ABSTRACT

MILLER, VERONICA ANN. Selected Demography and Population Estimation of *Trachemys scripta* (Yellow-bellied Slider) in North Carolina as it Relates to Turtle Harvesting. (Under the direction of Harold Heatwole.)

In the year 2000, a reported 460 turtles were removed from North Carolina for commercial use. In 2002, the reported take of turtles soared to a staggering 23,311 turtles. A continuation of this trend could severely deplete the turtle populations of North Carolina in a short time. Therefore a moratorium on commercial turtle harvesting was instituted by the North Carolina General Assembly on July 1, 2003, effective until the NC Wildlife Resources Commission could determine rules and regulations for harvesting. It is crucial to know the level of harvest that populations can sustain, and, if a population is harvestable, which age groups are most sensitive to harvest. Regulations on reporting and validation of numbers, identifications, sizes, and sex of turtles will be crucial. I conducted a mark-recapture survey of freshwater turtles in six eastern Piedmont ponds: three of which had been harvested and three of which had no record of harvest. I tested for differences in sex ratios, size and age distributions, and population densities between the harvested and unharvested populations of Yellow-bellied Sliders (*Trachemys scripta*). Although no significant differences were found between the harvested and unharvested populations, the amount of variance of the estimates does not allow any clear conclusions to be drawn. Severe weather impacts on habitat may have influenced sampling results. More research is required to determine the true effects turtle harvesting has on populations, including extensive stage-based simulation modeling and determination of metapopulations.

SELECTED DEMOGRAPHY AND POPULATION ESTIMATION OF TRACHEMYS SCRIPTA (YELLOW-BELLIED SLIDER) IN NORTH CAROLINA AS IT RELATES TO TURTLE HARVESTING

by

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Chair of Advisory Committee

BIOGRAPHY

Veronica Ann Miller was born in Charlottesville, VA, while her mother was completing her Ph.D in Counseling at the University of Virginia. Veronica's family then moved to Fredonia, NY, where her only sibling was born. Veronica then grew up in Charleston, WV, where her love of wildlife and nature and also of gymnastics bloomed. After moving to Durham, NC in 1996, Veronica switched from gymnastics to dance, but her desire to work with animals continued.

Veronica graduated from C.E. Jordan High School in 2000. She attended North Carolina State University where she graduated as a valedictorian of the Class of 2003 with a B.S. degree in Biological Sciences. While an undergraduate student at N.C. State, Veronica was a member of the N.C. State Modern Dance Company and a Resident Advisor for University Housing. She was also a member of the 2002 Women's and 2003, 2004, and 2005 Co-recreational Championship Intramural Bowling Teams.

In the fall of 2003, Veronica became a Master of Science Candidate in the Zoology Department at N.C. State. She continued dancing with the Modern Dance Company and became a Teaching Assistant, both of which she did until she left N.C. State in May 2006. She was also on the student leadership team as the Service Ministry leader for Campus Christian Fellowship from August 2004 to May 2006. In April of 2005, Veronica became engaged to Cristopher (CJ) Barnes and they were married shortly after her graduation in May 2006.

Acknowledgements

I am completely indebted to everyone who helped to make this project a reality. This first and foremost includes my committee, Hal Heatwole, Ken Pollock, Phil Doerr, Jamie Collazo, and Alvin Braswell, for their support and helpful input into the project. Without them there would have been no project. The NC Wildlife Resources Commission, especially Sarah Cross, was instrumental in providing both financial support and most of the field equipment for the project. The NC Museum of Natural Sciences Research Lab was also an incredible supporter and provided the use of their boat and traps and provided a parking place for my equipment. And finally my undying gratitude goes out to everyone who came out in the field with me to get down and dirty, especially my two research assistants, Anita Iannacchione and Aminat Oki, as well as my parents, Holly Forester-Miller and Gary Miller, my fiancé, CJ Barnes, and my friends Megan McAndrew, Renee Coley, Jenn Miller, Ed Corey, Lauren Pugh, and Courtney Coddington. And lastly, but most importantly I thank God for the strength, wisdom, and determination needed to complete this project.

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INTRODUCTION

In the year 2000, a reported 460 semi-aquatic freshwater turtles were removed from North Carolina for commercial use. In 2002, the reported take of turtles increased by 5,000% to 23,311 individuals (Henderson 2003). In response to this increase in turtle harvests, the North Carolina General Assembly passed Senate Bill 825 (North Carolina General Assembly 2003), which states, “the commercial taking of any turtle or terrapin within… the families Emydidae and Trionychidae…is prohibited until such time as the Wildlife Resources Commission adopts rules to regulate the taking of turtles or terrapins….”. Before any rules and regulations can be set in place for the commercial taking of freshwater turtles in North Carolina, additional information is needed regarding the current status of turtle populations. The purpose of this project was to provide the North Carolina Wildlife Resources Commission (NCWRC) with some of the data needed to determine sustainable harvest levels and optimal age and sex ratios of harvestable turtles for a commonly harvested freshwater turtle species, *Trachemys scripta* (Yellow-bellied Slider).

History of Human Use of Turtles

Turtle harvesting has occurred throughout human history. The heaviest harvesting has traditionally taken place in Asia, specifically Southeast Asia, where turtle meat is considered a delicacy and may sell for six times the price of lamb (TRAFFIC 2000). Turtles are also important in traditional Chinese medicine where turtle jelly, made from the shell, is claimed to cure cancer. Various other turtle products are used as general health tonics. Taiwan alone imports an average of 30 metric tons of turtle shells per year. Of the 90 turtle species found in Asia, 74% are considered threatened and over 50% are listed as endangered (TRAFFIC 2000).

Although turtles are becoming rare in Asia, the demand in the food, pet, and medicinal markets has not decreased. Asian turtle markets are now looking to other parts of the world to supply their needs. Between 1996 and 2000 more than 51 million turtles were exported out of the United States, roughly half of these were exported to various parts of Asia (Reed and Gibbons 2003). Turtle harvesting in North Carolina drastically increased between 2000 and 2003 (Henderson 2003), leading to the need for Senate Bill 825 (SB 825).

Targeted Species

Twelve species and subspecies of turtles are protected by SB 825 in North Carolina. Of those twelve, five are known to occur in at least one of the areas where trapping for this project was conducted. These five types, *Chrysemys picta picta* (Eastern Painted Turtle), *Clemmys guttata* (Spotted Turtle), *Pseudemys concinna concinna* (Eastern River Cooter), *Pseudemys concinna floridana* (Coastal Plain Cooter), and *Trachemys scripta scripta* (Yellow-bellied Slider), were the target turtles for my research. Eastern Painted Turtles, Spotted Turtles, Eastern River Cooters, and Yellow-bellied Sliders can be found in all of the areas being studied. Coastal Plain Cooters are found mostly in the southeastern part of the state (Palmer and Braswell 1995). Yellow-bellied Sliders were the only species captured in numbers high enough for analysis.

Trachemys scripta elegans (Red-eared Slider) was also found in the trapped areas. The Red-eared Slider is in the family Emydidae and therefore is protected by SB 825. Future management of this subspecies may differ, however, from the other Emydidae species since the Red-eared Slider is not native to North Carolina.

Three species of turtles not protected by SB 825 also occurred in the areas trapped in the project: *Kinosternon subrubrum subrubrum* (Eastern Mud Turtle), *Sternotherus odoratus* (Stinkpot), and *Chelydra serpentina* (Common Snapping Turtle). Although these species were not the targets of the project, their presence was recorded.

Life History of Freshwater Turtles

There is a paucity of knowledge about the life history characteristics of many turtle species. The long life span of most turtle species can require studies spanning decades to obtain enough information for a reliable estimation of longevity, survival, maturation, and reproduction rates. Some such studies have been conducted, such as the study started by Sexton (1959a) and continued by Wilbur (1975) on the Painted Turtle of the E.S. George Reserve in Michigan, which lasted 20 years, and the study conducted by Frazer et al. (1991) on Common Mud Turtles, which also spanned two decades. Congdon et al. (1994) conducted a 28 year study on the life history of Common Snapping Turtles and Cagle (1950) studied the life history of Yellow-bellied Sliders over 13 years. Below is some information on various aspects of freshwater turtle life history.

Sexual Maturity

In general, turtles are slow-growing, late-maturing animals. The age at which sexual maturity is reached can vary not only among species, but even from one individual to another within a species (Cagle 1950, Wilbur 1975, Congdon et al. 1994). Size is usually a better indication of sexual maturity since the growth of juveniles can be exceedingly variable

(Cagle 1950). Growth rates of an individual can be affected by both environmental factors, such as temperature, food availability and quality, and factors intrinsic to that individual or even the population itself (Dunham and Gibbons 1990).

Male Yellow-bellied Sliders reach sexual maturity when they reach a plastron length between 9 and 11 cm and can be identified as mature by the enlargement of the preanal glands and elongation of the fore claws (Cagle 1950, Gibbons and Green 1990). Females may reach maturity at plastron lengths between 14 and 20 cm (Grant 1936, Cahn 1937, Cagle 1950).

Delayed sexual maturity in a species may mean that there will be a large number of juvenile and subadult turtles in a population. These juveniles are crucial to the continued success and replenishment of the breeding population. These features, however, can often mask the effects of intense harvest for years, making overexploitation appear to be sustainable harvest (Bjorndal 1999).

Clutch Size and Frequency

Female Yellow-bellied Sliders lay between 4 and 23 eggs per clutch (see Appendix; Cagle 1950, Gibbons and Greene 1990, Palmer and Braswell 1995, Aresco 2004), while Painted Turtle females average between 6 and 8 eggs per clutch (Wilbur 1975, Tinkle et al. 1981). Clutch size tends to increase with plastron length, and both species may lay two clutches in a season (Cagle 1950, Tinkle et al. 1981, Gibbons and Greene 1990, Reed and Gibbons 2003, Aresco 2004). Clutch size may also vary seasonally and among different habitats, although there is little annual variation (Gibbons and Greene 1990). The factors affecting clutch frequency are not well known, but are presumably linked to the availability and acquisition of food resources by the turtles (Gibbons and Greene 1990).

Nest Success and Hatchling Survival

Reports on nest success for Painted turtles vary greatly. Wilbur (1975) reported an 18.5% survival rate from egg to hatching, while Tinkle et al. (1981) reported an 80% survival rate, for nests in Michigan. Both, however, reported that the largest contributor to nest failure was egg predation. Nest predators include Raccoons (*Procyon lotor*), Red and Grey Foxes (*Vulpes vulpes* and *Urocyon cinereoargenteus*), Skunks (*Mephitis mephitis*), Kingsnakes (*Lampropeltis getula*), crows (*Corvus* spp.), beetle larvae, and Fire Ants (*Solenopsis invicta;* Tinkle et al. 1981, Frazer et al. 1990, Tuberville and Burke 1994, Litzgus and Brooks 1998, Aresco 2004, Donlan et al. 2004).

The nest success of snapping turtles supports lower nest success rates. Congdon et al. (1994) reported that snapping turtles in the same part of Michigan had a nest survival rate of 23% and a first year survival rate of 47%. Little is known about the nest success of Yellow-bellied Sliders. The factors threatening nest success are similar for most turtle species, so nest success may be similar for most species. The extent to which predators affect nest success, however, can be variable depending on factors such as predator abundance, nest-to-predator ratio, other food sources for the predators, and the concentration of nests in an area.

There is similar disparity between the survival rates from hatching to the second year: Wilbur (1975) reported 14% survival, while Tinkle et al. (1981) reported a 51% survival for Painted Turtle hatchlings. Yellow-bellied Slider first-year survival is reported to range between 53.9% and 82.9% (Frazer et al. 1990).

The survival rates of eggs and young turtles are important in understanding the effect that harvesting has on turtle populations. If the survival rates are low, then recruitment into a population is likely going to be low, making it more difficult for a population to recover from harvesting. One harvester from Maryland told me he would only take Yellow-bellied Sliders larger than 5 inches (12.5cm; Rodney Wilson, personal communication), indicating that most of the turtles removed are sexually mature, thereby further reducing the potential recruitment in the harvested population. Additionally, he reported catching more females than males, at least in certain parts of the year (Rodney Wilson, personal communication), which may skew the sex ratios of harvested ponds, making them male-biased.

Longevity

Very little is known definitively about the longevity of any turtle species. It is known that some captive turtles will live over 100 years (Cagle 1950), but that is unlikely to be true in nature or for all species. Long-term studies from the Savannah River Ecology Laboratory in Aiken, South Carolina, have reported Yellow-bellied Sliders up to 37 years old (Frazer et al. 1990). It is possible, although unlikely, that the life span could be as long as 50-75 years for this species (Cagle 1950) as it is difficult to know the exact age of a turtle unless it has been followed since hatching. Another slider species, *Trachemys decussate angusta* (North Antillean Slider) has a maximum lifespan of 35 year, although the average is probably around 30 years (Seidel 2003).

Sex Ratios

Sex ratios in most natural populations of Yellow-bellied Sliders are roughly equal, although they can vary (Cagle 1950, Earnst and Barbour 1972, Wilbur 1975, Gibbons 1990). Demographic factors that can influence the sex ratio of a population are the sex ratios of hatchlings, which can be affected by temperature of the nest, differential mortality of the sexes, differential migration rates of the sexes, and differences in age at maturity of the sexes

(Gibbons 1990). One must be careful when determining the sex ratio of a population as many capture techniques lead to biased ratios. Sampling biases can result from the trapping method used, the season in which sampling takes place, and determination of maturity (Gibbons 1990). Using multiple sampling methods, multiple trap sizes, sampling over several seasons, and conservatively determining maturity can reduce the amount of sampling bias in a study. For instance, terrestrial traps tend to produce a female-biased ratio because of the nesting activity, while aquatic traps tend to produce a male-biased ratio, possibly because males move around more looking for receptive mates and encounter traps more often (Gibbons 1990).

Migration

The migration of turtles between bodies of water will also affect how quickly a population can recover from harvesting (Reed and Gibbons 2003). Turtles will migrate as far as 5km from one body of water to another (Wilbur 1975, Morreale et al. 1984). They generally congregate, however, in shallow areas with high quality basking sites (Cagle 1950). Males migrate more often than do females (Morreale et al. 1984). Male Yellow-bellied Sliders often move from pond to pond and long distances within larger bodies of water, possibly in search of mating opportunities (Morreale et al. 1984). Female turtles may migrate a short distance, usually to nest, but tend to stay in smaller areas for longer periods of time compared to males (Morreale et al. 1984). In general, the purposes of interpopulational movement are related to feeding, reproducing, basking, and hiding while migration between ponds is often due to migration between seasonally variable habitats, abandoning unsuitable habitats, nesting by females, and searching for mates by males (Gibbons et al. 1990, Burke et al. 1995). The difference in migration rates between males and females is crucial in determining harvestability since harvesters often collect more females, but only males may be migrating into the population.

Hypotheses

Based on the life history characteristics of freshwater turtles and the trends in turtle harvests I developed three major hypotheses. I hypothesized that harvested turtle populations would have a higher proportion of males over females as opposed to the even sex ratios reported for most natural populations (Cagle 1950, Earnst and Barbour 1972, Wilbur 1975). I also suspected that harvested ponds would have a higher ratio of small, young turtles to large, older turtles than unharvested ponds and that the population densities of harvested ponds would be lower than the population densities of unharvested ponds.

METHODS

Trapping Sites

Six ponds, all located in the eastern Piedmont of North Carolina, were included in the survey. The ponds were paired based on trapping history and location. One pond in each pair was known to have a history of commercial turtle trapping and one pond had no record of being trapped within the past five years. Harvested ponds were selected from Wildlife Collecting License records provided by the NCWRC. The ponds chosen had to be located in the eastern

Piedmont region and to have had 100 or more turtles removed in a single harvesting event. Ponds within an hour’s drive of the harvested ponds for which no record of harvesting existed and that had similar habitat features were chosen for the unharvested ponds. The NCWRC only keeps Wildlife Collecting License reports on file for three years so data on any harvesting that occurred before 2001 was unavailable. Additionally, the collecting license is not specific to the collection of turtles and can be used for a number of wildlife species, so the information reported varies from harvester to harvester.

The three harvested sites were Holt’s Pond in Johnston County, Perry Pond in Franklin County, and Everett Lake in Richmond County. The respective non-harvested sites were Shelley Lake in Wake County, Clifton Pond in Franklin County, and Arrowhead Lake in Anson County. All of the sites were planned to be sampled for five sessions over two seasons, two sessions in 2004 and three sessions in 2005. Each session consisted of three trapping days for a total of six trapping days per site in 2004 and nine trapping days per site in 2005.

Holt’s Pond was a 25.24-acre millpond in Johnston County near Princeton, NC (WGS84: DMS 352749N, 0781110W) that was divided by Highway 70. It was fed by Moccasin Creek and another unnamed creek from the north. The pond was surrounded by typical Piedmont loblolly and hardwood mixed forest and there were few places for turtles to bask. The surrounding area was rural, but with a growing human population and was about two miles from the small town of Princeton, NC. The pond was harvested for at least three years before the moratorium on harvesting was implemented in 2003. In 1996, the dam was washed out by hurricane Fran. In May 2005 the pond was drained by the owner so a new boat ramp and dock could be built. The draining prohibited trapping of the pond in the 2005 season. A new housing development was also being built on the eastern shore of the pond and there was little buffer vegetation to protect the pond from sedimentation and construction runoff.

Figure 1. Satellite photo of Holts Pond. Modified from Google Maps on January 31, 2006. Scale unknown.

Shelley Lake was located in a city park in Raleigh, NC (WGS84: DMS 355125N, 0783941W) and was 37.1 acres. Suburbs surround the park, although there was a Piedmont mixed loblolly-hardwood forest greenway around the pond itself. Emergent rocks, a few tree trunks, and a sand bar provided some opportunities for turtle basking. Because the pond was in a city park, turtle harvesting was never been allowed, although the pond was open for fishing and non-motor boating. A large population of geese and ducks inhabited the pond because of abundant food sources from humans. Lead Mine Creek fed the pond.

Figure 2. Satellite photo of Shelley Lake. Provided by Google Maps on January 31, 2006. Scale unknown.

Perry pond was a 63.5-acre millpond located in Franklin County near Zebulon, NC (WGS84: DMS 355601N, 0781753W). The pond was fed by Norris Creek and a mixed loblolly/hardwood forest surrounded the area. The area around the pond was rural with six or seven properties adjacent to the pond. The pond was open to the public and fishing from the shore and from boats was allowed for a fee. The owner stocked the pond with common freshwater game fish. There were abundant places for turtles to bask formed from fallen trees and limbs. The dam and the mill were washed out several times, most recently during hurricane Fran in 1996. Perry pond was harvested for about 3 years before the moratorium became effective.

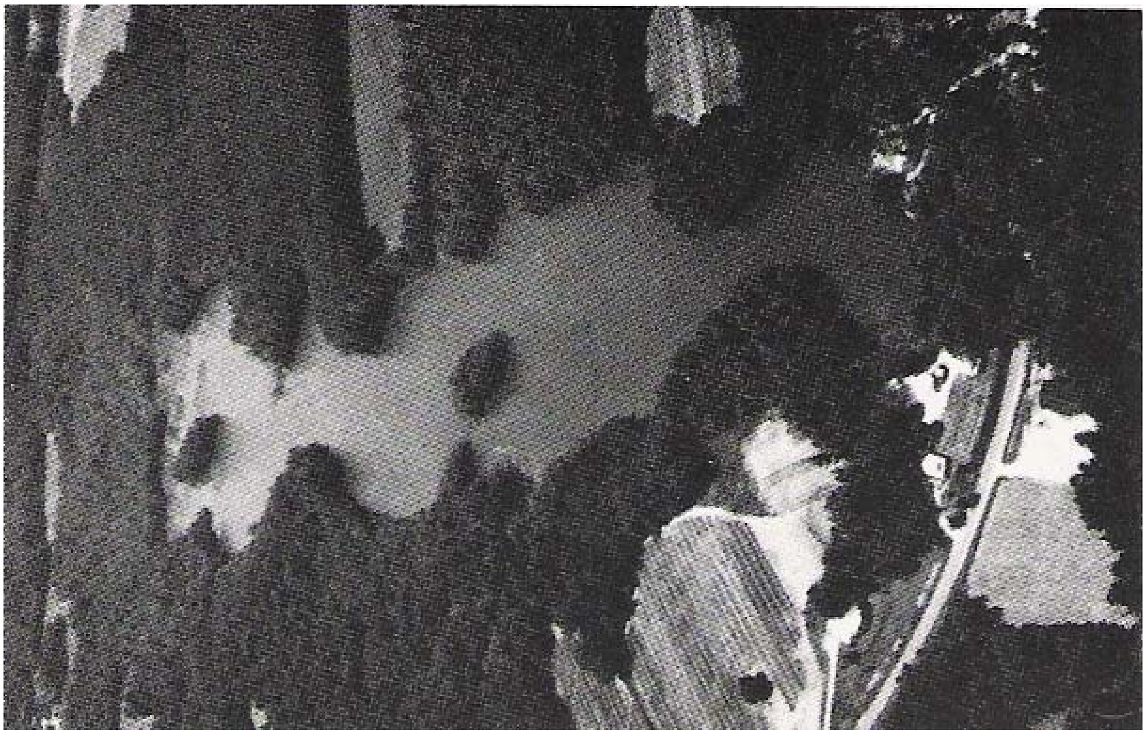


Figure 3. Aerial photo of Perry Pond. Photo Credit: Malcom Martin.

Clifton Pond was also in Franklin County, near Louisburg, NC (WGS84: DMS 355957N, 0782102W). Clifton Pond (28.0 acres) was a dammed pond, although it was not a millpond. It was fed by Crooked Creek. There was no concrete boat ramp into the pond, only a rough dirt path. The pond was open to the public for free fishing both from the shore and from a boat. The area around the pond was very similar to that around Perry Pond, being mostly farmland, with forest surrounding the pond itself. As in Perry Pond there were many excellent basking sites for turtles. There was no record of turtle harvest at this pond.

Figure 4. Satellite photo of Clifton Pond. Modified from Google Maps on January 31, 2006. Scale unknown.

Everett Lake was the largest of the six sites in the study, being 127.99 acres. Everett Lake was harvested at least in 2002, but there was no other record of harvesting occurring there. Because of the large size difference between Everett Lake and the other sites and restrictions on time and the number of traps available, Everett Lake was divided into two unequal sections and sampling alternated between the sections. The lake was fed by Mark's Creek and was part of the Pee Dee River Basin. It was dammed at the southwestern side just before the highway. The lake was surrounded by mixed hardwood and pine forest and there were many good places for turtles to bask. It was in Richmond County in a very rural area off US1, on the South Carolina border. The nearest urban area was Cheraw, SC about 10 miles south. There were a few houses that surround the lake, two of which had docks and one, the caretaker's house, had a ramshackle boathouse. The eastern half of the lake was shallow and covered the stumps of hundreds of trees making motor-boating dangerous.

Figure 5. Satellite photo of Everett Lake. Modified from Google Maps on January 31, 2006. Scale unknown.

Arrowhead Lake was a 26.6-acre pond on the Pee Dee National Wildlife Refuge in Anson County, NC (refuge coordinates WGS84: DMS 350501N, 0800259W). It was surrounded on three sides by farmland growing corn and soybeans and on the fourth side by mixed hardwood and pine forest. The part of the pond that was surrounded by fields has few good basking spots. The forested end of the pond, however, was covered with floating water plants and scattered with logs that provided excellent basking areas. The pond was fed by springs and watershed runoff. Because the pond was on a national wildlife refuge the harvesting of turtles was prohibited. Fishing, however, was allowed and open to the public. The pond was located in a rural area just outside Ansonville, NC and could only be accessed from a dirt road that cut through one of the fields.

Figure 6. Satellite photo of Arrowhead Lake. Modified from Google Maps on January 31, 2006. Scale unknown.

Capture and Marking

The most common method for studying turtle populations is the mark-recapture method (Wilbur 1975, Lindeman 1990, Burke et al. 1995, Koper and Brooks 1998), which is the method used in this study. While it can be difficult to determine the accuracy of the estimates made from mark-recapture studies (Koper and Brooks 1998), there are ways to make the capture-recapture design more robust against violations of the basic assumptions (Pollock 1982). The robust design involves having primary sampling periods that have enough time between them to allow for additions and deletions from the population with secondary sampling periods, within the primary periods, that are close enough together to assume a closed population. Having both the primary and secondary sampling periods helps to alloaw for unequal catchability that may occur among the turtles and for the open nature of most animal populations (Pollock 1982, Williams et al. 2002). The robust method is the basis for the design of the current study.

In this project, hoop traps of three different sizes, 3’, 2.5’, and 1.5’ diameter, were used to capture turtles. Hoop traps were chosen for several reasons. The first is that hoop traps have been shown to be the most effective type of trap for collecting turtles (Cagle 1950).

a)  b) 

Figure 7. Traps used in the field. a) 1.5’ diameter trap that has been set. Pieces of Fun Noodles were attached to the traps to ensure that part of the trap remained above water so that the animals could breath. b) 3’ diameter trap in place. “Research: Do not disturb” signs were also placed on traps that were set in spots likely to be reached by humans.

Second, hoop traps are easily collapsible which allows for easy transport in a boat (Feuer 1980), and third, commercial trappers have been seen using this kind of trap. Commercial harvesters generally trap an area for one or two days, catching as many as 500 turtles in a day. A harvester will set about 50 traps baited with fish meat. Hoop traps are used in most cases, although D-pot traps, which are half-circle shaped traps, are sometimes used in water too shallow for regular hoop traps. In this project, seven to nine traps, depending on the number of traps available for use, were evenly distributed around the edge of the water and the size of the trap was chosen based on the depth of the water at each location during the first session of trapping.

Figure 8. Collapsed traps and support poles being transported in a small boat.

The same trap locations were then used throughout the study. Two exceptions to this occurred; one at Clifton Pond, where a trap had to be moved because the water became too deep to have one part of the trap above water, and another at Shelley lake where one of the traps was stolen.

Figure 9. Wildlife Enforcement officer pulling up a trap used by a commercial harvester. (Photo provided by Wildlife Resources Commission).

One 3' trap at each pond was modified to float in deep water and was placed in approximately the deepest and most open part of the pond. Commercial trappers have been known to use floating traps (Sarah Cross, NCWRC Herpetologist, personal communication) and I simulated the commercial harvesting methods as closely as available resources would allow in order to accurately assess the effects of harvesting. Trap placement and type were replicated for subsequent trapping sessions. At each site, traps were placed on the first day and then checked once every 24 hours for the next three days. Traps were baited with sardines packed in soybean oil and bait was changed every day.

Figure 10. 3' diameter trap modified to float in deep water.

When a target species was captured a unique three-letter or four letter code was assigned to the turtle. The marginal scutes of the carapace were assigned letters and notches were filed into the scutes corresponding to the turtle's code (Dorcas 2003). The letters were assigned to the scutes so that the code was read in the clockwise direction when the plastron was facing upwards. Letters assigned to scutes that made up the bridge of the shell were not used.

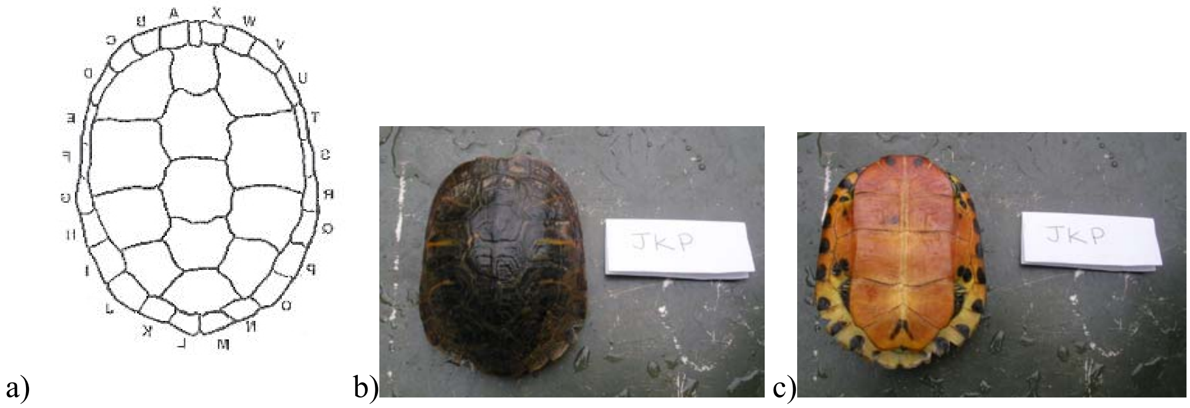


Figure 11. Marking scheme for target turtle species. a) Letter assignment to the marginal scutes of a Yellow-bellied Slider carapace. (Dorcas 2003). b) Top view of a marked turtle. Code read in counter-clockwise direction. c) Bottom view of a marked turtle. Code read in clockwise direction.

Once marked, each turtle was aged by counting the growth rings on the second costal scutes (Sexton 1959b, Congdon et al. 1994), sexed (Dorcas 2003), and weighed. Calipers were used to measure the midline length of the carapace and plastron, the width at the middle of the bridge, and the depth at the deepest point of each target species turtle (Dorcas 2003). A photograph was then taken of the carapace and the plastron before the turtle was released at the site of capture.

Most species of non-target turtles were simply recorded as being present and then released. Stinkpots, however, were all given one shell notch for recognition of previously caught turtles and were sexed in order to get a general idea of the abundance and sex ratios of a species that is not commonly harvested. A simple index of Stinkpots per trap night was calculated (See Appendix).

Statistical Analysis

Only one species, *Trachemys scripta,* had large enough sample sizes for statistical analysis. Programs MARK and CAPTURE were used to estimate population sizes of this species using closed population models that allowed one to fit multiple models (Lindeman 1990). I had initially planned to use the robust design approach to estimate populations, but sample sizes were inadequate for this type of analysis. Instead, population sizes were estimated using four different models: the null model (M_0), the temporal variation model (M_t), the behavioral response model (M_b), and the heterogeneity model (M_h). Model M_0 holds the capture probability constant across both individual animals and sampling occasions. In model M_t, all individuals have the same capture probability within sampling occasions, but capture probability can change from one occasion to the next. Model M_b accounts for trap response by allowing the capture probability of animals being captured for the first time (p_c) to differ from those that have been previously captured (p_r). The trap response may be positive (trap-happy, $p_r > p_c$) or negative (trap-shy, $p_r < p_c$). In the M_h model there is no temporal or behavioral variation, however, each individual is permitted to have its own capture probability, independent of every other individual (Williams et al. 2002). The populations were assumed to be closed within each field season and mark retention was assumed to be 100 percent.

SAS T&R 8.2 was used for other statistical analysis of the data. Two way ANOVA tables were used to test each of the three hypotheses: that harvested populations will have a higher proportion of males over females, have a higher ratio of small, young turtles and will have lower population densities than unharvested populations. Each pond was considered an experimental unit and ponds were arranged in a block design with each block consisting of a geographical pair of ponds (Ott and Longnecker 2001). For each test except the density analysis, the data were pooled over the two field seasons. The turtles were grouped into age categories spaced in 5-year increments with Category 1 consisting of turtles from age 0 to age 4, Category 2 being ages 5 – 9, etc. Each age category was then tested separately to determine any differences in the occurrence of age categories in harvested and unharvested ponds.

RESULTS

The number of individual turtles captured varied greatly between trapping sites. In the 2004 season, Clifton Pond had the highest catch with a total of 162 turtles captured. Clifton Pond's partner site, Perry Pond had the next highest catch with 136 turtles. Everett Lake, the largest site, resulted in a catch of 130 turtles, including 14 *Apalone spinifera* (spiny softshell). Softshell turtles are in the family Trionychidae and therefore are protected under the harvest ban of SB825. We did not have the proper equipment for marking a softshell species, however, so only the presence of the turtles was recorded. Arrowhead Lake produced a catch of 94 turtles. There were 118 caught at Shelley Lake. Holt's Pond had the lowest catch with only 48 individuals.

In the 2005 season, Clifton Pond again had the highest catch with a total of 168 turtles. There were 119 turtles captured in Perry Pond, 100 in Arrowhead Lake, 131 in Everett Lake, and 107 in Shelley Lake. Trapping did not occur in Holt's Pond in 2005 because the owner drained the pond. Yellow-bellied Sliders are the only target species that have large enough sample sizes at all six sites to give meaningful results (See Appendix).

Population Estimates

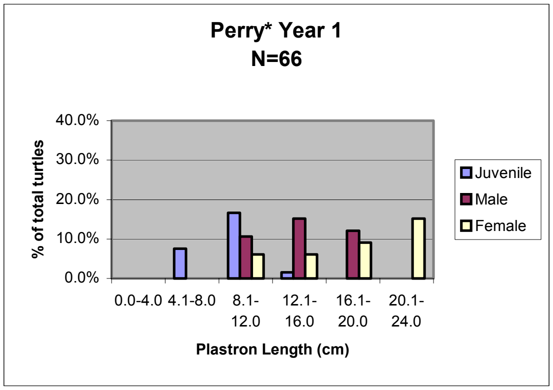
In order to meaningfully compare population densities, I decided it would be best to compare estimates from the same model. The M_0 and M_t models were the only models that provided reasonable estimates for all the populations studied in this project. The more general M_t model (Table 1) was used for analysis because it is believed to be very likely that there was variation in capture probability between sampling occasions. Ideally, I would have liked to use even more general models that allowed for heterogeneity and/or trap response, but sample sizes and recapture rates were not large enough. The numbers of turtles captured and recaptured as well as the estimates produced by other models are given in the appendix.

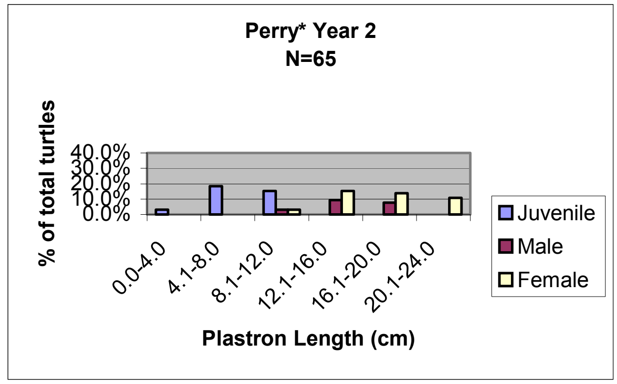
Table 1. Population and density estimates for each pond in each field season. *=harvested pond. **0.16E-16 = 0.16×10^{-16}

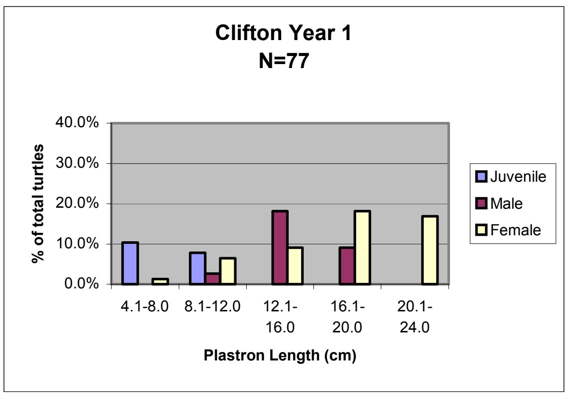
Pond	*'04 Pop. Size (S.D.)*	*'05 Pop. Size (S.D.)*	*2004 Density (turtles/acre)*	*2005 Density (turtles/acre)*
Arrowhead Lake	62 (0.16E-16)**	253 (104.22)	2.33	9.51
Everett Lake*	757 (420.17)	286 (69.52)	5.91	2.23
Clifton Pond	347 (111.26)	204 (53.40)	12.39	7.29
Perry Pond*	321 (119.64)	483 (228.60)	5.06	7.61
Shelley Lake	89 (16.46)	95 (13.75)	2.30	2.56
Holts Pond*	69 (34.26)	--	2.73	--

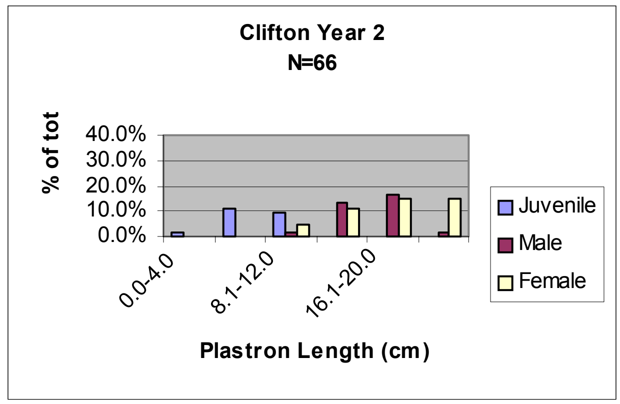
Population Dynamics

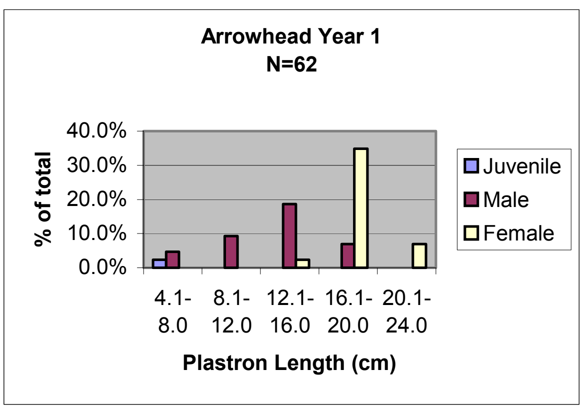
The size and age distribution of each population was highly variable between ponds and even variable between field seasons. There is no consistent difference between harvested and unharvested populations (Figure 12).

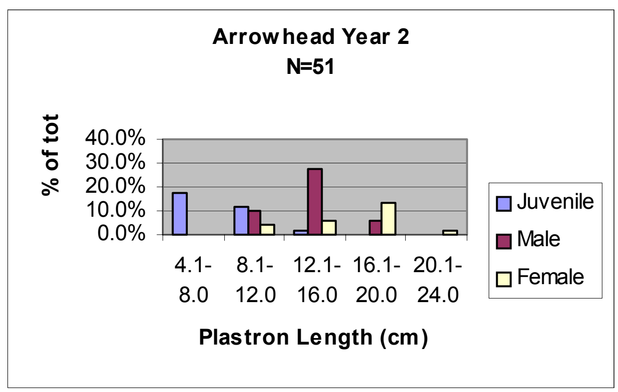

Perry* Year 1
N=66
% of total turtles
40.0%
30.0%
20.0%
10.0%
0.0%
0.0-4.0
4.1-8.0
8.1-12.0
12.1-16.0
16.1-20.0
20.1-24.0
Plastron Length (cm)
Juvenile
Male
Female

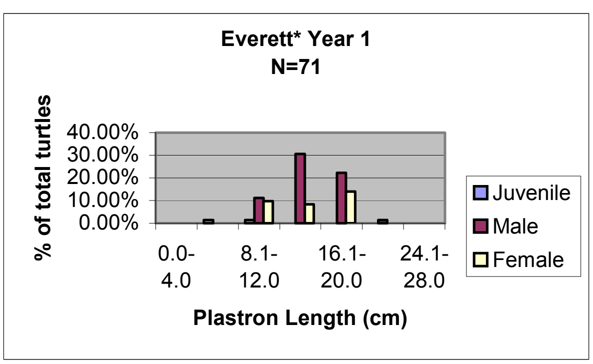

Perry* Year 2
N=65
% of total turtles
40.0%
30.0%
20.0%
10.0%
0.0%
0.0-4.0
4.1-8.0
8.1-12.0
12.1-16.0
16.1-20.0
20.1-24.0
Plastron Length (cm)
Juvenile
Male
Female

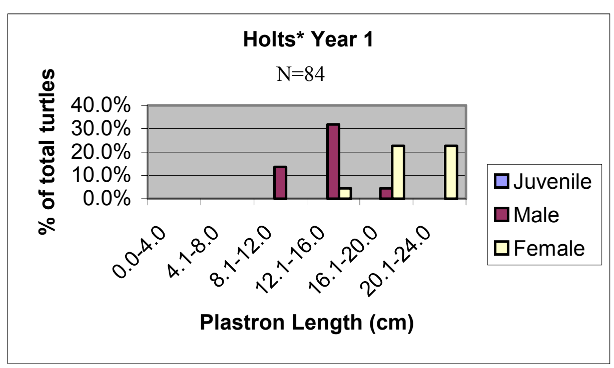

Clifton Year 1
N=77
% of total turtles
40.0%
30.0%
20.0%
10.0%
0.0%
4.1-8.0
8.1-12.0
12.1-16.0
16.1-20.0
20.1-24.0
Plastron Length (cm)
Juvenile
Male
Female


Clifton Year 2
N=66
% of tot
40.0%
30.0%
20.0%
10.0%
0.0%
0.0-4.0
8.1-12.0
16.1-20.0
Plastron Length (cm)
Juvenile
Male
Female


Arrowhead Year 1
N=62
% of total
40.0%
30.0%
20.0%
10.0%
0.0%
4.1-8.0
8.1-12.0
12.1-16.0
16.1-20.0
20.1-24.0
Plastron Length (cm)
Juvenile
Male
Female


Arrowhead Year 2
N=51
% of tot
40.0%
30.0%
20.0%
10.0%
0.0%
4.1-8.0
8.1-12.0
12.1-16.0
16.1-20.0
20.1-24.0
Plastron Length (cm)
Juvenile
Male
Female


Everett* Year 1
N=71
% of total turtles
40.00%
30.00%
20.00%
10.00%
0.00%
0.0-4.0
8.1-12.0
16.1-20.0
24.1-28.0
Plastron Length (cm)
Juvenile
Male
Female


Holts* Year 1
N=84
% of total turtles
40.0%
30.0%
20.0%
10.0%
0.0%
0.0-4.0
4.1-8.0
8.1-12.0
12.1-16.0
16.1-20.0
20.1-24.0
Plastron Length (cm)
Juvenile
Male
Female

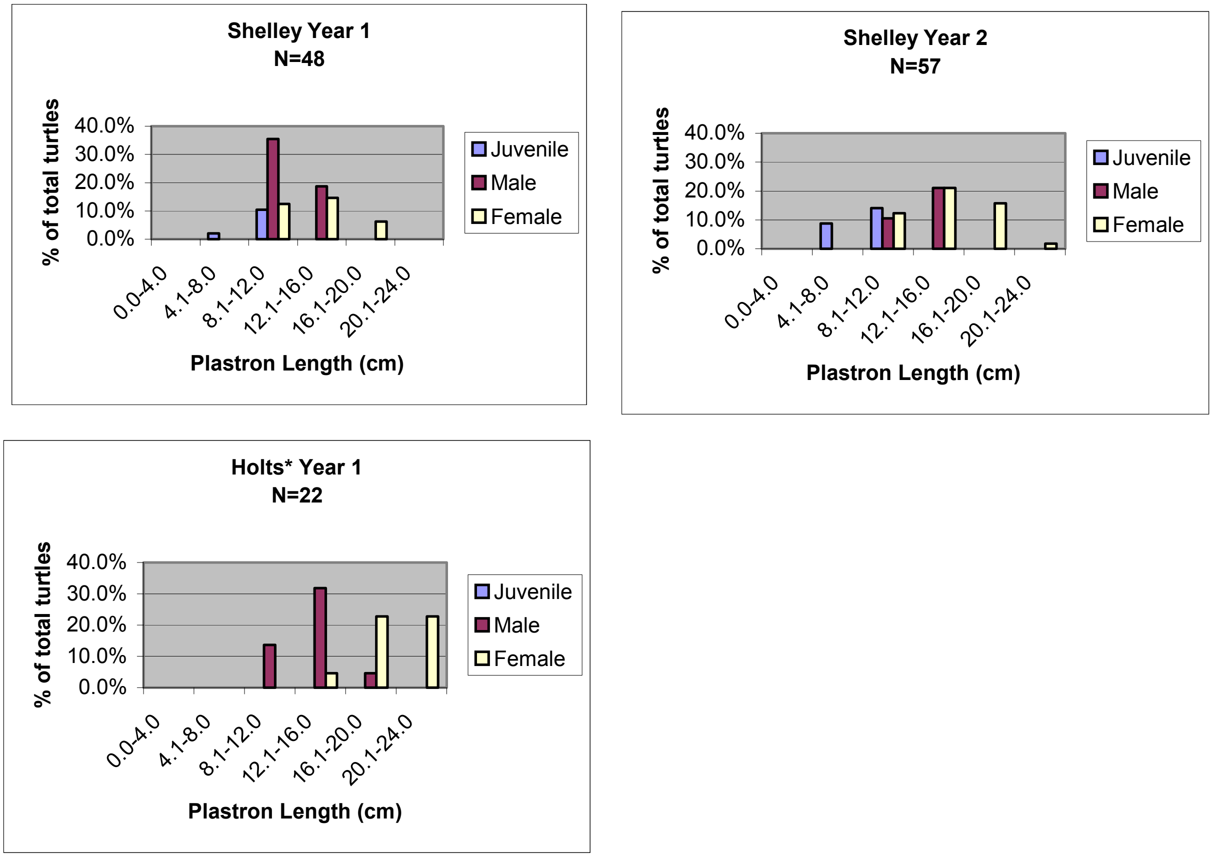


Figure 12. Plastron length comparisons by sample year and by sex. *= harvested pond.

Turtle Growth

Comparing the number of growth rings to the plastron length of males and females separately (Figure 13) produced a positive linear relationship (Female r =0.828, Male r =0.817) with females growing faster and larger than males (Female slope=0.479, Male slope=0.345, p<.0001). There was little difference in the growth rates of females and males between ponds (Figure 14).

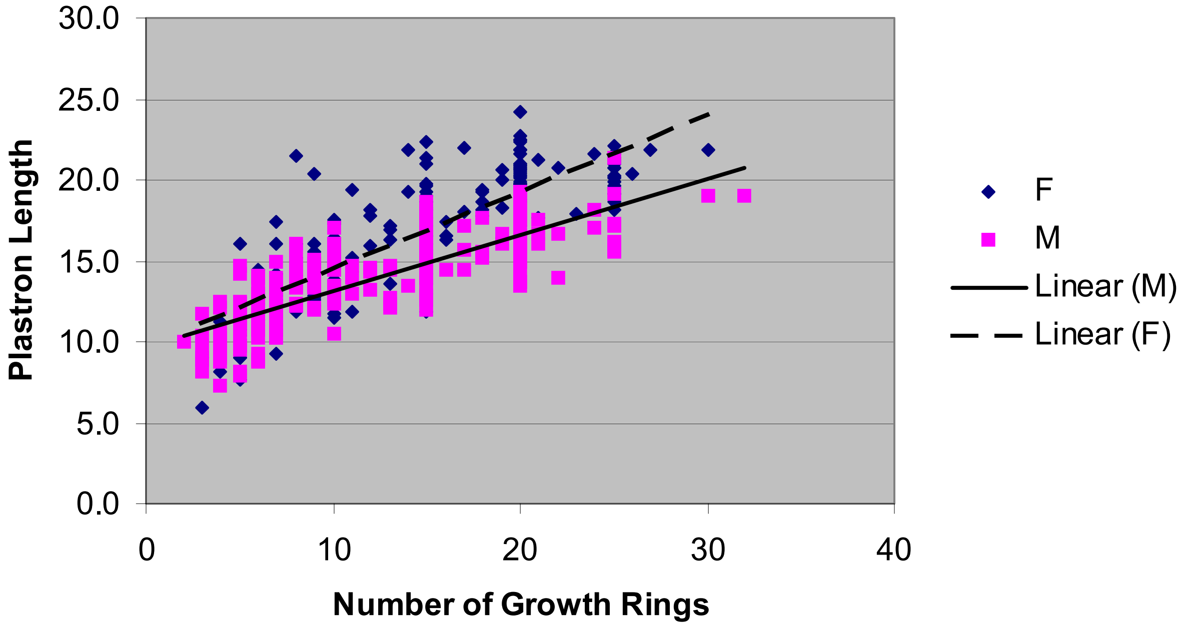
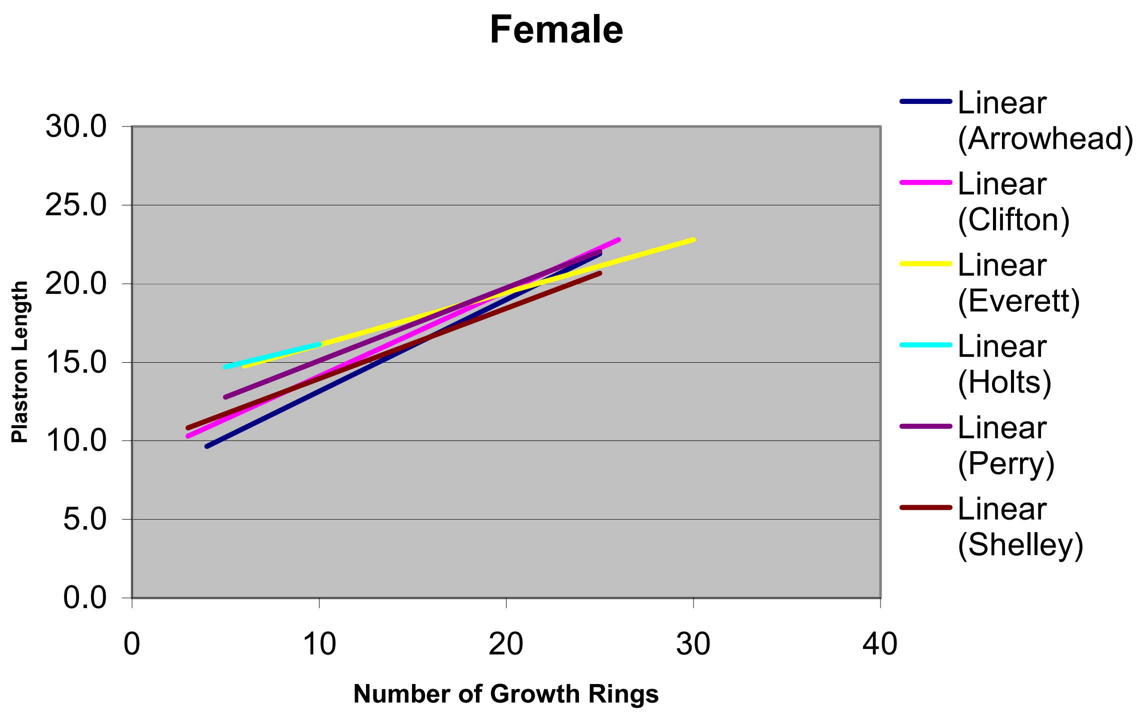


Figure 13. Male and female Yellow-bellied Slider growth rates across all ponds combined.

a)



b)

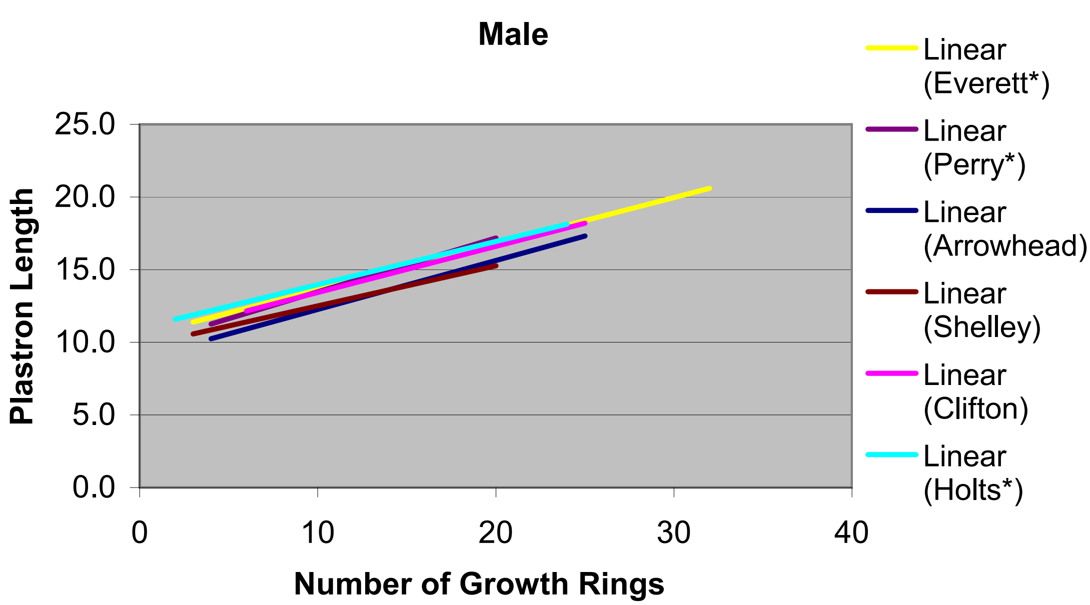


Figure 14. Turtle Growth for each pond**.** a) Female growth lines for each population. b) Male growth lines for each population. *=harvested populations.

There was a strong linear relationship (r = 0.9644) between the length of the plastron and the depth of the shell (Figure 15). The relationship between the plastron length and mass of the turtle was a strong curvilinear relationship (r =0.9695, Figure 16).

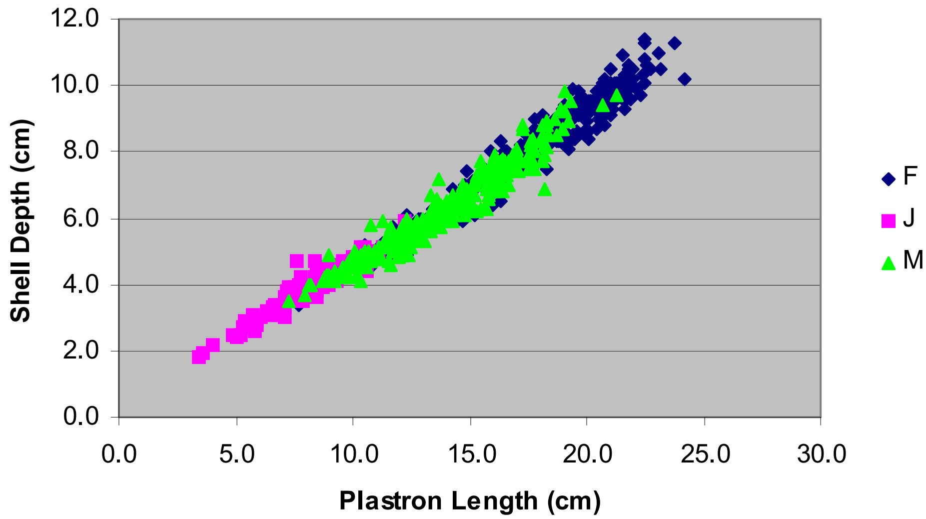


Figure 15. Linear relationship between plastron length and shell depth (r= 0.9644) for male, female and juvenile Yellow-bellied Sliders.

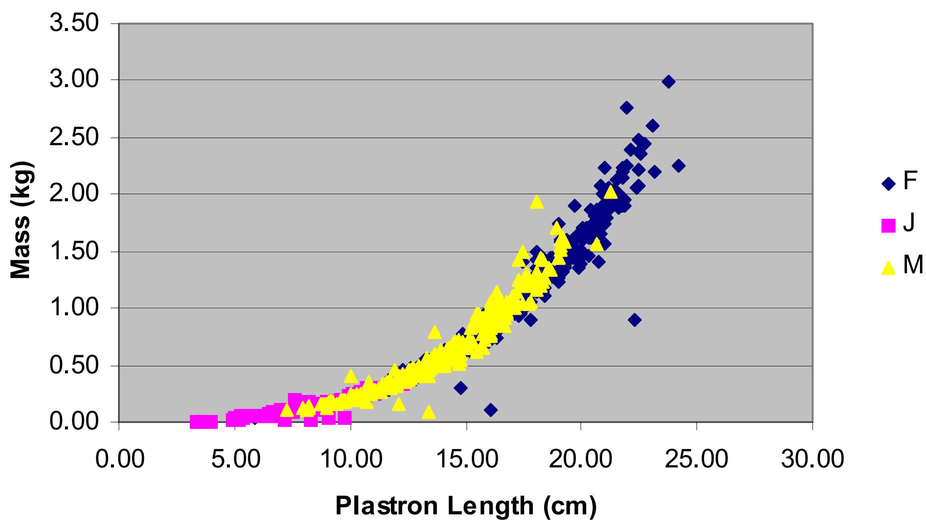


Figure 16. Curvilinear relationship (r = 0.9695) between plastron length and mass for male, female, and juvenile Yellow-bellied Sliders.

Sex Ratio Differences

I believed that harvested populations would have a higher proportion of males over females as compared to unharvested populations (which should have roughly even sex ratios) because female turtles tend to be larger than male turtles (Spenser 2002, Congdon et al. 2003, Znari et al. 2005) and harvesters generally take the largest turtles (Rodney Wilson, personal communication), though there is no written record of size selection. The general trend in this project supports this hypothesis. A significant difference, however, was not detected (Table 2).

Table 2. Trends in percentage of male turtles and population density for harvested and unharvested populations of Yellow-bellied Sliders.

	Average % males	*Average '04 pop. Density (turtles/acre)*	*Average '05 pop. Density (turtles/acre)*
Harvested (N=233)	52.522	5.707	8.398
Unharvested (N=287)	47.959	4.568	4.921

Size and Age Distribution Differences

Similarly, because harvesters generally remove the largest turtles from a population, I hypothesized that harvested populations would have smaller, younger turtles than unharvested populations. The opposite trend was seen in the populations of this study. Although the differences were not statistically significant, the average size of turtles in harvested populations seemed to be larger than the average turtle size in unharvested populations (Table 3). In addition, the percentage of turtles in the lower age categories was actually higher in unharveted populations and the percentages of turtles in age categories 4 and 5 were higher in the harvested populations (Table 4). Interestingly, the percentage of turtles in age category 3 was equally low in both types of populations.

Table 3. Mean plastron length (PL), carapace length (CL), and weight (Wt) for harvested and unharvested populations of Yellow-bellied Sliders.

	Mean PL (cm)	*Mean CL (cm)*	*Mean Wt (kg)*
Harvested (N=233)	14.967	16.391	0.8671
Unharvested (N=287)	13.407	14.645	0.6528

Table 4. Mean percentage of turtles in each age category from all the harvested and unharvested populations of Yellow-bellied Sliders.

	1	*2*	*3*	*4*	*5*	*6*
Harvested (N=233)	16.493	30.290	7.932	19.713	28.313	4.765
Unharvested (N=287)	19.477	31.967	7.947	14.978	20.589	5.042

Density Differences

Since harvesters remove hundreds of turtles from a population and migration into a population tends to be slow (Morreale et al. 1984), I hypothesized that the density of harvested populations would be lower than that of unharvested populations. Analysis suggested the opposite (Table 2), although again the differences were not significant. The Shelley Lake/Holts Pond pair was removed from the 2005 population density analysis because of the lack of data for Holts Pond in 2005.

DISCUSSION

Population Estimates

The population estimates for each pond generally varied greatly between field seasons. It seemed unlikely that the size of the turtle populations actually changed that much over the course of one year, and the change was more likely to be due to the difference in the number of sampling occasions per season. In the second field season there were three sampling occasions for each pond, whereas in the first season there were only two sampling occasions. The third occasion greatly increased the number of recaptures for the second season, allowing for a more precise estimate in the 2005 season (see Appendix).

The M_t model estimates allowed for changes in capture probability between sampling occasions. However, there may also be heterogeneity between individuals, which is likely in most field studies (Gilbert 1973), which is not accounted for in the model and may cause a negative bias on the estimates (Table 1). This bias may be totally or partially offset, however, by not accounting for a possible trap shy response, which seemed to be indicated by the low number of recaptures and may cause a positive bias on the estimates. Trap placement may also cause a negative bias on the estimates. Since the number of traps placed in each pond was relatively low compared to the size of the ponds, especially in Everett Lake, some turtles may have had a capture probability of zero simply because there were no traps within the area they occupied. Future studies should have a much higher density of traps, possibly as many as 1 trap/aquatic acre, and trap placements should be randomly selected for each trapping occasion to avoid the possibility of a turtle having a capture probability of zero.

Population Dynamics

The variation in the size distributions of plastron length for each pond between field seasons may be due to the increased number of sampling occasions in the second field season. The larger sample sizes of the second season may more accurately portray the true size distributions. Continued sampling of the populations is required to get a precise picture of both the age and size distributions of these populations.

Turtle Growth

The different patterns of growth between male and female Yellow-bellied Sliders (Figure 13) support the general findings that females grow faster and larger than males (Dunham and Gibbons 1990, Spenser 2002, Congdon et al. 2003, Znari et al. 2005). Strong positive relationships between plastron length and shell depth and plastron length and mass were also expected since the variables are dependent.

It was not surprising that no differences were found among the growth rates of turtles in various ponds. Growth rates for a species of turtle tend to be consistent between populations and can be reliably modeled as long as data are available from all age classes (Frazer et al. 1991, Spencer 2002). Most growth models, however, lack data on juvenile age classes because it is difficult to catch sufficient numbers of small, hatchling and two-year-old turtles (Spencer 2002). Therefore, only mature male and female turtles were used in the growth comparisons here.

Hypothesis Testing

The high amount of variance in the data does not allow for any valid results from the hypothesis testing that was conducted. Below is a brief discussion of the trends that were seen in the results, but I would stress that no definite conclusions can be drawn from these results.

Sex Ratio Differences

Harvested populations had a higher proportion of males as hypothesized, however the difference was not statistically significant.

Size and Age Distribution Differences

The differences between the size and age distribution of turtles in the two types of populations was surprising. I expected harvested populations to have a higher proportion of young turtles than unharvested populations and have fewer old turtles because they were removed from the population at harvest. The exact opposite trend was seen it the populations studied and may be due to differences between the ponds unrelated to harvesting or to sampling bias.

The low number of turtles found in age class 3 (10-14 years) may be an anomaly of this sample of populations. It may also be a result of a myriad of natural disasters that occurred in the years this group of turtles were hatched. This group of turtles would have been hatched between 1990 and 1995. While few highly destructive weather events occurred in the Piedmont from 1990 through 1992, several disasters resulting in billions of dollars in damage occurred between 1993 and 1996. It began with one of the largest snowstorms in history, covering 1/3 of the United States in March of 1993, bringing 2-4 feet of snow, hurricane forces winds and tornados. This “Storm of the Century” caused over $3 billion dollars in damage and killed 270 people (Lott et al. 2006). Following this super storm came a severe heat wave and drought that brought the driest and second hottest summer on record for North Carolina since 1895 (Lott 1994). Another severe winter storm in February of 1994 covered much of the western half of the state in ice and brought extremely cold temperatures to the entire state (Lott and Sittel 1996). The severe weather of these two years could have greatly reduced both the nest success and hatchling and juvenile survival rates. Hatchling and juvenile survival may also have been low in 1996 when Hurricane Fran washed out many of the dams across the Piedmont, including those of several of the ponds used in this study. Further sampling both in the ponds studied here and in additional ponds is required to determine if this decline is seen in populations across the state or is simply an anomaly.

Density Differences

The population density was found to be higher in harvested populations than in unharvested populations, although again the difference was not statistically significant. This result may also be an anomaly of a small sample size, especially since one pair of populations was not used in the 2005 analysis. Other explanations of this difference are not clear, other than natural variation between the populations. The harvested ponds may have some habitat features, such as less herbaceous emergent vegetation, a larger amount of nesting habitat around the ponds, or higher isolation from other wetlands, that may increase the abundance of turtles in a particular pond (Sexton 1959a, Marchand and Litvaitis 2004), thus making them appealing to harvesters in the first place.

Conclusions and Conservation Implications

Overall, none of the hypotheses set forth in this study were supported statistically. This does not mean, however, that harvesting has not affected turtle populations. The amount of variation in the estimates of the study make drawing any clear conclusions impossible. Therefore, more research is required before the effects of harvesting on freshwater turtle populations can truly be understood. Examples from sea turtle and large mammal harvests provide useful comparisons for the effects of harvesting on freshwater turtles.

The incidental capture of sea turtles by fish and shrimp trawlers resulted in a situation similar to that now facing freshwater turtles. While the specific life histories of sea turtles and freshwater turtles are somewhat different the general characteristics of being long-lived and late maturing are the same. These similarities suggest that methods used to study the effects of harvesting on sea turtle populations could also be used to study the effects on freshwater turtle populations.

Stage-based models proved useful in assessing the effects of harvesting on sea turtle populations. Stage-based models involve dividing the life history of an organism into broad stages, rather than analyzing the population by age (Crouse et al. 1987, Heppell et al. 1996). The stage-based modeling method is useful for organisms that have easily defined life stages, but for which it is difficult to know the exact age, such as turtles. The life history of freshwater turtle populations could be analyzed using just four life stages: hatchling, juvenile, subadult, and adult. Data on the fecundity and survival rates for each stage, as well as some measure of the probability of remaining in a stage or moving on to another stage could be used to develop a population projection matrix to estimate population growth rates (Crouse et al. 1987, Heppell et al. 1996, Williams et al. 2002).

The advantage of a population matrix, in addition to estimating population growth rates, is that changes in parameters can be simulated to test the sensitivity of the population growth rate to these changes. Changes in the survival of the juvenile and subadult stages, measured as elasticity, have the largest effect on the population growth rate in both sea turtles (Crouse et al. 1987, Heppell et al. 1996, Heppell 1998) and freshwater turtles (Reed and Gibbons 2003). Reed and Gibbons (2003) ran population simulations for all the non-marine turtle species native to the United States, including the Yellow-bellied Slider. They set Yellow-bellied Slider age-at-maturity at 8 years and annual female survival at 0.83 and found that the elasticity of fecundity was 0.0776, the elasticity of survival of juveniles was 0.5434, and the elasticity of survival of adults was 0.3790 (Reed and Gibbons 2003). Reed and Gibbon's (2003) results support claims made by sea turtle researchers that no amount of effort put into egg protection alone can prevent the eventual extinction of a model population (Crouse et al. 1987, Heppell et al. 1996, Heppell 1998), although it is an essential part of the conservation process (Heppell 1997).

Reed and Gibbons (2003) then developed an index of turtle vulnerability based on the geographic range area, adult survival elasticity, and the median sale price of an individual as reported by the Law Enforcement Management Information System (LEMIS), which is maintained by the U.S. Fish and Wildlife Service. Of the ten most vulnerable species native to the United States that are subject to legal commercial harvesting most have high adult survivorship, require 5-11 years to reach sexual maturity, have some of the smallest clutch sizes of all turtle species native to the United States, and often have restricted geographic ranges, although they may be locally abundant (Reed and Gibbons 2003).

Two of these "Top 10"species, the Striped Mud Turtle (*Kinosternon baurii*) and the Red-bellied Turtle (*Pseudemys rubriventris*), occurred in North Carolina. Seven other North Carolina turtle species fell at the opposite end of the spectrum. The species determined to be the least vulnerable to harvest was the Yellow-bellied Slider (Reed and Gibbons 2003). It is important to keep in mind, however, that even species with wide geographic ranges and relatively high clutch sizes, such as the Yellow-bellied Slider, can be locally vulnerable to population declines (Reed and Gibbons 2003). Continued harvest of sliders in Louisiana lead to a loss of large-bodied females in the exploited populations (Close and Seigel 1997).

Comparing the life history of turtles to that of mammals helps to put things in better perspective. Among mammals only a few large-bodied species such as elephants, hippos, whales, and chimpanzees have an age at maturity (7-15 years) and total life span comparable to turtles (Reed and Gibbons 2003). Many of these species, and a few others, also exhibit adult female survivorship comparable to that of turtles (0.85-0.96; Reed and Gibbons 2003). Not many resource managers would argue that these mammalian species could be heavily harvested without causing population declines. Many are now of concern to conservationists because of previous over-exploitation, especially elephants and whales. Acknowledgment of the need for conservation of these mammalian species should also warrant acknowledgment of the need for conservation of turtle species that display similar life and exploitation histories. "To do otherwise is rampant taxonomic chauvinism" (Reed and Gibbons 2003, pg 21).

The vulnerability of freshwater turtles to harvesting is likely even higher than Reed and Gibbons (2003) reported. Many of the studies done on Yellow-bellied Sliders were conducted on reserve lands, specifically the E.S. George Reserve in Michigan and the Savannah River Ecology Reserve in South Carolina, where turtles are somewhat protected from mortality due to humans and human constructions. Populations that are not on protected lands or in highly rural areas will be exposed to a higher incidence of road mortality. Road mortality has been implicated as a significant source of female-biased mortality in semi-aquatic and terrestrial turtle species (Marchland and Litvaitis 2004, Steen and Gibbs 2004, Aresco 2005, Gibbs and Steen 2005). Female freshwater turtles may travel as far as 1km from water in search of a nesting site (Congdon et al. 1987) and often must attempt to cross roads (Aresco 2004, Marchland and Litvaitis 2004). Up to 66% of road-killed turtles in an area may be female (Gibbs and Steen 2005), greatly reducing the adult female survival rate from the 0.82-0.96 used by Reed and Gibbons (2003) in their calculations of vulnerability.

Future Research

The weakness of the current study should be a starting point for future studies. This study was an observational study in which the "treatment" ponds could not be chosen randomly, and there was no precise matching of unharvested ponds to the harvested ponds. Because of these factors the results are confounded by any environmental and habitat differences that the ponds may have had. Additional variation was caused by the small sample size for each "treatment" (n=3/treatment). Many more ponds of both types, with a higher density of traps, need to be surveyed to get a general idea of the state of current populations.

Additionally, more work needs to focus on the migration of turtles between ponds and the possible existence of metapopulations, regional populations that are stratified into geographically defined local populations occupying relatively homogenous subranges (Williams et al. 2002). Turtles will migrate over land and through stream channels up to 5km (Wilbur 1975, Morreale et al. 1984, Burke et al. 1995). Migration violates the assumptions of a closed population necessary for the validity of the population estimators used in this study. Acquiring enough data to attain valid estimates requires spatially extensive sampling, high marking effort, and studies of sufficient duration to detect movements to distant populations, which may be 20 years or more (Burke et al. 1995). Terrestrial capture methods such as drift fences and pitfall traps, as well as placing traps across the streams that feed ponds, should be used to determine migration paths. Radio telemetry tracking, in addition to the traditional mark-recapture study, would also be useful in studying the movement and migration of freshwater turtles.

In addition to movement over land and between ponds, movement within the ponds should be assessed. The types of vegetation in a pond can dictate where most turtles will be found throughout a season. Turtles will move to areas that have their preferred plant species as those plants emerge onto the surface of the water (Sexton 1959a). Saturation trapping, with a corresponding mapping of the emergence of plant species, would help to define within-pond movements and is necessary in assessing the effects of harvesting.

Ideally, a study on the effects of harvesting would have a before-after, control-impact (BACI) design (Strickland et al. 1996, Williams et al. 2002), where information is known about the population before harvesting occurred so that, assuming all other factors are the same, harvesting is the only change to the population (Ott and Longnecker 2001). In many cases of harvesting, including turtle harvesting in North Carolina, there is little or no information on the population before harvesting occurred (Bjorndal 1999). When there is no "before" data, a control-impact design with very precise pairing of treatment and control populations can be used. The pairing of wetland sites needs to match the soil type, water depth and quality, surrounding habitat, aquatic vegetation and geographic location (vicinity to roads and/or communities) of harvested and unharvested sites as closely as possible to isolate the effect of harvesting as much as possible and reduce confounding factors.

Another tool that would be extremely helpful in understanding the effects of harvesting on turtle populations is simulated population modeling, specifically stage-based modeling. As described above, staged-based modeling has been useful in the assessment of sea turtle populations. Freshwater turtle life histories have properties similar enough to those of sea turtles that this type of simulation modeling would also be useful in assessing these populations. The modeling can be used to not only predict how current populations will fare in the future, but also assess the effects of future harvesting at various levels and of various life stages. Modeling is also relatively easy and some models can be generated with only age at maturity, adult female annual survival, which is similar among many turtle species, and population multiplication rate, which would allow modeling for species about which little is known (Heppell 1998). These models have the added benefit of including many aspects of turtle biology, which is essential in formulating a management plan for any species (Heatwole 1997).

Reed and Gibbons (2003) determined that Yellow-bellied Sliders were the species in the U.S. least vulnerable to harvesting. Therefore, modeling and study should begin with this species in North Carolina. If any level of harvesting is determined to be unsustainable for Yellow-bellied Sliders, it can then be assumed that it would be unsustainable for all other turtle species that occur in North Carolina since all other species are more vulnerable to harvesting (Reed and Gibbons 2003).

Much research needs to be done on all North Carolina turtle species, both on individual species and on the interactions between groups of species, before it can be determined whether any of them could withstand any amount of harvesting. Research from other parts of the country would suggest, however, that harvesting at any level, of even the most abundant species, would not be sustainable (Reed and Gibbons 2003).

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APPENDIX

Table A1. Life history characteristics of four common species of freshwater turtles. Size is the straight line length of the carapace.

Family	*Species*	*Common Name*	*Eggs per clutch*	*Clutches per season*	*Longevity*	*Size at sexual maturity*
Chelydridae	Chelydra serpentina	Snapping Turtle	20-50	1	30-40 yr	16.8-25cm
Emydidae	Chrysemys picta	Painted turtle	6-8	2 or 3	~30yr	16-16.5cm
	Psuedemys concinna	River Cooter	10-25+	1 or 2	40+ yr	24.5-30.2cm
	Trachemys scripta	Yellowbelly Slider	5-23	1 or 2	35+ yr	9-20cm

Table A2. Index of Stinkpot abundance. Calculated as number of stinkpots per trap night and given for each pond in each year. *=harvested pond

Traping Site	*2004*	*2005*
Arrowhead	0.20	0.28
Everett*	0.60	0.56
Clifton	1.00	0.88
Perry*	0.60	0.33
Shelley	0.54	0.33
Holts*	0.25	--

Table A3. Capture and recapture totals by species for 2004. Totals are the number of individual turtles captured. The number of recaptures for each species is in parentheses. Rcp= recaptures; RES = red-eared slider; YBS= Yellow-bellied Slider. *=harvested pond.

Trapping Stie	*Trap Nights*	*Total # of turtles*	*Cooter (Rcp)*	*Painted (Rcp)*	*RES (Rcp)*	*YBS (Rcp)*	*Mud (Rcp)*	*Stinkpot (Rcp)*
Arrowhead	54	87	3 (0)	5 (0)	0	62 (6)	6 (0)	11 (0)
Everett*	60	113	6 (0)	0	0	71 (3)	0	36 (0)
Clifton	54	151	2 (0)	17 (4)	0	77 (6)	1 (0)	54 (3)
Perry*	60	131	5 (0)	24 (2)	0	66 (5)	0	36 (1)
Shelley	54	103	7 (0)	12 (4)	6 (2)	48 (5)	1 (0)	29 (1)
Holts*	60	46	1 (0)	8 (0)	0	22 (3)	0	15 (0)
Totals	342	631	24 (0)	66 (10)	6 (2)	346 (28)	8 (0)	181 (5)

Table A4. Capture and recapture totals by species for 2005. Totals are the number of individual turtles captured. The number of recaptures for each species is in parentheses. Rcp= recaptures; RES = red-eared slider; YBS= Yellow-bellied Slider. *=harvested pond.

Trapping Site	*Trap Nights*	*Total # of turtles*	*Cooter (Rcp)*	*Painted (Rcp)*	*RES (Rcp)*	*YBS (Rcp)*	*Mud (Rcp)*	*Stinkpot (Rcp)*
Arrowhead	72	100	5 (0)	4 (2)	0	51 (19)	20 (7)	20 (5)
Everett *	81	131	1 (0)	1 (0)	0	84 (23)	0	45 (0)
Clifton	75	168	1 (0)	30 (8)	0	66 (21)	5 (1)	66 (7)
Perry*	81	119	8 (0)	19 (6)	0	65 (16)	0	27 (1)
Shelley	72	107	5 (2)	15 (9)	5(2)	57 (44)	1 (0)	24 (2)
Totals	381	625	20 (2)	69 (25)	5 (2)	323 (123)	26 (8)	182 (15)

Table A5. Population estimates for each pond under all models. *=harvested pond. **=estimates unavailable.

	2004			2005			
Site	M0	Mt	Mb	M0	Mt	Mb	Mh (Chao)
Arrowhead	84 (15.1)	62 (.16E-16)	84 (15.1)	259 (106.67)	253 (104.22)	69(13.8)	419(238.9)
Everett*	772 (429.34)	757 (420.17)	**	292 (71.54)	286 (69.52)	**	380 (121.81)
Clifton	352 (113.08)	347 (111.26)	118 (27.55)	210 (55.19)	204 (53.40)	**	261 (87.99)
Perry*	338 (126.84)	321 (119.64)	74 (5.71)	502 (238.75)	483 (228.60)	**	530 (262.18)
Shelley	90 (16.71)	89 (16.46)	80 (28.78)	97 (14.41)	95 (13.75)	**	111 (23.83)
Holts*	77 (39.20)	69 (34.26)	35 (17.94)				