Life History Traits and Spatial Ecology of the Striped Mud Turtle, *Kinosternon baurii*, in Central Florida

Leyna R. Stemle
Department of Biology
Dr. Gabriel Langford
Florida Southern College

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Abstract

The roles that turtles and tortoises (Testudines) play in their environments make them vital to protect, conserve, and study for the continued health of our world. In recent literature, the Striped Mud Turtle (*Kinosternon baurii*) has been studied only a minute amount in Florida. Radio telemetry was used at Circle B Bar Reserve (CBR) on nine *K. baurii*, and long-term mark and recapture and life history data was collected that was essential for determining the size of this population. It was hypothesized that these mud turtles do not have a large home range, and that their overall health would be excellent due to the general lack of anthropogenic factors in their environment on the reserve. Our data indicates that these mud turtles have a fairly small home range (1,111.2-14,395.5 m^2) with some males and gravid females generally having a larger area that they frequent. The health of the turtles was generally very good, as our marked turtles had clear eyes, energetic movements, and sturdy bodies. The population in the main area in which we set traps appeared to be fairly small (estimated at 38 adult individuals with the software program MARK), and we recaptured many of the same turtles. However, we did catch unmarked turtles occasionally and the age of the turtles in the reserve was varied, as multiple age classes were found. The sex ratio of the main canal in the reserve was female skewed (65.4 % females, p-value= .26). The data that was collected has helped Circle B Bar Reserve (CBR) understand more about their mud turtle population and expand their knowledge of the wildlife they protect. With unexpected low numbers and a female-biased sex ratio, the future of *K. baurii* must be carefully monitored, especially with the continued rise of urbanization and a warmer climate. If a small population is continually found, management practices may become a key component in conserving mud turtles. With more knowledge on their ecology, population size

and movements, Circle B and other reserves/parks can better accommodate these turtles for the maximum protection from anthropogenic effects in the future.

Introduction

The Importance of Conservation Biology and Basic Ecology

A primary goal of conservation biology is to establish baseline data about species in order to conserve biodiversity and thus ecosystem stability. Indeed, biodiversity is central to the field of conservation biology, which measures diversity from genes to species to ecosystems (Pough et al., 2004). Diverse systems are resilient and required for natural ecosystem function (Thomson et al., 2004). Yet, without knowledge of a species' life history traits it is impossible to understand their role in an ecosystem. For many turtle species, we do not have adequate background data to be able to formulate conservation and management plans (Ernst, Lovich, & Barbour, 1994). This knowledge gap must be filled for understudied turtles, primarily because of the concerning population declines in recent years amongst once common turtle species. This decline is a well-documented global decline of both turtles and other reptiles, as well as amphibians (Gibbons et al., 2000; Christiansen et al., 2012). If this downward trend continues, all turtle species in the US and Canada will be threatened with possibility of extinction within the 21st century (Ernst, Lovich, & Barbour, 1994). Thus, it should be a top priority to understand how turtles use natural, relatively undisturbed habitats prior to population declines, which provides us with the best conservation tools if a species is threatened (Harden et al., 2009).

Turtles as Umbrella and Indicator Species

Furthermore, by conserving turtles and their habitats, we also protect the flora and fauna that reside in these ecosystems. By protecting the environments of one animal, it can provide shelter for many more organisms; this can be described by the term “umbrella species.” Turtles serve as optimal umbrella species for a wide variety of other taxa of conservation concern because they are very tied to their landscapes (American Turtle Observatory, 2017). Likewise, turtles are frequently used as indicator species in conservation programs because they are long-lived, inhabit both aquatic and terrestrial habitats, transfer energy between habitats, and are susceptible to anthropogenic effects (Dunson, 1992; Butler et al, 2016; Gibbons et al., 2000; Harden et al., 2009; Burke and Gibbons, 1995). Vital energy can be transferred by turtle deposition of eggs while nesting, or by their bodies being eaten by predators during their time on land (Gibbons, 1990). Additionally, presence of pesticides in turtles can be a sign of habitat breakdown (Ernst, Lovich, & Barbour, 1994). Turtles are of both ecological and economical importance.

Human Importance of Turtles

Moreover, turtles may be of considerable importance to humans in various different economical aspects. In many countries, they are still an important source of meat. Additionally, humans spend millions of dollars each year on turtles within the pet trade. On a negative note for human wellness, many common species of turtles transmit the bacteria *Salmonella* to people (Ernst, Lovich, & Barbour, 1994). Overall, the economic, cultural, and scientific value of turtles all make them a valuable part of our world’s ecosystems.

The Decline of Turtles

As mentioned, turtle populations are declining at an alarming rate. This is mainly because of 1) habitat destruction and 2) the pet trade/foreign food market. Forests have been cut and marshes/wetlands drained for the addition of farmland, construction of roads/highways, housing, shops, etc. Without a habitat, turtles are decimated. Even though it is not the main cause of decline, habitat degradation is also a major threat to turtle populations and health (Ernst, Lovich, & Barbour, 1994). Furthermore, the pet trade and collection for consumption have over exploited many turtle species. Most individuals collected are adults. With the removal of adults, turtle numbers are sure to plummet because their slow maturation and reproduction rates do not allow them to recover. Without knowledge of turtle biology, we are unable to formulate a complete conservation plan (Ernst, Lovich, & Barbour, 1994). Therefore, we may lose many turtle species before getting to understand their basic biology.

Mud Turtles

The family Kinosternidae, mud and musk turtles, is a relatively unknown family (Wilson, Mushinsky, & McCoy, 1999). It includes four extant genera and 26 species that range from Canada to Argentina (van Dijk et al., 2014). *Kinosternon* (mud turtles) is the most specious genus in the family with 18 described species (Meylan, 2006). The highest diversity of mud turtles is found in the Southern US and Mexico (van Dijk et al., 2014). Mud turtles are small to medium-sized, mostly, freshwater turtles (Ernst, Lovich, & Barbour, 1994). The major threat to members *Kinosternon* in Florida is the loss of suitable habitat because they require wetlands surrounded by uplands. The *Kinosternon* present in Florida are great examples displaying how uplands adjacent to wetlands must be conserved to protect certain species (Burke and Gibbons, 1995). If both the wetland and uplands are not sheltered, their population would not be able to sustain itself. Upland is needed for females to lay the eggs, and wetland is needed for them to feed and reside. When nesting, females often move a great deal from their normal residence

(Wilson, Mushinsky, & McCoy, 1999). There are three Kinosternidae species present in Florida (Ernst, Lovich, & Barbour, 1994).

The Striped Mud Turtle, *Kinosternon baurii,* is a small semi-aquatic turtle that resides along the Atlantic Coastal Plain of the US from Virginia to the Florida Keys (Ernst, Lovich, & Barbour, 1994). *Kinosternon baurii* spends a significant time on land when aquatic conditions are not suitable (Wygoda, 1979; Dunson, 1992). Wygoda (1979) found that *K. baurii* in West-central Florida prefer shallow, still water and may aestivate, a form of temporary dormancy, during the summer. Contrastingly, Ernst et al. (1972), in South Florida, found they preferred deep, flowing, water and do not aestivate. Habitat requirements for hatchlings and juveniles are unknown (Wilson et al., 2006). Many aquatic turtles inhabit areas that have seasonally dependent water levels (Ligon & Stone, 2003; Wygoda, 1979). When subject to shallower or absent water turtles can migrate to permanent bodies of water, congregate in the water that is left, or aestivate (Ligon & Stone, 2003). In southern latitudes, it is documented that *K. baurii* may compensate for their relatively small clutches by extending their nesting seasons to have a peak season in the fall with a debated smaller one in June (Wilson, Mushinsky, & McCoy, 1999; Mushinsky & Wilson, 1992). Our study strives to determine if the favored habitat and aestivation tendencies by *K. baurii* resemble that of the Hillsborough Watershed, Big Cypress Swamp, or neither. Additionally, the family Kinosternidae, like most turtle families, has Temperature-dependent Sex Determination (TSD) which adds interest to their timing of nesting and nesting habits because it could possibly influence sex ratios (Vogt, Bull, McCoy, & Houseal, 1982). In *K. baurii*, sexual dimorphism is present, with females being larger (Wilson, Mushinsky, & McCoy, 1999).

A study on the Yellow Mud Turtle, *Kinosternon flavescens*, in the Midwestern US, reports drastic declines in their populations in recent years, from 519 individuals in 1988 to 2 in

2009 (Christiansen et al., 2012)**.** This brings concern for the numbers and stability of mud turtle populations elsewhere, especially since numbers in central Florida do not appear to have been surveyed since Karl & Wilson, 2001. Wilson *et al.* 2006 stated that no data currently exist on *K. baurii* survivorship within a population and that more detailed research must be done on their population biology to better understand Striped Mud Turtle habits. Conservation initiatives and areas should be put in place to protect these Kinosternidae because we do not have a proper estimate of their numbers in Florida.

Urbanization and Conservation

Additionally, urbanized areas where turtles still live in small numbers, such as golf courses and parks, can be critical for survival of turtles when natural unsegmented habitats are dwindling. These systems can be ideal for studying turtles in urban environments (Harden et al., 2009). This can be related to restored areas/parks and their importance since urbanization is ever increasing and threating habitat. Since mud turtles use both aquatic and terrestrial habitats, they can serve as a model for other turtles; therefore, they can help generate recommendations on terrestrial habitat preservation in human altered environments (Harden et al., 2009). The learned habits and knowledge gained from such studies can be used for conservation oriented management practices.

Vulnerability of Turtles

Traits of semi-aquatic turtles**,** such as delayed sexual maturity, make them vulnerable to the direct and indirect influences of human (anthropogenic) developments. Since they have delayed sexual maturity, it is hard to have a stable population when members are not sexually mature until very late in their lives. With the ability to mate limited to individuals who have survived many years, turtles become susceptible to human disturbances and are not able to rebound quickly (Marchand and Litvaitis, 2004). Furthermore, the presence of roads/highways near to aquatic habitats is a threat to many species of reptiles (Wilson *et al.,* 2006).

Our study site is a restored cattle ranch that includes wetland and upland habitats; this site may be an important mud turtle habitat in the fragmented area of central Florida. The reserve has many trails and roads that the turtles must cross over occasionally. Moreover, upland habitats are critical for many semi-aquatic turtles because they provide area for nesting and aestivating (Wilson, Mushinsky, & McCoy, 1999). Overall, we did not find any studies on *K. baurii* in an anthropogenically modified area; therefore, our study was implemented to learn about these turtles in a restored habitat and to survey their numbers here.

Importance of the Home Range

Another important aspect of an animal's role in its environment is the general area in which it spends its time, otherwise known as its home range. Many studies determine home range through the use of telemetry (Wygoda, 1979). Although it's considered a mostly aquatic turtle, *K. baurii* spends a large amount of time on land when aquatic conditions are not proper (Wygoda, 1979; Dunson, 1992). The habitat at the study site provides unique insight into movement of mud turtles' in a restored habitat. Furthermore, estimating the home range size of an animal provides insights about its reproductive biology and its habitat preferences (Powell, 2000). In addition, the movement of individuals is implicitly intertwined with the population's genetic structure (Manel et al., 2003). Determining the home range of an organism gives insight into its ecology and life history traits.

Summary of Project Importance

In spite of its wide distribution in the US, the Striped Mud Turtle's home range size and many life history traits have not been well-documented; therefore, this study strived to examine the spatial ecology of this population of *K. baurii* in central Florida. We expect this information, as well as gathered life history data, will contribute to the better understanding of movement and life history traits in this species and provide insight for future conservation management and restoration plans.

Methods

Study Site

This study occurred at Circle B Bar Reserve, a restored former cattle ranch adjacent to Lake Hancock, Polk County, Florida, along the canals of known mud turtle habitat (Figure 1). The Reserve started restoration in 2004, where it was flooded to restore the hydrology, and restoration was completed in 2006. Since the initial restoration, native plants have been added and invasive plants are (continuously) removed; also, prescribed fire has been used as a management tool. However, after its initial disturbance of building a dike in the 1930s, the main study site – Alligator Alley – is thought to have been relatively untouched by the effects of the cattle ranch. The reserve consisted of 1,267 acers, of permanent marsh, semi-permanent wetlands, as well as upland habitat. Upland habitat was approximately 2 kilometers from the studied wetlands.

Representative tree species in the area sampled (along Alligator Alley) were Bald Cypress (*Taxodium districhum*), Cabbage palm (*Sabal palmetto*), Live Oak (*Quercus virginiana*), Pond

Cypress (*Taxodium ascendens*), Hackberry (*Celtis laevigata*), Red Mulberry (*Morus rubra*), Ash (*Fraxius spp.)* and Slippery Elm (*Ulmus rubra*). Dominant ground cover was Basket Grass (*Bidens alba*), Torpedo Grass (*Panicum repens*), *Sambucus spp.*, *Oplismenus spp.*, Posion Ivy (*Toxicodendron radicans*), Poke Weed (*Phytolacca decondra*) and Virginia Creeper (*Parthenocissus quinquefolia*). Dominant aquatic vegetation included Fire-flag (*Thalia geniculate*), Duckweed (*Lemna spp.*), Pig Weed (*Amaranthus spp*.), Pickerelweed (*Pantederia cordata*), and Wild Taro (*Colocasia esculenta*). Most of the species present were native plants, with a few invasive plants in the area. Areas of the marsh and wetlands dry up in some years during the dry season (October – May), but frequently flood June - September.

Turtle Sampling

This project included a 2 year sampling period with a mark-recapture and tracking study on *Kinosternon baurii*. Traps were constructed and placed, approximately 8-31 at a time. For the first 6 months, traps were placed in multiple locations before it was decided to focus only on Alligator Alley (See Figure 1). Traps were mesh wire modified box-like minnow traps and had a ramp for turtles to walk up, dimensions 39 cm x 36 cm x 29 cm (similar to Karl & Wilson, 2001). Various traps were tested in the area to try and ensure maximum capture rates; the modified Karl & Wilson (2001) worked the best. For similar studies, hoop traps have been used (Ligon & Stone, 2003; Harden et al., 2009; Van Loben Sels et al., 1997; Ceballos et al., 2016); however, they were not seen as a viable option at CBR due to the abundant alligator population (see http://abcnews.go.com/US/video-captures-massive-alligator-nature-preserve-central-florida/story?id=44813600). It was not feasible to use big hoop traps due to the large wildlife present in the reserve; therefore, smaller traps were used to only catch the small target species when they walk up a ramp and then get trapped in the box. Traps were in place a majority of the time between October 2015 – September 2017, except during flooding events (Hurricane Matthew, Hurricane Irma, Tropical Storms, etc.) and also most of December 2016. Traps were baited with sardines and/or bologna 1-2 times per week. Traps were checked 2-4 times per week, dependent on turtle activity (less in winter), being checked an average of 3 times a week for most of the time they were out. All turtles, besides 2 hatchlings, were assigned a number that correlated with marginal scutes.

Scutes were notched using a triangular file according to the numbering system standard for Florida Fish and Wildlife Conservation Commission protocol of notching gopher tortoises (Figures 1 and 2; FWC, 2013). In addition, morphometrics were taken upon capture/recapture that include carapace (top shell) length (CL), width, and height as well as plastron (bottom shell; segmented into plastron 1, 2 and 3) to the closet mm. A weight of the turtle was obtained in grams with a Pesola scale. General notes on health (including presence of leeches) and physical injuries were recorded. Gender was determined for adult turtles by using claw length, shell shape, and tail length (Ernst, Lovich, & Barbour, 1994). If the turtle was a female, she was palpated for eggs by sticking pinky fingers into the sides of the shell while the turtle was held vertically. Water temperature was recorded every other day during summer 2017 using an infrared temperature gun.

Radio Telemetry

Once trapped, certain individuals were tagged with ATS radio telemetry tags (3.5 g, Figure 3). Tags were only 3.5 g. This was so that it did not disrupt the turtle by being more than

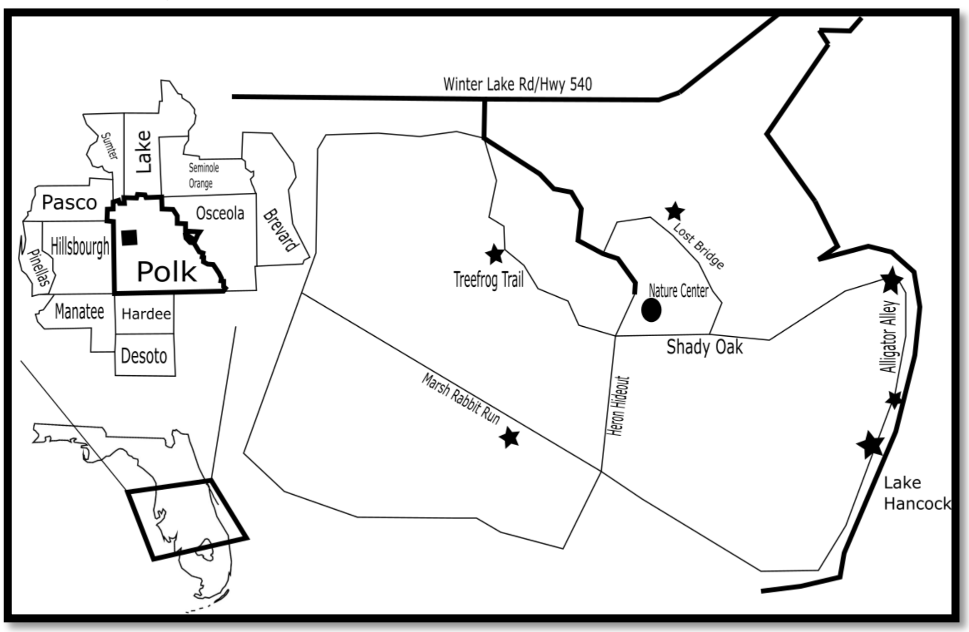
5 % of their body weight, as the turtles were an average of around 100 g. These tags were attached with marine epoxy (Loctite® Marine 2 hour Epoxy) to the carapace, near the head of the turtle on the right side of the carapace, with the whip facing backwards and up. Turtles were kept for no more than three days during the tagging/untagging process in order to not stress them out too much. Nine turtles were tagged with 1 turtle having her first tag replaced when the tag stopped working, for a total of 10 tags. The first turtle was tagged on September 2nd, 2016 and the last turtle was tagged on June 23rd, 2017. The nine turtles were tracked 1-3 times every week (less during winter months when movement was minimal) and a GPS point was taken. When visual confirmation of a turtle's location was not feasible, the receiver was used to triangulate a bearing and approximation of the location. This approximation of location was done by using the geofunction version of Excel and the NewPostLat/NewPostLong equation. Tracking continued until the end of the battery life, approximately 260 days, or until there was no signal found. When no signal was found, the signal was checked in multiple locations every 1-3 weeks to make sure the signal did not reappear.

Analysis

The GPS points were put into ArcGIS Explorer version 10.1 (ESRI) in order to view the movements and home ranges of each turtle. Home range was estimated by using the polygon and area feature to ensure a fairly confident estimate of their normal range. Straight-Line Distance (SLD) was also measured to show the greatest distance between two found GPS locations within the home range (Figure 5). A Mann-Whitney test was done on the average of male vs. female home range size and average male and gravid female vs. non-gravid female home range size.

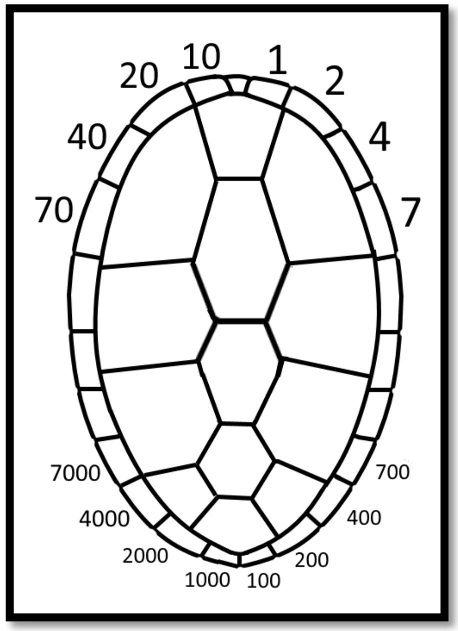
Turtle carapace vs. weight was graphed for both male and female turtles in Excel. Also, a 2-sample T-test was done on CL of males vs. females. Additionally, a regression was made for days tracked vs. home range area. MiniTab -18 and Excel were used for statistical analyses. The sex ratio of adult turtles in the same habitat was found and a Chi-Square was used to see if the difference in ratio was significant from 1:1. Also, the number of trap hours was calculated for month (and in total) to compare the amount of turtles caught vs. amount of trap effort. Lastly, the software program MARK was used with a Cormack-Jolly-Seber (CJS) model to determine survivorship and find an estimated population size for the Alligator Alley population.

Figure 1. Map of Study Site



This is a map of Circle B Bar Reserve, its trails, our trapping locations, and the location of the Reserve in relation to the state of Florida and Florida Counties.

Figure 2. Notching Pattern Used



Notching system used on turtle carapace.

Figure 3. Trap Used to Capture Mud Turtles

Examples of our modified box traps used to catch *K. baurii*.

Figure 4. Radio Tracker Being Used Along Alligator Alley

VHF tracker being used along the main canal.

Figure 5. Example SLD for Turtle Frequency 191 on ArcGIS

Frequency 191 home range polygon (red), orange points are each GPS point, and yellow line is maximum straight line distance.

Results

Along Alligator Alley, there were 9 individual adult males caught to 17 individual adult females caught (9:17, 65.4% female). This ratio is considered female-biased but it is not different than the normal ratio of 1:1 (X^2 = 1.26, p-value =.26). For the captures in the rest of the reserve, excluding Alligator Alley, the sex ratio was male-biased 1:5, but it isn't a big enough population to do a Chi-Square. Alligator Alley females had a mean carapace length of 93.62 mm (max of 112.414 mm) and mean weight of 156.89 grams (max of 272 g). Males had a mean CL of 82.81 mm (max of 96 mm) and mean weight of 106.89 grams (max of 180 g; Figure 30). Carapace length was plotted against weight for both males and females (Figure 31 and 32). For females, the equation found was y = 4.9226x - 304.64 with R^2 = 0.9336 (n =30; Figure 32). Male turtles had the equation y = 2.0157x - 64.119 with R^2 = 0.6685 (n=10; Figure 31). For testing if male vs. female CL was different, the p-value was .006.

Within Alligator Alley, 32 total individual turtles were caught and the adult population was estimated around 38 adults with the software program MARK. Including Alligator Alley, 38 individual turtles were found and notched across the whole reserve. There was a total of 58 captures when recaptures are considered (52 captures being Alligator Alley). Two hatchlings and 3 juveniles were caught along Alligator Alley.

Trapping effort in the main canal at Alligator Alley averaged about 136,752 total trap hours over the two year span (Figure 15). In Alligator Alley, the highest number of turtles was found in spring 2017 (14) and the highest amount of turtles caught per trap hours was found in winter 2016-17 (1,344 hours per turtle).

Nine home ranges were found for the 9 tagged turtles using GIS (Figure 4). The largest home range found was 14,395.5 m^2 (male turtle frequency 110) and smallest was 1,111.2 m^2 (male turtle frequency 310). The largest straight line distance (SLD) was 283.1 m (male turtle frequency110) and smallest was 66.6 m (female turtle frequency 191). Turtles were tracked between 66 and 369 days with an average of 174 days (Figure 16). Mean home range did not vary significantly due to sex (p-value > .05). Additionally, mean home range did not vary significantly due to females vs. gravid females and males (p-value= .540). A male, 110, and a gravid female, 209, had the largest home ranges. Females had an average home range of 4,507.8 m^2 and males had an average home range of 7,753.4 m^2. A graph of the relationship between number of days tracked vs. home range area was made to make sure the sporadic number of days tracked was not influencing home range size. The equation was $y = 0.0043x + 149.7$ and the $R^2 = 0.0315$ (Figure 33).

During summer 2017, water temperature was taken in the middle of Alligator Alley every 2-3 days and the equation was $y = 0.0271x - 1137.7$ and $R^2 = 0.2084$ (Figure 29). Number of movements by tracked turtles was also compared across the same time frame (Figure 35). The equation of the line was $y = 0.0161x - 690.33$ and $R^2 = 0.2158$. These graphs were paired showing if there was any relationship between water temperatures and if turtles moved from one period of tracking to the next (Figure 36).

Figure 6. Typical Female *K. baurii* Plastron (left) and Carapace (right)

These are pictures of two different adult turtles and good examples of female key characteristics: larger size, flat plastron, and small tails.

Figure 7. Typical Male Carapace

This is a picture of an adult turtle and a good example of key male characteristics: concave plastron, smaller size, large tail, and long claws.

Figure 8. Interesting Pattern Found on Adult Female Carapace

This is a picture of an adult carapace with strange coloration.

Figure 9. Interesting Ridge Marks Noticed on Front Legs of All Adults

This is a picture of a typical adult with two ridges on the front legs that were noticed on every turtle.

Figure 10. Swollen Eye of Female Turtle Frequency 131

This is a picture of an adult turtle with a swollen eye.

Figure 11. Common Turtle Leech

This is a picture of a typical leech found on *K. baurii*.

Figure 12. Radio Tag on Female Turtle Frequency 209

This is a picture of a tag, frequency 209, on female turtle notch 20.

Figure 13. Marks on Female Turtle Notch 31

This is a picture of an adult with scratch marks along the sides, from possible predator attack.

Figure 14. Curious Holes on Female Turtle Frequency 191 Carapace (before tagging)

This is a picture of an adult carapace with strange pits/bite marks.

Figure 15. Turtles per Trap Hours in Alligator Alley

Season	Trapping Effort (hrs)	Turtles Caught	Trap Hours per Turtle
Winter 2015-16	19,224	7	2,746
Spring 2016	12,240	3	4,080
Summer 2016	25,200	0	n/a
Fall 2016	19,944	9	2,216
Winter 2016-17	13,440	10	1,344
Spring 2017	23,472	14	1,677
Summer 2017	20,352	8	2,544
Fall 2017	2,880	1	2,880
Total	136,752	52	2,629

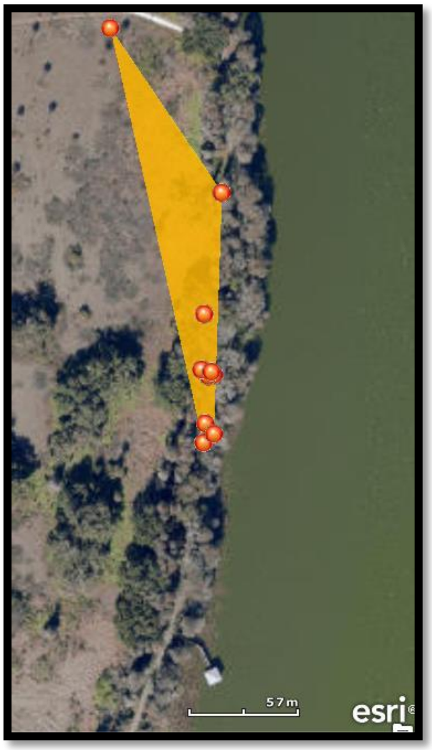
This table separates each trapping season by showing the hours that traps were out (trapping effort). It was found by multiplying the number of traps placed at each time period by the hours each trap was out. Turtles caught in the traps were then added and trapping effort was divided by turtles caught to give trap hours per turtle in each season.

Figure 16. Home ranges and Maximum Straight Line Distance for Tracked Turtles

Turtle ID (Frequency)	Sex	Home Range Area (m^2)	Straight Line Distance (SLD)	Days tracked
209	Female (gravid)	9,199.7	247.3	369
171, 151	Female	5,791.0	153.5	245 (period of time with dead tracker on not counted)
310	Male	1,111.2	169.9	230
131	Female (gravid)	5,183.9	175.3	120
110	Male	14,395.5	283.1	152
250	Female	3,146.4	88.1	203
228	Female	2,083.0	122.6	110
290	Female	4,434.5	217.6	66
191	Female	5,716.1	66.6	72

This table shows the nine tracked turtles' frequencies, sex, home range, max straight line distance, and number of days each turtle had a radio tracker. Turtle 171/151 was tracked, her tracker died, she was recaptured and her tag was replaced with frequency 151 and she was continuously tracked until Hurricane Irma (she was found after the reserve was reopened but data not included in home range).

Figure 17. Home Range Polygon of Turtle 290 from 3/28/17 to 5/29/17

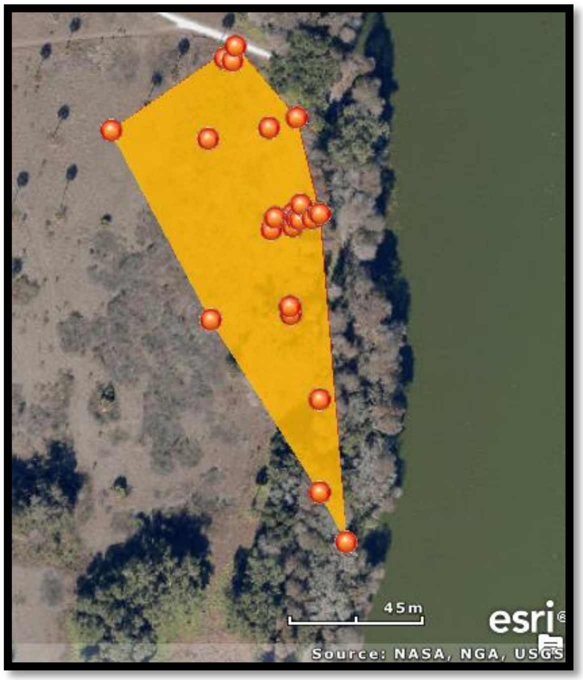


Home range for female turtle 290 during her tracking period from March 2017 to May 2017. Orange dots represent each individual GPS point found.

Figure 18. Home Range Polygon of Turtle 131 from 09/25/16 to 1/15/17

Home range for gravid/nesting female turtle 131 during her tracking period from September 2016 to January 2017. Orange dots represent each individual GPS point found.

Figure 19. Home Range Polygon of Turtle 310 from 09/25/16 to 6/1/17

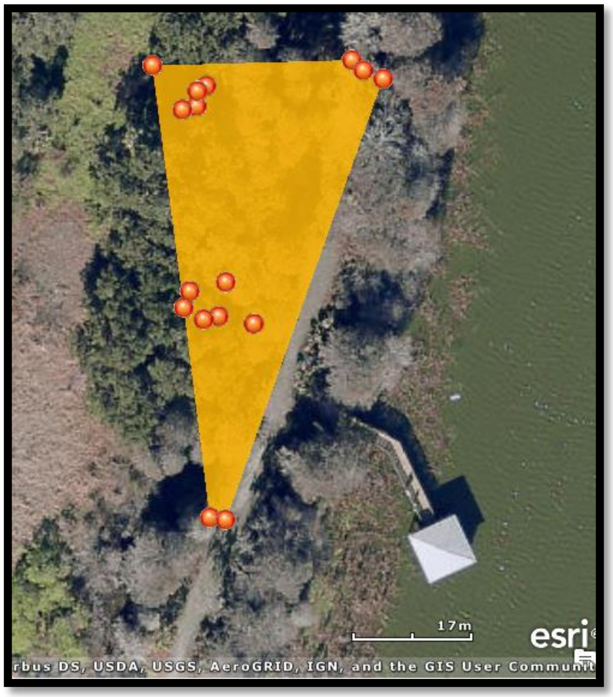


Home range for male turtle 310 during his tracking period from September 2016 to June 2017. Orange dots represent each individual GPS point found.

Figure 20. Home Range Polygon of Turtle 110 from 09/28/16 to 4/15/17

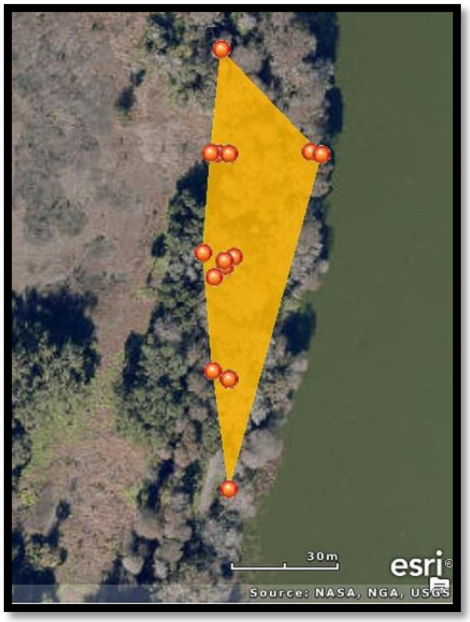
Home range for male turtle 110 during his tracking period from September 2016 to April 2017. Orange dots represent each individual GPS point found.

Figure 21. Home Range Polygon of Turtle 191 from 6/23/17 to 9/12/17



Home range for female turtle 191 during her tracking period from June 2017 to Sepetmber 2017. She was not found after Hurricane Irma. Orange dots represent each individual GPS point found.

Figure 22. Home Range Polygon of Turtle 228 from 2/1/17 to 6/1/17

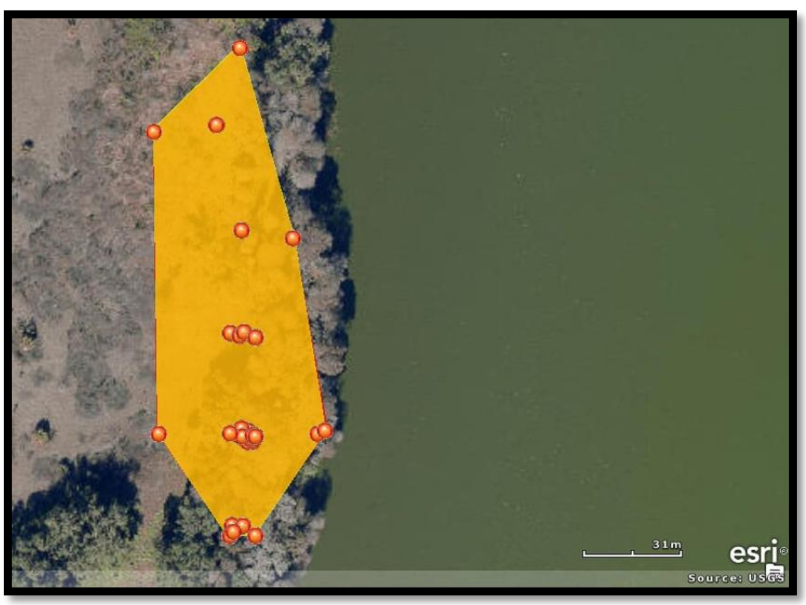


Home range for female turtle 228 during her tracking period from Febuary 2017 to June 2017. Orange dots represent each individual GPS point found.

Figure 23. Home Range Polygon of Turtle 250 from 11/19/16 to 6/12/17

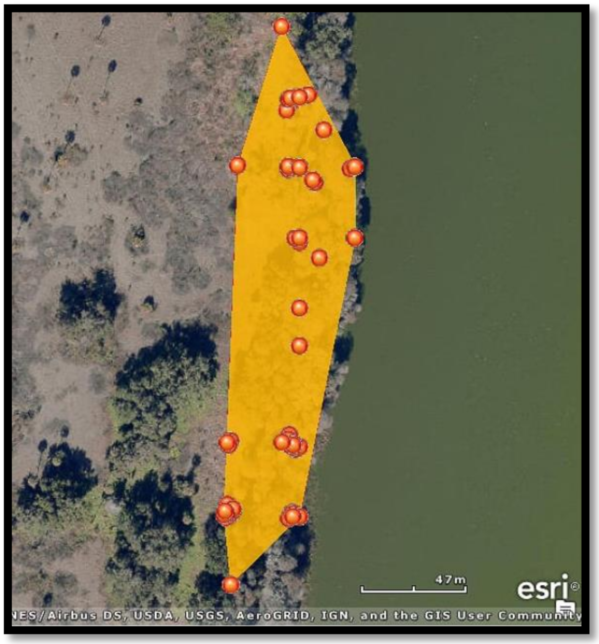
Home range for female turtle 250 during her tracking period from November 2016 to June 2017. Orange dots represent each individual GPS point found.

Figure 24. Home Range Polygon of Turtle 171/151 from 09/23/16 to 9/12/17



Home range for female turtle 171/151 during her tracking period from September 2016 to September 2017. She was found after Hurricane Irma, but tracking data is not included in home range map. Orange dots represent each individual GPS point found.

Figure 25. Home Range Polygon of Turtle 209 from 09/02/16 to 9/12/17



Home range for gravid female turtle 209 during her tracking period from September 2016 to September 2017. She was found after Hurricane Irma, but tracking data is not included in home range map. Orange dots represent each individual GPS point found.

Figure 26. Home Range Polygons of the Two Males Turtles (310 and 110)

Home ranges of the two tracked male turtles were put on the same map to see overlap and differences.

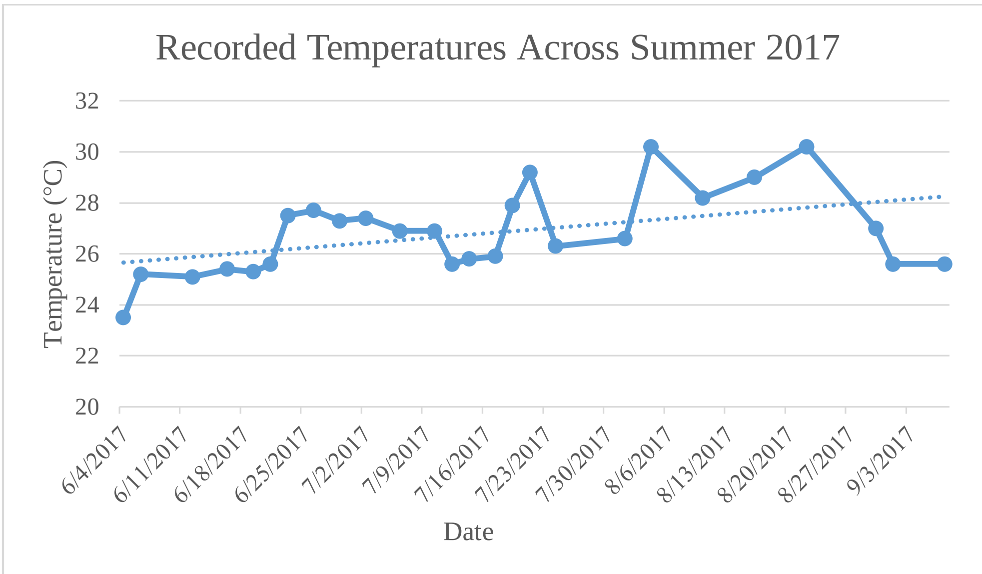
Figure 27. Home Range Polygons of the Female Turtles (209,228,250,290,191,131,171/151)

Home ranges of the tracked female turtles were put on the same map to see overlap and differences.

Figure 28. Home Range Polygons of all Nine Turtles

Home ranges of all the tracked turtles were put on the same map to see overlap and differences.

Figure 29. Recorded Temperatures of Alligator Alley Water in Summer 2017



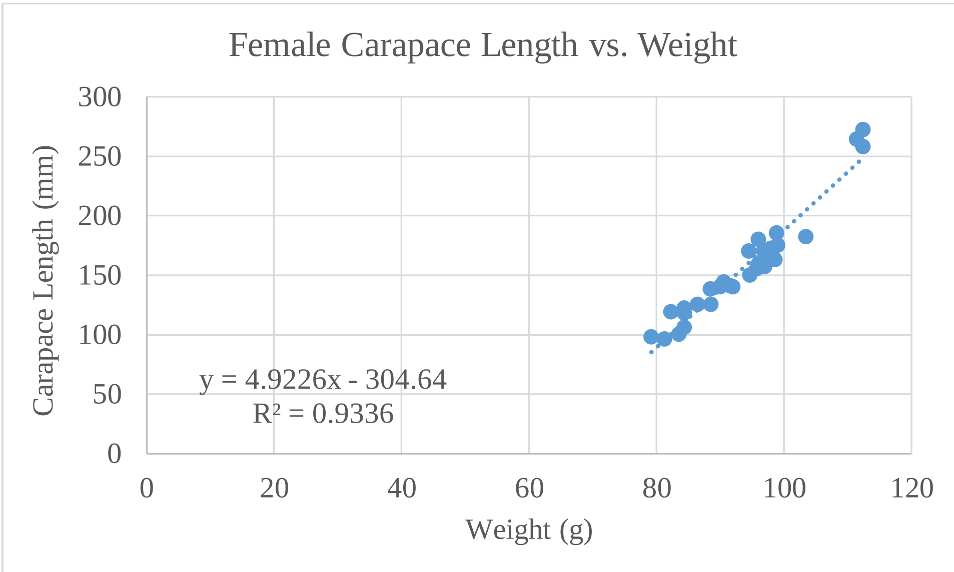
Water temperature was taken over summer 2017 every few days to be able to compare it to movement.

Figure 30. Life History Traits

Location	Sex	Individuals	Weight Range (g)	Carapace Length Range (mm)	Weight Average (g)	Carapace Length Average (mm)
Alligator Alley	F	17	96-270	79.19-112.41	156.89	93.62
Alligator Alley	M	9	70-122	64.54-96	106.89	82.81
Rest of Reserve	F	5	110-235	87.44-113.44	160.8	98.05
Rest of Reserve	M	1	N/A	N/A	98	84.32

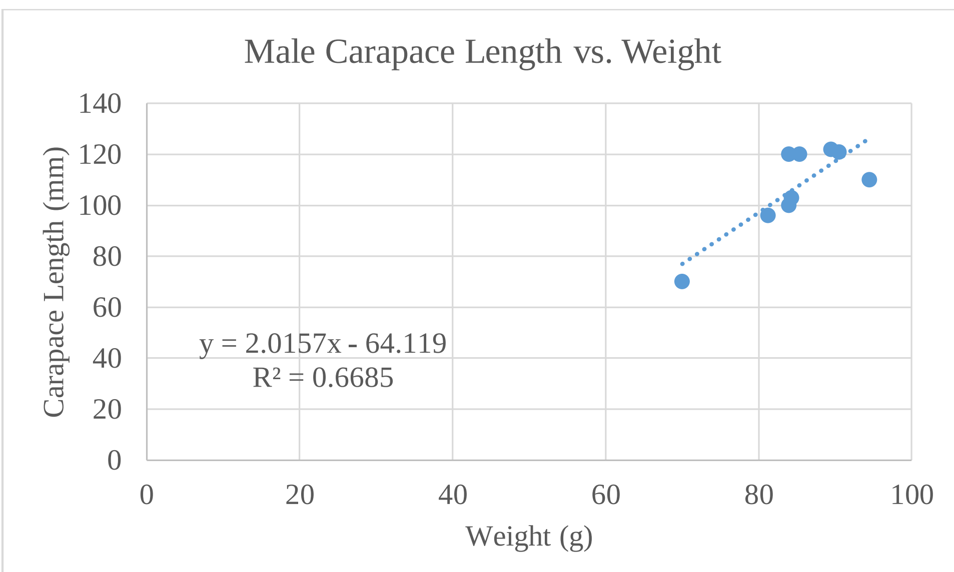
Life history traits were listed for Male vs Female and Alligator Alley vs. Non-Alligator Alley to compare any differences.

Figure 31. Female Alligator Alley Turtle Carapace Length vs. Weight



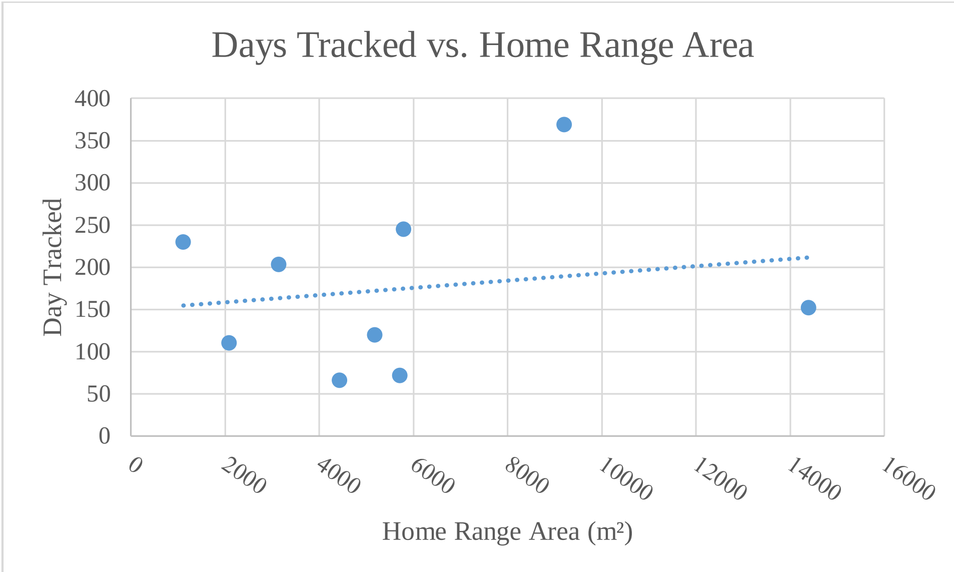
The CL of females from Alligator Alley vs. weight was plotted for each capture/recapture.

Figure 32. Male Alligator Alley Turtle Carapace Length vs. Weight



CL of males from Alligator Alley vs. weight was plotted for each capture/recapture.

Figure 33. Days a Turtle Was Tracked vs. Home Range Size

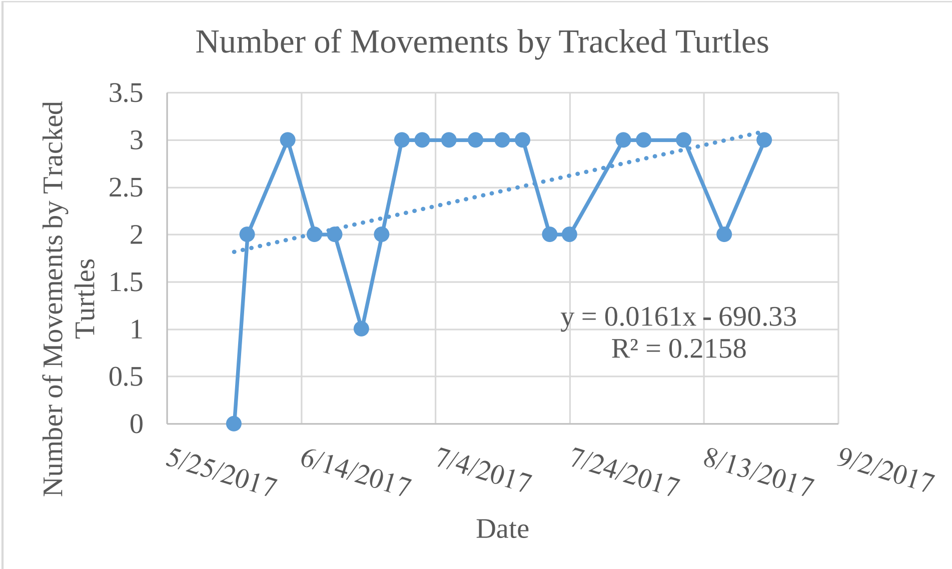


This is a graph showing the relationship between days a turtle was tracked and its home range size.

Figure 34. Home Range Polygons of Eight Alligator Alley Turtles

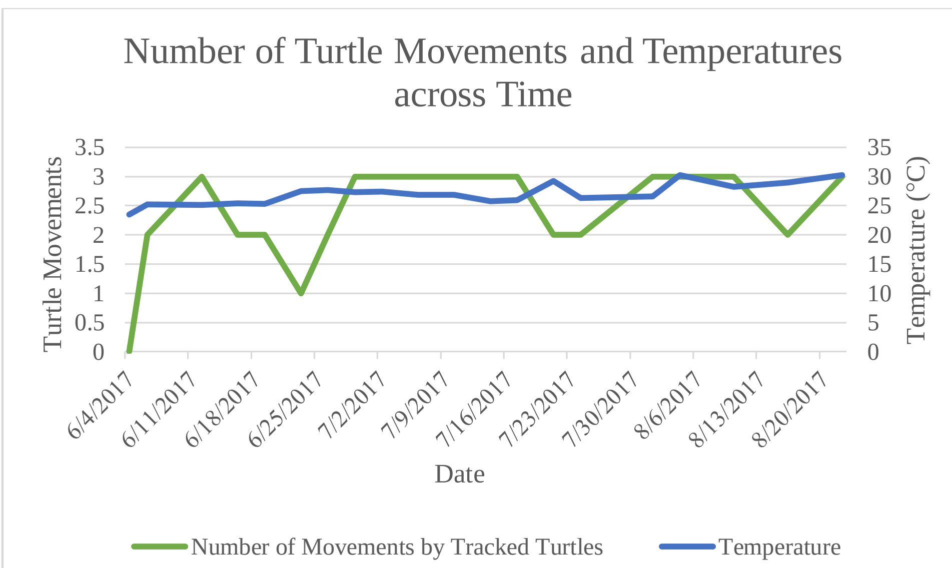
Home ranges of the tracked turtles in Alligator Alley were put on the same map to see overlap and differences. A star is where a large alligator resides.

Figure 35. Number of Tracked Turtle Movements across Time



Number of tracked turtle movements across summer 2017.

Figure 36. Number of Tracked Turtle Movements and Temperatures vs. Time



Number of tracked mud turtle movements and temperatures of Alligator Alley canal across summer 2017.

Discussion

Movement

Larger home ranges of gravid females (frequency 209, Figure 25; frequency 131, Figure 18) and some males were found and this is consistent with reports that nesting forays often take females beyond their normal home range (Williams and Parker, 1987; Stickel, 1989). However, the home ranges were not statistically significant from non-gravid females (p-value>.05), which is most likely because of the small sample size (n=9). Still, female's home ranges, in general, were found to be only 58.1 % of the male home ranges (2 males to 7 females). The largest home range was a male (14,395.5 m^2) and the second largest was a gravid female (9,199.7 m^2). Similar but also nonsignificant results were found in box turtles (Cook, 2004).

One of the two males (frequency 110) had the largest home range. This may be for a few reasons. First, it could be so he could have a home range that covers multiple female's home ranges so that he has a better chance of disseminating his genetic material. Additionally, the two male home ranges barely overlap (Figure 26), but the female polygons overlay very much (Figure 27). Now, this may be because there were seven tracked females to two tracked males (Figure 28). However, on two instances, it has been shown that male *K. baurii* are aggressive to each other; thus, the avoidance of each other's home ranges may be because of this aggression (Car, 1952). Therefore, the fact these two home ranges didn't cross much may not be by chance.

In Figure 30, it shows that 5 males and 1 female were found outside the main sample site of Alligator Alley, crossing roads/trails. This suggests, along with a larger home ranges for one of the tracked males, that males and gravid females are sometimes more mobile than females. A similar pattern was also noticed in a box turtle study (Cook, 2004). Nevertheless, it should still be remembered that in this study, the p-values for home range differences were not significant.

Throughout the study, it was noticed that home ranges were fairly predictable for each turtle a majority of the time. On occasion, a tracked turtle would not be where they were expected. Frequency 110 took off on a big trek shortly after we caught and tagged him (Figure 20). Additionally, when frequency 209 was known to be gravid she took off down a part of the canal she had never been in before (the northern most area of home range, Figure 25).

During the end of the drought of spring and summer 2017, some of the tracked turtles exhibited interesting behaviors. Frequencies 250, 228, and 290 ended up together in a very shallow pool of water, which was once the canal, for a few days. When that pool became even shallower, frequency 250 retreated to the lake, which had an abundant water source. This action likely increased the risks that she faced each day, and it ended up with her survivorship chances being lower. After tracking her twice in the lake, her signal was lost and not picked up again even though her signal was tried for months across all of Alligator Alley. Frequency 131 had a curious story as well. Firstly, she was the only tracked turtle technically outside of the Alligator Alley canal, even though she was close. Also, when she was found crossing the road, she was gravid. After a little bit of movement in the weeks after we tagged her, she became sedentary for a while. We found a single spot where we concluded she was buried, likely resting after laying her eggs. This has been found in mud turtles before (Wilson et al., 1999). After a few days of her being buried in this spot, her signal was lost and not able to be picked up. The area surrounding her home range was searched extensively including Lost Bridge Trail, Lake Hancock, and Alligator Alley Trail. The area she was dormant in had a large number of feral pigs was rooted up from the pigs. After much thought, it seems that the feral pigs likely found her resting while rooting up the area.

It is peculiar that a majority of the turtles caught were in the middle of the canal; this area also happened to be the home range of a large gator. This gator may have dissuaded medium sized predators of mud turtles such as smaller gators, big turtles, otters, and raccoons. Turtles were found distributed in the whole reserve, but they were the densest right around the gator (Figure 34 star is where gator resides). It is unlikely such as large gator would target mud turtles so it is probably providing an area of protection for them. However, there could be other factors contributing to the gathering of turtles along the middle of the canal.

The mean straight line distance for the turtles was found to be 169.3 m (88.1-283.1 m) and was through mostly shallow, still wetlands and canals, with the occasional trail or road. This was a much larger average (compared to 119.2 m), but smaller range (36.3- 581.3 m) than found of Eastern Mud Turtles in suburban environments (Harden et al., 2009). Additionally, this was a considerably larger mean than found in a study on Sonoran Mud Turtles (range of 1-79 m and mean 19 m; Ligon & Stone, 2003). For gravid female *K. baurii* in another study, the average movement from the wetland to nest site was 137 m with a range of 60-180 m (Wilson, Mushinsky, & McCoy, 1999). The mud turtles in the study may move greater distances than other mud turtles due to the small population size in the canal requiring them to travel further to find mates, or opening up more available space to forage with less competition. The drought that occurred in spring/summer 2017 seemed to also cause a few turtles to expand their range, probably to find water or available food.

Seasonality

During the period of drought in spring and summer 2017, frequency 310 aestivated when the water in his home range dried up. It was interesting that he was the only turtle that aestivated during the drought. The other five tracked turtles at the time found other methods of coping with the lack of water.

In the fall, many females (frequency 131, plus 5 Mark-Recapture turtles) were found to be gravid and one in May (frequency 209). This supports the notion that *K. baurii* has a peak nesting season in the fall in Central Florida, with a possible secondary one in June (Wilson, Mushinsky, & McCoy 1999; Mushinsky & Wilson, 1992). The graph of temperature for Alligator Alley canal was compared to movement by tracked turtles (Figures 35 and 36). This relationship seems to be fairly similar ($R^2 = 0.2158$ and $R^2 = 0.2084$), though not significant, but the lines seem to overlap and follow a similar trend (Figure 36). Even though this relationship seems to be related, there may be a stronger relationship between precipitation and movement as previously noted by Wygoda (1979). This relationship has been noted in box turtles as well (Donaldson & Echternacht, 2005).

Habitat Preferences

Mud turtles in the reserve were found mostly in a shallow canal of still water (Alligator Alley). This study found habitat preferences that agreed with the Wygoda (1979) study of *K. baurii* in the Hillsborough Watershed, as opposed to the Ernst (1972) study in Big Cypress Swamp. Although no attempt was made to collect turtles in Lake Hancock during this study, the absence of many terrestrial migrants on the trail between the canal and the lake, as well as the general trend of movement away from the lake, suggests that the lake was generally avoided. This was not the case for one turtle, frequency 250, who was found two times along the shoreline of the lake during the spring/summer drought of 2017 before disappearing (noted in movement paragraph in detail). A majority of the turtles were found in the canal, but a few turtles were found crossing roads or trails near ephemeral wetlands. However, there was no flowing water at Circle B Bar Reserve to see if, given the choice, *K. baurii* would choose still water over moving water.

Sex Ratios

This ratio that was found in Alligator Alley is considered female-biased but it is not significant in its difference from the normal ratio of 1:1. This is possibly because of the low population size (n=26). Of our 26 adult individuals along Alligator Alley, only 9 were male, and 17 were females. This is not significantly different than the expected ratio of around 13 males and 13 females, but it is still a skewed sex ratio. Wygoda (1979) found a similar skewed sex ratio in Hillsborough County, FL. These trends could be because males have a smaller body size; thus, they are potentially more vulnerable to predators than a larger female. Additionally, one of the males had a larger home range and moved more frequently than most of the females. If this is a characteristic of males, it might explain why males could be more susceptible to predators.

Lastly, the Kinosternidae have TSD, with cooler temperatures during egg development creating males and warmer temperatures making females (Vogt et al., 1982). The threshold temperature is defined as the temperature producing 50% males (Bull, 1980). The climate of Central Florida, as well as the variability of nesting times, may be influencing a female-biased ratio. *Kinosternon baurii* range from the Florida Keys to Virginia so the threshold temperature between males and females may create more females in the Central Florida climate (Wilson, Mushinsky, & McCoy 1999; Mushinsky & Wilson, 1992). The threshold temperature of Striped Mud Turtles does not seem to be known in the literature. However, it is curious that the peak nesting season for *K. baurii* in Florida is found to be in fall, yet the ratio found in the study is still resulting in adult female-biased ratios. Questions involving TSD are just starting to be explored so there's a whole avenue for many interesting studies on the Kinosternidae involving TSD.

Implications of Climate Change on Sex Ratios

When climate change is considered, the found female-biased sex ratios in this study and the Wygoda (1979) study could have serious implications for *K. baurii* in the future. As the average temperatures in Florida continue to rise, the ratio will become increasingly female-biased. This could negatively impact turtle population in a couple different ways. At some point, there could be so few male adults that not every female will have a male that mates with her. Furthermore, a male's home range could have so many females or be so large that he is not able to mate with all the available females. Even though males would still be able to find ample mates, the results would not be good for the genetics of the population. When only a few males are putting their genes into the population, the genetic variation would be limited and the population could be susceptible to mutations or diseases.

Additionally, with increasing temperatures, as females still continued to nest, their nests would produce mostly females. Changing the threshold temperature of the Striped Mud Turtle would take time to evolve since turtles are relatively slow at evolutionary changes (Gibbons, 1990; Gibbons et al., 2000). Therefore, *K. baurii's* change in the threshold temperature would not likely be fast enough, evolutionarily, to save the female-biased populations. *Kinosternon* species often rely on rain before they nest to make sure that nesting is energetically possible (Van Loben Sels, Congdon, and Austin, 1997; Wilson, Mushinsky, & McCoy 1999). Thus, shifts in periods of rainfall could influence peak nesting seasons in the future. Overall, climate change has serious implications for mud turtles because of TSD and less available habitat that could cause distribution shifts (Butler et al, 2016).

More Life History Traits and Their Implications

On every turtle found, two ridges were found on each of the front legs (Figure 9); these were thought to be used for digging in the mud. Furthermore, in Alligator Alley, the average carapace length for the females was 93.62 mm (n=17) and 82.81 mm for males (n=9). These results are consistent as to what was found for *K. baurii* by Wygoda (1979) of 93.5 mm (n=44) for females and 83.4 mm for males (n=22). The hatchlings, found in July, had a CL of 28.1 mm and 30.2 mm, compared to the Wygoda (1979) hatchling with 25.6 mm. When the CL of females vs. males is tested in a 2-sample t-test, the result is a statistically significant difference (p-value = .006). Thus, the notion that mud turtles have size sexual dimorphism is correct.

Moreover, of 497 female turtles caught in another study during the reproductive seasons of *K. baurii*, there was an average carapace length of 98.8 mm that was closer to the length of 98.05 mm (n=5) found in this study along the roads and trails excluding Alligator Alley (Wilson, Mushinsky, & McCoy, 1999). This suggests that female turtles that are more active, or are gravid and moving to nest, may be the larger size subset of the female population. This could be because the turtles are older, and thus bigger, or have the best chance of survivorship as a result of their robust size. Their larger size protects the females slightly from predators, such as raccoons, but their increased movement to go to a nest site, and the act of nesting leaves them vulnerable to other threats. These threats include human disturbance, human capture of the turtle, vulnerability to cars on roads, etc. With increasing urbanization, the risks of increased female movement during reproductive seasons will continue to grow. Increased vulnerability in urban and fragmented areas caused by nesting of females and mate searching by males has been noted in box turtles as well (Iglay, Bowman, & Nazdrowicz, 2007).

Additionally, with warmer weather produced by climate change, the amount of time for ideal nesting conditions of *K. baurii* in Florida will decrease. Previously in Central Florida, it was found that *K. baurii* avoids nesting most of the time during the hottest months of July and August (Wilson, Mushinsky, & McCoy, 1999). Our study agrees with these findings because no gravid females were found during July or August. As a result of rising temperatures, females will likely not be able to lay as many clutches per year and, therefore, not be able to make up for their inherently small clutch size. There could be more months that would be too energetically costly to nest in, like July and August currently are, where nesting would be normally avoided.

Lastly, many mud turtles' nesting practices leave them susceptible to increased predation and low survivorship of nests. A 1991-1995 study found 100% mortality in *K. baurii* nests that were left exposed to predators (Wilson, Mushinsky, & McCoy, 1999). With amplified urbanization, more raccoons and other "nuisance" predators are often present and can cause more nest predation (Harden et al., 2009). In a 1999 study of Striped Mud Turtles, females walked a few meters from their nest and buried themselves for as long as 35 days (Wilson, Mushinsky, & McCoy, 1999). This is what we assumed happened for frequency 131, but with the added problem of a high density of raccoons and feral pigs that most likely found her. These added disadvantages could leave an even lower survivorship of *K. baurii* eggs or hatchlings and further decimate their numbers.

Relationship of Carapace Length vs. Weight

When thinking of the details on life history traits, a relationship between carapace length and weight was noticed. In a statistically significant way for females, as carapace length increased weight increased (females R^2= .9336, males R^2= .6885: Figures 31 and 32). This trend has been noted in other turtle species and is sometimes used to estimate weight for larger species (Georges & Fossette, 2006; Santos, Freire, Bellini, & Corso, 2010; Schwartz, 2000). These loftier turtles are often sea turtles and so the relationship is normally only explored for nesting females. It is peculiar that the males (Figure 32) do not have as strong of a relationship in carapace length to weight as females. However, there were less males (9 males to 17 females) to make these trend lines because females were more commonly caught, so the sample size may be too small to show the true relationship. It is good to note, for at least female *K. baurii*, that length and weight have a similar relationship that corresponds to what has been found in other Testudines' (turtles and tortoises).

Parasites and Disease

Very little has been studied on *K. baurii* parasites and disease (Wilson, Mushinsky, & McCoy, 1999). Almost all individuals found in the reserve appeared healthy. Many individuals had leeches in their arm cavities or on their shells (Figure 11). Yet, no individual was inundated with leeches, like more commonly found in other turtle species. The leeches ranged from about 1.5-2.5 cm, but all appeared to be from similar species.

While an attempt was made during the study to take blood from an individual turtle to do a blood smear in order to look for parasites, the process but was very difficult to execute and minimal blood was obtained. It was decided that there would be no further attempts to take blood. One individual had a swollen or infected eye (Figure 10), but all other turtles had clear eyes and nose area. The turtle with frequency 110 had only 3 legs, but his leg stub appeared to be healed well and it did not seem to impact his movement (he had the largest home range of all 9 turtles). Overall, the health of the captured turtles was surprisingly good.

Disturbances

Throughout the study, a few different human interactions as well as other disturbances were noted. In addition, the varied history of the reserve land may have had significant impacts on the findings of the study. Despite these occurrences, the reserve is still a safe haven for wildlife from many anthropogenic effects. One type of human disturbance in CBR could be from minor noise pollution by visitors, but *K. baurii* is known to be fairly nocturnal (Ernst, Lovich, & Barbour, 1994). This could disrupt mud turtle's habits. Secondly, the landscape itself has had exposure to a direct human disturbance: cattle ranching. Almost 90 year ago, the whole reserve was a cattle ranch. The area by Alligator Alley was probably only altered once to make the main canal and a dike, but this has not been confirmed. Once it was transferred to a reserve around 2004, most of the land was flooded to restore the hydrology. Is it possible that pasture land would be better habitat for *K. baurii* because it could have shaded shallow wetlands? In any matter, the reserve is relatively new in its current state and there is a relatively low population of Striped Mud Turtles as compared to other studies within more established habitats in Florida (Mushinsky & Wilson, 1992; Wilson, Mushinsky, & McCoy, 1999; Wygoda, 1979). However, it is known that turtles have a long recovery period and are vulnerable because of characteristics such as late sexual maturity (Ernst, Lovich, & Barbour, 1994). Thus, the turtle population may just be taking a long time to rebound from the wetland it originally was, to being pasture land and now being restored.

Nonetheless, there may be factors influencing the population size of *K. baurii* in Alligator Alley other than the initial human disturbance. Next, in CBR and around it, the numbers of a key perpetrator of turtle eggs has increased: raccoons. Raccoons are known as human-subsidized predators, meaning that they increase with urbanization. The reserve has many raccoons that frequent Alligator Alley and many reptile nests are found dug up along the trail. With an abundance of raccoons, turtle populations can be greatly reduced (Harden et al., 2009). Lastly, through personal observation, it has been noted that many people in Florida find mud turtles and keep them as pets, so this could be a possible threat to mud turtles in the future. A smaller than expected population and many adult turtle disappearances may be because of the increased threats caused by a variety of disruptions, disturbances, and threats in the reserve.

Unexpected Low Numbers

In theory, a small area should be able to hold a large number of *K. baurii* because, at least females, have small and overlapping home ranges. The most surprising aspect of the study was the number of expected turtles at Alligator Alley. It was unanticipated to find an estimated adult population to be only around 38 individuals, by the software program MARK. However, it was promising that varying age ranges were found during the study. During the Wygoda (1979) study, there was almost a complete lack of juvenile and hatchling *K. baurii*. A few juveniles and two hatchlings were caught in the traps; thus, it is also assumed that the traps were sufficient at catching all age groups and that the population has some recruitment, meaning that there’s an increase in the population as offspring grow and immigrants arrive.

A larger sample size of males needs to be tracked to further understand the male dynamics in movement, but it is intriguing that one male had the largest home range and the other male had the smallest. As mentioned, the human-subsidized problem of raccoons may be a contributor to the unexpected low numbers found in the study (Harden et al., 2009). Additionally, possible male aggression could be a factor that the *K. baurii* are spread out and not densely populated in a seemingly healthy and fruitful habitat (Wygoda, 1979). This could explain part of why the male numbers in Alligator Alley are seemingly small.

Moreover, another part of the low population numbers could be because there is not very much nesting habitat close to Alligator Alley. One turtle was found nesting along the sandy trail of Alligator Alley, and many reptile nests have been observed on the sides of the trail. The trail is the main sandy and dry area besides the upland habitat that is about 2 kilometers from Alligator Alley; thus, it is the main nesting area within the vicinity. Furthermore, frequency 131 was found with eggs in a seasonally dry area by the Nature Center, so females may be finding suitable spots to nest by going further away from Alligator Alley.

In the Wygoda (1979) study, 67 turtles were caught 157 times throughout March 1975 to April 1976 by using mostly drift fences. During another study, 515 turtles were caught 1557 times from September 1991 to February 1995 with drift fences. These older Florida studies show a much larger population of *K. baurii* for a similar study time frame. Moreover, it should be noted that drift fences involve a different method of catching and may be a more comprehensive trapping method. Nonetheless, this method alters the landscape and requires more frequent checking of traps to minimize death and would not have been possible to use in this study due to the limited time available during an undergraduate research career.

When talking about low numbers, it should also be noted that no Eastern Mud Turtles, *Kinosternon subrubrum*, were captured during this study. This is very peculiar because the traps used should be capable of catching them, even Musk Turtle were caught, and the area around and in CBR is within the expected range of *K. subrubrum* (Ernst, Lovich, & Barbour, 1994). Therefore, Circle B could be an example of niche exclusion as opposed to resource partitioning and has therefore caused *K. subrubrum* to not be able to inhabit the reserve (to our knowledge). Nonetheless, there could be other unknown causes to the lack of *K. subrubrum* in CBR.

Trapping Effort

Trapping effort was quite extensive along Alligator Alley and other locations throughout the reserve. A study on Sonoran Mud Turtles had 3,240 net trapping hours across one season in their cattle pond and found 50 individual turtles in this pond (Ligon & Stone, 2003). For our study we had 136,752 net trapping hours across 2 years and only caught 32 individual turtles. This comparison supports the notion that this population has low numbers for the habitat and the amount of study time.

Limitations of the Study

It should be noted that only 2 males were tracked, but 7 females were tracked. This resulted for two reasons 1) it was difficult and unpredictable when male turtles would be caught and 2) it was representative of the female-biased population. One female (frequency 171/151) was tracked, lost, and then recaptured in a trap with her tracker dead. Her tracker was then replaced to be frequency 151; therefore, when you see 171/151 throughout the study it is designating the same female turtle. Even though turtles 191, 209, and 171/151 have number of days tracked listed as a definitive number, their battery life did not die during the study. These three turtle’s last data points had to be excluded from data analyses because CBR was closed indefinitely after Hurricane Irma. After the reserve was accessible, turtles 171/151 and 209 were found, but the signal from the tag 191 was not able to be picked up. Hurricane Irma flooded Alligator Alley and connected the canal and Lake Hancock, but we were not able to access the trail to see what the turtles did during this event because of downed trees.

Furthermore, all turtles besides frequency 209 and 191 were lost at some point (before Hurricane Irma). This could be because of long meanderings of turtles that were not able to be picked up by the limited range of the tracker; however, this is not likely because every lost turtle was looked for extensively for weeks after signal was lost. Other possibilities include disappearances caused by feral pigs, gators, cars, humans, tracker loss, or tracker malfunction.

In addition, tracked females were palpated when caught or re-caught; however, there were extended periods of time where tracked females were not able to be checked for eggs. Thus, some of the tracked females may have laid clutches without us knowing because around 1 clutch is estimated for an adult female *K. baurii* a year. Yet, a lot of tracking was done in the summer during the low period of nesting.

Furthermore, the R^2 of the relationship between number of days tracked and home range had no relation ($R^2 = 0.0315$). Therefore, the slight inconsistency of number of days tracked didn’t influence the final home range area significantly.

Management

From this study, it has become clear that nesting is a large area of concern for the future prospects of *K. baurii*. This problem could be diminished by placing protection over mud turtle nests. Mesh boxes could be placed over and around known nests to protect them from predation by raccoons. This is currently being done for sea turtles and was done in the 1999 nesting study of *K. baurii* (Wilson, Mushinsky, & McCoy, 1999). Even if only some nests were protected, a few hatchlings could be added to the population, as opposed to a high mortality that is probable in unprotected nests.

Also, if the population numbers continue to decline, a head start program, where eggs/hatchlings are raised to give them a jump start at overcoming predation, could be implemented by some reserves and parks. This has been suggested by other studies with declining reptile species (Nelson, Langford, Borden, & Turner, 2009). Similarly, the problem could be mitigated from a different approach by having some raccoons be trapped if their populations continue to reduce susceptible reptile species. Although this is not ideal, it would greatly increase survivorship of mud turtle eggs and hatchlings. If urbanization continues, and with it more raccoons, then turtle survivorship may become a growing concern.

Overall, *K. baurii* is a long-lived species that is susceptible to population decreases and disturbances; we know this because of extensive studies on turtle species that have delayed adult maturity (Congdon, Dunham, & Van Loben Sels, 1993). These studies also show how sensitive turtles are to adult and juvenile loss. Thus, adult survival is imperative for maintaining adult populations of mud turtles (Harden et al., 2009). Survivorship in non-urbanized areas is likely higher for small turtle species (Harden et al., 2009). In this study, high nest predation and juvenile loss by raccoons is assumed and could have resulted in the low population numbers that were found. There are also feral pigs that may be causing some disruption to the population as they root around prime mud turtle habitat often. Hence, it is important to properly manage mud turtle numbers in urbanized and restored areas, if possible.

Buhlmann & Gibbons (2001) estimate the critical upland habitat for mud turtles involves 135-90 m of surrounding wetlands; this should be viewed as essential associated upland that is adjacent to wetlands. Upland habitat is still critical to *K. baurii* as a semi-aquatic turtle that depends on land for nesting and aestivating (Wilson, Mushinsky, & McCoy, 1999). In the Harden et al (2009) study, it states that for 100% of Eastern Mud Turtle locations to be included in the "buffer zone" it would require upland to extend 581 m from the wetland or pond habitat. Because of this and the mud turtle's slow rebound process, it is vital to watch their numbers in urbanized and disturbed areas and perhaps implement management solutions, as mentioned above. If antropogenically altered areas, such as reserves and urban areas, are to be managed for both people and fauna, land managers should reflect upon the behavioral patterns and spatial ecology of wildlife (Bowne, Bowers, & Hines, 2006). Setting aside or restoring uplands that are close to wetlands would benefit numerous species and would help to conserve wildlife that depend on land and water within fragmented and disturbed habitats (Bowne et al., 2006; Harden et al., 2009). This has definitely been confirmed in this study by the low numbers found in the wetland with minimal upland habitat for nesting nearby. Reptiles and amphibians are decreasing on a global scale so numbers and populations of mud turtles and other herpetofauna species should be continually monitored (Christiansen et al., 2012).

Sharing Scientific Knowledge in a Practical Way

Every time the researchers visited CBR, they conveyed the results of the study (so far) to the general public and the staff and volunteers at Circle B. Similarly, when in the field, the study researchers educated any visitors that were curious regarding the study, as well as explained the importance of wildlife research and conservation and the impact on the overall global environment. These wonderful educational opportunities and knowledge sharing situations are a prime example of another reason that reserves and restored areas are vitally important.

Future Studies

Moreover, not much research has been done on the threshold temperature for Kinosternidae species, and there were no found studies that stated the *K. baurii* threshold temperature (Vogt et al., 1982). Additionally, it would be interesting, yet incredibly challenging, to determine if a skewed sex ratio is present in hatchlings or if it is due to TSD (or another factor). These questions involving skewed sex ratios should be investigated to further understand how Kinosternidae species will be affected by climate change. Furthermore, clutch sizes of *K. baurii* are still unknown and would be very interesting to find out because nesting ecology is crucial to understand in a species that is possibly in distress (Wilson, Mushinsky, & McCoy, 1999). Aestivation is also a fairly understudied area in mud turtles and there are many questions regarding how mud turtles use aestivation. As always, continually educating the public on turtles and their conservation threats can help bring awareness to park and reserve guests. If guests are educated on how to properly move a turtle across the road/trail, by placing them on the other side towards where they were facing, possible car mortality could be reduced. Lastly, it would be interesting to continue tagging male mud turtles to track their movement, especially because the two males in this study had the biggest or smallest home ranges.

Conclusions

Although this study was statistically inconclusive on Striped Mud Turtle movement, it appears that some males and gravid females have larger home ranges than many females. Additionally, results on female- skewed sex ratios, habitat preferences and life history characteristics were similar to what was found in older studies. Somewhat surprisingly, a fairly low population size (n=38) was estimated for the adult mud turtles found in a fairly ideal habitat of CBR.

With TSD and low population numbers found in restored areas, global climate change has serious implications for the future of turtle species, including *K. baurii*. As their distribution becomes increasingly urbanized and in fragmented areas, it is important to continue studying mud turtle ecology and how they respond to restored and urban areas. Like many other turtles, *K. baurii* is a good indicator organism for ecosystem health and is an umbrella species. Hence, it should be considered for further scientific research. In an increasingly urbanizing society, restored habitats and reserves will continue to serve as an essential habitat for mud turtles and it is vital to better understand turtle ecology and movement within these areas.

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