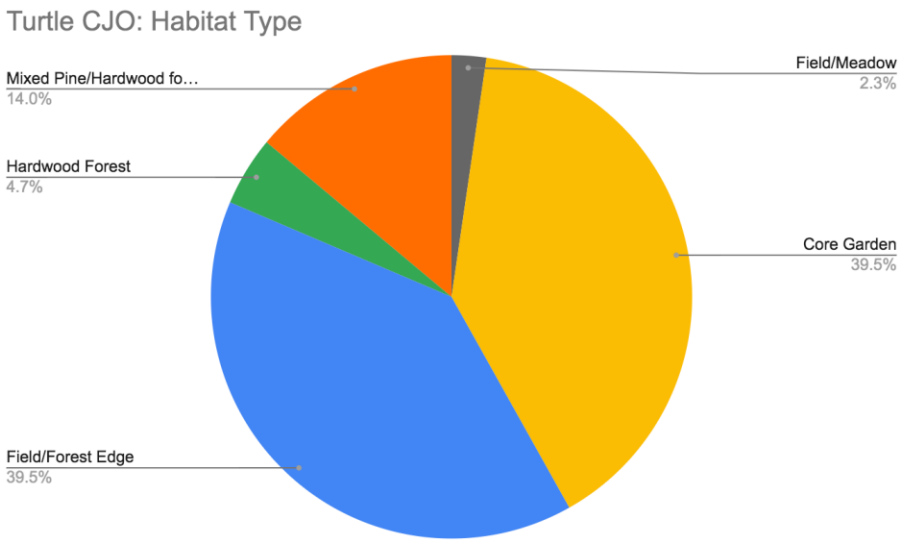

Figure 4. Turtle CJO Habitat Preferences from 2018 to 2020.

Turtle CJO was the only female turtle surveyed and spent most of her time equally distributed between the Core Gardens (Baker's Garden) and the forest edge near the Core garden from 2018 to 2020. CJO was found on July 8th at 10:22 a.m mating in the forest edge with turtle CMP, a turtle in the data system; however, he is not tracked with a transmitter.

3.3 Movement Using Thread-Trailing

The actual distance a turtle traveled was measured using thread-trailing (Figure 5). Since the thread is pulled tight around branches, the path can be approximated by a sequence of straight lines followed by angles turned. Using thread-trailing, the total string length was measured, and GPS start and end coordinates were used to orient, wherein the arboretum the turtle was moving. Observations and examinations of thread-trailing maps showed that the turtles do not move in straight lines; instead, turtles change directions frequently due to structures like logs.

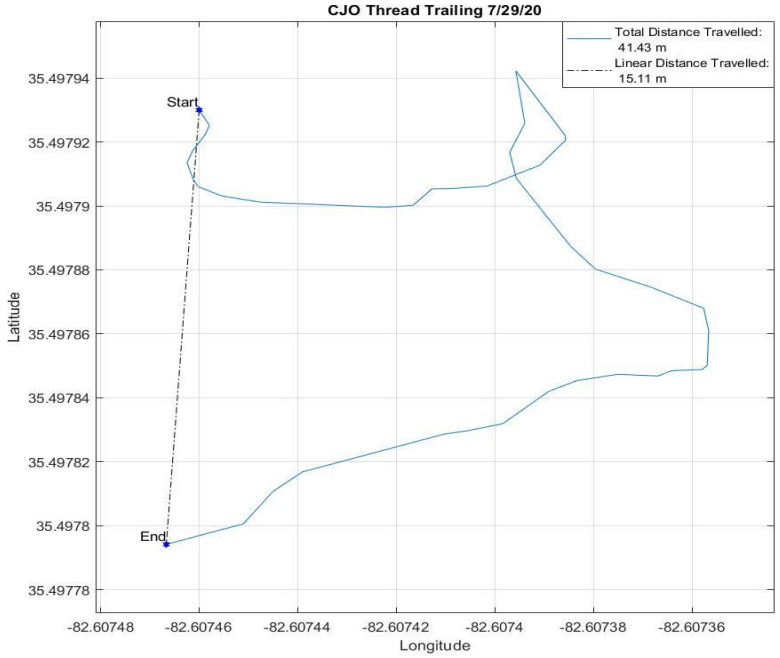

Figure 5. An example of the distance traveled by turtle CJO during a 1-day sample of thread-trailing (July 29th).

The GPS start coordinates and end coordinates are indicated with the dotted black line, while the exact movement recorded by CJO is represented in blue. This figure examples how the linear distance does not account for the total distance traveled. Thread-trailing maps also showed how the turtle's movement patterns differed from one another (see Figure 6 and Figure 7).

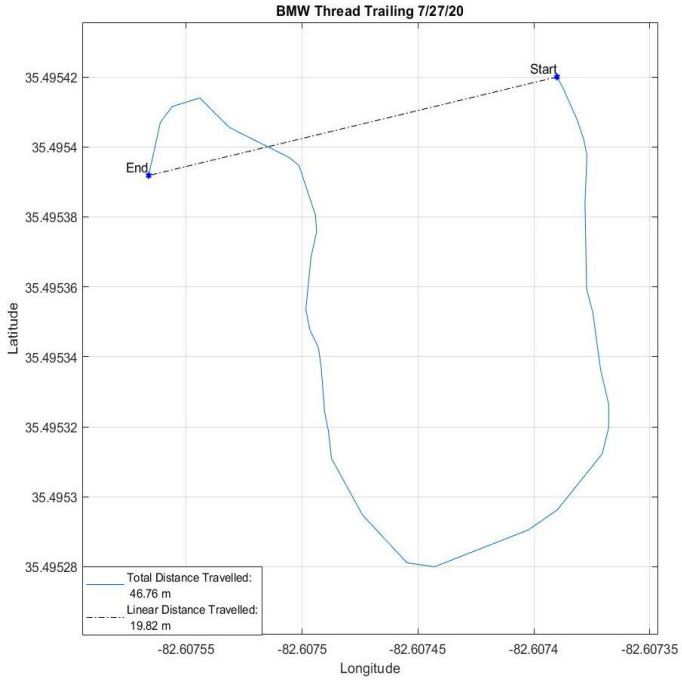

Figure 6. An example of turtle BMW's distance traveled during a 1-day sample of thread-trailing (July 27th).

BMW traveled a total distance of 46.76 m, which is significantly greater than the linear distance recorded at the GPS start and GPS endpoint. Furthermore, this figure demonstrates that BMW's movement is a meandering pattern instead of a direct route. On this same day, turtle BCM was also tracked, and the pattern varies (Figure 7).

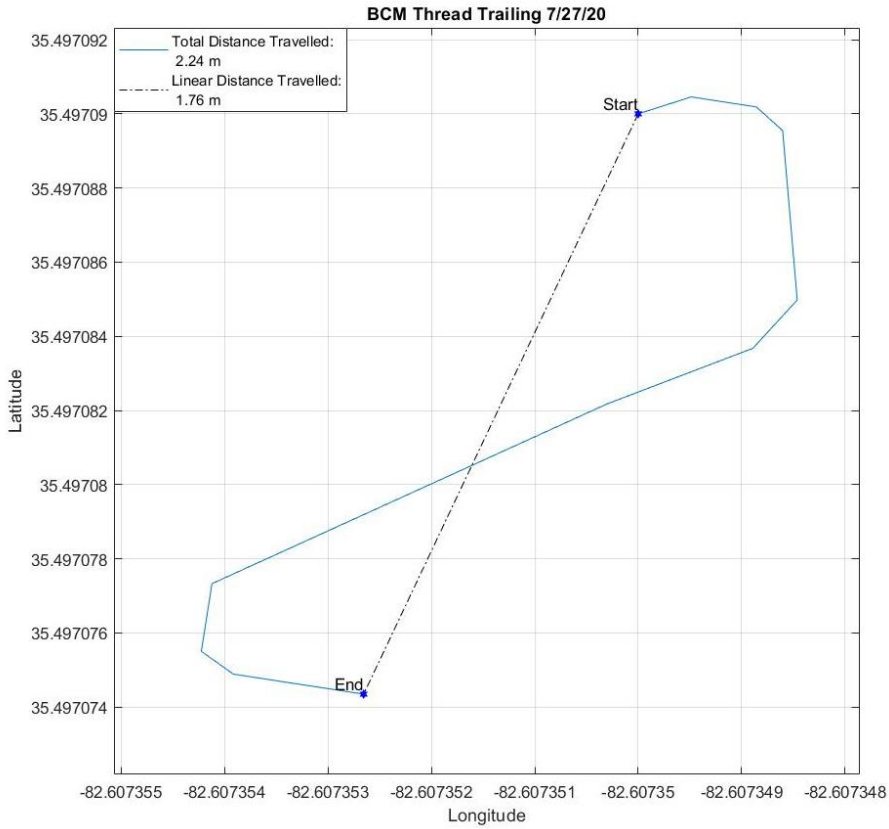

Figure 7. An example of the distance traveled by turtle BCM during a 1-day sample of thread-trailing (July 27th).

Turtle BCM and BMW were thread-trailed for the same amount of time, but turtle BCM only traveled 2.24 m. BCM was continuously the turtle that traveled the least during thread-trailing sampling. Though BCM did travel less than BMW, both turtles did indicate meandering; however, these patterns still are unique. Meandering is an animal behavior that is caused by disturbances. In this case, meandering occurred due to obstacles such as logs and collapsed animal burrows.

4. Discussion

My study found that box turtle movement patterns and habitat preferences are related to the turtle's home range[14]. Turtles in my study were observed to stay close to their homerange with a preference for particular habitats. MCPs (minimum convex polygons) averages of home ranges vary among studies. One study reported an average MCP size of 6.424 [14], which is larger than my study's results, an average of 4.285 ha. In other studies, homerange average MCP for eastern box turtles sizes was estimated at 0.38 ha in Tennessee, USA [17]. MCPs estimates for female turtles in New York, USA had an average of 2.0 ha and in the Piedmont of North Carolina found females had an MCP average of 1.30, and my results show that CJO had an MCP estimate of 1.994[18].

Habitats utilized throughout the study included mixed pine/hardwood forests, fields/meadows, hardwood forests, core gardens, and streams. Generalist species such as box turtles thrive in various habitats; however, my research and other studies show that individual turtles have variations in home ranges and habitat preferences. My findings found for the overall turtle population that meadows and fields were the most preferred habitats (see figure 2) rather than

habitat associations to hardwood-mixed forests[14]. However, turtle BMW who had the most extensive homerange preferred hardwood-mixed woods the most out of every turtle studied. Each turtle utilized a different habitat.

Thread-trailing data from this study support that straight-line distance does not account for total-distance traveled as studies such as Marchland's predicted [12]. Monitoring movement patterns with thread-trailing supports evidence showing that box turtles demonstrate movement patterns like meandering and direct routes [18]. On several occasions, while thread-trailing, I observed individuals that undertook large bouts of movements. Only once was mating observed; however, multiple encounters with turtles close to one another were observed.

Using thread-trailing to monitor plants' interactions was difficult because each turtle occupied a unique area. Creating a quadrant to calculate plant percentage cover was not feasible. Because plant percentages and plant diversity were not accounted for, the findings are merely speculation. The plant observations from my study demonstrated that recurring plants were present in each habitat. For example, R.multiflora and D.punctilobula were predominantly found, although this information could coincide instead of a preference. It is worth noting that several photos and observations show turtles such as IMO and CJO were hiding under D.punctilobula, which is a fern native to eastern North America. It should also be noted that R.multiflora is an invasive species, yet in other studies, box turtles have been shown to interact with this plant species often [13]. Overall, plant observations from this study support strong evidence from McKnight's study that box turtles prefer dense vegetation rather than sparse vegetation[13].

Research indicates that box turtles can persist in developed areas; however, they survive better in forested areas rather than urban areas due to road mortality[19]. For example, in Alabama, Dodd's study found that 85% of the turtle fatalities were due to automobile accidents[20]. Two turtles I researched, BMW and IMO, were discovered by volunteers after car accident injuries that damaged their shell. Even in rural, protected areas like the North Carolina Arboretum, turtles are susceptible to human-caused threats. The North Carolina Arboretum is a protected area that fosters an ideal habitat for its box turtle populations; however, in other North Carolina regions, habitat fragmentation is harming box turtle populations[21].

As urbanization continues to increase in North Carolina, the human-caused threats box turtles face will likely increase [22]. Due to projected deforestation rates, as risks increase, research suggests box turtle extirpation in North Carolina will continue to grow [23]. My study and past literature show that although box turtles are generalist species, habitat needs and spatial requirements vary based on the individual [21]. Each turtle's unique needs highlights the importance of conservation measures and the need for environmental education advocating for box turtles.

Environmental education is one of the leading ways to effective change behavior, it strives to teach "children and adults how to learn about and investigate their environment, and to make intelligent, informed decisions about how they can take care of it"[24]. Moving forward on box turtle conservation, there must be educational resources and educators that foster motivations and commitments to take responsible action [25]. To increase responsibility for the negative human behavior and care for nature, a driving force to motivate people into action is connection to the natural world[26].Therefore, promoting turtle citizen science will be a crucial way to confront the threats box turtles face, not only habitat loss, roadway accidents but also the pet trade that is damaging box turtle populations. Over-collection for the pet trade is a serious threat to box turtles, and the laws prohibiting this behavior can be difficult to regulate, because turtles are not federally protected[1]. In my educational video about studying box turtles, I addressed this issue and why it is so damaging to box turtle populations. Furthermore, I also elaborated that turtles have a very small home and if removed from it, they will spend the rest of their lives trying to return home[1]. In the future, this will continue to be important information to relay to young children and adults. My research supports the importance of environmental education and highlights how my maps and visuals produced could continue to help the program and also help others, particularly young children, understand complex ideas.

5. Conclusion

Reviews of past literature and my results from this study indicate that spatial movements and habitat preferences vary based on the individual box turtle needs[14]. This variation of behavior and preferences strengthens the importance of conservation efforts for the eastern box turtle. For this species to thrive, habitat variety is essential. Long-term studies that incorporate larger sample sizes will be necessary to understand further the box turtle population's movement patterns and habitat preferences that live in the North Carolina Arboretum[19].

Yet, further studies are needed for habitat preferences since I could only track a small number of turtles. Since the North Carolina Arboretum began its box turtle research, 102 turtles have been documented and identified using a 3 letter notch system on the carapace. During the study, the transmitter on the turtle KOW died, and I could not relocate

him. I also discovered the other turtles, MOX, CMP, and AOW. Unfortunately, there are no more transmitters available, and because of the high costs of the transmitters, only five turtles can be tracked at a time.

More access to transmitters to be able to study a larger population is crucial moving forward. There is potential for the GPS logger and radio telemetry transmitter to be one device that would be inexpensive; however, this would require further development. The cost of GPS logger technology is affordable, with an estimated price of 40 dollars. Initially, the GPS logger device was meant to determine movement patterns, as thread-trailing does. However, the GPS logger device was not as reliable. It did not consistently publish timestamps within 10 minutes like it was programmed to do. I could not use the information in the way I had hoped. However, it still contributed to data needed to establish a home range and learn more about habitat preferences. A more accurate count of all turtles would be significant for future studies to understand box turtle populations' trends at the North Carolina Arboretum. The GPS logger would also be an excellent tool for the citizen science program to continue to use because it can attach easily to the carapace and tracks GPS information for up to 24 hours.

Although the original concept for this research changed due to Covid-19, this study is an excellent framework for the North Carolina Arboretum and EcoExplore to use for educational purposes. Thread-trailing exercises along with home range exercises can help children and adults see how box turtles navigate through their habitats. In the future, online educational resources about home ranges and turtle spatial movement like videos and access to graphs could provide educational material to a larger audience in North Carolina and the east coast that would allow children to engage not only at the Arboretum but in their own communities. Promoting conservation through better understanding box turtles is a great way to empower children to be lifelong environmental stewards. Box turtles play important ecological roles in their habitats and are a wonderful animal that children can easily connect to.

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