# POPULATION STATUS, DISTRIBUTION, AND HOME RANGE OF THE ALLIGATOR SNAPPING TURTLE (*MACROCHELYS TEMMINCKII*) IN THE SUWANNEE RIVER, FLORIDA

BY

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LIST OF ABBREVIATIONS

| | |
|---|---|
| ANOVA | Analysis of variance |
| CITES | Convention on International Trade in Endangered Species |
| CL | Midline carapace length |
| CPUE | Capture per unit effort |
| CW | Carapace width |
| DNA | Deoxyribonucleic acid |
| ESU | Evolutionarily significant units |
| FWC | Florida Fish and Wildlife Conservation Commission |
| FLMNH | Florida Museum of Natural History |
| GPS | Global positioning system |
| HW | Head width |
| MTDNA | Mitochondrial deoxyribonucleic acid |
| NDNA | Nuclear deoxyribonucleic acid |
| PCL | Precloacal tail length |
| PIT | Passive integrated transponder |
| PL | Plastron length |
| PVC | Polyvinyl chloride |
| RCC | River continuum concept |
| SDI | Sexual dimorphism index |
| SRWMD | Suwannee River Water Management District |
| TL | Tail length |
| USFWS | United States Fish and Wildlife Service |

Abstract of Thesis Presented to the Graduate School
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POPULATION STATUS, DISTRIBUTION, AND HOME RANGE OF THE ALLIGATOR SNAPPING TURTLE (*MACROCHELYS TEMMINCKII*) IN THE SUWANNEE RIVER, FLORIDA

By

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The alligator snapping turtle (*Macrochelys temminckii*) has experienced population declines throughout much of its range because of extensive harvest. Little is known about the genetically and morphologically distinct population of *Macrochelys* in the Suwannee River. In Georgia, efforts failed to capture *Macrochelys* in the Suwannee River, creating concern about this species status. To determine the status of *Macrochelys* in the Suwannee River, a mark-recapture and telemetry study was conducted between 2011 and 2013. In total, 132 individual *Macrochelys* were captured (21.2% juveniles, 17.4% females, and 61.4% males). Sex ratio was male-skewed (3.5:1) and 41% of males weighed ≥45kg. Relative abundance and density estimates revealed an uneven distribution of turtles throughout the river, with more productive river sections maintaining higher population densities and larger turtles. Mean linear home ranges were 1,896 m ± 252 m for males and 1,615 m ± 301 m for females. Telemetry data revealed habitat use patterns not previously reported for *Macrochelys*, with individuals making overland movements between the floodplain and river channel. Side-scan sonar maps paired with turtle locations indicated coarse woody debris, undercut

banks and large rocks are important habitat during low water levels. Bush hook surveys and radiographs revealed a positive correlation between bush hook abundance and number of ingested hooks. *Macrochelys* in the Suwannee are more numerous than previously thought; however, several threats exist including fish hook ingestion, boat propeller damage, and the removal of woody debris.

CHAPTER 1
INTRODUCTION

## The Alligator Snapping Turtle

### Natural History

The alligator snapping turtle (*Macrochelys temminckii*) is the largest freshwater turtle in the western hemisphere (Ernst et al., 1994; Pritchard, 2006). *Macrochelys* possesses a carapace that is heavily serrated posteriorly with three longitudinal rows of prominent keels. Pritchard (2006) discussed historical size of *Macrochelys*, but many accounts are unconfirmed and anecdotal in nature. Pritchard (2006) mentioned a record-sized (404-lb) specimen reported by Hall and Smith (1947); however, after correspondence with one of the authors, he suggested that this record should not be accepted. One well known trapper, Al Redmond, a 142-kg (313-lb) *Macrochelys* in the 1970's from the Flint River system in Georgia, but this record is also questionable. The largest *Macrochelys* on record with a verifiable mass was an individual that was captured in Texas and then kept in captivity in the Metropolitan Toronto Zoo. In 1984, this turtle weighed 104.3 kg (230 lbs). While males potentially reach large sizes, *Macrochelys* exhibit sexual dimorphism and females weigh much less (Ernst et al., 1994; Pritchard, 2006).

Alligator snapping turtles are restricted to river systems and associated wetlands that drain into the northern Gulf of Mexico from Florida to Texas (Pritchard, 2006). *Macrochelys* is characterized as a secretive turtle, often difficult to study in the wild (Zappalorti, 1971; Elsey, 2006). Despite this, a considerable amount of information is available on this species (Dolbie, 1971; Pritchard, 1979, 2006; Ernst et al., 1994; Roman et al., 1999; Elsey, 2006; Riedle, 2006), but much remains unknown about its basic ecology and conservation status (Pritchard, 2006; Roman et al., 1999).

*Macrochelys* possesses a large head and powerful jaws used for crushing prey items (Pritchard, 2006). For example, a 54.5-kg (120-lb) individual recorded a bite force of nearly 4448 N (1000 lbs) (T.M. Thomas, unpublished data). Most knowledge concerning food habits of *Macrochelys* is derived from anecdotal reports (see Pritchard, 2006) and a few studies conducted in the western part of their range (see Sloan et al., 1996; Harrel and Stringer, 1997; Elsey, 2006). Dobie (1971) noted an unusual quantity of acorns and palmetto berries in turtles from Louisiana. *Macrochelys* have been reported feeding on fish, mollusks, crustaceans, small alligators (*Alligator mississippiensis*), snakes, turtles, insects, birds, mammals, aquatic salamanders, and plant material (Allen and Neill, 1950; Dobie, 1971; Sloan et al., 1996; Harrel and Stringer, 1997; Elsey, 2006). This suggests that adult *Macrochelys* are opportunistic scavengers (Elsey, 2006), but juveniles may be more reliant on their “lure” (a modified tongue that resembles a worm) for prey capture (Spindel et al., 1987; Pritchard, 2006). The diet of *Macrochelys* in Florida has not been studied.

*Macrochelys* are characterized as relatively sedentary (Ernst et al., 1994); but Pritchard (2006) proposed that some individuals may constantly move upstream during their lifetime. Telemetry studies in Missouri, Kansas, Oklahoma, and Louisiana showed extensive turtle movements throughout available aquatic habitat, with resting or core sites generally associated with greater habitat structure and denser canopy cover (Sloan and Taylor, 1987; Shipman, 1993; Shipman et al., 1995; Riedle et al., 2006). Most of these studies took place in the western part *of Macrochelys’* range and were conducted in lakes, impoundments, and small streams. Thus very little information exists on turtle movements in large, free flowing river systems or in the eastern part of their distribution.

Dobie (1971) dissected 231 *Macrochelys* that were harvested for meat by a commercial fish-house in Louisiana and estimated that sexual maturity is reached in 11–13 years. However, other studies have shown sexual maturity requires 15–21 years (Sloan et al. 1996, Tucker and Sloan 1997, Reed et al. 2002, Woolsey 2005). Information on courtship is absent in this species (Pritchard, 2006), but copulation has been witnessed by Allen and Neil (1950). According to Allen and Neil (1950), copulation lasted from 5–25 minutes. Nesting typically occurs in the months of April, May, and June (Dobie, 1971, Ewert, 1994). Nests are typically constructed in sandy soil within 20 m of the water, but some nests may be as far away as 200 m (Ewert, 1994). *Macrochelys*, like many other reptiles, has temperature-dependent sex determination. It is believed that higher nesting temperatures produce more female turtles (Ewert, 1994). Typically, *Macrochelys* lay one clutch a year, but some individuals may lay every other year (Dobie, 1971). Clutch sizes in Louisiana had a mean of 24.5 (range 16–52). In Florida, Ewert (1994) found clutch sizes averaged approximately 36 eggs (range 17–52). In Florida, most eggs hatch in late August after 100−110 days of incubation (Ewert, 1994).

Molecular studies conducted on *Macrochelys* using both mitochondrial (mtDNA) and nuclear (nDNA) revealed considerable genetic variation across its range (Roman et al., 1999, Echelle et al., 2010; Figure 1-1). Roman et al. (1999) used mtDNA to propose three distinct genetic assemblages (western, central, and Suwannee), with turtles from the Suwannee River assemblage being the most distinct and showing a deep separation from other drainages. Nuclear (nDNA) results suggests the presence of six Evolutionarily Significant Units (ESU's) within rivers inhabited by *Macrochelys*: (1) Trinity, Neches, and Mississippi, (2) Pascagoula, (3) Mobile and Perdido, (4) Pensacola, (5) Choctawhatchee, Econfina, Apalachicola, and Ochlockonee, and (6) Suwannee River drainages, and this analysis also identified the Suwannee River assemblage as most genetically distinct (Echelle et al., 2010).

Recent research suggests that morphological differences, corresponding to previous molecular findings, also exist among *Macrochelys* populations, and currently two new species of *Macrochelys* have been proposed based on these differences (Thomas et al., in review).

**Distributional Gap**

Although this species is restricted to river systems that drain into the Gulf of Mexico from Florida to Texas, there appears to be a distributional gap in the range of this species. There are no confirmed records from several small coastal rivers including the Steinhatchee, Fenholloway, Econfina, Aucilla, Wacissa, Saint Marks, and Wakulla rivers (Ewert et al. 2006; Figure 1-2). Pritchard (2006) notes there are two undocumented sightings from the Wacissa River. Additionally, the Florida Natural Areas Inventory records include a live specimen observed in the Wakulla River, a dead specimen from the St. Marks River, and a photo of a specimen in the "Woods and Water" newspaper reportedly from the Aucilla River; however, it is impossible to truly verify these anecdotal reports. To date, no official vouchered specimens exist between the Suwannee and Ochlockonee River systems, and this apparent distributional gap and geographic isolation have likely resulted in *Macochelys* in the Suwannee River drainage being the most genetically and morphologically distinct (Thomas et al., in review).

**Conservation Status**

Due to extensive commercial and non-commercial harvest, *Macrochelys* populations have experienced significant declines across much of their geographic range (Dobie, 1971; Ewert et al., 2006; Pritchard, 2006). Campbell's Soup Company was an alleged buyer of *Macrochelys* during the 1960's and 1970's for its canned snapper soup (Pritchard, 2006). Officials from the Florida Game and Freshwater Fish Commission reported that turtles were caught in great numbers from the Apalachicola and Ochlockonee Rivers and presumably trucked to New Orleans to be sold for soup (Pritchard, 2006). Al Redmond, a commercial fisherman, reportedly harvested 4000–5000 adult *Macrochelys* from the Flint River system from 1971–1983 (Johnson, 1989). Redmond reported that from the mid 1960's until 1973, turtles were harvest in great numbers in Mississippi, Louisiana, Georgia, Alabama, and Texas (Pritchard, 2006). In 1972, Florida was the first state to limit take on *Macrochelys* by passing regulation that limited possession to one turtle per person. While this regulation still allowed for minimal non-commercial harvest, it effectively banned any and all commercial harvest in Florida.

In 1983, Peter Pritchard petitioned the United States Fish and Wildlife Service (USFWS) to list the species as Threatened under the U.S. Endangered Species Act; however, according USFWS, it did not meet the requirements for listing. Today, the management of this species continues largely at the state level, and *Macrochelys* is afforded some protection in every state in which it occurs (Pritchard, 2006). In 2006, responding to reports of extensive export to Asian food markets, *Macrochelys* was listed in Appendix III of the Convention on International Trade in Endangered Species

(CITES), which now requires federal oversight and export permits that monitor and limit international trade.

In addition to population declines due to harvest, human-altered landscapes and the modification of rivers and subsequent loss of habitat are also a concern for the viability of these populations ( Ewert et al., 2006). Abandoned trotlines (a long line with shorter lines attached at intervals that possess hooks that are usually baited) have been reported as a major problem in Georgia, and have been known to unintentionally capture and drown *Macrochelys* (Pritchard, 2006). Ingested fishing tackle is a concern because fishhooks can perforate the digestive tract and eventually cause death in turtles. Several turtles in the Santa Fe River, a tributary of the Suwannee River, were found to have ingested fishhooks (Thomas, unpublished data). Bush hooks set for fish (a single baited fishhook, line, and and sinker attached to a branch overhanging the river) are common in this system and are usually set in the evening and checked the next day. Because of this, *Macrochelys* are more likely to come in contact with these baited hooks due to their nocturnal activity. These and other anthropogenic threats that lead to increased mortality rates represent a major concern to the long-term viability of *Macrochelys* due to long generation times and low reproductive rates (Tucker and Sloan 1997, Reed et al. 2002); therefore, *Macrochelys* may require a long period of time for populations to recover.

**Status of *Macrochelys* in the Suwannee River**

The Suwannee River is the southeastern most limit of the range of *Macrochelys*, and questions concerning this population's status have persisted for some time. Although Moler (1996) reported the presence of *Macrochelys* in the Suwannee and Santa Fe Rivers during a statewide survey, Pritchard (2006), citing mainly park naturalists in Florida and Georgia, concluded that *Macrochelys* are scarce within the Suwannee River and the Okefenokee Swamp. He suggested *Macrochelys* was more numerous in years past, and populations may have declined since the 1930's (Pritchard, 2006). Surveys conducted in Georgia (Jensen and Birkhead, 2003) failed to capture *Macrochelys* in the upper Suwannee despite intensive sampling, and the authors suggested low pH and its effect on prey items along with impacts associated with commercial harvest were possible explanations. Alternatively, Jensen and Birkhead (2003) suggested that *Macrochelys* may not be common throughout the easternmost part of their range.

Recent research has suggested that *Macrochelys* in the Suwannee are unique from other populations which make the evaluation of its status important. As a proposed new taxon limited to single river drainage, if *Macrochelys* is as scarce as previously suggested, it may be of significant conservation concern and require special management and protection. Therefore, establishing its true status (including distribution, density, population structure, home range, habitat use, and threats), is critical for the future management of this species. These are the questions I addressed in this thesis.

## Geomorphic Riverine Processes

Rivers, in their natural state, are linearly connected and highly dynamic ecosystems (Decamps, 2011). Typically, rivers exhibit changes in a multitude of characteristics (i.e., width, depth, velocity, flow volume, and temperature) from the headwaters to the mouth (Vannote et al., 1980). The changes in patterns and processes within lotic systems are oriented downstream (Ward, 1989; Townsend, 1996). The constant change along a river can impede the detection of biological patterns crucial to the management of imperiled species (Duncan, 2009). The River Continuum Concept (RCC) is one construct to help explain how patterns and processes change longitudinally in rivers and how they potentially affect biotic communities. Rivers possess a continuous gradient of physical conditions that results in a continuum of biotic adjustment as water travels downstream from the headwaters to the lower reaches (Vannote, 1980). The RCC is based in part on the premise that energy input, organic matter transport, storage, and use by macroinvertebrate feeding groups (shredders, collectors, grazers, and predators) may be regulated largely by fluvial geomorphic processes such that resources tend to increase downstream (Vannote, 1980).

Much of our current knowledge of stream and river ecology has come from studies on fishes. Past studies have revealed that changes in riverine habitat can potentially affect biological communities of aquatic insects (Roy et al., 2003), and fish communities (Sutherland et al., 2002; Walters et al., 2003). However, little is known of how changes in rivers potentially influence turtle communities.

The Suwannee River is the second largest river by drainage in Florida and serves as a key geological and ecological break between the peninsula and panhandle regions. During its course through North Florida, the Suwannee River experiences geologic and physiogeologic longitudinal changes in water chemistry (Ceryak et al., 1983). These changes in water chemistry led the Suwannee River Water Management District (SRWMD) to divide the river into 6 distinct ecological reaches (Hornsby et al., 2000). These ecological reaches within the Suwannee can be thought as sections of river that share similar physical, chemical, and ecological conditions, and presumably, different resources for *Macrochelys.*

## Objectives

For this study, my goal was to answer questions regarding the status of *Macrochelys* within the Suwannee River. Also, I investigated the effect of geomorphic riverine processes, embodied by the six distinct ecological reaches, on *Macrochelys* relative abundance, density, population size structure, and home range. Lastly, I investigated the prevalence of ingested fish hooks in *Macrochelys* within the Suwannee River.

### Turtle Relative Abundance and Density

Question: Does ecological reach affect population abundance of the alligator snapping turtle within the Suwannee River?

Hypothesis: Based on the RCC, I predict alligator snapping turtle abundance will increase in the middle and lower reaches relative to upper reaches.

### Turtle Population Structure

Question: Does ecological reach affect population structure (sex ratio and size distribution) of the alligator snapping turtle within the Suwannee River?

Hypothesis: Based on the RCC, I predict that alligator snapping turtles will exhibit no change in sex ratio among reaches and smaller size classes in the upper reach relative to middle and lower reaches.

### Turtle Home Range

Question: Does linear home range size differ in two distinct river reaches (Reach 1 and Reach 3)?

Hypothesis: Due to the increase in river productivity (predicted by both the RCC and observed by the SRWMD (Hornsby et al., 2000), I predict alligator snapping turtles in Reach 3 will exhibit smaller home ranges than turtles in Reach 1.

**Prevalence of Ingested Fish Hooks**

Question: Is the impact and threat to turtles from non commercial fisheries (e.g. bush hooks) different in different reaches.

Hypothesis: I predict that the prevalence of ingested fish hooks will be higher in the site with a higher number of bush hooks.

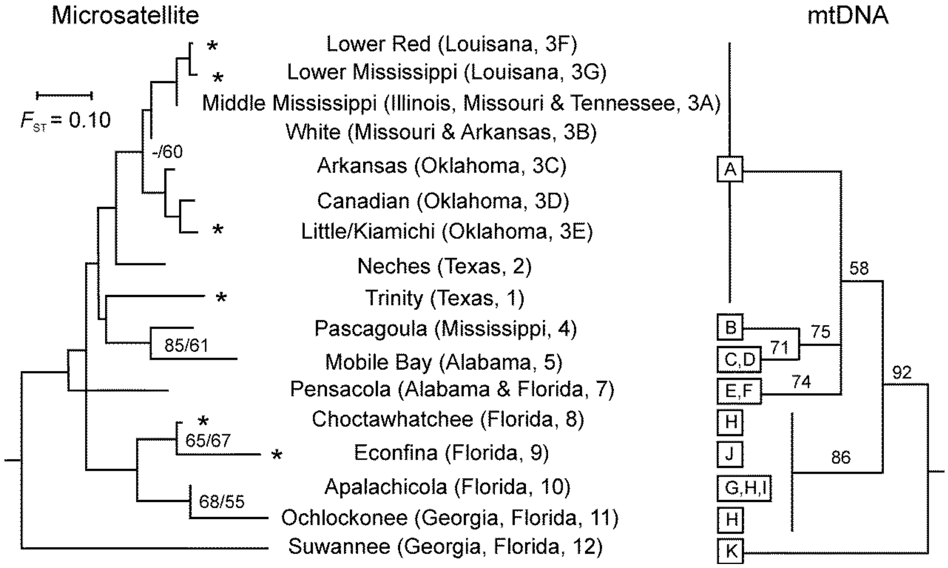


Figure 1-1. Genetic structure of *Macrochelys* showing both nuclear and mitochondrial genetic variation among drainages. Used with permission from the authors (Echelle et al., 2010).

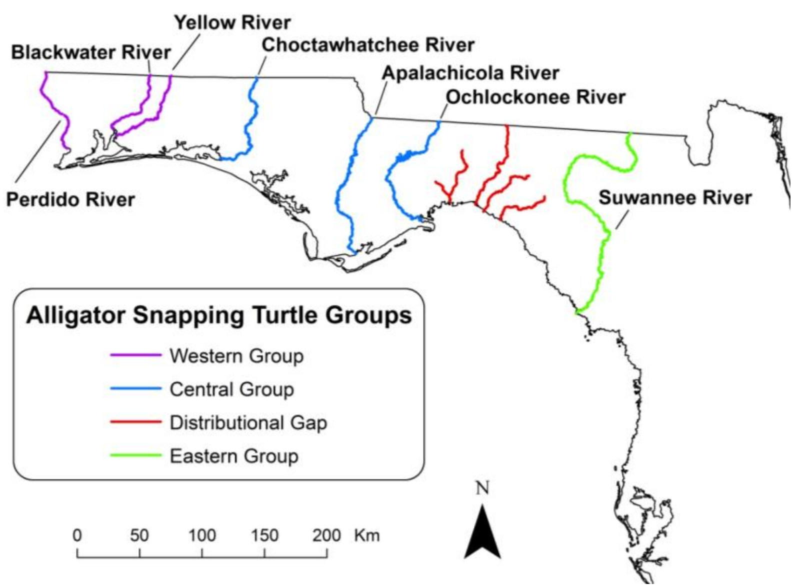


Figure 1-2. Map of distributional gap within the range of *Macrochelys*. The distributional gap is made up of small coastal rivers including: the St. Marks, Aucilla, Ecofina, Fenhollaway, and Steinhatchee Rivers.

Figure 1-3. Photograph of the open mouth of an adult *Macrochelys* (top to bottom) showing the nostrils, upper jaw, modified wormlike tongue, and lower jaw. Photo courtesy of Travis Thomas.

# CHAPTER 2
# METHODS

## Study Site

The Suwannee River is a major river system of Florida and southern Georgia that flows 378 km (235 miles) from the Okefenokee Swamp in southeastern Georgia to the Gulf of Mexico in Florida (Figure 2-1). The Suwannee River experiences longitudinal changes in water chemistry from the headwaters to the mouth (Ceryak et al., 1983) that led the Suwannee River Water Management District (SRWMD) to divide the river into 6 distinct ecological reaches: Upper River Blackwater, Cody Scarp Transitional, Middle River Calcareous, Lower River Calcareous, Tidal Riverine, and Estuarine (Hornsby et al. 2000; Figure 2-2). These reaches are characterized by their chemical and ecological features, including differing levels of biological productivity.

Reach 1 (Upper River Blackwater Reach; Figure 2-3) is characterized by deeply incised limestone banks with a mostly shallow < 1m channel. The width of the river varies from ca. 30–49 m with some shoals exposed along the river. The river in Reach 1 is a typical low-nutrient acidic blackwater stream.

Reach 2 (Cody Scarp Transitional Reach; Figure 2-4) has moderately incised limestone banks; however, the channel widens to ca. 40–80 m in width. The channel is still somewhat shallow with depths averaging ca. 1–2 m with numerous sandy and rocky shoals along the river. Reach 2 experiences an increase in nutrients and biological productivity, and this reach includes the confluences of two tributaries: the Alapaha and the Withlacoochee Rivers. The Cody Scarp is a steep face that constitutes the most prominent topographic feature in the state; it divides the Northern Highlands and Gulf

Coastal Lowlands physiographic regions. The Suwannee River is the only major stream that does not go underground while crossing the Cody Scarp (Raulston et al. 1998).

Reach 3 (Middle River Calcareous Reach; Figure 2-5) has higher flows and a larger floodplain. The river is significantly larger with deep pools and a wider channel of ca. 80–100 m or more. Some limestone outcrops are still visible. Major springs are fairly common within this reach. This reach crosses the Central Florida Ridges and Uplands subregion and the Gulf Coast Flatwoods subregion.

Reach 4 (Lower River Calcareous Reach; Figure 2-6) begins at the Santa Fe River confluence and lies entirely within the Gulf Coast Flatwoods subregion. The river channel is 6−18 m deep and 122−152 m wide with coarse sand and exposed limestone (Fig. 8). Shoals are absent, and major springs are found throughout the floodplain.

Reach 5 (Tidal River Reach; Figure 2-7) begins at the town of Fanning Springs and also lies entirely within the Gulf Coast Flatwoods subregion. The river channel is 245−305 m wide and surrounded by tidal freshwater marsh. The deep channel is made up of substrates such as limestone, coarse sand, and sandy mud. Two major springs, Fanning and Manatee, are present. Tidal variation is evident, particularly during low-flow conditions, and normally extends ca. 43 km upstream from the mouth.

Reach 6 (Estuary; Figure 2-8) has variable salinity and extends ca. 16 km upstream from the mouth. About 10 km before it reaches the Gulf, the Suwannee branches into West Pass and East Pass, which are up to 6 m deep and flow through a broad delta area.

## Sampling

The Suwannee River was divided into 5 km sections from White Springs to the Gulf of Mexico. Two sections in each of the six distinct ecological reaches were randomly selected as survey sites (Figure 2-9). Alligator snapping turtles were trapped using custom single-funnel 4-ft (122 cm) diameter fiberglass hoop net traps with #36 twine and 1 7/8" (4.76 cm) square mesh. Typically, 12 traps were set at each site; however, on a few occasions, inclement weather and water level extremes prevented the full complement of traps from being set. Traps were baited with fresh-cut or fresh-ground fish obtained from local fish markets and our trap by catch, and consisted of a variety of different species such as Florida gar (*Lepisosteus platyrhincus*), red snapper (*Lutjanus campechanus*), American gizzard shad (*Dorosoma cepedianum*), bowfin (*Amia calva*), striped mullet (*Mugil cephalus*), grass carp (*Ctenopharyngodon idella*), gulf flounder (*Paralichthy albigutta*), and triggerfish (*Balistes sp*). In order to effectively sample for population data, traps were dispersed throughout each site. Traps were not always set upstream from fallen trees, log jams, and undercut banks as suggested by Moler, 1996; Jensen and Birkhead, 2004. Instead, traps were set from overhanging branches, roots, or rocks in depths of 0.9– 2.7m (2-6 ft) in moderate current and with the funnel opening facing downstream. The two front hoops were always sitting on the bottom and traps were parallel to the bank with current moving directly through the throat of the trap (Figure 2-10). In the estuary, modified traps were made by attaching two traps together at the back with cable ties so that funnel openings would be facing both upstream and downstream directions (Figure 2-11). This allowed traps to function in shifting currents. Due to the lack of hanging branches in the estuary, we hammered 3 inch polyvinyl chloride (PVC) pipe into the substrate to which traps were attached. Traps were set in the afternoon and checked the next morning.

All captured *Macrochelys* were measured for straight midline carapace length (CL), carapace width (CW), maximum head width (HW), plastron length (PL), precloacal tail length (PCL), and postcloacal tail length (TL) (Figure 2-12). Straight line measurements (CL, CW, HW, PL) were taken to the nearest 1mm with 95 cm Haglof™ aluminum tree calipers. The remaining measurements (PCL, TL) were taken with a nylon measuring tape. Mass was taken to the nearest 100g with a 10 kg or 20 kg Pesola™ scale, and for large turtles, mass was taken to the nearest 500g with a100 kg Pelouze™ scale (Figure 2-13). Sex was determined by size and precloacal tail length. Generally, turtles with a CL> 370 mm and a PTL> 115 mm were considered males and turtles with CL >330 mm and a PTL< 115 were considered females (Dobie, 1971). When available, radiographs were obtained using an Eklin™ Mark III digital radiograph machine and a MinXRay™ generator. Turtles were placed in dorsal recumbency on a 13” x 11” plate and a ventral-dorsal view was captured. For larger turtles, multiple images were taken until the desired area was investigated. Radiographs were used to examine for the presence of ingested fishing hooks within the gastrointestinal tract. All turtles were marked by drilling combinations of marginal scutes (Cagle, 1952) and inserted with Biomark™ HPT12 (12.5mm) passive integrated transponder (PIT) tag in the ventrolateral tail muscle (Trauth et al. 1998; Figure 2-14). These are approved marking techniques for turtles (Herpetological Animal Care and Use Committee 2004). Turtles were photographed, and at least one turtle from each captured locality was photo-vouchered at the Florida Museum of Natural History (FLMNH). After measuring and marking was completed, all turtles were returned to their capture location within 3-4 hours of removal from trap.

## Ultrasonic Telemetry

To determine if home range varied between different reaches, 18 turtles were equipped with ultrasonic telemetry tags (Sonotronics™ CT-05-48-E; CT-82-2-E) in Reach 3 (n=11) and Reach 1 (n=7). Transmitters were attached by drilling holes in the posterior marginals and using plastic or metal cable ties and marine epoxy to secure to the carapace (Figure 2-15). All turtles were located with a manual receiver (Sonotronics™ USR-08), and typically found by trolling with a towable hydrophone (Sonotronics™ TH-2). Once turtles were detected, I used a directional hydrophone (Sonotronics™ DH-4) to triangulate exact locations. Turtles were located weekly at each site from December 2012–June 2013. *Marcochelys* are thought to be nocturnal; therefore, in order to provide a more realistic depiction of home range, turtles were additionally located at night in each site twice per month. Upon locating a turtle, locations were marked with a GPS coordinate using a Garmin™ GPSmap 76Cx (location error ~4 m). Location data was then imported into GIS using Environmental Systems Research Institute (ESRI) ArcGIS 10 software.

## Habitat Mapping

In 2013, a 15-km sonar mapping survey was conducted in each telemetry site (Reach 1 and Reach 3) on the Suwannee River using side-scan sonar (SSS) (Humminbird™ 998c Side Imaging system). Side-scan sonar transmits and receives reflected acoustic signals that produce a two-dimensional image of the underwater landscape (Fish and Carr, 1990). I recorded images of the river bottom with associated geographic coordinates. Sonar images were georeferenced and rectified to create a continuous, instream map of each telemetry site using methods described in Kaeser and Litts (2008, 2010). Sonar maps were used with telemetry location data to help identify subsurface habitat used by turtles.

## Bush Hook Surveys

Bush hooks are a known source of ingestion of fish hooks by *Macrochelys*, and to determine the abundance of available hooks, two surveys for bush hooks were conducted in Reach 1 and Reach 3. Bush hooks were surveyed by floating a 5-km section of river along each side of the river and counting the number of hanging lines with baited and non-baited hooks.

## Data Analyses

### Turtle Relative Abundance and Density

Capture per Unit Effort (CPUE) can be used to approximate relative abundance. CPUE for a given sampling event was determined by dividing the number of individuals captured by the total number of trap nights or effort during the sampling event (1 trap set over 1 night = 1 trap night). Because CPUE is a ratio and does not meet assumptions of parametric analyses, I used program R to perform a non-parametric analysis of variance (Kruskal-Wallis test) to determine if CPUE was equal in each reach.

In addition, Program MARK (version 2.0) was used to estimate population abundance in each ecological reach. Adult capture-recapture data was organized in a matrix and imported into Program MARK. I estimated capture-recapture probability and abundance for each reach by treating reaches as groups in Program MARK. I fit two models. The first model assumed capture-recapture probability differed by reach, and the second model assumed capture-recapture probability were the same among reaches. A closed model was used because telemetry data suggests *Macrochelys* have limited linear home ranges within the Suwannee River. We assumed no immigration or emigration during this short study period.

**Turtle Population Structure**

A chi-square test was used to determine if sex ratio differed significantly from 1:1. Population structure was determined for the entire river and for each ecological reach. A Mann-Whitney Rank Sum was used to compare morphological data between sexes. A sexual dimorphism index (SDI, Equation 1) was used to compare mean sizes between sexes (Lovich and Gibbons, 1992).

$$SDI = -\left(\frac{\bar{x}_{larger}}{\bar{x}_{smaller}}\right) + 1 \qquad \text{Eq. 2-1}$$

ANOVA was used to compare CL, CW, HW, PL, and mass among reaches. Separate ANOVAs were conducted for males and females for each response variable. Data for all analyses were inspected to verify the assumptions of parametric analyses were satisfied and data transformations were applied when necessary. All analyses were conducted in Program R (R Development Core Team, 2012).

**Turtle Home Range**

Telemetry was used to locate turtles in Reach 1 and Reach 3. To determine if home range varied between these two reaches, I measured the linear distance traveled between the farthest upstream and downstream locations for 15 individual turtles. To help minimize error, each turtle was analyzed independently. All measurements were analyzed in ArcGIS 10 (ESRI, 2011). A t-test was used to determine if linear home range differed between reach and sex. All statistical analyses were conducted in Program R (R Development Core Team, 2012).

## Prevalence of Ingested Fishhooks

In order to determine if the abundance of available fishhooks in two different reaches had an effect on the prevalence of turtles with ingested hooks, data were examine visually.

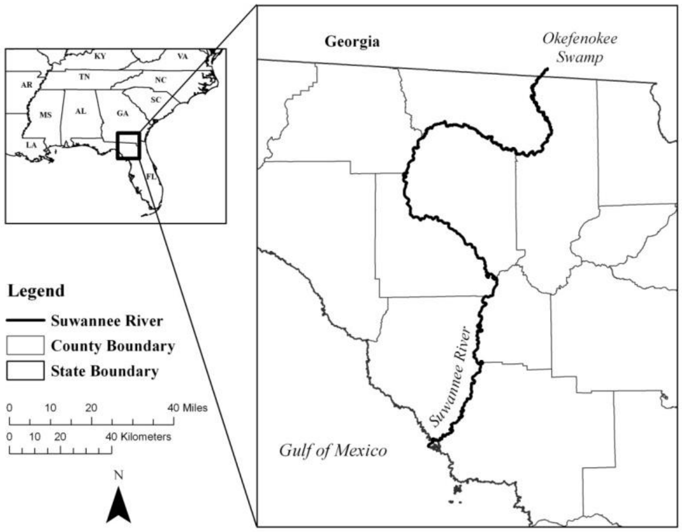


Figure 2-1. Map of the Suwannee River.

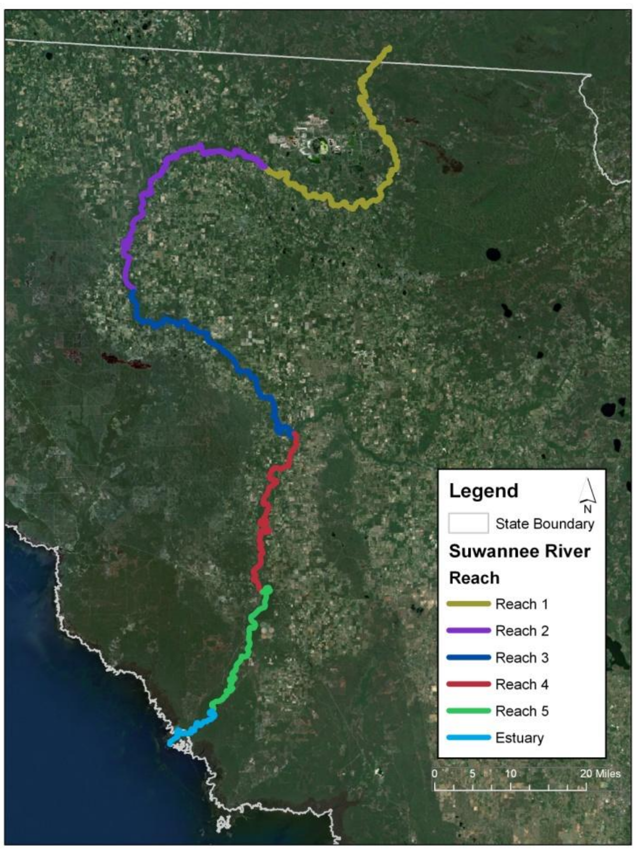


Figure 2-2. Map of the Suwannee River showing 6 ecological reaches.

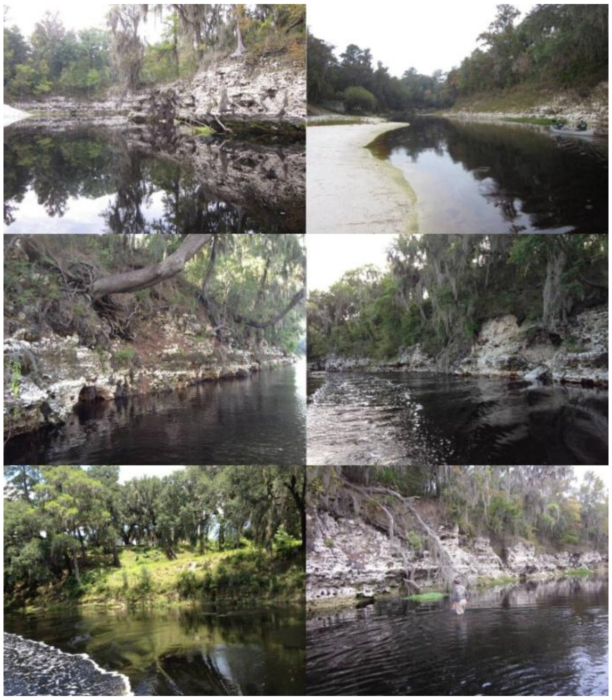

Figure 2-3. Photographs of Reach 1 showing high limestone banks and a narrow river channel. Photos courtesy of Travis Thomas and Kevin Enge.

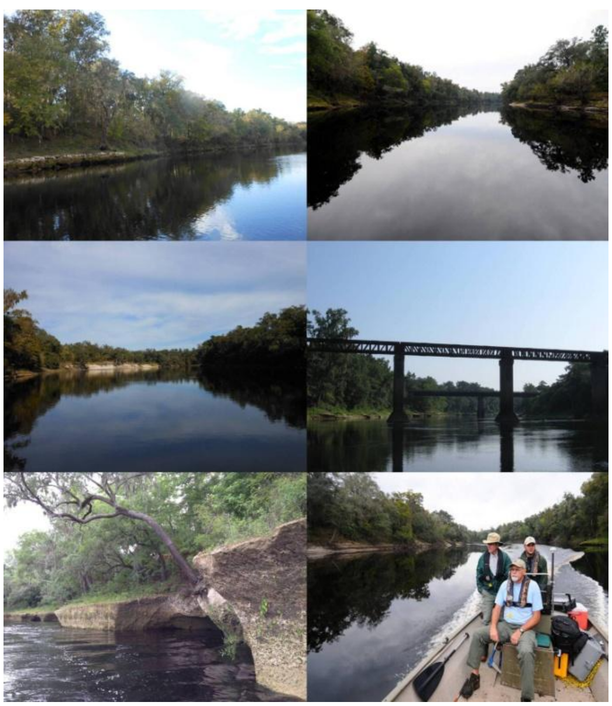

Figure 2-4. Photographs of Reach 2 showing an increase in channel width and a reduction of limestone banks. Photos courtesy of Travis Thomas, Kevin Enge and Tim Donovan.

Figure 2-5. Photographs of Reach 3 showing a wider channel and spring water flowing into the channel. Limestone banks are less frequent. Photos courtesy of Travis Thomas and Kevin Enge.

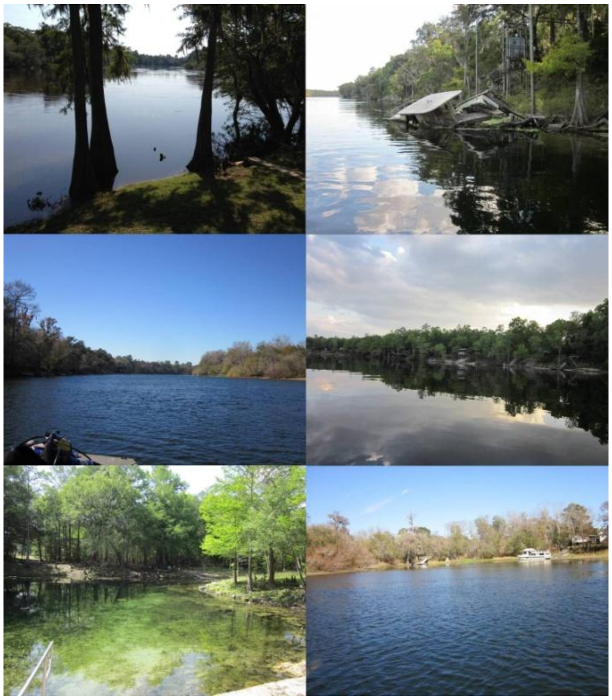

Figure 2-6. Photographs of Reach 4 showing wide channel with major spring input. Photos courtesy of Travis Thomas and Kevin Enge.

Figure 2-7. Photographs of Reach 5 showing very wide channel, emergent vegetation, and expansive flood plain. Photos courtesy of Travis Thomas and Kevin Enge.

Figure 2-8. Photographs of Reach 6 (estuary) showing very wide channel, tidal salt marsh, and floodplain creek. Photos courtesy of Travis Thomas and Kevin Enge.

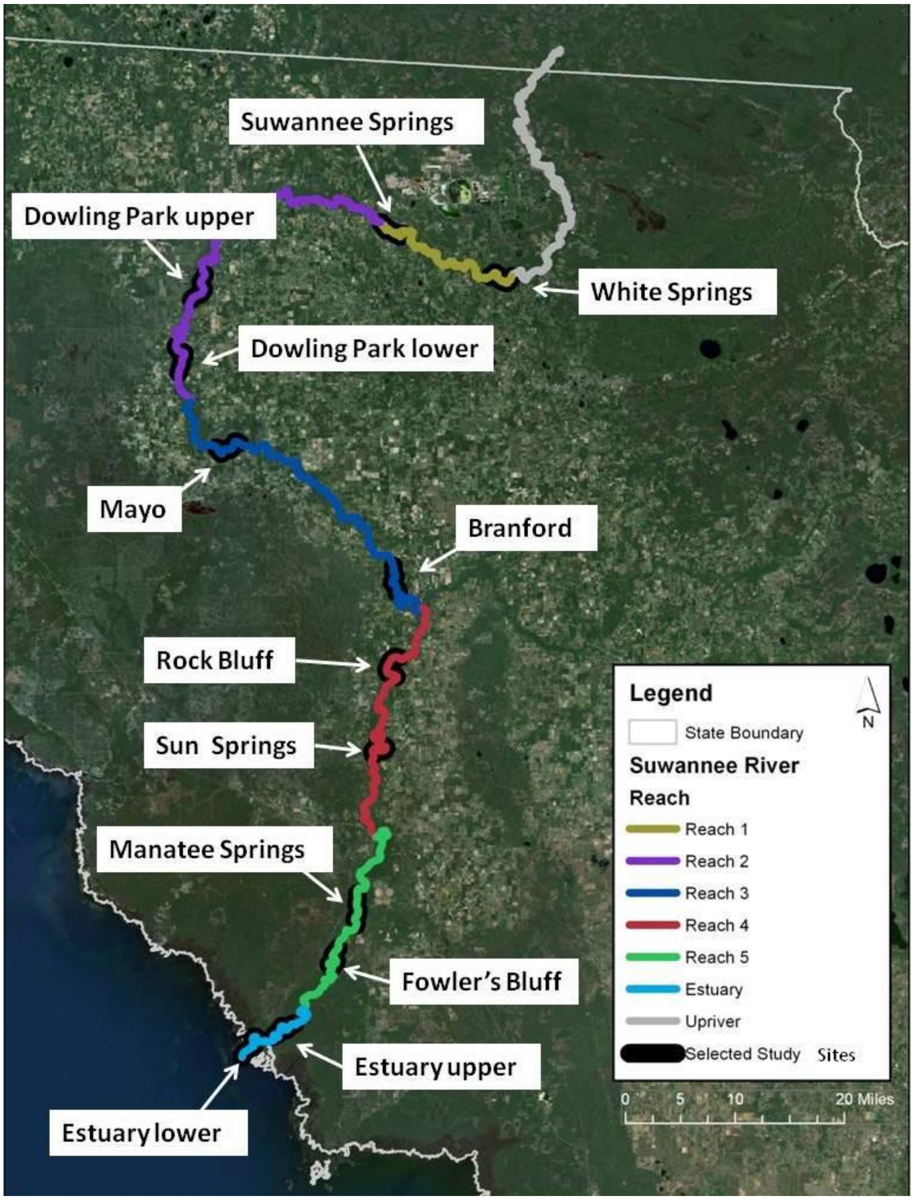


Figure 2-9. Map of the Suwannee River showing 2 randomly selected study sites within each reach.

Figure 2-10. Photographs showing traps set during this study. Photos courtesy of Travis Thomas, Kevin Enge, and Tim Donovan.


Figure 2-11. Photograph showing modified trapping technique utilized within the estuary. Photo courtesy of Travis Thomas and Kevin Enge.

Figure 2-12. Photographs of morphologic measurements being taken. Photos courtesy of Travis Thomas and Kevin Enge.

Figure 2-13. Photographs showing mass of adult (above) and immature (below) turtles being taken. Photos courtesy of Travis Thomas and Kevin Enge.

Figure 2-14. Photograph showing the insertion of a Passive Integrated Transponder (PIT) tag into the ventral tail of a *Macrochelys* captured in the Suwannee River. Photo courtesy of Travis Thomas and Kevin Enge.

Figure 2-15. Photograph showing the attachment of an ultrasonic transmitter to the posterior carapace of a *Macrochelys* captured in the Suwannee River. Photo courtesy of Travis Thomas and Kevin Enge.

# CHAPTER 3
# RESULTS

## Turtle Relative Abundance and Density

In all, 132 individual *Macrochelys* were captured (161 total captures and 29 recaptures) within the Suwannee River in 742 trap nights (CPUE=0.217). One turtle was opportunistically hand captured and 5 turtles were captured outside of the 5-km sampling sites; however, these turtles were not included for capture-recapture or CPUE analysis. Turtles were captured in 11 of 12 sites and 6 of 6 ecological reaches (Table 3-1). The only site that did not produce a capture was the lower estuary.

When data were subdivided according to reach, capture per unit effort (CPUE) varied significantly among reaches (Kruskal-Wallis $F_{5,57} = 21.8935$, $p < 0.001$). Multiple pairwise comparisons revealed Reach 6 had significantly lower CPUE than Reaches 2, 3, and 4 (Figure 3-1). Although not significantly different, Reaches 1 and 5 had an observably lower CPUE than reaches 2, 3, and 4.

The model assuming different capture-recapture by reach did not converged for several reaches due to the low number of recaptures. Perimeter estimates from the second model which assumed a common capture-recapture probability among reaches produced reasonable estimates of capture probability and recapture probability as well as abundance. Abundance estimates from this model strongly agreed with CPUE results and showed different abundances among different reaches. Reach 1 and 5 had relatively lower estimated abundance than Reaches 2, 3, and 4 (Table 3-2; Figure 3-2).

## Turtle Population Structure

The total sample consisted of 28 (21.2%) immature individuals, 23 (17.4%) adult females, and 81 (61.4%) adult males. For the entire river, sex ratios differed significantly from 1:1 ($\chi^2$=32.3, $p < 0.0001$) and was 3.5:1 in favor of males. Sex ratio varied among reaches and were significantly biased towards males in Reaches 2, 3, and 4; however, sex ratio did not differ significantly from 1:1 in Reaches 1 and 5 (Table 3-3). All size classes between 152 mm and 650 mm were represented. The heaviest individual captured was a turtle with a mass of 57.15 kg, while the lowest mass recorded was a 500-g individual. As expected, adult males were significantly larger than adult females for CL, CW, PL, HW, and mass, and sexual dimorphism indices were -0.33 (CL), -0.28 (CW), -0.28 (PL), -0.32 (HW), and -1.29 (mass) (Table3-4).

The entire sample exhibited a right skew toward larger (CL) individuals (Figure 3-3), but when data are examined by reach, it is obvious that larger individuals are observed more frequently in Reaches 2, 3, and 4 (Figure 3-4). In total, 33 out of 81 (41%) adult males weighed 45 kg (100 lbs) or greater. The number of 45-kg males observed varied dramatically among reach, with the greatest number of large males observed in Reaches 2, 3, and 4 (Figure 3-5).

Adult males were significantly larger in CL, CW, PL, HW, and mass within the middle river, Reaches 2, 3, and 4 (Figure 3-6). Adult females were not significantly different in CL and mass among reaches, but significance was detected in PL in Reach 2 and CW in Reach 5 (Figure 3-6).

## Turtle Home Range

Sixteen of the18 turtles were located after release. In Reach 3, 2 turtles were never located, and 1 turtle was lost after a month of tracking and was excluded from analysis. Linear home range did not vary significantly between reach ($t$=1.1723, $p$=0.2681). Turtles in Reach 3 had a mean linear home range of 2,013 m ± 243 m, and turtles in Reach 1 had a mean linear home range of 1,533 m ± 329 m. Overall, adult males exhibited a slightly larger mean linear home range (1,896 m ± 252 m) than females (1,615 m ± 301 m); however, there was a no evidence that these were statistically different ($t= -0.7174$, $p=0.4947$). Although no significance was detected, several interesting behaviors were observed. Turtles at each site were tracked repeatedly moving back and forth between the floodplain and the river channel with no aquatic corridor (i.e. overland movement). Telemetry conducted at night found turtles were mostly active, whereas day time tracking found turtles to be inactive and under some type of cover or refuge. Sonar mapping revealed turtles used different habitat as water levels fluctuated. During high water levels turtles were located in floodplains and were more likely to be located under trees and among roots systems associated with trees (Figure 3-7). During periods of lower water levels turtles were found using undercut banks, large rocks, and wood debris within the channel of the river (Figure 3-8). A large male turtle was frequently located in a spring and spring run in Reach 3 (Figure 3-9).

## Prevalence of Ingested Fish Hooks

Two separate surveys for bush hooks were conducted in June of 2013 and September of 2013 in Reach 1 and Branford Reach 3. During the June sample, 7 bush hooks were observed in Reach 1 and 34 bush hooks were found in Reach 3. In September, 4 bush hooks in Reach 1 were observed and 24 in Reach 3; however, high water levels made lines difficult to detect. Overall, Reach 3 averaged more bush hooks than Reach 1. Seven turtles were radiographed in Reach 1 and 12 turtles were radiographed in Reach 3 for the presence of ingested fishing hooks. Radiographs revealed 3 turtles, all in Reach 3, had fishing hooks within the gastrointestinal tract and one turtle possessed 3 fishing hooks (Figure 3-10). Results for the bush hook survey are shown in Figure 3-11, and although more data are needed, preliminary results suggest that a higher prevalence of bush hooks leads to higher fish hook ingestion by turtles.

Table 3-1. Captures, trap nights, and mean Capture Per Unit Effort (CPUE) by reach and site.

| Reach | Site | Sessions | Trap Nights | Captures | CPUE |
|---|---|---|---|---|---|
| 1 | White Springs | 5 | 52 | 7 | 0.183 |
| | Suwannee Springs | 5 | 60 | 12 | 0.217 |
| | | 10 | 112 | 19 | 0.200 |
| 2 | Dowling Park up | 5 | 55 | 23 | 0.383 |
| | Dowling Park down | 6 | 68 | 14 | 0.208 |
| | | 11 | 123 | 37 | 0.288 |
| 3 | Mayo | 5 | 60 | 6 | 0.100 |
| | Branford | 6 | 64 | 24 | 0.361 |
| | | 11 | 124 | 30 | 0.242 |
| 4 | Rock Bluff | 5 | 60 | 29 | 0.483 |
| | Sun Springs | 6 | 72 | 17 | 0.235 |
| | | 11 | 132 | 46 | 0.348 |
| 5 | Manatee Springs | 5 | 60 | 14 | 0.233 |
| | Fowler's Bluff | 5 | 59 | 8 | 0.133 |
| | | 10 | 119 | 22 | 0.183 |
| 6 | Estuary up | 5 | 60 | 1 | 0.017 |
| | Estuary down | 5 | 60 | 0 | 0.000 |
| | | 10 | 120 | 1 | 0.008 |

Table 3-2. Sex ratios for the entire sample and by reach. No adults were captured in Reach 6.

| Reach | Male | Female | chi-squared | p-value |
|---|---|---|---|---|
| 1 | 7 | 5 | 0.3 | 0.563 |
| 2 | 26 | 4 | 16.1 | < 0.005 |
| 3 | 18 | 4 | 8.9 | < 0.005 |
| 4 | 21 | 7 | 7 | 0.008 |
| 5 | 9 | 3 | 3 | 0.083 |
| 6 | - | - | - | - |
| Total | 81 | 23 | 32.3 | < 0.001 |

Table 3-3. Morphological measurements and masses of 132 *Macrochelys* captured in the Suwannee River. Data consists of mean, standard deviation, and minimum-maximum. Body sizes were compared using a Mann-Whitney Rank Sum Test and a sexual dimorphism index (Lovich and Gibbons, 1992).

| | Immature (n = 28) | Female (n = 23) | Male (n = 81) | *P* | SDI |
|---|---|---|---|---|---|
| | 243.46 | 415 | 550.3 | | |
| CL (mm) | 63.8 | 33.1 | 62.9 | < 0.001 | -0.33 |
| | (152 – 325) | (344 – 470) | (431 – 650) | | |
| | 214.78 | 356.9 | 457.1 | | |
| CW (mm) | 57.1 | 29.7 | 46.64 | < 0.001 | -0.28 |
| | (134 – 292) | (295 – 407) | (363 – 524) | | |
| | 186.82 | 312.9 | 399 | | |
| PL (mm) | 49.1 | 27.5 | 38.2 | < 0.001 | -0.28 |
| | (116 – 261) | (253 – 367) | (325 – 458) | | |
| | 81.64 | 133.5 | 176.4 | | |
| HW (mm) | 19.7 | 12 | 20.4 | < 0.001 | -0.32 |
| | (53 – 109) | (107 – 152) | (138 – 222) | | |
| | 4.08 | 16.46 | 37.75 | | |
| mass (kg) | 2.8 | 3.5 | 11.3 | < 0.001 | -1.29 |
| | (0.5 – 8.7) | (10 – 22.5) | (18 – 57.1) | | |

Table 3-4. Mean linear home range of *Macrochelys* with standard error for sex and reach.

| Sex | n | Mean linear home range (m) |
|---|---|---|
| Male | 11 | 1896 ± 252 |
| Female | 4 | 1615 ± 301 |
| Reach | | |
| Reach 1 | 6 | 1533 ± 329 |
| Reach 3 | 9 | 2013 ± 243 |

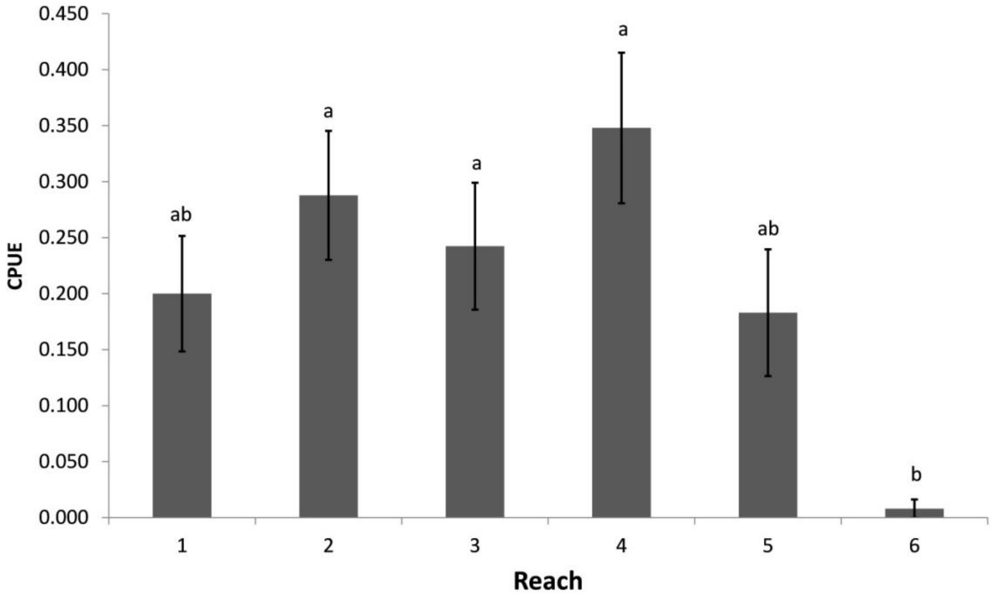


Figure 3-1. Catch Per Unit Effort (CPUE) by reach with standard error. Letters indicate significance. Reach 1 and 5 had relatively lower estimated abundance than Reaches 2, 3, and 4.

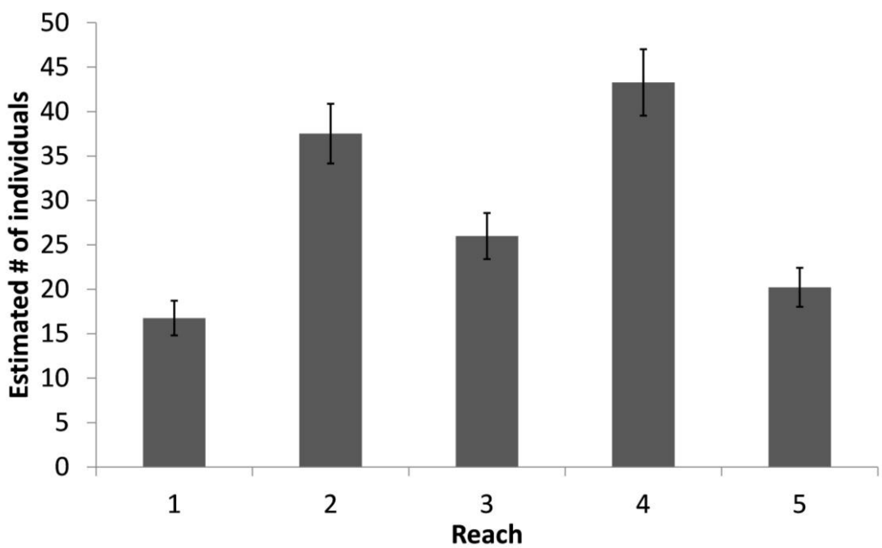


Figure 3-2. Estimation of adult turtle density by reach from a closed population model with standard error. Estimate is for 10km of river in each reach.

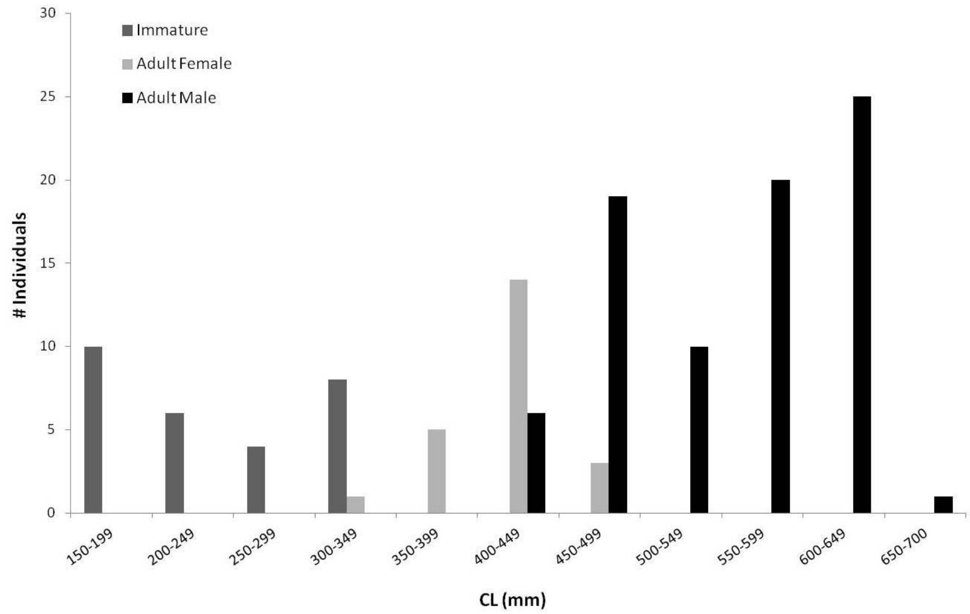


Figure 3-3. Size distribution for *Macrochelys* captured in the Suwannee River from 2011–2013.

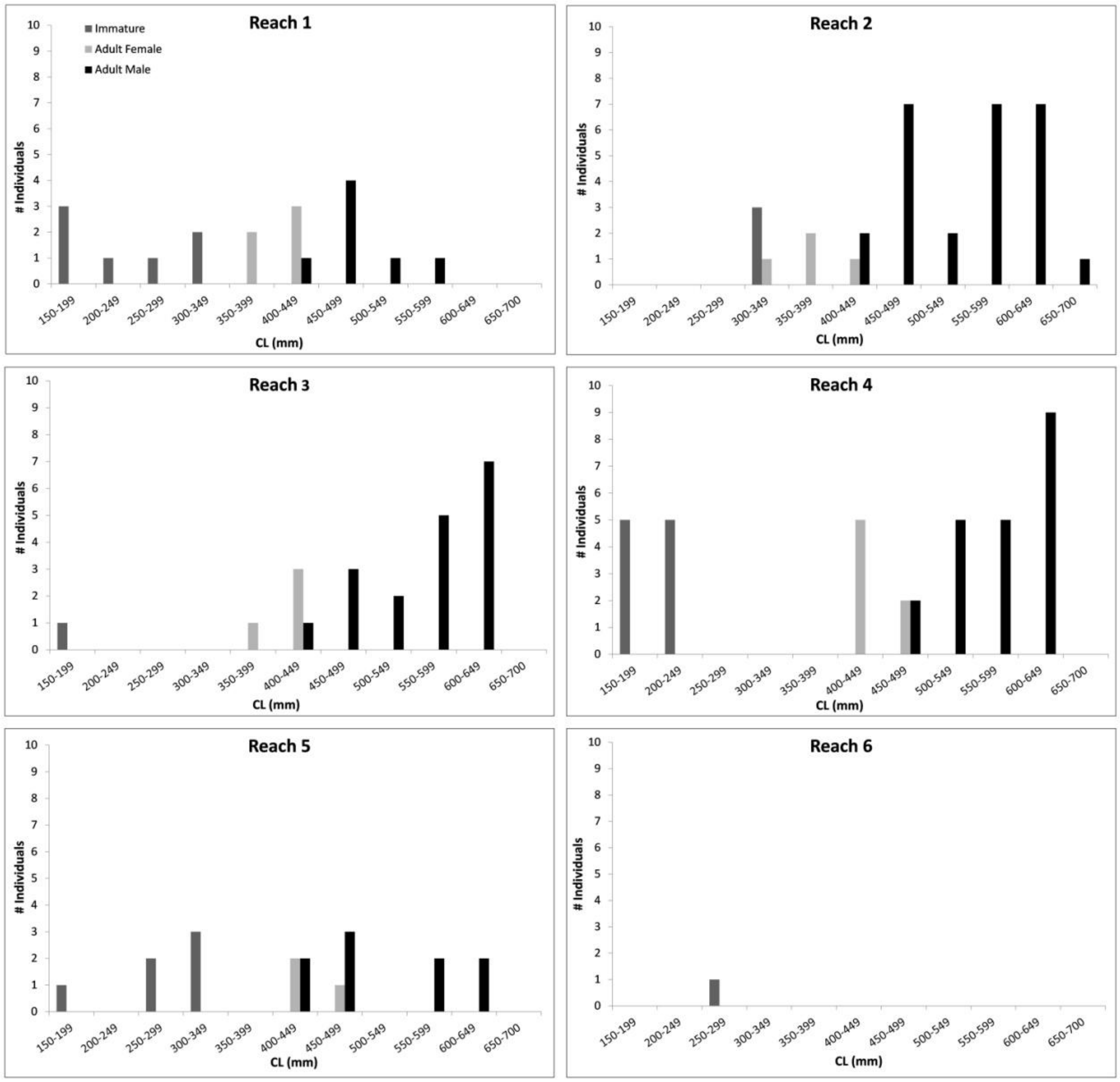


Figure 3-4. Size distribution for *Macrochelys* captured in the Suwannee River by reach from 2011–2013.

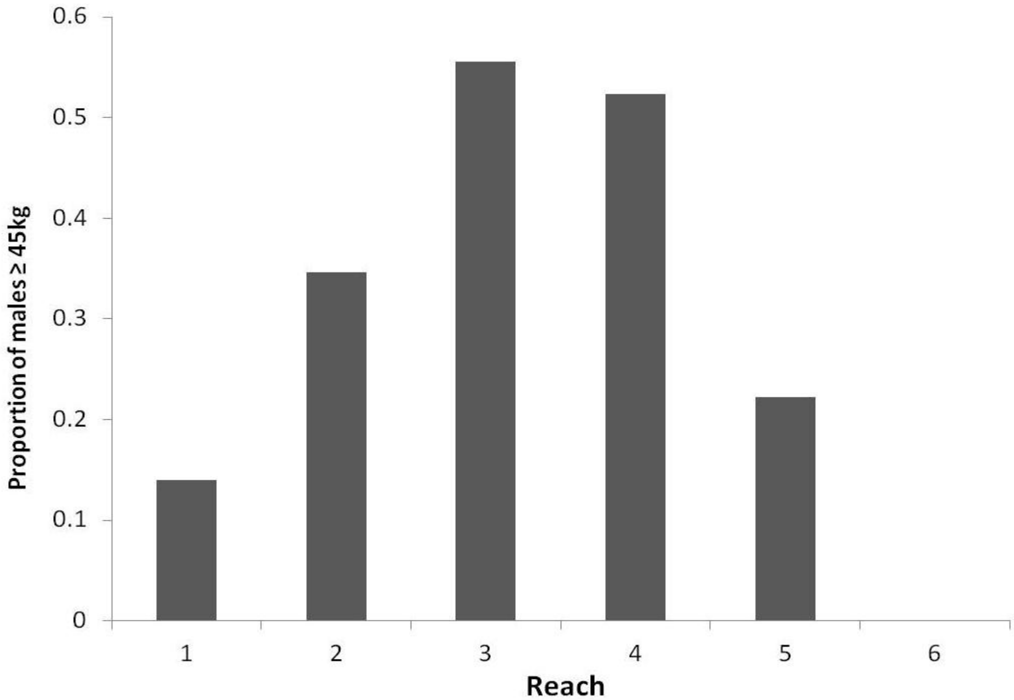


Figure 3-5. Frequencies of captured *Macrochelys* in the Suwannee River with mass ≥ 45 kg by reach.

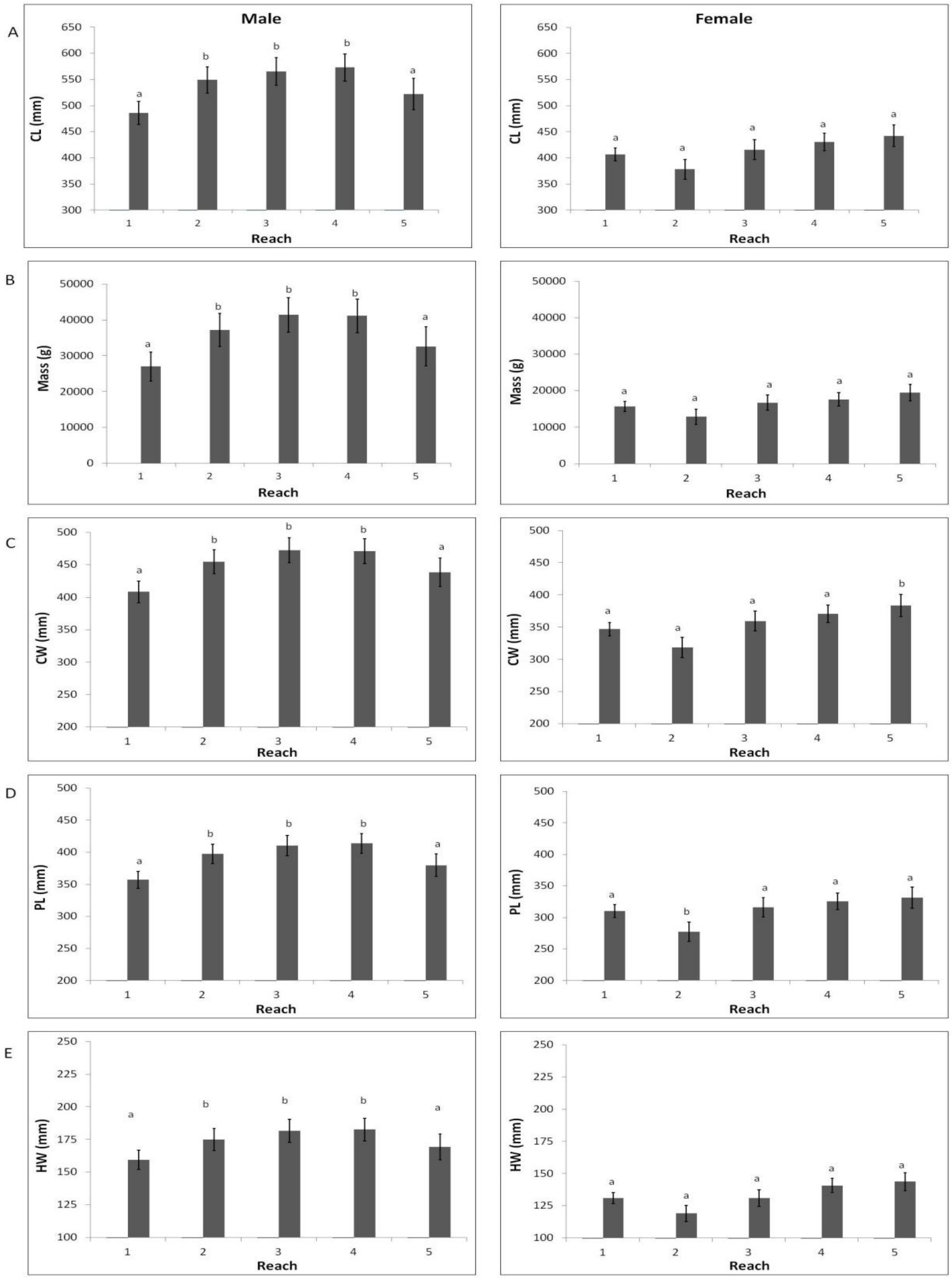


Figure 3-6. Measurements of A) carapace length, B) mass, C) carapace width, D) plastron length, and E) head width of adult male and female *Macrochelys* using ANOVA with reach as a factor. Letters indicate significance.

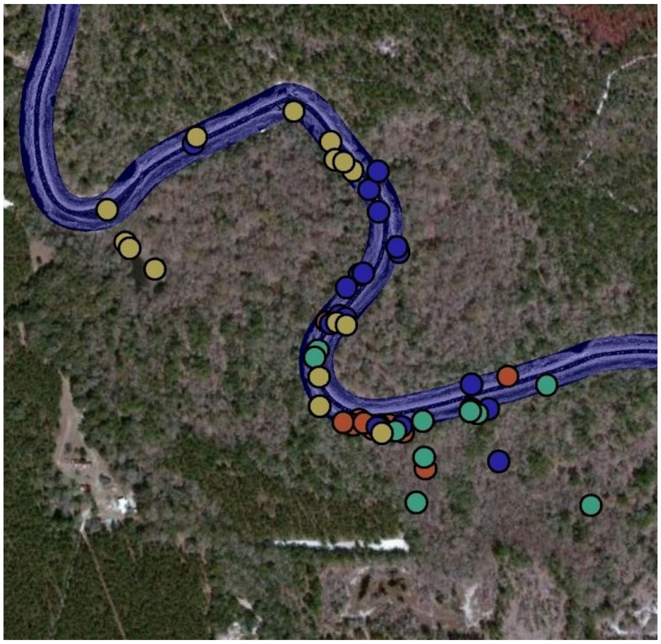

Figure 3-7. Map showing 4 turtles located within the floodplain during high water levels in Reach 1. Different colors represent different turtles.

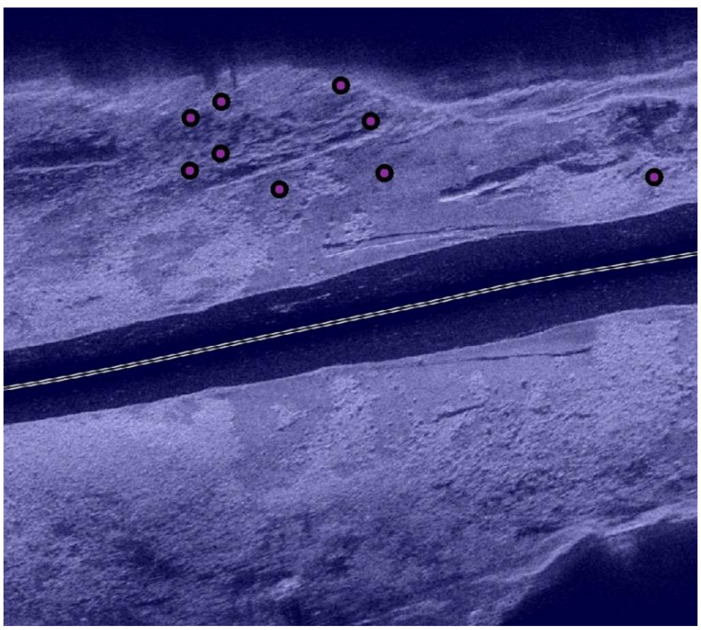

Figure 3-8. Sonar map image showing turtle #115 frequently located around a cluster of submerged woody debris.

Figure 3-9. Map showing turtle #31 frequently located in a small spring and spring run.

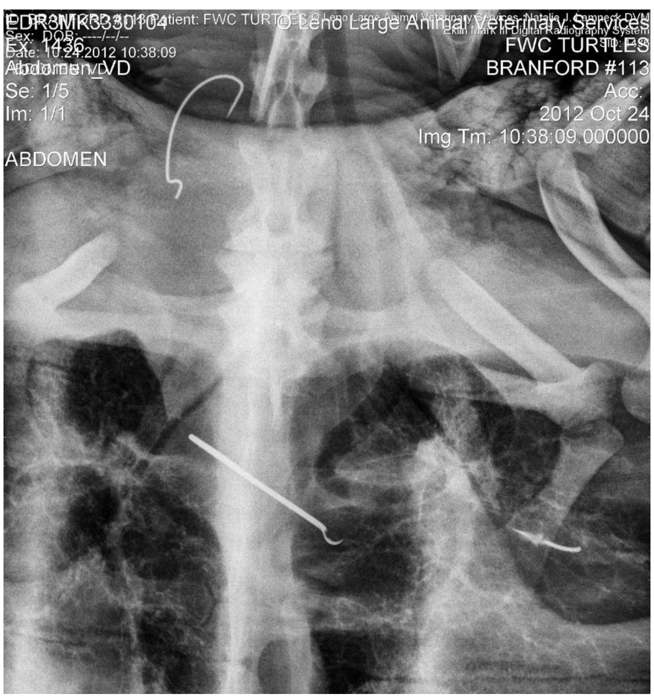


Figure 3-10. Radiograph showing 3 fishing hooks in the upper gastrointestinal tract of a *Macrochelys* from the Branford site (Reach 3).

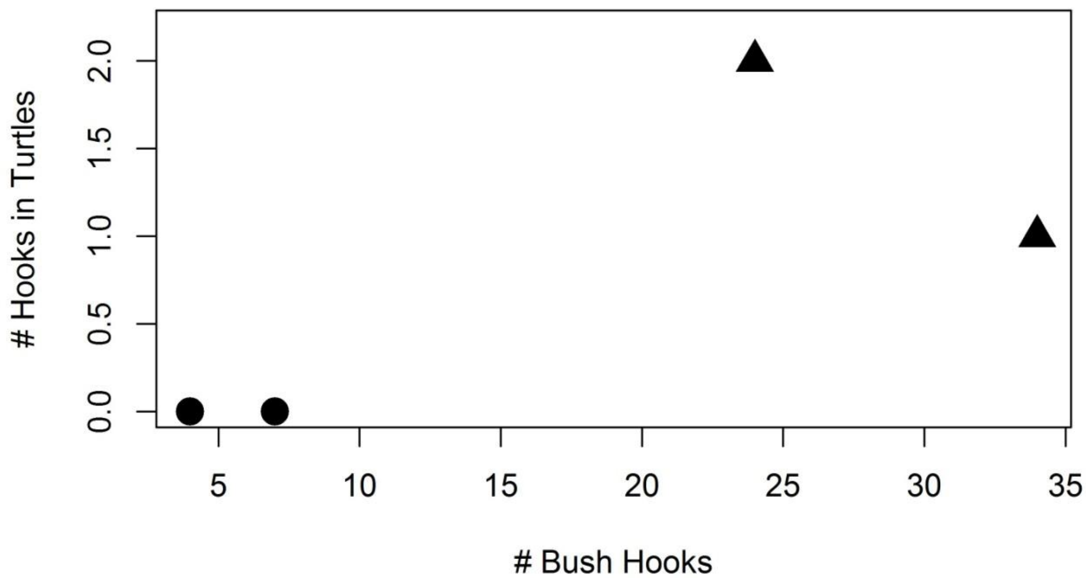


Figure 3-11. Plot showing the relationship between number of bush hooks present and ingested fish hooks found in turtles in Reach 1 (circle) and Reach 3 (triangle). Although a trend seems to emerge, more data are needed to investigate this potential threat.

# CHAPTER 4
# DISCUSSION / CONCLUSION

A previous study found *Macrochelys* to be absent within the Suwannee River in Georgia, and this was a major concern due to the Suwannee River population of *Macrochelys* being genetically unique from other populations (Jenson and Birkhead, 2003; Roman et al., 1998). Although Moler (1996) captured *Macrochelys* in the Suwannee River in Florida as part of a statewide distribution survey, questions and concerns remained regarding the status of this unique population. Data from this study show that *Macrochelys* within the Suwannee River are more numerous than previously thought.

## Hypotheses Revisited

I predicted that alligator snapping turtle abundance would increase in the middle and lower reaches relative to upper reach (Reach 1) due to differences in habitat driven by water chemistry and geomorphic riverine processes predicted by the RCC. My prediction was partially confirmed as turtle relative abundance and estimated density was lower in the upper reach and higher in the middle reaches (Reaches 2–4); however, I found reduced abundance within the lower reaches (Reaches 5 and 6). In fact, Reach 6 had the lowest relative abundance. These results were supported by capture per unit effort (CPUE) data and density estimates derived from a closed population model.

I predicted that alligator snapping turtles would exhibit smaller size classes and different population structure in the upper reach relative to the middle and lower reaches due to differing levels of productivity predicted by the RCC. Examination of reach specific population data revealed that turtles within the middle reaches (Reaches 2–4) had sex ratios skewed toward males and significantly different from 1:1. Not only were there more males within the middle reaches, but males in the middle reaches were significantly larger in size when compared to males in the upper (Reach 1) and lower reaches (Reaches 5 and 6). Females did not show this pattern, but significant differences were observed for females in PL in Reach 2 and CW in Reach 5.

I predicted that alligator snapping turtles would exhibit smaller home ranges in Reach 3 than turtles in Reach 1 due increases in river productivity from upstream to downstream. This was not confirmed. No significant difference was detected in linear home ranges between reaches.

I predicted the prevalence of ingested fish hooks would be higher in the reach with the most observed bush hooks. We observed more bush hooks set in Reach 3 than Reach 1, and radiographs revealed that turtles captured in Reach 3 ingested fish hooks, whereas turtles captured in Reach 1 had not.

## Discussion

Overall, the mean CPUE for this study was 0.22, which is comparable to other studies conducted in Florida, Arkansas, and Oklahoma (Moler, 1996; Wagner et al., 1996; Trauth et al., 1998; Riedle et al., 2008). Jensen and Birkhead (2003) found a slightly lower CPUE (0.20) during a survey of rivers in Georgia, but in 53 trap nights, no *Macrochelys* was captured in the Suwannee River; low pH and aspects of commercial harvest were possible explanations (Jensen and Birkhead, 2003). The authors alternatively suggested that *Macrochelys* may not be common in the easternmost part of its range (Jensen and Birkhead, 2003), but data from my study cast doubt on that hypothesis. Capture per unit effort data from my study revealed that relative abundance is low in the upper and lower reaches (Reaches 1 and 5) of the Suwannee River, whereas the middle reaches (Reaches 2, 3, and 4) have the highest relative abundance. Results from the closed population model suggested that the middle reaches (Reaches 2, 3, and 4) have the highest estimated density of turtles. The closed population model assumed no immigration or emigration, and I believed this to be appropriate because telemetry data revealed small linear home ranges (~1–2 km) in the Suwannee River. Sampling with baited traps may be biased towards adult turtles because immature individuals are more likely to lure for prey (Pritchard, 2006); therefore, I only included adult turtles in the model. The overall estimated population density was 3.5 adults/km for the entire river, though density was not equal along the river. The upper and lower reaches (Reaches 1 and 5) had the lowest estimated abundance (1.7 adults/km and 2 adults/km), whereas the middle reaches (Reaches 2, 3, and 4) had the highest estimated abundance (3.75/adults/km, 2.6 adults/km, 4.3 adults/km). The model strongly agreed with CPUE results and provides further evidence that turtle relative abundance and density are heavily influenced by river reach. Other studies estimated population densities, including juveniles, to be 28−34 turtles/km in Oklahoma streams (Riedle et al., 2008) and 18 turtles/km in an Arkansas stream that had been commercially harvested in the past (Howey and Dinkelacker, 2013). Although these studies incorporated immature individuals, even if only adults are considered, the estimates are much higher than those found in this study. One explanation could be detectability. Other studies have been restricted to smaller streams and rivers, whereas my study was conducted in a large free-flowing river. Traps are typically more effective in smaller streams because the bait scent covers a greater percentage of the area and potentially both banks; however, in a large river, coverage is reduced due to the sheer volume of water and the distance between banks.

In total, males were captured significantly more often than females and immature individuals (3.5:1 sex ratio); conversely, other studies found predominantly females (Howey and Dinkelacker 2013, Lescher et al. 2013) or equal sex ratios (Trauth et al. 1998, Jensen and Birkhead 2003, Boundy and Kennedy 2006, Riedle et al. 2008). Although our total sample was male biased, sex ratios were not significantly different from 1:1 within Reaches 1 and 5. Reaches 2–4 were extremely male biased, which skewed the entire sample. Although individuals of breeding size were captured in all reaches except Reach 6 (estuary), my data indicate that sex ratios are different along the river. *Macrochelys* has temperature-dependent sex determination, and although we did not locate any nests during this study, past studies have shown that sandy beaches and warmer nest temperatures produce more females (Ewert, 1994). Nesting habitat changes as the river makes its way downstream towards the Gulf of Mexico. There are more upland and open nesting habitats available in the upper river (Reach 1), and as the elevation decreases and floodplains become more extensive, nesting habitat becomes potentially more shaded. This pattern could explain why turtles are male biased in the middle river (reaches 2–4). However, the sex ratio within Reach 5 was not significantly different from 1:1, and this reach has nesting habitat that is very similar to the middle reaches. Therefore, differences in nesting habitat among reaches is an unlikely explanation for the unequal sex ratios found in this study. A more likely explanation for biased sex ratios in the middle reaches is that adult males, which dominate the middle reaches, may control juvenile and female populations by competitive exclusion, forcing smaller individuals into less desirable habitat. Although *Macrochelys* are occasionally found in estuarine habitat (Jackson and Ross, 1971; Ewert, 2006), my data suggest that *Macrochelys* are rare within the Suwannee estuary. This may be due to the lack of appropriate habitat and an influx of salt water. A study of the upper Suwannee River estuary found maximum salinity concentrations as high as 31 ppt (Tillis, 2000). The salinity of sea water is approximately 35 ppt.

Overall, I captured a higher proportion of large turtles than any other published study, but most large turtles were captured in the middle reaches (Reaches 2–4). Pritchard (1979) proposed that *Macrochelys* may wander upstream until they reach large sizes, but data from this study cast doubt on this hypothesis. The headwaters are far less productive and would not be ideal for optimal growth. Data from this study suggest that *Macrochelys* are most abundant and largest in the more productive sections of the river. Adult males were significantly larger than females in CL, CW, PL, HW, and mass within the middle reaches (Reaches 2–4). These data suggest that males potentially grow to larger sizes within these highly productive reaches. Females were not significantly different in CL, HW, and mass, although significant differences were detected in PL (Reach 2) and CW (Reach 5). This could potentially be due to low statistical power caused by the small female sample size. Boundy and Kenney (2006) reported the heaviest turtle captured in a study (51.4 kg) to date, and the heaviest turtle reported in my study had a larger mass (57.1 kg). Pritchard (2006) reported much heavier turtles, but many of these weights may represent estimated weights and should be interpreted with caution. As a further complication, Pritchard (2006) reports to the size of many captive animals. In captivity, *Macrochelys* readily eats and lacks normal movement patterns. This has most likely led to captive turtles being obese, and their weights are not representative of wild turtles. For example, a turtle in the Brookfield Zoo in Chicago, Illinois, grew to 66 cm CL and weighed 114 kg (Pritchard 2006), whereas an apparently healthy turtle from my study measured 65 cm CL and weighed 54.5 kg.

Studies in Georgia, Louisiana, Missouri, Arkansas, and Oklahoma found a lack of large adult turtles, which has usually been attributed to historical harvest (Wagner et al. 1996, Jensen and Birkhead 2003, Boundy and Kennedy 2006, Riedle et al. 2006; 2008, East et al. 2013, Howey and Dinkelacker 2013, Lescher et al. 2013). Harvest has been well documented in this species and has certainly played a role in declines in many populations (Pritchard, 2006). The reported rarity of *Macrochelys* in the upper reaches of the Suwannee River has also been attributed to harvest (Jensen and Birkhead, 2003; Pritchard, 2006). Many of these population parameters can potentially be explained by simple ecological stream theory. The upper Suwannee River (Reach 1) derives most of its water from direct surface runoff, and the water is acidic, high in organic material, and dark in color (Hornsby et al., 2000), which inhibits benthic and water column photosynthesis. Due to the low pH, many of the nutrients are biologically unavailable. As the river flows downstream it passes over an important geological feature known as the Cody Scarp. The Cody Scarp is a karst escarpment that divides the Northern Highlands and Gulf Coastal Lowlands physiographic regions (Hornsby et al., 2000). The Cody Scarp possesses mostly carbonate rock (limestone) near or at the surface. Upon reaching the Cody Scarp (Reach 2), the acidic water from upstream comes into contact with carbonate rock that buffers the water, resulting in an increase in pH. This increase in pH causes nutrients that were previous unavailable to become biologically available increasing invertebrate and fish resources. This increase in the potential turtle prey base could explain the dramatic increase in turtle CPUE, density, and size from Reach 1 to Reach 2. Farther downstream in Reaches 3−5, the river receives increasing amounts of water from the Floridan aquifer, which changes the water to a slightly colored, alkaline stream (Hornsby et al., 2000) and increases aquatic productivity. My data indicate that turtle density and size are the highest from downstream of the Cody Scarp to Reach 4, but turtle CPUE, density, and size decrease in Reach 5. One explanation for this is saltwater incursion. The Suwannee River experiences tidal influences within Reach 5 (Hornsby et al., 2000), and during periods of low flow, pockets of salt water have the potential to form on the river bottom. *Macrochelys* are bottom-dwelling turtles, and saltwater incursion could potentially reduce the availability of preferred habitat. While the ecological reaches described by Hornsby et al. (2000) help to distinguish different sections of river, my data suggest that the Cody Scarp is perhaps the most important influence on the population dynamics of *Macrochelys* in the Suwannee River.

During my telemetry study, two turtles were never located after release, and one turtle was lost after being located consistently for a month. Although extreme movements have been reported in this species (Pritchard, 2006), I searched 32 km upstream and 35 km downstream of the release site with no success. The most likely explanation is equipment failure. *Macrochelys* have been known to wedge themselves under rocks and limestone banks, and this behavior could have resulted in damage to the transmitters. Turtles in Reach 3 had a larger mean home range, but there was a large amount of inter-individual variation, and home range did not differ significantly between reaches. Although the mean linear home range was greater in males than females, no significant difference was detected. This is contrary to a study in Oklahoma in which adult females tended to have larger home ranges than adult males, and juveniles had larger home ranges than adults (Riedle et al., 2006). In my study, small sample size could have played a factor in detecting a significant difference.

Although no significant differences were detected between sexes and reaches in linear home-range size, I observed several interesting behaviors. Two large male turtles (>45kg) were frequently located in springs and spring runs within Reach 3. Springs may provide a thermally stable refuge for turtles. A study conducted in the Santa Fe River, a tributary of the Suwannee River, resulted in very few *Macrochelys* captured in springs. It is important to note that springs trapped in the Santa Fe River experience high levels of recreation (e.g. swimming, boating, and fishing), and this could explain the rarity of *Macrochelys* within these habitats (Johnston, pers. obs.). My data confirm that *Macrochelys* do use spring habitats, but the spring in my study is very small and lacks recreational use. Unaltered floodplain springs could be important refuges for *Macrochelys* within the Suwannee River drainage, and more research is needed to examine habitat use in *Macrochelys*.

During periods of high water, turtles were observed in each site moving from the river channel into the floodplain. During high-water periods the floodplains were inundated with water and likely utilized as new foraging habitat by turtles. These floodplains remained inundated for weeks. When water levels fell, the aquatic corridors between the river channel and the floodplain disappeared. Surprisingly, turtles were located on multiple occasions moving back and forth between the floodplain and channel without an aquatic corridor. Past studies claim that overland movement is rare or absent in this species (Pritchard, 2006), but my data suggest that these movements do take place and could be more common than previously thought. Additionally, turtles were observed using 2–4 core sites, which has been reported in previous studies (Riedle et al., 2006). Core sites typically consisted of subsurface rocks, woody debris, and undercut banks.

As water levels fluctuated, turtles were located in different habitat types. Side-scan sonar (SSS) revealed turtles were usually associated with limestone bank outcrops, subsurface rocks, or woody debris, including deadhead logs (pre-cut timber lost during transport), during low-water periods. As water levels increased, turtles were located in and around fallen trees and root systems that were previously out of the water. This suggests that *Macrochelys* habitat preferences may change with availability. Data from this study suggest that *Macrochelys* rely on submerged woody debris as habitat and refuge, especially during low-water periods when other habitat types are perched. The state of Florida initiated a deadhead log removal program in 2000. From 2000 to 2008, more than 16,000 logs were removed from Florida's rivers; however, this is likely a conservative number (Kaeser and Litts, 2008). The removal of any woody debris from the Suwannee River could have a negative impact on *Macrochelys* due to the high importance of woody debris as a primary refuge during low-water periods.

Ingested fish hooks can perforate the digestive tract lining, and monofilament or gel spun fishing line attached to the hook can cause severe digestive blockage and potentially death in turtles (Heard, pers. obs.). Ingested hooks are likely the result of bush hooks, which are single hooks suspended from tree branches to catch catfish and other forms of wildlife. Bush hooks are typically baited and set in the evening and left out overnight. Because *Macrochelys* are primarily nocturnal, they have a higher chance of an encounter with a bush hook than a manned fishing line. An FWC regulation requires that bush hooks be clearly labeled with the fisherman’s name and address. However, most bush hooks we observed were not labeled. My study found bush hooks to be more abundant in Reach 3. This is most likely due to higher fish abundance and greater access to the river. Although our sample size was small, the results provided some insight. We found three individuals, all in Reach 3, with ingested fish hooks, and one turtle had ingested three hooks. These turtles appeared healthy, and two of the three turtles have been recaptured and equipped with telemetry transmitters. These turtles have exhibited normal movements. Fish hooks are possibly not the primary cause for concern; the associated fishing line attached to the fishhook may pose the greatest health threat. Additionally, a turtle in Dowling Park (Reach 2) was observed upon capture to have a fish hook embedded in the upper left forelimb. The hook also had a line weight and about 3 feet of heavy test, braided monofilament attached. The hook was removed and the turtle released. Further studies are necessary to determine the impact, if any, of ingested hooks and associated fishing tackle on *Macrochelys* populations. Other than ingested fishhooks, *Macrochelys* faces additional threats within the Suwannee River drainage. Injuries obtained from boat propellers are one concern. Much of the Suwannee River receives heavy recreational use by boaters, especially the middle and downstream portions of river. Boat propeller scars were observed on the carapaces of eight turtles, and some damage was extensive but had healed (Figure 4-1). If the population in the Suwannee River is recognized as a new species, it would likely meet the criterion of threatened in Florida because of its restricted distribution (FWC, 2011). Because this population is restricted to a single drainage, a catastrophic chemical spill or similar event could potentially be devastating. These types of events seem unlikely; however, in 2013, the city of Valdosta had major sewage spills into the Withlacoochee River, a tributary of the Suwannee River, from its wastewater treatment plant in which spilled millions of gallons of solid waste into the drainage.

Bycatch of other turtle species primarily consisted of the pond slider (*Trachemys scripta*), Suwannee cooter (*Pseudemys suwanniensis*), and Florida softshell turtle (*Apalone ferox*) but included the peninsula cooter (*Pseudemys peninsularis*), Florida red-bellied cooter (*Pseudemys nelsoni*), loggerhead musk turtle (*Sternotherus minor*), and Florida snapping turtle (*Chelydra serpentina*). Eight exotic red-eared sliders were captured throughout the river (*Trachemys scripta elegans*). Numerous fish species were captured, including a bull shark (*Carcharhinus leucas*).

## Conclusions

Fisheries biologists have used basic principles of stream ecology to help explain population abundance and community structure of organisms within fluvial systems. My data suggest that the RCC provides a useful framework for understanding the dynamics of fluvial process and how they affect the distribution of riverine freshwater turtles. Lower densities of *Macrochelys* should be expected in less productive sections of river because these sections lack the resources needed to sustain high population densities. Furthermore, low turtle densities found in sections of rivers with low biological productivity are not always indicative of harvest or an unhealthy population, but they are caused by natural riverine processes that help shape population dynamics within fluvial systems. The RCC could potentially be a practical tool to help resource managers predict abundance and density levels in order to help focus conservation efforts within riparian systems. My data indicate that Macrochelys is more abundant in the Suwannee than previously thought and provides a framework for its future conservation and management.

Figure 4-1. Photographs of damage ascertained from a boat propeller on 2 *Macrochelys* in the Suwannee River. Photos courtesy of Travis Thomas and Kevin Enge.

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