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Physical and Health Assessment of a Population of Raccoon (Procyon lotor) in Northeastern Florida

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Albert Einstein once wrote "The most beautiful thing we can experience is the mysterious. It is the source of all true art and all science. He to whom this emotion is a stranger, who can no longer pause to wonder and stand rapt in awe, is as good as dead: his eyes are closed."

I can honestly say that my eyes have been open since I was five and wanting to study dinosaurs. The world and its massive variety of animals and beauty has and will forever intrigue me. I owe a debt of love and gratitude to my parents; who never uttered the phrase "Eric do not touch that it's a snake!" Who even went out and bought my first snake, my ball python Sid for me. They who allowed, strengthened, and helped cultivate my passion and love for reptiles.

As a freshman at The Pennsylvania State University I had the opportunity to go to the country of Belize for a month to study tropical biology. During this trip I met a biology professor, Dr. Brian Hauge. During the month that I was in Belize Dr. Hauge would take me out on night hikes and we would find all sorts of herps; from coral snakes and ferdelances to the red-eyed tree frogs. Through all of our experiences we built a friend/mentor relationship. When we came back to the states I learned that he had a turtle population study in Wekiwa Springs State Park, Florida. Through the next 7 years I took classes for this project, became a teaching assistant, and would eventually inherit the project. I sincerely thank Dr. Brian Hauge for being what a professor should be; a teacher, mentor, and friend, who will always be valued beyond words.

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ABSTRACT

The purpose of this research was to study the potential negative effects that mesopredators have on their environment and to promote control of mesopredator populations. Overabundant predatory species such as the raccoons (*Procyon lotor*) and Virginia opossums (*Didelphis virginiana*) can have significant pernicious effects on populations of autochthonous prey species, particularly when super predators such as the red wolf (*Canis rufus*) and Florida panther (*Felis concolor coryii)* are absent. These overabundant species, coined as mesopredators, are often responsible for extreme levels of predation on prey species and/or their young. The mesopredator release hypothesis involves the "release" or increased density of a generalist/opportunistic consumer species. This release hypothesis has two main predictions: first the absence of top predators lowers nest success of prey populations; the second there is a subsequent positive relationship between hyperabundant mesopredators and nest/prey predation. This phenomenon occurs because super predators such as the wolves and big cats have been driven to extinction or extirpation.

To study the effects of mesopredators I used several approaches. Overabundant raccoons (29) were removed from a

known diamondback terrapin (*Malaclemys terrapin centrata*) nesting beach to evaluate the reduction in terrapin nest predation. Next, I studied age structure, stomach content, and parasite load of the removed raccoons to determine several criteria. By determining the negative impacts such as over-predation of listed and ecologically important species and mesopredator potential to spread infectious diseases and parasites, I hope to promote population control of these animals.

Analysis of sex ratios showed that adult males dominant (6/23). Gut content analysis showed that raccoons partook in over 11 different prey items including terrapin hatchlings. The parasite load included five nematode species, one acanthocephalan, and one cestode, and two protozoan parasites. Several parasites found pose a threat to human health and the control of such species is a concern.

By studying mesopredator life history traits (population age, diet, and parasite population) we hope to understand the various negative effects it may place upon its environment. With this knowledge, further research and possible control methods may be proposed.

INTRODUCTION AND LITERATURE REVIEW

The overabundance of native species has become an important ecological issue in the past several decades (Maclaren 1992, Garrott et al. 1993, Goodrich and Burkirk 1995, Crouchamp et al. 1999 and 2000, Engeman et al. 2003, Schmidt 2003). These expanding "overabundant" native species often negatively affect other more uncommon native species. Populations of rarer, threatened or endangered species may be exposed to unnaturally high densities of native predators and some cannot cope with the added stress put upon them by predation (Crouchamp et al. 1999 and 2000, Schmidt 2003).

The mesopredator release hypothesis, a term coined by Soule et al. (1988), describes the "release," or increased density, of such generalist/opportunistic consumer species as raccoons (*Procyon lotor*), Virginia opossum (*Didelphis virginiana*), and the nine-banded armadillo (*Dasypus novemcinctus*) (Rogers and Caro 1998, Terborgh et al. 1999, Engeman et al. 2003, Schmidt 2003). This hypothesis has two main predictions: the absence of top predators such as red and grey wolves (*Canis rufus* and *Canis lupus*), Florida black bears (*Ursus americanus floridanus*), Florida panther (*Felis concolor coryii*), and coyotes (*Canis latrans*) lowers nest success of the prey populations themselves. There is a subsequent positive relationship between hyper-abundant predators (raccoons) and nest/prey-predation levels (Soule et al. 1988, Maclaren 1992, Garrott et al. 1993, Palomares et al. 1995, Rogers and Caro 1998, Crooks and Soule 1999, Engeman et al. 2003). Rogers and Caro (1998) found that during the years when coyotes were present, the survival of ground-nesting birds increased significantly due to the coyotes' ability to control the abundance of raccoons in the study area.

Raccoons and other mid-level predators have been shown to have population densities 4-10 times higher than normal in continental habitats and up to 35 times higher in insular landscapes without some form of control (Soule et al. 1988, Terborgh et al. 2001, Gerht et al. 2002, Lariviere 2004). Akin to exotic species, overabundant native species have the same capacity to reduce native prey densities or diversity by causing local extinctions and decreased relative abundance (Garrott et al. 1993). Terborgh et al. (2001) studied super predator-free islands in Venezuela, and found that the consumer species (middle-down predators), on these super predator-free islands achieved densities 10-100 times higher than those that are living on the South American mainland where super predators such as red wolves existed. This suggests that the absence of top-predators can allow middle-down consumer species to reach well above normal population densities.

Palomares et al. (1995) illustrated that the absence of top predators can have a direct impact on game species, resulting in population crashes. They also suggested that by protecting and conserving the top predators in an environment, the game species populations will increase over time and become sustained. The Iberian Lynx (*Lynx pardinus*) was removed from Spain and over time the middle-down predator, the mongoose (*Herpestes ichneumon*), became overabundant. This led to extensive predation pressure on rabbits (*Oryctolagus cuniculus*), causing rabbit populations to decrease (Livaitis and Villafuerte 1996).

Increase of mesopredator release has been documented to affect songbirds, waterfowl, and turtles (particularly sea turtles) (Greenwood 1982, Maclaren 1992, Rogers and Caro 1998, Engeman et al. 2003, Schmidt 2003). Gerht (2002) performed spotlight surveys in Illinois on raccoon (*P. l. lotor*) populations from 1981-2000 and documented a threefold increase in raccoon abundance on a statewide level. As a result, songbird diversity declined steadily throughout those years (Gerht 2002, Gerht et al. 2002, Schmidt 2003).

Schmidt (2003) conducted research on the songbirds in Illinois (using Gerht et al. 2000 and 2002 data), choosing to study the effects of the high mesopredator population by looking at the differences between "raccoon vulnerable" species, those that primarily nest on the ground or in low-lying trees, and "raccoon invulnerable" species, those that nest high in the trees. Due to the height of their nests, raccoon invulnerable species were mostly protected from predation. Raccoon vulnerable species had predominantly negative population trends in the twenty-year period (1981-2001). Anecdotal observations in the years prior to his study suggested that raccoon abundance was not a factor in songbird population decline (Gerht et al. 2000 and Schmidt 2003). This increase in raccoon predation was attributed to the loss of their natural predators such as the coyote and the shortening of the raccoon hunting season (Schmidt 2003).

Soule et al. (1988) studied the effects of mesopredator release on chaparral-requiring birds. When the top predator, the coyote, was absent, predation by raccoons upon these scrub-breeding birds increased significantly. This drastic increase in predation has fast become a catalyst, speeding up extinction rates of these birds.

Overabundant mesopredator populations also increase the mortality of herpetofauna, and this has lead to research on methods to limit this predation. Raccoons have become a particular concern, affecting turtle populations mainly due to their propensity to predate nests (Erickson and Scudder 1947). Predation by raccoons on sea turtle nests and hatchlings has been documented to range from 16%-100% (Davis and Whiting 1977, Seigel 1980, Stancyk 1982, Ratnaswamy et al. 1997, Engeman et al. 2002, Burke et al. 2005, Garmestani et al. 2005).

Raccoons are also the primary nest predator of the diamondback terrapin (*Malaclemys terrapin*), and all seven subspecies are affected (Erickson and Scudder 1947, Burger 1976, Roosenburg and Place 1994, Butler 2002, Fienberg and Burke 2003, Butler et al. 2004). Raccoons have been shown to depredate nearly 100% of nests on some beaches in the United States (Fienberg and Burke 2003, Butler et al. 2004). Walker and Sunquist (1997) suggested that periodic removal of the overabundant raccoon populations would reduce predation on Suwannee river cooter (*Pseudemys concinna suwanniensis*) nests. Christiansen and Gallaway (1984) studied the effects of such a raccoon removal program on yellow mud turtle (*Kinosternon flavescens*) nests in Iowa, and found higher hatching and hatchling success.

Overabundant animals can also introduce and spread parasites and infectious diseases, such as rabies and *Giardia* (Schad et al. 1984, Robel et al. 1989, Pimentel et al. 1998, Pozio and Rosa 2000, Weis 2001). As animal populations become more abundant, frequency of contact becomes a concern to humans, pets, and livestock (Soule 1990, Mankin et al. 1999, Engeman et al. 2002, Lariviere 2004). Many furbearing mammals have been recently labeled as vectors of various diseases or parasites with the capacity to spread them with ease (Shaw et al. 1998, Stephenson et al. 2000, Weis 2001). It is hoped that this study will help in the management of this overabundant and voracious predator by learning more about its life history and biology relative to brackish turtle biology and nesting in Florida.

Raccoon life history characteristics. - The raccoon is a medium-sized mammal that ranges extensively throughout the Nearctic realm. It is easily recognizable by the black mask on a grayish face with approximately four to seven alternating dark rings on the tail. Its size varies throughout its range, typically being larger in northern climates (Kaufmann 1982). There are 25 subspecies known; *P. l. lotor* occupies most of the state of Florida (Johnson 1970, Kaufman 1982). Raccoons are extremely adaptive, being found in abundance in rural and urban habitats. They have even thrived and increased in numbers as a result of human alteration of the environment and, at times, direct human interactions (being fed or exploiting refuse), to the point of becoming an overabundant native or nuisance species in some areas (Johnson 1970, Sealander 1979, Bigler et a. 1981, Richardson 1990, Maclaren 1992, Garrott et al. 1993, Goodrich and Burkirk 1995, Reynolds and Tapper 1996, Crooks and Soule 1999, Engeman et al. 2002, Burke et al. 2005). Raccoons are opportunistic and cunning, and they will eat a variety of foods including plants (nuts and berries), invertebrates (insects and crustaceans), reptiles (including turtles and eggs), birds (waterfowl and songbirds) and even small mammals (Kaufmann 1982, Maclaren 1992, Reynolds and Tapper 1996, Schmidt 2003, Barton 2005). Though generally nocturnal, they have been known to adapt their activity periods with the availability of food and water (Bigler et al. 1981, Hasbrouck et al. 1992, Mankin et al. 1999).

A variety of control methods have been implemented on various beaches and other habitats in the United States to alleviate turtle nest depredation. Nest translocations and barrier methods (fencing) have been used to protect sea turtle and diamondback terrapin nests from depredation

(Stancyk et al. 1980, Reynolds and Tapper 1996, Ratnaswamy et al. 1997, Bailey et al. 1998, Engeman et al. 2002, Feinburg and Burke 2003).

Maclaren (1992) states that the DNR suggests that biologists determine when control measures should be undertaken to protect listed species. When it is decided that control measures are needed the preferred method is selective and lethal removal of the offending species. Other methods such as translocation, besides being expensive (usually $ 50.00 per animal), have met with poor success. In North Carolina, 300 raccoons were translocated; of these only 16% survived (Maclaren 1992). Lethal removal projects have had some success (Bailey et al. 1998, Ratnaswamy and Warren 1998, Wright et al. 2000, Garmestani et al. 2005). Garmestani et al. (2005) removed 14 raccoons from several sea turtle nesting beaches in the Ten Thousand Islands Archipelago. These islands reportedly had previous predation rates of 76-100% and after removal of the raccoons, predation decreased to 0%.

Another study (Wright et al. 2002) examined the re-introduction of natural raccoon predators, such as the red wolf, to a sea turtle nesting area. The wolves managed the mesopredator population, decreasing the sightings of raccoons and the predation they caused upon the sea turtle nests. However, the wolves learned to dig for sea turtle nests themselves causing predation rates to rise again.

It is important to learn how to manage overabundant species like the raccoon due to the problems they can cause to other species of wildlife and to humans. In the coming decades, problems such as their ability to cause decreases in diversity and abundance of rare species, their susceptibility to harmful diseases and parasites coupled with their ability to become vectors, could lead to biotic impoverishment and increasing conflict with humans (Garrott et al. 1993, Rogers and Caro 1998, Engeman et al. 2002). Garrot et al. (1993) stated that overabundant or expanding native species that negatively affect other native species should be treated as exotic species in certain circumstances. It should be determined if the predator is genuinely overabundant in the area and if its level of predation is detrimental to the stability of the native biota's populations. The populations of adversely abundant species should be monitored and perhaps manipulated to avert these increasing negative effects (Maclaren 1992, Garrott et al. 1993, Schmidt 2003).

The objectives of this study were twofold: (1) to remove raccoons from a diamondback terrapin (*Malaclemys terrapin centrata)* nesting beach via lethal methods while monitoring the beach for nesting and hatching success; (2) to collect data on the raccoons including age, the prevalence and accumulation of helminth fauna, past reproductive success of females, and stomach contents that indicate their food habits.

Past Research at Study Site (Terrapin nesting /predation studies). - In 1997 and 2000, a nesting, nest predation, and hatching emergence study of the Carolina diamondback terrapin, (*Malaclemys terrapin centrata*) was undertaken (Butler 2002, Butler et al. 2004). The nesting beach was monitored daily from 1 May through 31 October in both years, and nests were assessed for depredation, washout, and hatching success. Raccoons were found to be the major nest predator throughout the nesting season in both years, resulting in predation rates of 82.0% and 86.5%, respectively. Raccoons not only depredated the eggs from nests, but they actually preyed upon adult terrapins as well. Many carcasses of adult dead female terrapins were found on the nesting beach; they had been eviscerated by raccoons in order to reach the eggs inside.

In 1997, 454 nests were found, 372 of which were destroyed by raccoons (82% depredation rate). In 2000, 475 nests were found, and 411 were preyed upon (86.5% predation rate). Numerous raccoons were found living on the nesting island and evidence of their presence (scat and tracks) was recorded nearly every day (Butler 2002, Butler et al. 2004). To help determine the results of the nesting/predation study, a 2001 study on the raccoon population of the nesting beach island was performed.

Raccoon Activity/Home range/ and Refugia study 2001. - A trapping and monitoring study was conducted from 1 May to 9 December 2001 to determine when the raccoons were active, to calculate their home ranges, and to determine types of refugia used (J. Butler, unpublished data). Eight raccoons (6 males and 2 females) were captured and fitted with radiotelemetry collars. Throughout the study, no consistent pattern of activity was determined, as raccoons were seen active day and night and at low and high tides (J. Butler, unpublished data). Home ranges were calculated for the animals using Home Range Extension (HRE) program from ArcView. It was found that the raccoons preferred cedar trees (*Juniperus silicicola*) for refuge. We used this information in our study as we often placed our traps under or near southern cedar trees.

MATERIALS AND METHODS

Study area. - The nesting beach is on an island in Duval County, Florida. The island is somewhat triangular in shape and approximately 100 ha in area (Fig. 1). It is 90% salt marsh habitat, and criss-crossed with interconnecting tidal creeks. The island is bordered by three waterways: the Intracoastal Waterway (ICW) on the west, the Nassau River on the north, and Sawpit Creek on the southeast. Three other islands are adjacent to it: Amelia Island is situated to the north with a bridge that connects the two; another bridge connects the nesting island to Big Talbot Island to the south; and Black Hammock Island is located to the west across the ICW (Fig. 1). The Atlantic Ocean is approximately 4.8km to the east by way of the Nassau Sound. The 750m long beach occupies the northeastern side of the triangle and ranges in width from about 10 - 25m at high tide. Salt marsh vegetation on the island consists primarily of saltgrass (*Distichilis spicata*), saltwort (*Batis maritima*), needle rush (*Juncus roemerianus*), sea oxeye daisy (*Borrichia frutescens*), and cordgrass (*Spartina alterniflora* and *S. patens*).

Two adjacent tree stands are located on the western (ICW) side of the island, and we named these West Woods

North (WWN) and West Woods South (WWS) (Fig. 1). There are similar wooded areas on the northeastern corner of the island referred to as East Woods North (EWN) and East Woods South (EWS), and several stands of trees at the southern end of the island, named South Woods (SW) (Fig. 1). Areas of higher elevation on the island, including the five wooded areas, contained a mix of sabal palm (*Sabal palmetto*), saw palmetto (*Serenoa repens*), wax myrtle (*Myrica cerfera*), slash pine (*Pinus elliottii)*, and southern red cedar (*Juniperus silicicola*).

Trapping. - Raccoon trapping began 7 February 2005 and ended 1 November 2005, the later date corresponding to the end of the terrapin nesting and hatching study (E. Munscher and J. Butler, unpublished manuscript). Trapping was conducted in the vegetation along the beach and the various wooded areas of the island. Traps were set in and moved to areas where we found raccoon tracks, trails, or scat. Raccoons were trapped using a combination of nine single-door Tomahawk (model # 108) and Havahart (#1079) live-traps (both 81.3cm x 30.5cm x 25.4cm, Tomahawk Live Trap Co., Tomahawk, WI. and Woodstream Havahart Co. Steamboat Rock, IA.), usually baited with canned sardines in oil.

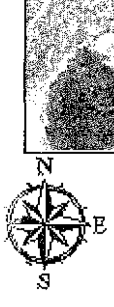


Figure 1: Location map and 2004 aerial photograph of study site.
Listing beach and wooded sites.

Depending on capture success with sardines, peanut butter and marshmallows were sometimes substituted (Garmestani et al. 2005). Longitude and latitude were recorded for all raccoon captures and by-catch with a hand-held GPS unit (Garmin model #GPSII, Olathe, KS). Traps were checked once daily and individual trapping events varied from one to four days per week depending on weather conditions and availability of personnel.

Study animals were weighed, anesthetized and sexed in the field. Trapped raccoons will drag nearby vegetation and sand/soil into the trap for bedding. In order to weigh the raccoon accurately, the debris had to be removed from the trap. Using a hook, the trap was upended so debris would accumulate near the trap door. The trap was then returned to its normal position, and we then pushed a pitchfork through the top of the trap to isolate the raccoon in the rear. With the raccoon secure, we opened the trap and swept the debris out by hand. With debris removed, the animal and trap were weighed together. Mean weight of the empty traps (4.6 kg) was determined prior to trapping using a 20 kg hanging Pesola scale (0.1 kg). Empty trap weight was subtracted from total weight to determine the weight of the animal.

Raccoons were injected intramuscularly with an anesthetic to immobilize them. With the pitchfork still in place, we introduced a "plunger" to press animal to the back of the trap. The plunger was a piece of plywood cut to the size slightly smaller than the trap door opening and attached to a metal pole 1.3m long. With the plunger inserted, the pitchfork was removed and pressure applied to the plunger to isolate the raccoon against the back wall of the trap. Gentle probing through the trap wall allowed us to locate an appropriate leg muscle for injection. Raccoons were anesthetized with ketamine at a dose of 10 mg/kg using a 22G x 1" needles and 3cc syringes (Seal and Kreeger 1987, Bigler and Hoff 1974). We often found that raccoons needed an extra 1.0cc over the recommended dose to fully immobilize them.

When raccoons succumbed to the ketamine, they were removed from the traps, muzzled, and placed in right lateral recumbency. The location of the heart was determined by palpation of the thoracic cavity with fingertips; once the heart was located raccoons were euthanized by injecting sodium pentobarbital at a dose of 1 ml/4.5kg into the heart using (18G x 1.5") needles and (3cc) syringe (Seal and Kreeger 1987, Bigler and Hoff 1974).

A post-mortem examination, including a search for ectoparasites and an assessment of other physical attributes or abnormalities such as scars or injuries, was performed. Raccoons were sexed in the field by observing external genitalia and deposited into marked plastic bags for storage in a laboratory freezer prior to further analysis and as a precaution to protect researchers from rabies (Kramer et al. 1999).

Laboratory Analysis. - Body measurements, age, gut contents, present/past reproductive success, and parasite load were determined in the lab. Before necropsy the following measurements were recorded to the nearest 0.1cm with a flexible tape measure: head and body length, tail length, head circumference, neck circumference, chest circumference, right hind foot length, shoulder to elbow length, and ear length from notch. Other characteristics such as sex ratio, parasite load, and parasite species were also calculated and recorded.

Age. - A combination of methods was used to determine the raccoon age: dry mass of the eye lens, dental characteristics, baculum size in males and uterine scarring in females (Sanderson 1961a and b, Linhart and Knowlton 1967, Johnson 1970, Grue and Jensen 1976, Fancy 1980). Sanderson (1961a) surveyed 119 raccoons for which he determined a relationship between age and weight of the lens of the eye. He concluded that the rate of growth of the lens varies little before 12 months of age and can be used to estimate the age of juvenile raccoons to the nearest month. Johnson (1970) found that the juvenile eye lens usually weighs less than 100 mg, sub-adults between 105-120 mg, and adults greater than 120 mg. This method becomes much less accurate as age increases, because lens growth slows and becomes more variable between the sexes (Johnson 1970).

We removed the eyeballs carefully during necropsy and preserved them in 10% formalin. Later the lenses were dissected from the eyes, dried to a constant mass in a drying oven at 80°C for four days (Sanderson 1961a and b, Johnson 1970, Kramer et al. 1999), and weighed using an electronic balance.

The lower mandible of each individual was removed to determine the age by measuring size of the pulp cavity of each incisor and by cementum annuli analysis (Linhart and Knowlton 1967, Johnson 1970, Fancy 1980, Barton 2005). The jaw was broken by hyper-extending it with physical pressure, and the lower mandible was removed and placed into 8M urea for four weeks to remove all leftover flesh. Mandibles were then placed into water for another four weeks to loosen connective tissue holding the teeth in place. Teeth were then extracted from mandibles and sent to Matson's Laboratories, Milltown, Montana for tooth cementum analysis (Richardson 1990). This technique counts the number of annuli in each tooth, and a certainty code is given to each tooth to assert how certain they are of the age given to each tooth. Highest reliability is designated as an A, which indicates that the tooth in question matches up almost perfectly with standardized cementum aging model for that species. Teeth given an A are given a 99% certainty that the tooth in question is the age it is estimated to be. Teeth that are not in near perfect shape are designated B, C, and D according to the condition and degree of wear of the tooth. These certainty codes are not guaranteed total accuracy due to the age or damage of the tooth so an age range is given instead of an exact age estimate.

Further aging criteria was obtained by examining the bacula. The baculum weight, length, conformation, and ossification have been reported to be very reliable characteristics in determining immature from mature male raccoons (Johnson 1970, Kramer et al. 1999). Adult males possess heavier and longer bacula with a gradual curvature towards the distal end. Johnson (1970) found that juvenile baculum weight was less than 1.2g, sub-adults typically were less than 3.0g and adults were greater than 3.0g. He asserted that with a high degree of certainty that sub adult raccoons would have a bacula weighing less than 2.5g. Kramer et al. (1999) classified adult males as having bacula weighing > 2.5g and having a length of > 90mm as sexually mature individuals.

We removed the bacula during necropsy and froze them for future assessment. For analysis bacula were thawed for a 24-hour period, then boiled in water for five minutes to loosen the extra tissue. Excess tissue was removed by scalpel and the bone was left to air dry for three hours. The bacula were weighed on an electronic balance and measured (1.0mm) using a ruler (straight measurement) and with a length of string to measure the curvature of the bone. Two bacula measurements were taken because upon literature review only the straight length method was used. We wanted to determine if there was a statistical difference between straight length and total length (with curvature).

In female raccoons the size and pigmentation of teats can provide a means of distinguishing females that have produced litters versus those that have not (Johnson 1970, Sanderson and Nalbanov 1987). Darkened, swollen teats typically indicate that a female has had offspring, while a

pink coloration usually indicates that the female has yet to reproduce (Kramer et al. 1999). Nipples were also manipulated by manually squeezing them to determine if lactation was occurring. This method proved to be beneficial because lactating indicates reproduction has occurred. Female raccoons often produce litters when they are 10-12 months of age (Kaufmann 1982, Kramer et al. 1999). Placental scars, thick dark bands around the lining of the uterus, can be used to determine how many seasons the female has been reproductively active. With this information, a minimum age can be determined assuming a minimum of one litter per year (Johnson 1970).
Reproductive tracts were examined for evidence of uterine scaring, corpora lutea, and fetuses.
The uterus was sliced open (cuts originating from both horns inferior to the uterine canal). The presence of uterine scars were detected with the naked eye and dissected uteri were then placed under a variable powered (4-40X) dissecting microscope to count the number of scars.

During dissection we noticed that intestinal length varied greatly between individuals and sexes. The intestines were subsequently measured with a tape measure (cm) and those lengths were compared to the other aging data using correlations to see if there were any significant similarities to determine if the differences in length were correlated with any aging methods.

Diets. - The thoracic and abdominal cavities were opened by slicing under the right forearm and continuing the incision down the rib cage to the right hind leg. Another incision was made vertically (right side to left side) along the abdominal cavity. We then cut through the rib cartilage and separated the diaphragm from the thoracic cavity wall. We removed the omentum surrounding the intestines and then removed the intestines themselves (from pyloric sphincter to anus), tying off the previously mentioned sections with string. We then removed the stomachs and preserved them in 10% formalin. Stomach contents were washed with distilled water and sieved using Hubbard sieves #548 No.10 (2mm openings), No.40 (0.42mm openings), and No.100 (0.149mm openings). Gut contents were identified using voucher specimens caught/gathered on the island and published stomach content lists (Barton 2005) as references to establish food habits. The contents were then quantified to determine the frequency of specific foods ingested (Anthony et al. 2000). We also determined if there was a significant difference between male and female raccoon diets. Intestines were removed and frozen for parasite analysis. The hearts were removed from each animal and incinerated due to the potential biohazard the injected euthasol inside them poses.

Parasites. - Stomach and intestines were surveyed for helminth fauna, which were then removed, and identified to the lowest possible taxonomic level when possible, and counted (Schad et al. 1984, Schmidt et al. (1989), Richardson (1990), Radomiski et al. 1991, Richardson et al. 1992, pers. Comm. Dr. J. Mitchell Lockhart). Other organs such as lungs, pancreas, bladder, and liver were not evaluated in this study. The small intestine was opened longitudinally and pulled through the handle of a pair of stainless steel scissors to scrape the mucosa and dislodge any parasites. Contents were washed and sieved (as described above for diet) to obtain ingested materials and small helminths.

A dissection microscope was used to examine intestine scrapings for parasites (Schad et al. 1984, Cole and Shoop 1987, Richardson 1990, Richardson et al. 1992). Helminths were initially fixed in individual specimen jars in 10% formalin and later transferred to 95% ethanol for preservation. Fecal samples were checked for parasite eggs by using Fecatect Dry Flotation Medium (Burns Veterinary Supply Inc, Rockville Centre NY). Each sample was placed into a 10ml specimen jar and filled to the top (creating a reversed meniscus) with Fecatect (a flotation medium ideal for identifying protozoan including giardia) (Shad et al. 1984). A cover slip was then placed on top of the specimen jar allowing parasite eggs to adhere to it. The cover slip was then observed using a compound microscope to identify helminth and other potential parasite eggs.

Tongues were removed and examined for the presence of *Trichinella spiralis*, a parasite often found associated with this organ. We used and adapted the methods described by Schad et al. (1984) and Richardson (1990) to process the tongues. Briefly, we took 5g tissue samples from each individual. We then combined all 29 samples, blended, and digested them in 1L of 1.0% HCl-pepsin for a minimum of four hours at 37°C in a constant temperature oven. We found that it actually took 6-8 hours to digest the tongues to an optimal viewing level. This mixture was shaken constantly throughout the 6-8 hour time period using large stir bars and a hot plate. This was then strained through a 0.84mm wire mesh screen, washed with distilled water three times, and viewed under a compound microscope. When a pooled sample was found to contain *T. spiralis* larvae, we repeated the trial using individual tongues, with a slightly larger sample size of less than or equal to 10g (Schad et al. 1984, Richardson 1990).

Parasites were identified by comparing them to pervious published descriptions by Schmidt et al. (1989), Richardson (1990), Sullivan (2000), and by J.M. Lockhart personal communication). Parasitic organisms were identified to the lowest possible taxonomic level.

Statistical tests were used to determine significance of raw data. Correlations and chi square tests were used on the gut and parasite data. To determine if there was a significant difference in the numbers of helminthes (#'s and species) between males and females, a chi-square test was performed. All data analyzed had expected values calculated to reflect differences in the sex ratio, number of captures per season, and other variable measurements (bacula size and weight). When testing for differences in response variables (e.g. stomach contents, body weight, and parasite species composition) between males and females data were corrected (following Yates 1934); to account for the skewed sex ratio.

Correlations and ANOVAs were also run on the aging data to determine which method of age assessment proved to be more accurate (Yates 1934). A correlation was run to determine whether or not there was a significant difference between the age classes of raccoons in regards to parasite/ helminth load and species composition. Aging data was compared to the tooth cementum analysis data due to Matson's laboratories 99% accuracy of true age.

Ghost crab burrow counts. - Ghost crab holes were counted daily to track their numbers throughout the hatching season to determine if the removal of the raccoons would "release" this potential mesopredator. Holes were counted each day by beach section (EB, EMB, WMB, and WB) and totaled for that given day. The ghost crab data was then put through a series of correlations to determine if there was a significant increase in the number of burrows on the island with the removal of the crabs primary predators.

Licenses and Permits. - A Drug Enforcement Administration (DEA) license was obtained in order to purchase and handle ketamine and sodium pentobarbital (Permit # RB0320387). A collecting permit was obtained from the Florida Department of Environmental Protection to trap and euthanize the raccoons (Permit # 11190412). The study area is within the Talbot Islands State Park therefore, it was necessary obtain a permit from Florida Fish and Wildlife Conservation Commission for the project (Permit # 04SR-159). Permission was granted from the University of North Florida Institutional Animal Care and Use Committee (IACUC).

RESULTS

Mesopredator analysis. - Removal of the mesopredators from the study area had a significant impact on the rate of diamondback terrapin nest predation. In 2005, 192 nests were marked and 23 of these were predated by raccoons, resulting in a 12% predation by raccoons and a 24.5% total predation rate (E.C. Munscher, J.A. Butler, and C. Cox unpublished manuscript). Comparing this year to the previous two study years where the predators were not removed (86.5% and 82% predation respectively), an average of 60% fewer nests were predated (E.C. Munscher et al. unpublished manuscript).

Twenty-nine raccoons were captured from 7 February to 31 October 2005. Monthly capture numbers ranged from one in April to six in June, and raccoons were captured in every month except October (Table 1). The first eight raccoons were captured within a 31-day period, and the ninth raccoon was not captured until 34 days after the eighth raccoon. Because of this long delay between captures of the eight and ninth raccoons, we believe that the first eight were residents of the study area.

Table 1: The number of raccoons captured and sex ratio during each month of the study.

Month	# Raccoons Captured (29)	Sex Ratio (M/F)
February	3	2/1
March	5	3/2
April	1	1/0
May	5	5/0
June	6	5/1
July	3	3/0
August	3	1/2
September	3	3/0

The sex ratio of captured raccoons differed significantly from month to month, and was significantly different from 1:1 for the entire study (chi-square = 8.83, d.f. =1, $P < 0.01$) (Table 1). The sex ratio was highly skewed, toward males (23/6).

Comparing male and female captures between the study months, there were significant size differences between males and females in almost every measured variable (Table 2) except those pertaining to males alone (bacula length and weight). Variables measured such as bacula length and weight varied during the trapping season with larger males being caught earlier in the season (Table 2). Eye lens weight differed between sexes and months of capture; males and individuals captured earlier in the season had heavier dried lenses (0.275 P = 0.203) (Table 3) (Appendix B).

Table 2: Raccoon length and weight differences by month; values are shown as means in centimeters (cm) and grams (g). NA represents a period of time when no raccoon was captured.

Month	Male (23 males)		Female (6 females)	
	Total Length (cm)	Weight (kg)	Total Length (cm)	Weight (kg)
February	90.3 (2)	6.3 (2)	84.3 (1)	3.6 (1)
March	92.9 (3)	5.9 (3)	77.9 (2)	3.4 (2)
April	98.3 (1)	6.4 (1)	NA	NA
May	89.3 (5)	5.3 (5)	NA	NA
June	87.8 (5)	5.5 (5)	80.8 (1)	3.4 (1)
July	83.6 (3)	5.8 (3)	NA	NA
August	79.7 (1)	4.6 (1)	76.0 (2)	4.1 (2)
September	85.0 (3)	5.2 (3)	NA	NA

The physical variables measured such as mass, body weight, ear to notch, shoulder height, girth, neck, length, tail, and body condition differed significantly between the sexes and the months when the animals were captured. Significantly larger raccoons were captured earlier in the season (Tables 1, 2, and Appendices A, B, and C).

Several physical variables were significantly correlated, such as: body weight and total length (54.4%, $P < 0.01$), total length and hind foot (42.4%, $P < 0.05$), and girth and total length (60.5%, $P < 0.001$) (Appendix A, B, and C).

Table 3: Differences in dried eye lens weight between sexes and month of capture. Shown as averages in milligrams (mg).

Month	Average Eye Lens Dry Weight (mg)		
	Male (23males)	**Female (6 females)**	**Difference (M – F)**
February	140.3 (2)	169.9 (1)	-29.6
March	141.1 (3)	130.1 (2)	11.0
April	132.3 (1)	NA	NA
May	112.1 (5)	NA	NA
June	145.0 (5)	131.8 (1)	13.2
July	124.5 (3)	NA	NA
August	100.6 (1)	113.2 (2)	-12.6
September	118.6 (3)	NA	NA

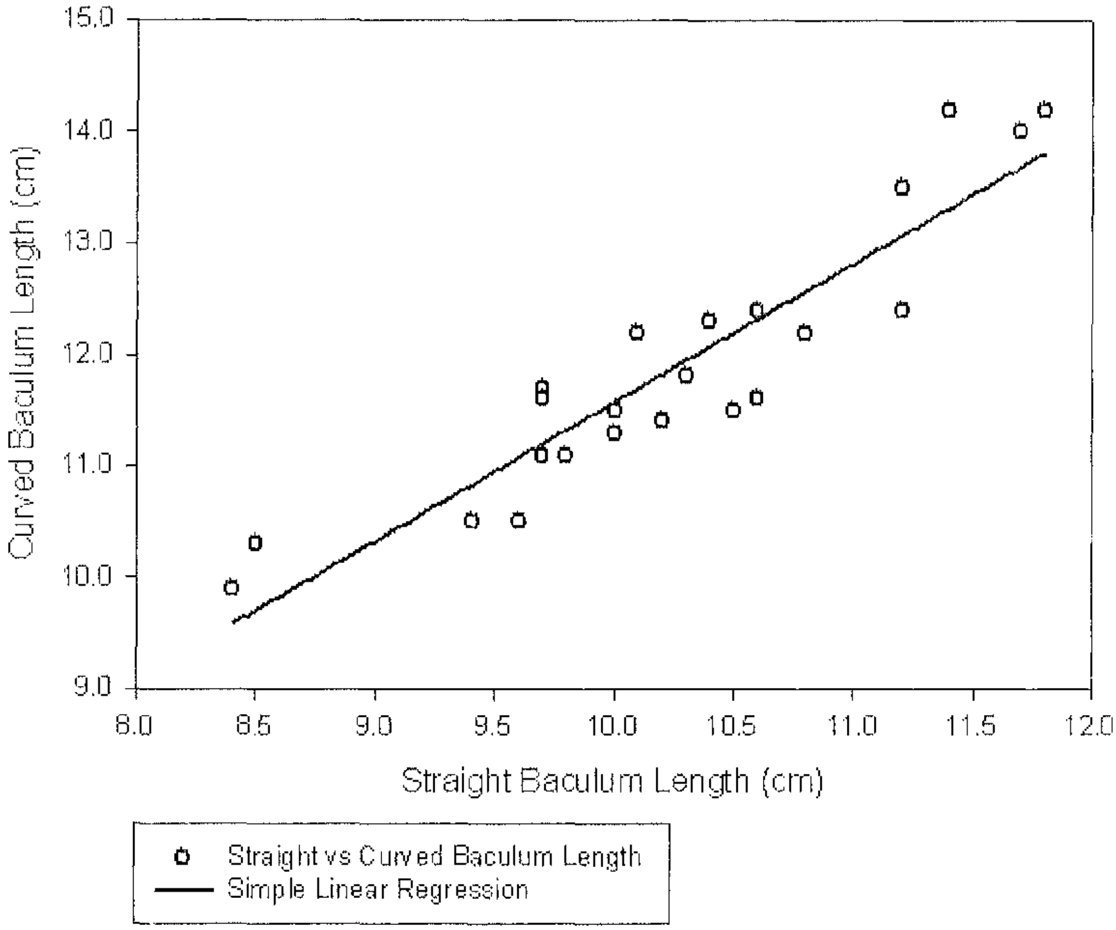
Age data analysis. - The age data corresponded well with the physical variable data described above. Comparison of the two methods of measuring baculum length, straight versus curved, determined that either method would be sufficient, as these variables had a 92.1% Pearson correlation coefficient ($P < 0.001$). Likewise, a pairwise comparison of baculum straight length and curved length showed a very high correlation of these two factors (Figure 2, R = 0.9985). Baculum length, (either measurement) and baculum weight were significantly correlated within an individual (straight: 0.728, $P < 0.001$; curved: 0.665, $P < 0.001$) (Table 4). The baculum sizes indicated an age class dominated by adults, with a 78% adult male ratio (Table 4).

Table 4: Differences in size of bacula by month of capture; using two methods of measurement (straight and curved length) and weight.

		Averages	
Month (# males)	**Bacula Length – Straight (cm)**	**Bacula Length – Curved (cm)**	**Bacula Weight (g)**
February (2)	10.3	12.0	5.6
March (3)	10.7	12.4	5.2
April (1)	11.4	14.2	7.3
May (5)	9.9	11.3	3.9
June (5)	10.8	12.6	5.1
July (3)	9.4	10.8	3.1
August (1)	9.4	10.5	1.8
September (3)	10.3	11.8	4.0

The results of the uterine examination of the six females suggested an age range of two to greater than six years (Table 5); therefore all females were labeled as adults for this aging method. Only five uteri were evaluated, because raccoon #4 had a pyometra (diseased uterus) with degradation that rendered it unsalvageable.

Figure 2: Paired data comparison of straight vs. curved baculum length measurements



The average age determined by the teeth was approximately 3 years (Table 6). Male age as determined by the tooth cementum analysis was significantly correlated with straight baculum length (0.454, P = 0.030) and baculum weight (0.522, P = 0.011) but not with curved baculum length (0.317, P = 0.141) (Tables 4 and 6) (Appendix B).

There was no correlation between intestine length and age as determined by tooth cementum analysis.

Table 5: Approximate age in years of female raccoons calculated by the number of uterine scars observed. Uterine scar # designates age in years.

Raccoon ID#	Date Captured	# Uterine Scars
R3	2/24/05	4
R4	3/3/05	Pyometra*
R5	3/22/05	4
R20	6/28/05	3
R24	8/5/05	2
R25	8/6/05	6

Note: * Raccoon number four had a diseased and unusable uterus.

(straight or curved), or baculum weight (Tables 4, 6, Appendices B and C).

All of the various aging methods except uterine scaring showed that the age ranged from several months (raccoon #'s 24 and 26) to about six years (raccoon # 19) (Table 6 and 7). In a comparison, we used the teeth age data to determine how correlated the eye lens weight was to approximate known age. Figure 3 shows a growth curve by lens weight using raccoon approximate "known" age, which is the estimated tooth age. The curve shows that as eye lens weight increases so does the age of the raccoon. The curve ascends very rapidly in the beginning and levels off as raccoons are older. There was no significant difference in age found between the sexes.

Table 6: Raccoon age determined by tooth cementum analysis performed by Matson's Laboratory, Milltown Montana. Column four (CC99% correct age), stands for the level of accuracy that Matson's laboratory gives for each tooth. Teeth with an A are 99% accurate for the age listed. If any tooth is below an A, Matson's always gives an age range, which can be seen in column five.

Raccoon ID #	Capture Date	Age (years)	CC/ 99% Correct Age	Age Range
R1	2/22/05	3	A	
R2	2/24/05	3	A	
R3	2/24/05	4	A	
R4	3/03/05	3	A	
R5	3/22/05	2	A	
R6	3/22/05	3	A	
R7	3/23/05	2	A	
R8	3/24/05	2	A	
R9	4/27/05	2	A	
R10	5/01/05	1	A	
R11	5/05/05	3	A	
R12	5/08/05	4	B	3-4
R13	5/09/05	4	A	
R14	6/01/05	5	A	
R15	6/06/05	3	A	
R16	6/07/05	3	A	
R17	6/09/05	2	A	
R18	6/17/05	5	A	
R19	6/17/05	6	B	6-7
R20	6/28/05	2	A	
R21	7/31/05	4	A	
R22	7/31/05	1	A	
R23	7/31/05	1	A	
R24	8/05/05	0	A	
R25	8/06/05	2	A	
R26	8/31/05	0	A	
R27	9/11/05	1	A	
R28	9/14/05	3	A	
R29	9/20/05	1	A	
R30	2/23/05	3	A	

* Note: Raccoon 30 was a carcass found on the island while trapping started in February.

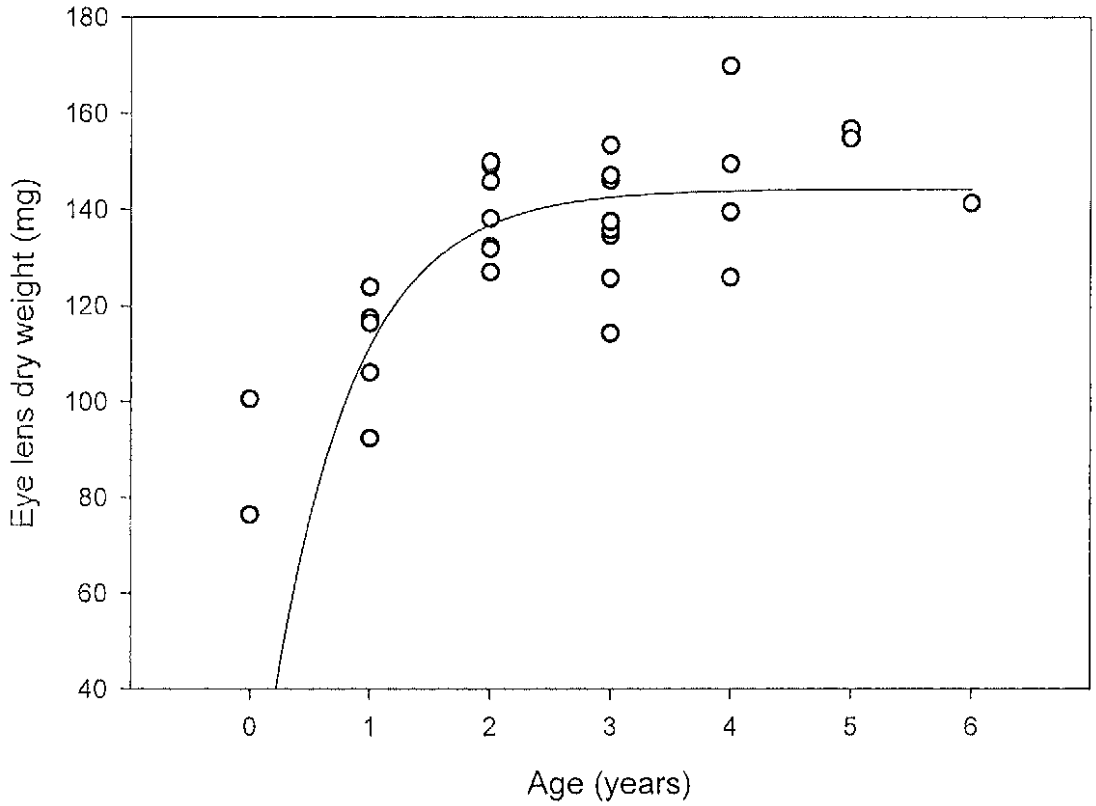
Table 7: Estimated sexual maturity class for all raccoons based on three age estimators.

	Females			Males		
Age class	**Eyes**	**Uterus**	**Teeth**	**Eyes**	**Bacula**	**Teeth**
Juvenile	1	0	1	3	0	1
Sub-adult	2	0	0	4	5	5
Adult	3	5	5	16	18	17

Teeth were sent to Matson's Laboratory Milltown Montana for age determination by cementum analysis. Cross sections were taken and annuli counted for age. Eye weight classifications were based off of Sanderson 1961a, b; Johnson 1970. Females with placental scaring were tabulated on how many scars were present. One female could not be counted due to the fact of her having a pyometra (diseased uterus).

Analysis of stomach contents revealed that the foods/materials eaten most frequently by raccoons were: vegetation (65.5%) (most preferred were wax myrtle), dirt (65.5%), crustaceans (58.6%) (most commonly fiddler crabs, *Uca pugnax*), and the sardine bait (48.2%) (Table 8). The individual raccoon stomach contents are listed in Table 9. There is very little sexually based preference for foods (Tables 8 and 9). The exception is that females were significantly more likely to prey upon vertebrates than were males (chi-square = 4.26, d.f. =1, $P < 0.05$) (Tables 8 and 9). Only three raccoons had eaten diamondback terrapin recently (Table 8). Trash was found in some stomachs,

Figure 3: Raccoon eye lens dry weight vs. age



including fishing line, cement, and a piece of a channel marker, but trash made up a small portion of the raccoons' diet (Table 8).

To ensure that there was no trap bias in the raccoon diet data, another chi-square test was run comparing the stomach contents of those animals captured with bait (n = 15) and those captured without bait (n = 14). All animals that ingested the bait (sardines) had other food in their stomachs as well. They had significantly more hair (chi-square = 7.39, d.f.=1, P < 0.01), raspberries (chi-square = 5.57, d.f.=1, P < 0.05), and vegetation in general (chi-square = 3.95, d.f.=1, $P < 0.05$) in their stomachs (Tables 8 and 9). Another significant finding was that animals that did not have bait in their stomachs were significantly more likely to have no other food in their stomachs (chi-square = 5.66, d.f.=1, $P < 0.05$).

To test for seasonality in the raccoon diet, I compared spring (February-May, n = 14) and summer and fall (June-October, n = 15). Raccoon diets did not change significantly during the study period. The only statistically significant result was that raccoons were more likely to have eaten the sardine bait in the spring than the fall (chi-square = 4.00, d.f.=1, $P < 0.05$).

Parasite analysis. - Seven helminth and two protozoan species were found in the gastrointestinal tracts which were portioned into stomach, duodenum, jejunum, ileum, and the large intestine (Tables 10 and 11). The worms were categorized according to their position and proximity to other worms within the gut (Tables 10 and 11). Each raccoon harbored at least one parasite species (helminth or protozoan). Females had a much higher likelihood of stomach helminths than males (chi-square = 11.04, d.f. =1, $P < 0.001$) (Table 11). No other significant difference between the sexes was detected.

Table 8: Stomach/intestinal contents of raccoons removed from a island in northwest Florida during the study year 2005. Values are total number of individuals with food types present.

Food Category	Males (23)	Females (6)
Hair/fur	9	3
Vegetation (fruits/seeds/berries/leaves)		
Raspberry (*Rubus idaeus*)	5	2
Saw palmetto (*Serona repens*)	4	2
Needle rush (*Juncus roemerianus*)	1	1
Cord grass (*Spartina alterniflora, S. patens.*)	2	2
Wax myrtle (*Myirca cerfera*)	11	3
Slash pine (*Pinus elliottii*)	6	2
Sand bean (*Strophostyles helvula*)	2	1
Crustaceans		
Fiddler crab (*Uca pugnax*)	15	2
Atlantic ghost crab (*Ocypode quadrata*)	2	0
Insects/invertebrates		
Grasshoppers (Family: Acrididae)	4	3
Beetles (Family:Carabidae)	2	0
Orb weavers (Family: Araneidae)	0	1
Deer tick (male) (*Ixodes scapularis*)	1	0
Biting fly larvae (Family: Tabanidae)	5	2
Vertebrates		
Carolina Diamondback terrapin (*Malaclemys terrapin centrata*)	2	1
Fledgling bird (Order: Passeriformes)	0	1
Bait		
Sardines	11	3
Marshmallows	0	0
Peanut Butter	0	0
Debris (dirt/sand/wood)	17	3
Trash		
Fishing line	1	0
Cement piece	1	0
Piece of a Buoy	0	1
Empty Stomachs	6	2

Table 9: Diet for individual raccoons. Note: raccoons **3, 4, 5, 20, 24, 25** are females.

	Raccoon ID #																												
Food Category	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**
Hair/fur	X	X	X	X		X	X	X				X		X						X								X	X
Vegetation																													
Raspberry			X						X	X			X							X								X	X
Saw palmetto	X		X											X		X				X									X
Needle rush			X					X																					
Cord grass				X			X																	X				X	
Wax myrtle	X		X			X		X	X	X	X	X	X					X		X				X			X		X
Slash pine		X						X	X	X				X						X				X					X
Sand bean			X								X																		X
Crustaceans																													
Fiddler crab	X	X					X	X	X	X	X	X	X	X		X		X	X	X				X			X	X	
Atlantic ghost crab										X			X																
Insects/invertebrates																													
Grasshoppers	X		X					X		X				X						X				X					
Beetles													X			X													
Orb weavers				X																									
Deer tick	X																												
Biting fly larvae						X	X	X		X				X						X				X					
Vertebrates																													
Diamondback terrapin			X				X													X									
Fledgling bird				X																									
Bait																													
Sardines	X	X	X	X			X	X	X	X		X	X	X						X								X	X
Marshmallows																													
Peanut Butter																													
Debris	X	X	X	X		X	X	X	X		X	X	X	X		X		X	X	X							X	X	X
Trash																													
Fishing line			X																										
Cement piece																											X		
Piece of a Buoy								X																					
Empty Stomachs					X										X		X				X	X	X		X	X			

All species of helminth were found either in the stomach or the small and large intestines; prevalence of one species in an area always resulted in only that particular species being found in that area; precluding others (Ellis et al. 1999). Because of this individual position of parasites, the location of each helminth was recorded for future niche-partitioning studies (Ellis et al 1999).

There was no significant difference in parasite species prevalence and number found between the age classes (adult vs. juveniles) ($P < 0.05$). All criteria are summarized in Tables 10 and 11 and individual correlation data is summarized in appendices B and C.

Ghost crab data was put through a correlation to determine whether or not ghost crab numbers increased or decreased during the study period. The total number of ghost crab burrows found on each section of the study beach declined (July through October) (Pearson correlation coefficient -0.883, $P < 0.001$), (Table 12) (Yates 1934). There was no correlation between the total number of crab burrows in each beach section and the number of raccoons captured (correlation coefficient 0.165, $P = 0.542$), (Table 12) (Yates 1934).

Table 10: Prevalence of helminthes in 29 raccoons from northeastern Florida. Number present indicates all life states (eggs, larval, and adult). Table abbreviations are as follows: ST- stomach, D- Duodenum, J - Jejunum, I - Ileum, SI-Small Intestine, LI-Large Intestine.

Parasite name	**Site of Infection**	**Number present (% hosts infected)**	**# of Parasites (range)**
NEMATODES			
Arthocephalus lotoris	(J, I) SI	28 (97%)	4-78
Capillaria spp.	ST (D, J) SI	15 (51%)	1-43
Molineus barbatus	(D, J, I) SI	20 (68%)	1-52
Physaloptera rara	ST, (D) SI	26 (89%)	4-98
Trichinella spiralis	Tongue	4 (14%)	NA
CESTODA			
Mesocestoides spp.	(J, I) SI, LI	12 (41%)	1-11
ACANTHOCEPHALA			
Macracanthorhynchus ingens	(D, J, I) SI	22 (76%)	1-26
TREMATODA			
NA			
PROTOZOA			
Coccidia	Feces	2 (6%)	NA
Giardia lamblia	Feces	9 (31%)	NA

Table 11: Intestinal data showing parasite location, intensity in the stomach and the intestines; also showing actual size of the intestine from each raccoon necropsied.

Raccoon ID #	Small Intestine (# parasites)			Large Intestine (# parasites)		Parasite Total in Intestines	Parasite Total in Stomach	Intestine Length (cm)
	Duodenum	Jejunum	Ileum	Colon	Rectum			
R1	2	1	2	0	0	5	0	474.8
R2	1	3	0	1	0	5	0	468.5
R3	0	0	2	0	0	2	2	484.0
R4	4	4	2	0	0	10	7	452.0
R5	2	0	3	0	1	6	0	418.5
R6	5	5	0	0	0	10	17	500.2
R7	33	13	26	0	0	72	98	464.7
R8	3	0	2	1	2	8	4	448.0
R9	1	8	5	1	2	17	2	478.0
R10	10	2	2	1	0	15	4	481.0
R11	2	2	3	0	0	7	3	510.9
R12	2	0	0	0	0	2	5	436.7
R13	0	0	0	0	3	3	5	523.8
R14	3	3	0	2	1	9	9	493.0
R15	11	0	0	0	0	11	40	396.2
R16	0	2	2	0	1	5	3	487.5
R17	3	0	0	0	0	3	36	453.7
R18	8	0	11	4	0	23	4	414.0
R19	12	12	2	1	1	28	16	367.5
R20	5	2	5	1	0	13	67	409.5
R21	0	2	2	2	0	6	2	369.5
R22	2	1	2	1	1	7	2	492.5
R23	3	3	3	0	0	9	3	323.5
R24	0	0	0	2	2	4	0	513.5
R25	46	22	17	2	0	87	7	436.5
R26	14	6	14	0	0	34	8	327.0
R27	1	4	4	0	0	9	6	381.9
R28	1	2	1	0	0	4	4	412.0
R29	2	2	2	1	0	7	4	404.0
Total	176	99	112	20	14	421	358	NA

Table 12: Number of Ghost crab burrows counted each week by beach section (EM, EMB, WMB, and WB).

	# Ghost crab holes observed					
Sample period	EB	EMB	WMB	WB	# Raccoons captured	Total # Crabs
June 30 - July 7	25	30	73	77	0	205
July 8 – 15	24	27	67	72	0	190
July 16 – 23	23	23	79	68	0	193
July 24 – 31	14	26	78	27	3	145
August 1 – 7	20	22	138	23	2	203
August 8 – 15	24	19	126	27	0	196
August 16 – 23	32	38	113	30	0	213
August 24 – 31	21	30	119	26	1	196
September 1 – 7	16	22	72	23	0	133
September 8 – 15	10	17	70	21	2	118
September 16 – 23	13	12	57	27	1	109
September 24 -October 1	9	12	56	22	0	99
October 2 – 9	5	4	27	8	0	44
October 10 – 17	6	7	13	12	0	38
October 18 – 25	8	13	19	14	0	54
October 26 - November 1	5	15	10	13	0	43

Discussion

The removal of raccoons had a significant effect on the terrapin nesting success on this particular beach. Previous studies have considered raccoon and other mesopredator removals from nesting beaches and demonstrated that such control methods are often immediately successful. How long this success lasts is still largely unknown. An average decrease of 60% (86.5-24.5= 62% and 82.0-24.5=57.5%) in predation pressure by raccoons on the diamondback terrapin nests suggests that the terrapins had a higher chance of survival than prior to raccoon removal. However, many studies have shown that the removal of the primary mesopredator often releases successive mesopredators which then either equal or surpass the original predation levels. Barton (2005) found that predation pressure by ghost crabs increased on sea turtle nests and hatchlings when raccoons were removed. During my nesting beach study no such increase of predation by ghost crabs was observed. Burrow counts decreased throughout the turtle nesting season. During the final two months of the study the number of ghost crab burrows severely decreased because one hurricane (Ophelia) and a tropical storm

(Tammy) impacted the study island. Even though ghost crabs create more than one burrow the amount of burrows lost shows a significant decrease in the ghost crab population on the beach (Pearson correlation coefficient -0.883, $P < 0.001$). I did, however, observe that fire ants became a significant influence on hatchling mortality during the late months of the study.

Raccoon abundance differed significantly from month to month for several reasons. First, once the resident raccoons of the island were removed their niche was opened. Shortly after this, every successive raccoon capture was followed by another subsequent raccoon trapping event. After the first 66 days there was not a 10 day period without a raccoon capture indicating an influx of raccoons coming into the study island to fill an open niche.

It is also believed that turtle nest predation is a learned behavior, and as such raccoons remember when nesting and hatching occur and come to the island during these time periods (Bigler et al. 1981, Ratsamway et al. 1997, Butler et al. 2004, Barton 2005). Young raccoons will stay with their mother for a period of time following her and learning what she knows (Bigler et al. 1981, Ratsamway et al. 1997, Barton 2005).

Sex ratios differed significantly throughout the study and the sample population favored males approximately 4:1. Larger free ranging furbearing mammals often have skewed sex ratios because males are territorial and have large home ranges (Petrides 1950, 1959, Bigler et al. 1981). Greenwood (1982) found that raccoon movement varied greatly depending on time of season, with linear ranging movements from 14.5km in April to 1.5km in June. Home ranges were found to exceed 4500ha, with great increases in size during the breeding season. Males traveled significantly more than females and yearlings. Raccoons spent 38% of their time moving within their local home range and foraging on locally abundant food sources (Greenwood 1982). Walker and Sunquist (1997) performed home range estimates on a population of raccoons in north Florida and found that home ranges varied with age, sex, habitat, season, and food availability. Another significant finding was that males had home ranges almost four times as large as those of females.

Another possible reason why sex ratios differed so much comes from the study itself. Long term predator removal studies open a niche and habitat to new, younger roaming individuals (Petrides 1950, 1959, Greenwood 1982, Walker and Sunquist 1997). Normally younger male raccoons would be challenged by older resident males when trying to find a territory. The above listed criteria may provide some explanation for the skewed sex ratios and the abundance of male raccoons coming to the study site in such a short time.

Measurements between the sexes often revealed males to be significantly larger in almost every category. Variables such as weight and bacula length differed through the trapping year with larger males being caught early in the season. This may be because larger males usually have established territorial home ranges and breeding areas, and younger males are still trying to establish themselves (Petrides 1950, 1959, Kauffman 1982).

The stomach contents were composed of a wide variety of foods, which is to be expected from an omnivore such as the raccoon. Vegetation and crustaceans were the primary stomach contents, which reflect the habitat where they were trapped. The study island is adjacent to the Nassau River and has extensive salt marshes behind it; vegetation and crustaceans were in abundance. Both foods can offer reproductive females and free ranging males an energy dense food source (Barton 2005).

Mammals, reptiles, and fish were either completely absent or made up a minor percentage of the raccoons' diets. Of major interest was the fact that only three

(9.6%) raccoons (2 males and 1 female) had terrapin hatchling remains in their stomachs. There was also an absence of terrapin eggshell remains.

Nest depredation rates did decrease with the removal of the raccoons; however, there was still a 12% predation rate attributed to raccoons in 2005. Several possible reasons for this are as follows: traps were checked daily in the morning between 8:30-11:15hrs, but if a raccoon was captured shortly after the trap being checked it would sit there for approximately a 24-hour period until the following morning. During this time the raccoon would have defecated in the trap, processing much of the food that was in the stomach and intestines. Secondly, eggshells are often discarded or regurgitated after the contents are ingested (Butler et al. 2004, Barton 2005).

Bait was often found in the stomachs. Out of the three baits used only sardines were found during necropsy. A partial reason for this is the other two baits were peanut butter and marshmallows; two easily broken down and digested foods. Raccoons that had partaken of the sardine bait often had other food items in their stomachs. Raccoons that did not have bait in their stomachs were more than likely to only have dirt or completely empty stomachs. A possible explanation for this would be that these raccoons could have recently come to the island and were trapped before they had a chance to feed (Barton 2005).

The abundance of dirt in the stomachs was thought unusual; approximately 69% of the captured raccoons had dirt in their stomachs. A possible explanation for this would be that once raccoons are trapped they often pull in surrounding vegetation and dirt for bedding. During this process the raccoon could inadvertently ingest some of this material.

Barton (2005) performed a similar study on raccoon diets from two sea turtle nesting beaches in Florida. The results of his study were similar to ours. He found hair, fruits, and vegetation in highest frequency, and other foods which occurred far less frequently included vertebrate (particularly turtles) and invertebrate materials. He also found the occurrence of predated turtles in the diet to be very low.

The aging studies indicated a general expected trend; that young animals moved onto the nesting beach throughout the study year period. Of the four methods used to determine the age of the raccoon population, tooth cementum analysis was the most accurate. Approximately 91% of the raccoons examined were given a 99% accuracy of age determined by cementum analysis (Table 6). Tooth cementum analysis is regarded as the most accurate means of aging mammals available today (Linhart and Knowlton 1967, Grue and Jensen 1976, Fancy 1980). This is due to the seasonal development of incremental lines in the tooth cementum (Grue and Jensen 1976).

In comparison, the other methods revealed similar results (Table 7). Sanderson (1961 a and b) used an aging method on raccoons that was first described by Lord (1959) using rabbits and in (1961) using grey foxes. Lord (1959) took the lens of the eye, dried it and correlated it to known age. Sanderson (1961 a and b) used captive raccoons with known ages to test whether or not this method pertained to aging raccoons. His results indicated a good correlation between lens weight and age up to 12 months. Working with wild raccoons we had no "known" age with which to make a correlation. Because of its documented accuracy, I used the tooth cementum analysis age as my known age.

I then ran a correlation in which 35.7% of the variation in lens dry weight could be explained by age in years ($p = 0.057$), showing a nearly significant correlation between the two. An age graph similar to Sanderson's (1961 a and b) was then created to show the significance of correlation. The only difference is Sanderson used months as his age criteria and this study used years. Sanderson estimated that eye lens weight was only reliable for raccoons below 12 months of age. This study's findings show a significant correlation between the "known" tooth age, in years, and the eye lens weight, in grams. For the purposes of this study, I used years to make the correlation.

Lack of literature on baculum measurements prompted measuring in two ways as described above to determine which measurement is more accurate for aging criteria. Upon statistical review there was a very high correlation between the two measurements suggesting that either is accurate when determining raccoon age. Baculum aging showed a population of males dominated by adults (Table 7).

Uterine scars were counted as another means in determining the age of the female population. Five uteri showed a female population dominated by adults. Intestinal length was thought to be another means of determining age. Upon statistical review no significant value was obtained that showed intestinal length as a viable means of determining raccoon age. There was no true significant difference between the aging methods (Appendices A and B).

Parasite species accounts and descriptions. – Acanthocephala; Macracanthorhynchus ingens

This spiny-headed worm was recorded in the small intestines of 22 of 29 (76%) of the raccoons; with a worm load ranging from 1-26 (X=4) worms per a host and worm length ranged from 0.7 cm-15.3cm. All life stages of this parasite were detected in the raccoon. Eggs were found in the feces; juveniles and adults in the small intestine, but never together. This parasite has been previously reported in raccoons and other furbearing mammals such as grey fox (*U. cinereoargenteus*), Florida black bear, and the striped skunk (*Mephitis mephitis*) (Schad et al. 1984, Richardson 1990, Poizo et al. 2001). The life-cycle of *M. ingens* was described by Elkins and Nickol (1983) and summarized by Schad et al. (1984). This species uses several intermediate hosts of various taxonomic levels such as roaches, various amphibians, and even snakes. There are few reports of the of the spiny headed worm being dangerous to humans; however, transmission and the possibility of human infection does exist (Dingley and Beaver 1985).

In comparison to this study, Birch (1984) found that 20 (33%) of 60 raccoons were infected. Richardson et al. (1992) found that *M. ingens* had a prevalence of 14/30 raccoons or (47%), with an intensity of 1-18 worms.

Nematoda: *Physaloptera rara*.- Groups of 4-98 worms of this nematode were recovered primarily from the stomachs of 26 (89%) of the raccoons with scattered small clusters or individuals found in the duodenum. This is another species that has been reported in the raccoon throughout the nearctic realm. Other definitive hosts recorded for this species include: the black bear *(Ursus americans)*, bobcat, dog *(Canis familaris)*, and coyote (Richardson 1990). Smith et al. (1985) reported over 97% prevalence of infection in Kentucky and Tennessee raccoons, and Snyder and Fitzgerald (1985a) found 94% prevalence of this round worm in raccoons in Illinois. This worm was found less often in this study; however, the difference is statistically insignificant.

The life cycle of *P. rara* is indirect with several species of crickets and beetles acting as intermediate hosts (Harkema and Miller 1964, Barnstable and Dyer 1974, Birch et al. 1994, Richardson 1990, Richardson et al. 1992). Passage to the definitive host (mammals) comes through ingestion of an intermediate host containing parasite larvae. There is very little information regarding the potential harmful effects of this parasite. *Physaloptera rara* is most commonly found in the stomach of its hosts and may cause minor ulcerations where the worm attaches to the mucosal lining (Richardson 1990, Richardson et al. 1992). The prevalence of *P. rara* in this study was found to be similar with the results from other studies. For instance Cole and Shoop (1987) found that 52 of 70 raccoons (74%) were infected with this worm. Richardson et al. (1992) found that 29 (97%) of their 30 raccoons had this particular nematode.

Molineus barbatus. - This worm was found in the small intestine of 20 (69%) raccoons with a worm load ranging from 1-52. This is another nematode that has been frequently reported from raccoons and other furbearing mammals. Other definitive hosts include black bears, skunks, and mountain lions (Harkema and Miller 1964, Barnstable and Dyer 1974, Hoberg 1982, Birch et al. 1994, Richardson 1990, Richardson et al. 1992). It has a direct life cycle: eggs are passed in the feces, and the definitive host is infected via the oral-fecal route. In comparison to other studies such as Cole and Shoop (1987) who surveyed 70 raccoons of which 39 (56%) were infected. Richardson et al. (1992) found 27/30 (97%) of the raccoons they sampled had this species. The worm load of 1-270 was far greater in their study, compared to the 1-52 ratio that I found.

Caparillia spp. - This nematode could not be identified to species due to quality of specimens and confusion of taxonomy of related species (Richardson 1990). It was found in the stomach and small intestines of 15 (43%) raccoons; with an intensity of 1-43 worms per host. Richardson et al. (1992) found four species of this family in their raccoons; three of which were associated with organs that this study did not look at. The fourth species, *C. putorii,* was recovered from the stomachs and intestines of 21/30 (70%) with a range of 1-172 per host (Richardson et al. 1992). Although the range I found significantly differs from the previous mentioned studies, this species does seem to be the species we found. However a positive identification was impossible. *Caparillia putorii* is associated with furbearing mammals of the southeast (Conti et al. 1983, Richardson 1990, unpublished manuscript). The life cycles of this species and many species in this family are largely unknown (Richardson 1990, unpublished manuscript).

Arthrocephalus lotoris. - This worm was extracted from the three sections of the small intestine of 28 (98%) of the raccoons, with a range of 4-78 worms per host. *Arthrocephalus lotoris* is known as a hookworm. This worm utilizes a direct life cycle in that it uses fecal material to pass on its succession of life stages to new hosts. The intake of the organism orally through fecal oral contact seems to be its only method of transmission (Hoberg 1982, Richardson 1990, Richardson et al. 1992, Birch et al. 1994). Most *A. lotoris* found in the raccoons were in the jejunum and ileum, the more posterior portions of the intestine, away from the pyloric sphincter of the stomach. A possible explanation for this behavior would be the worm's inability to cope with the higher pH levels near the opening of the stomach (Richardson 1990, Richardson et al. 1992). The prevalence of this species was high in this study compared to other studies such as Bafundo et al. (1980) who surveyed 253 raccoons of which 55 (21.7%) were infected and Cole and Shoop (1987), surveyed 70 raccoons of which 56 (80%) were infected. Our results closely resembled Richardson et al. (1992); who surveyed 30 raccoons of which 29 (97%) were infected.

Trichinella spiralis. - The larvae of this roundworm were recorded in the tongues of four (14%) raccoons. *Trichinella spiralis* has been reported as one of the most ecologically and economically important and threatening parasitic species in the world (Zimmerman and Hubbard 1969, Scholten and Norman 1971, Schad et al. 1984, Leiby et al.

1988, Oksanen et al. 2000, Pozio et al. 2001). Over 75 wildlife species are known to host this parasite (Zimmerman and Hubbard 1963, Scholten and Norman 1971, Richardson 1990).

The natural cycle of this nematode occurs in sylvatic carnivorous species such as wolves, raccoons, opossums, and weasels, which often show scavenger and cannibalistic propensities. Humans can also host this worm (Schmidt and Roberts 1989, Richardson 1990, Poizo et al. 2001). This parasite's domestic population only exists due to improper livestock care (feeding livestock such as pigs, carcasses of wildlife vectors such as raccoons and opossums) and the presence of overabundant wildlife carriers such as raccoons, opossums, and foxes (Zimmerman and Hubbard 1969, Scholten and Norman 1971, Schad et al. 1984, Cole and Shoop 1987, Leiby et al. 1998).

Raccoons have been reported to harbor and spread this parasite due to their wide geographic range. Particularly in areas where these mammals are still hunted for their pelts and as food, the possibility of them acting as reservoir hosts for this important parasite needs to be studied and understood (Newsome and Wilhelm 1979). This parasite's ability to become widespread in a host population in a relatively short time is because of its life-cycle (Newsome and Wilhelm 1979).

Trichinella spiralis has a direct life cycle in that it only requires one host to propagate. The same host, whether raccoon, opossum, or human, can serve as its intermediate host and its definitive host. The transmission of this parasite from host to host can happen in several ways. Ingesting larvae through infected meat is often the primary way humans and human associated animals (livestock and family pets) get infected. Mammalian wildlife can also spread the parasite through maternal transmission (Cole and Shoop 1987). This route of transmission is often cited as the reason why prevalence of adult worms is higher in males. Females will exhibit lower intensities of adult parasites because larvae exit the female body through a transuterine pathway or remain in the body in immature stages (Cole and Shoop 1987). Larvae are also passed to offspring through lactation (Cole and Shoop 1987, Shoop et al. 1987).

Cestodes: *Mesocestoides spp.* - was found in 12 raccoons (43%) with groupings of 2-11 worms found. Collecting these worms was problematic because the carcasses had been frozen and the worms' tissues often tore during necropsy (Shoop et al. 1987). Therefore, the representation of this species may be artificially skewed high compared to what was found by others (Hoberg 1982, Shoop et al. 1987, Richardson 1992, Birch 1994) due to the possibility of counting one more than once. Richardson et al. (1992) found 12 (40%) of the 30 also infected by two species of tapeworm. Birch (1994) dissected 60 raccoons and found one species of tapeworm that infected 20 (33.3%) of the study population.

Several species of *Mesocestoides* have been reported in the raccoon throughout the nearctic realm. They are known to infect a variety of furbearing mammals including raccoons, opossums, dogs, mountain lions, and even humans (Hoberg 1982, Conti et al. 1983, Richardson 1990, Foster et al. 2003). Heavy prevalence of these tapeworms can result in severe malnutrition and emaciation (Schaffer 1979, Shaw et al. 1998, Stephenson et al. 2000).

Trematoda. - No trematode species were observed during necropsy of the 29 raccoons. Upon literature review we found that the way in which we preserved our raccoon carcasses negatively affected trematode preservation. Shoop et al. (1987) stated that freezing carcasses before necropsy will cause harm or even destroy less hard-bodied parasites such as flukes and tapeworms. The ice crystals that freeze in the body cavity can cause perferations (holes) in the worms' body tissues and often tear apart the worm before dissection (Shoop et al. 1987, Robel et al. 1989). Robel et al. (1989) performed a similar study with raccoon helminths and made the same error. Upon necropsy they discovered that freezing severely damaged the trematodes and made collection and identification impossible.

Protozoans: Coccidia-*Cystoisospora spp.* - This species was found in fecal samples of 2 (6%) raccoons. This protozoan infects the intestines often causing intense diarrhea. It most often is not life-threatening but can become so when infecting young animals. There are many species of *Cystoisospora,* and they are usually rare in wildlife populations. Fiorello et al. (2006) conducted a parasite study on felids and they only found one host (Geoffrey's cat) that contained coccidia. Coccidia comes from fecal-contaminated ground. Animals swallow contaminated dirt when a pet grooms/licks itself. In some cases, sporulated oocysts are swallowed by mice and the host is infected when it eats the mouse (Fayer and Frenkel 1979).

Giardia lamblia. - This protozoan is known as a common and dangerous protozoan often found in wildlife populations. Nine (31%) of the raccoons surveyed had *G. lamblia* cysts in fecal samples. This parasite is widely known as the most common human intestinal parasite worldwide (Teoh et al. 2000). This protozoan causes severe dehydration through acute/chronic diarrhea and subsequent weight loss. This species is most noticeably known for its stigma of causing travelers' diarrhea in humans (Buckley and Warnken 2003).

One of the most important aspects of this parasite is its ability to survive outside a host as a cyst or oocyst in the water or soil (Buckley and Warnken 2003). This species is extremely widespread in the wild and is known to be harbored by native wildlife in the U.S., Europe, and South Africa (Buckley and Warnken 2003).

The entire helminth fauna of the raccoons surveyed has been previously reported from most of the east coast or the continental U.S. (Ingram 1941, Jordan and Hayes 1959, Bafundo et al. 1980, Hoberg 1982, Conti et al. 1983, Corn et al. 1985, Birch et al. 1994). The list of parasites in this current study reveals a curious absence of several wide ranging and dangerous species. For instance, *Baylisascaris procyonis,* the only ascarid nematode found in the raccoon, was absent from this study. This round worm, while causing local extirpations of its intermediate host, the wood rat, is known as a potentially fatal parasite to humans (Barnstable and Dyer 1974). *Gnathostoma procyonis* was also absent from this population. This nematode has been documented in many raccoon parasite studies as having high prevalence and a large geographic range (Ash 1960, 1962).

Many studies have shown that intestinal worm infections can be pervasive and thrive in human communities that are unsanitary and in proximity of an abundance of wildlife vectors (Stephenson et al. 2000). Some parasites identified in this study are not known to have many perverse affects (*P. rara* and *M. barbatus*), however, some do pose severe threats to humans. *Trichinella spiralis* is known to affect intestinal motility either increasing it through diarrhea or dysentery or decreasing it and causing constipation and intestinal blockages. It also can affect the pancreas causing hypergastrinaemia and obstruction. Tapeworms can cause severe intestinal obstructions and decreased food intake and malnutrition (Shaw et al 1998, Stephenson et al. 2000).

As development of natural ecosystems by humans increases, chances of humans becoming infected with helminths increases. Pilmentel et al. (1998) cites an example using the country of Nepal where there is severe soil erosion (this erosion causes soils containing parasites and parasite eggs to enter human and wildlife used watering holes) and wildlife vectors such as mesopredators are in abundance. This has caused extreme disease problems and 87% of the country's population has been infected by at least one species of helminth. *Giardia lamblia* is known to be an increasing biological threat to humans. More of these organisms are spread throughout the environment by wildlife vectors such as beaver, raccoons, and elk. Infected wildlife often facilitate the parasite's ability to spread into the water systems; nearly 40% of treated drinking water in the United States is contaminated with a protozoan pathogen (Pilmentel et al. 1998, Soule 2000).

It has been estimated that nearly 2 billion people worldwide are infected with at least one helminth or protozoan parasite (Pilmentel et al. 1998). *Giardia lamblia* affects stomach processes causing complications such as achlorhydria or hypochlorhydria (decreased production of gastric acid). It also affects the liver impairing digestion often resulting in intestinal obstruction which can cause accentuating bacterial growth which causes bile acid deconjugation (Bonner and Dale 1986, Stephenson et al. 2000).

CONCLUSIONS

The original scope of this project was to determine nesting success of diamondback terrapins once the primary mesopredator was removed from their nesting beach. The results of that study are outside the scope of this thesis. This thesis focused on the questions surrounding the life history of the raccoons on the island. How old is the population in question? Is the sex ratio typical for furbearing mammals? What exactly are they eating? Is the target species a dominant part of their diets? Finally, what other possible problems can over-abundant species place upon the environment? Through this study these questions were answered with varying degrees of success.

The age of the trapped raccoon population was determined using four different aging criteria. The average age of the population was three years (Table 6) determined by the tooth cementum analysis and supported by the other aging criteria. The sex ratio was found to be (23/6) nearly a 4:1 male to female ratio, dominated by adult males which is usually the case with medium sized mammals due to males having a much larger homerange then females.

The diet analysis indicated a wide variety of food items were consumed by the raccoons. Only three raccoons had any evidence of diamondback terrapin in their gut contents. This, however, should not be taken as any indication that raccoons do not predate these turtles. As mentioned earlier, raccoons will often crush the eggs to extract the contents and leave the shells behind (Engeman et al. 2003). Typically necropsied raccoons were in the traps long enough to digest and defecate out ingested foods. Eight (28%) of the raccoons had empty stomachs, so I had no way of determining what they had previously ingested (Tables 6 and 7). Plant matter and macro-invertebrates such as fiddler crabs made up a large portion of the stomach contents surveyed. These study results matched very well with the stomach contents that Barton (2005) reported.

Parasite species composition was very similar to many studies done on raccoons living on the east coast. All of the species encountered have been reported as having the raccoon as a host. Several species of interest have been identified as threatening and potentially dangerous, including *T. spiralis*, G. *lamblia, and Coccidia*. Of the five nematode species found only *T. spiralis* is known to pose any health concerns to humans and livestock. The two protozoan parasites have been documented in many health concerns pertaining to humans. The number of raccoons infected by each of these parasites in this study may not seem excessive, however, the possibility of passing infection and being vectors for disease rises with every animal carrier.

Mesopredators do pose a problem to threatened and endangered species such as sea turtles and to species such as diamondback terrapins, which little is known about. Another nesting beach study was conducted on the same beach in 2006 the year after this removal study to determine if predation rates would stay lowered or would once again increase to levels comparable to the years prior to the removal project. Results indicated a drastic increase in predation as the mesopredator population once again took over the island (J.A. Butler, unpublished data).

So the overall question remains: What should be done with mesopredators? Should their populations be culled and monitored to more manageable/realistic natural numbers? Should more research be conducted on the possible implications of removing mesopredator populations? Should adaptable animals such as raccoons be punished for being so successful in the absence of top predators? Their habitat has been remapped by human hands and they have found means to adapt, preserve, and succeed (Maclaren 1992). There is no simple answer to these questions.

The literature is full of examples that show mesopredators can cause severe damage to threatened /endangered species populations. In these instances, population management by lethal means may be a viable option to consider (Maclaren 1992). There is evidence that raccoon nest predation is a cultural or taught phenomena passed from one generation to another (Engeman et al. 2003). If this is a learned ability, then it could be lost with successive removal projects for a few generations (Engeman et al. 2003). However, more research is needed to understand mesopredator populations as a whole. For instance, this particular population was dominated by animals that had an average age of three years. If there is a lack of top predators to naturally cull the young and old from the population, then why did this population show a large absence of both? Does the parasitic and disease presence cull the population?

We have shown through this study that removal of the prevalent mesopredator, raccoons, significantly enhanced the survival of diamondback terrapins, which was the focus of our study. Future studies on mesopredators should focus on other potential dynamics, as numerous questions remained unanswered. Will the removal of a mesopredator affect other non-target species? Does the removal of host mesopredators impact parasite populations of interest, and could these effects potentially cause shifts in community and ecosystem structure? An ecosystem level approach is necessary to study these topics and eventually answer these important questions.

Appendix A: Raccoon physical measurements data table.

Raccoon #	Capture Date	necropy	Time	Weight Kg	Total Length	Tail	Head-Body	HindFooot	Ear R	Neck	Head Circ	Girth	Should ht	Sex
R1	02/22/2005	03/29/2005	9:49	7.2	83.0	23.5	59.5	12.6	6.0	27.0	26.0	41.0	16.5	M
R2	02/24/2005	03/29/2005	8:50	5.4	97.5	28.0	69.5	11.3	5.6	24.5	25.8	45.5	10.6	M
R3	02/24/2005	03/29/2005	9:40	3.6	84.3	25.7	58.6	12.3	5.9	22.8	25.3	39.0	14.5	F
R4	03/03/2005	08/02/2005	9:00	3.8	77.5	21.5	56.0	9.5	5.3	20.7	23.0	33.8	11.5	F
R5	03/22/2005	09/03/2005	10:15	3.0	78.3	24.8	53.5	11.3	5.0	19.9	22.8	34.4	11.9	F
R6	03/22/2005	03/29/2005	11:00	6.9	104.5	32.7	71.5	13.5	5.6	25.7	27.5	42.8	16.0	M
R7	03/23/2005	03/29/2005	9:40	5.9	85.5	24.0	61.5	11.5	5.5	25.5	26.5	38.5	18.5	M
R8	03/24/2005	09/10/2005	9:40	5.0	88.6	26.4	62.2	11.5	6.0	22.5	27.3	37.5	13.0	M
R9	04/27/2005	06/14/2005	9:10	6.4	98.3	29.8	68.5	13.3	4.5	22.0	25.5	36.0	14.8	M
R10	05/01/2005	08/02/2005	9:40	3.8	82.6	25.5	57.1	12.5	5.9	21.4	24.2	35.2	14.3	M
R11	05/05/2005	06/14/2005	9:10	6.0	90.0	25.0	65.0	11.5	5.5	25.5	28.0	37.0	14.5	M
R12	05/08/2005	08/09/2005	9:07	4.6	89.6	27.3	62.3	11	5.0	22.0	26.2	36.3	15.7	M
R13	05/09/2005	06/14/2005	9:21	6.0	95.0	26.0	69.0	11.5	5.3	23.0	27.0	36.5	14.5	M
R14	06/01/2005	09/03/2005	9:24	6.2	89.2	25.2	64.0	11.5	5.0	25.3	27.4	40.3	15.7	M
R15	06/06/2005	06/14/2005	11:15	6.4	84.5	15	69.5	12.5	4.8	27.5	24.0	35.0	14.0	M
R16	06/07/2005	09/03/2005	9:32	4.6	87.3	25.5	61.8	11.2	6.8	21.5	24.3	37.7	12.6	M
R17	06/09/2005	09/10/2005	11:50	4.6	94.7	28.0	66.7	11.5	4.2	19.8	24.4	34.3	12.3	M
R18	06/17/2005	09/10/2005	11:15	6.5	91.0	22.3	68.7	11.5	5.0	25.5	27.0	39.4	17.6	M
R19	06/17/2005	08/09/2005	12:00	5.4	81.5	23.5	58.0	10.8	4.9	20.0	23.4	32.5	15.0	M
R20	06/28/2005	08/02/2005	10:11	3.4	80.8	25.3	55.5	12.1	5.1	20.8	23.1	32.0	11.3	M
R21	07/31/2005	08/09/2005	11:11	7.2	86.1	24.1	62.0	10.5	5.5	24.2	27.3	41.4	16.2	F
R22	07/31/2005	08/09/2005	11:35	7.0	86.1	26.7	59.4	11.9	4.4	19.8	21.1	35.5	12.1	M
R23	07/31/2005	09/10/2005	12:15	3.2	78.5	20.5	58.0	10.3	4.0	19.0	21.5	30.6	13.5	M
R24	08/05/2005	08/09/2005	9:33	3.7	70.5	22.0	48.5	11.1	3.8	18.8	23.0	34.3	10.5	F
R25	08/06/2005	09/03/2005	9:42	4.4	81.5	20.5	61.0	10.5	5.1	23.2	25.0	34.3	14.5	F
R26	08/31/2005	09/10/2005	10:37	4.6	79.7	24.4	55.3	11.5	5.3	20.3	22.7	33.0	11.3	M
R27	09/11/2005	09/22/2005	10:00	5.2	83.2	25.2	58.0	12.1	5.2	23.4	22.3	34.2	13.3	M
R28	09/14/2005	09/22/2005	10:20	4.4	88.0	26.0	62.0	10.3	4.5	25.5	27.1	35.2	14.5	M
R29	09/20/2005	09/22/2005	9:50	6.0	83.8	25.3	58.5	12.5	5.8	20.8	25.4	35.7	12.3	M

Appendix B - Male correlation data table using Pearson's product-moment correlation coefficients.

	Weight	Total length	Tail length	Head and body length	Hind foot	Ear right	Neck	Head circumference	Girth	Shoulder height	Month	BCI	Intestinal length	Bacula length, straight	Bacula length, curved	Bacula weight	Lens dry weight
Total length	0.334 0.119																
Tail length	0.057 0.796	0.687 0.000															
Head and body length	0.407 0.054	0.857 0.000	0.215 0.325														
Hind foot	0.446 0.033	0.365 0.087	0.277 0.201	0.291 0.178													
Ear right	0.120 0.585	-0.003 0.988	0.129 0.557	-0.097 0.659	0.209 0.388												
Neck	0.535 0.009	0.276 0.203	-0.184 0.399	0.499 0.015	0.211 0.311	0.242 0.265											
Head circumference	0.365 0.087	0.545 0.007	0.282 0.193	0.533 0.009	0.032 0.885	0.339 0.113	0.639 0.001										
Girth	0.563 0.005	0.576 0.004	0.352 0.100	0.524 0.010	0.210 0.336	0.477 0.021	0.623 0.001	0.643 0.001									
Shoulder height	0.395 0.062	0.079 0.721	-0.107 0.626	0.179 0.413	0.049 0.823	0.018 0.934	0.539 0.008	0.516 0.012	0.257 0.236								
Month	-0.271 0.210	-0.486 0.019	-0.273 0.208	-0.460 0.027	-0.318 0.139	-0.326 0.129	-0.375 0.078	-0.445 0.034	-0.619 0.002	-0.303 0.160							
BCI	-0.105 0.632	0.547 0.007	0.349 0.103	0.491 0.017	-0.578 0.004	-0.189 0.388	0.061 0.781	0.461 0.027	0.325 0.131	0.027 0.904	-0.132 0.548						
Intestinal length	0.337 0.116	0.625 0.001	0.504 0.014	0.484 0.019	0.414 0.049	0.318 0.140	0.292 0.177	0.460 0.027	0.495 0.016	0.143 0.515	-0.591 0.003	0.176 0.422					
Bacula length, straight	0.528 0.010	0.580 0.004	0.169 0.441	0.658 0.001	0.399 0.059	0.064 0.771	0.312 0.148	0.365 0.086	0.342 0.111	0.065 0.767	-0.208 0.340	0.150 0.495	0.200 0.361				
Bacula length, curved	0.551 0.006	0.575 0.004	0.157 0.473	0.659 0.001	0.576 0.004	0.007 0.976	0.326 0.129	0.333 0.121	0.343 0.109	0.158 0.471	-0.260 0.231	-0.009 0.967	0.242 0.267	0.921 0.000			
Bacula weight	0.391 0.065	0.639 0.001	0.251 0.248	0.681 0.000	0.174 0.427	0.091 0.678	0.422 0.045	0.584 0.003	0.428 0.041	0.210 0.335	-0.448 0.032	0.419 0.047	0.313 0.146	0.728 0.000	0.665 0.001		
Lens dry weight	0.253 0.245	0.368 0.084	0.036 0.870	0.468 0.024	-0.023 0.917	0.169 0.441	0.180 0.410	0.235 0.280	0.247 0.255	0.175 0.425	-0.275 0.203	0.344 0.108	0.122 0.580	0.404 0.056	0.335 0.118	0.568 0.005	
Age (years)	0.366 0.117	0.272 0.209	-0.075 0.733	0.419 0.046	-0.274 0.206	0.019 0.933	0.390 0066	0.521 0.011	0.362 0.089	0.521 0.011	-0.257 0.237	0.486 0.019	0.171 0.436	0.454 0.030	0.317 0.141	0.522 0.011	0.261 0.228

Appendix C- Male and female correlation data using Pearson's product-moment correlation coefficients

	Weight	Total length	Tail length	Head and body length	Hind foot	Ear right	Neck	Head circumference	Girth	Shoulder height	Month	BCI	Intestinal length	Lens dry weight
Total length	0.544 0.002													
Tail length	0.159 0.411	0.670 0.000												
Head and body length	0.611 0.000	0.901 0.000	0.282 0.138											
Hind foot	0.404 0.030	0.424 0.022	0.394 0.034	0.316 0.095										
Ear right	0.158 0.412	0.177 0.358	0.189 0.327	0.119 0.540	0.224 0.243									
Neck	0.604 0.001	0.449 0.014	-0.071 0.715	0.621 0.000	0.263 0.168	0.329 0.081								
Head circumference	0.482 0.008	0.619 0.000	0.318 0.093	0.615 0.000	0.134 0.488	0.374 0.045	0.697 0.000							
Girth	0.575 0.001	0.605 0.001	0.393 0.035	0.552 0.002	0.279 0.143	0.483 0.008	0.645 0.000	0.679 0.000						
Shoulder height	0.524 0.004	0.340 0.071	0.012 0.951	0.431 0.019	0.158 0.413	0.166 0.388	0.637 0.000	0.609 0.000	0.377 0.044					
Month	-0.069 0.723	-0.333 0.077	-0.273 0.152	-0.271 0.155	-0.229 0.233	-0.393 0.035	-0.267 0.162	-0.312 0.099	-0.524 0.004	-0.210 0.275				
BCI	0.152 0.431	0.560 0.002	0.267 0.161	0.569 0.001	-0.512 0.005	-0.021 0.912	0.204 0.288	0.471 0.010	0.322 0.088	0.183 0.341	-0.108 0.578			
Intestinal length	0.195 0.312	0.376 0.045	0.397 0.033	0.254 0.184	0.304 0.109	0.205 0.286	0.197 0.306	0.380 0.042	0.447 0.015	0.072 0.711	-0.465 0.011	0.071 0.715		
Lens dry weight	0.124 0.520	0.363 0.053	0.090 0.643	0.416 0.025	0.078 0.688	0.332 0.078	0.243 0.203	0.250 0.191	0.253 0.185	0.267 0.161	-0.342 0.069	0.276 0.147	0.021 0.913	
Age (years)	0.326 0.084	0.366 0.051	0.015 0.938	0.465 0.011	-0.154 0.426	0.197 0.307	0.443 0.016	0.530 0.003	0.406 0.029	0.547 0.002	-0.337 0.074	0.494 0.006	0.107 0.581	0.357 0.057

Appendix D: Ghost crab correlation data using Pearson's product-moment correlation coefficients.

	East beach	East middle beach	West middle beach	West middle beach	Month	# Raccoons captured
East middle beach	0.872 0.000					
West middle beach	0.786 0.000	0.681 0.004				
West beach	0.665 0.005	0.568 0.022	0.265 0.321			
Month	-0.806 0.000	-0.777 0.000	-0.666 0.005	-0.806 0.000		
# Raccoons captured	-0.061 0.822	0.148 0.583	0.343 0.193	-0.171 0.526	-0.268 0.316	
Total # crabs	0.948 0.000	0.853 0.000	0.892 0.000	0.657 0.006	**-0.883** **0.000**	0.165 0.542

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VITA

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Born in York, Pennsylvania
Parents: Wayne and Diana

Siblings: Karl ; Laura

Attended Wallace Elementary school (K-2), Trimmer elementary (3-6), West York Area Middle School (7-8), West York Area High School (9-12). Graduated # 27 of 183.

UNDERGRADUATE EDUCATION

Fall 1999 Hartwick University, Transferred

Spring 2000 Pennsylvania State University York Campus. Transferred.

Fall 2001-2004 Pennsylvania State University Main Campus, Bachelors of Science in Animal Science, Minor- Wildlife Science

EMPLOYMENT HISTORY

2000-2004 Pennsylvania State University, Student Work Study.

2002-2004 Pennsylvania State University, teaching assistant.

2002 summer internship as a wildlife rehabilitator. State College, PA. Logged over 220 hours of animal rehabilitation. Including feeding, medicating, and cleaning of orphaned/adult mammals, birds, and reptiles.

2004 summer job (Field Technician) for the United States Geological survey (USGS), Chesapeake Bay Maryland. Worked on a population study on Diamondback Terrapins. During the three month study we captured and marked over 1,200 turtles.

2004-2006 University of North Florida teaching assistant.

PUBLICATIONS

Published Abstracts:

American Society of Ichthyologists and Herpetologists: Society for the Study of Amphibians and Reptiles.

2004 Affects of raccoon (*Procyon lotor*) removal on survivorship of diamondback terrapin (*Malaclemys terrapin*) nests in northeastern Florida. Tampa Bay, Florida.

2004 Characteristics of the semi-aquatic turtle assemblage at Wekiwa Springs State Park. Tampa Bay, Florida.

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