EFFECTS OF INTENSIVE PREDATOR HARVEST DURING THE QUAIL NESTING SEASON ON DIET, AGE, AND REPRODUCTION OF MESO-MAMMALIAN PREDATORS

by

MAX LANG

(Under the Direction of Robert J. Warren)

ABSTRACT

Lethal control of predators is a method of game promotion has become a popular part of intensive quail management on Southwest Georgia plantations. Targeted predators include opposums (*Didelphis virginianus*), raccoons (*Procyon lotor*), bobcats (*Lynx rufus*) and coyotes (*Canis latrans*). During the last few decades much emphasis has been placed on the responses of quail to predator removal, however, little research has been done on the responses of the predators and the potential impacts of predator absence on the remaining community. To address these issues, meso-mammalian predators were removed March to September for three years from four different study sites. Two sites were trapped from 2001 to 2003. In 2004, trapping switched to the remaining two sites and was continued through 2006. Lower canines from were removed and cementum annuli analysis was done to estimate age. Stomachs and reproductive tracts also were removed to obtain diet and reproductive indices. Our age data revealed a decreasing trend in the age structure of all predators as trapping duration increased, but this trend was evident in only about half of the site-by-year groupings. The stomach analyses (n=638) were consistent with current food habits literature, but there were no consistent changes evident in diets that could be related to the predator removal treatments. Litter sizes were consistent with current literature for all species; however, no trends in reproduction were related to the trapping removals. Thus, the predator removal treatments we imposed did not appear to consistently alter diets, age, or reproduction of opossums, raccoons, bobcats, or coyotes.

INDEX WORDS: age, bobcat, coyote, diet, opossum, predator, raccoon, reproduction, removal

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MAX LANG

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MAX LANG

Major Professor:	Robert J. Warren
Committee:	L. Michael Conner W. Dale Greene

Electronic Version Approved:

Maureen Grasso
Dean of the Graduate School
The University of Georgia
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DEDICATION

This thesis is dedicated to my parents, Tom and Mechelle Lang. Your guidance and support throughout my life has led me where I am today. You put me on the path of becoming a wildlife biologist by instilling in me values of nature and the importance of its conservation. Without your support, none of this would have been possible. I love you both very much.

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CHAPTER 1

INTRODUCTION, LITERATURE REVIEW, AND THESIS FORMAT

INTRODUCTION

Humans have used predator removal as a means of enhancing game populations for centuries. This has recently become a popular management practice on areas in the Southeast that are intensively managed for the northern bobwhite (*Colinus virginianus*). The bobwhite is a popular game bird in southern Georgia, generating about $55 million of revenue to quail plantations throughout the Southeast (Burger et al. 1999). To support this sport, many quail plantations spend substantial amounts on management efforts each year. The average cost of quail management practices implemented on plantations in the Southeast has been estimated at $140 per ha/year (Burger et al. 1999). Part of this management includes predator removal.

Game managers and quail hunters alike have long blamed meso-mammalian predators for local declines in quail numbers. Much research has been conducted on responses of quail to predator removal; however, little has been done on the ecology of predators on these quail plantations (Miller and Speake 1978) or to quantify the population-level effects of removal on the predator community. There also is a lack of research that quantifies diets of predators on lands specifically managed for quail in the Southeast (Miller and Speake 1978, Schoch 2003).

Because many landowners believe that these predators have led to decreased quail populations, research is needed to understand the impact of these predators on quail populations and other ecosystem components in the Southeast. To this end, the USDA-Georgia Wildlife Services conducted the Wildlife Management and Gamebird Restoration Project during 2001-2006 to determine responses of quail populations to intensive meso-mammalian predator removal. This project afforded the opportunity to also quantify the biological responses of these targeted predator species to intensive removal. Removing large numbers of predators from an ecosystem also may have effects that extend beyond the managed prey species, and in some cases, may lead to an increase in smaller predators, which may in turn lead to higher predation rates (Paine 1969, Estes and Palmisiano 1974). The knowledge derived from my research will allow for development of improved management practices based on a better understanding of how the meso-mammalian predator community responds to intensive removal.

LITERATURE REVIEW

Removal of Meso-mammal Predators

For centuries, humans have removed predators from the natural landscape for many reasons, including fur for clothing, livestock protection, self protection, and to enhance game populations (Estes 1996, Reynolds and Tapper 1996). Predator removal for the promotion of games species in North America has been advocated since the 19th century. Today, this method is a part of quail management on many plantations in Georgia. These targeted predators include raccoons (*Procyon lotor*), opossums (*Didelphis virginianus*), bobcats (*Lynx rufus*), and coyotes (*Canis latrans*).

Raccoons and Opossums

The raccoon has been characterized as an opportunistic omnivore by several researchers (Dexter 1951, Schoononver and Marshall 1951, Greenwood 1981). Its diet consists of insects, fruits, birds, eggs, and many other types of food (Greenwood 1981). Raccoons also have been reported as a nest predator of the wild turkey (*Meleagris gallopavo*), feeding on eggs and poults (Cook 1972, Peoples et al. 1995). Raccoons also have been documented as predators of quail and quail nests (Schoch 2003, Staller et al. 2005)

The opossum is another animal that is known for having an omnivorous diet (Dexter 1951, Hamilton 1951, Hume 1999). The opossum’s diet is similar to the diet of the raccoon; it eats fruits, worms, insects, eggs, and birds (Hamilton 1951). Its diet is based on the seasonal availability of different food sources. Opossums may not only prey on quail eggs, but also are capable of catching incubating hens (Schoch 2003, Staller et al. 2005).

Bobcats

The bobcat is an apex predator in the Southeast. It preys mainly on small mammals, such as rodents and lagomorphs (Miller and Speake 1978, Godbois 2003, Doughty 2004). Age has been found to affect the bobcat's diet, with younger cats preying on easily captured food (Frits and Sealander 1978, Conner et al. 1999). Frits and Sealander (1978) also found a distinct separation of diet between males and females; males consumed more large mammals, such as deer, while females consumed more rodents.

Several studies in Georgia have shown that cotton rats (*Sigmodon hispidus*) make up a large portion of bobcat diets on areas managed for quail (Cochrane 2003, Godbois 2003, Schoch 2003, Doughty 2004). A study of bobcat diets in Florida also revealed a high dependence on cotton rats as a food source, with only a 1% occurrence of quail in stomachs of bobcats examined (Maehr and Brady 1986). Miller and Speake (1978) also found that bobcats were not a major predator of bobwhite quail on a quail plantation in Alabama. Young (1958) found only 1% of bobcat diets in North America to be upland game birds, the bulk of which was quail. However, bobcats are known to prey on turkey poults (Cook 1972, Peoples et al. 1995) and recent studies have shown that bobcats will consume both quail eggs and adult quail (Schoch 2003, Staller et al. 2005).

Coyotes

During the last 2-3 decades, coyotes have migrated into the southeastern United States (Hill et al. 1987). As non-native animals to the Southeast, coyotes present new challenges to wildlife managers. Coyotes are characterized as seasonal omnivores and scavengers, feeding on fruits, insects, mammals, and birds (Litvaitis and Shaw 1980, Wooding et al. 1984, Andelt 1985, Blanton and Hill 1989). Andelt (1985) found that mammals (mostly small rodents) made up 87% of coyote winter diets, whereas fruits (such as persimmon [*Diospyros virginiana*] and prickly pear cactus [*Opuntia* sp.]) composed 65% of the summer diet.

Coyotes may play an important role in meso-mammalian predator control (Sovada et al. 1995, Estes 1996, Henke and Bryant 1999). The presence of coyotes also has been shown to decrease nest predation from smaller predators, such as the red fox (*Vulpes vulpes*; Sovada et al. 1995). Several studies have shown that excluding or removing coyotes allows an increase in meso-mammalian predators and nest predation (Baker 1978, Estes 1996, Henke and Bryant 1999). The removal of coyotes also may lead to a decrease in diversity of smaller mammals, such as rodents, as shown by Henke and Bryant (1999). Baker (1978) observed coyotes killing young skunks, which have been identified as a nest predator. Schoch (2003) found bobwhite eggs in 10% of coyote stomachs, but no actual quail were found. Sperry (1941) observed little quail material in over 8,000 stomachs, so he concluded that the coyote was not a major predator of quail.

Response of Prey Populations and Communities to Predator Removal

Meso-mammal predators may be removed because it is believed they limit the amount of game available to humans (Reynolds and Tapper 1996). In the Southeast, they are often removed with the belief that they suppress bobwhite breeding populations and hatching success. However, there may be no significant increase in breeding populations of game after predator removal (Cote and Sutherland 1997). In addition, other species such as rat snakes (*Elaphe spp.*) and cotton rats may be nest predators, but are not targeted by plantation managers (Hawthorne 1983, Aldrich and Endicott 1984, Wheeler 1984, Farnsworth and Simons 2000).

There have been several studies that examined the success of a certain prey species after a predator removal treatment. Research has shown a higher nesting and hatching success when predators were removed in prairie regions of the United States (Garrettson and Rohwer 2001, Pearse and Ratti 2004). Pheasant (*Phasianus colchicus*) populations quadrupled after predator reductions during a 5-year period in South Dakota (Trautman et. al 1974). Nest success of the black brant (*Branta bernicla nigricans*) increased substantially after intensive removal of Arctic foxes (*Alopex lagopus*) (Anthony et al. 1991). However, there has been relatively little research conducted on the effects of predator removal on the predator community itself (Buger 2001).

Removing large numbers of predators may have negative effects on an ecosystem, such as an increase in smaller predators. Top carnivores, such as bobcats and coyotes, may suppress smaller predators, which may promote a diversity of other species (Palomares et al. 1995, Sovada et al. 1995, Rogers and Caro 1998, Courchamp et al. 1999). Therefore, it is important to understand the response of predator populations to removal. Having a better understanding of predator communities and their role in the ecosystem will allow for better management practices throughout the Southeast.

Response of Predator Populations to Removal

Effects of predator removal in an area could be offset by increased reproduction within the predator population (compensatory reproduction) or increased immigration of young individuals from surrounding areas. Research on reproductive responses of meso-mammalian predators after an intensive removal is absent from scientific literature. Areas with low food abundance and high coyote densities cause breeding suppression in yearling and subordinate coyotes (Windberg 1995). Conversely, high food abundance and low coyote densities trigger a response in which yearlings and subordinates began breeding (Windberg 1995). Compensatory reproduction can result from an increase in litter size or the number of females breeding in response to lower population density (Windberg 1995, Schoch 2003). This type of reproduction may occur in populations under intensive removal programs. The data collected from my study will add to the knowledge of reproductive responses to intense predator removal efforts.

Under intensive harvest regimes, meso-mammal predator populations are thought to progress toward younger age classes (Schoch 2003). The age of an animal has been found to affect a number of its natural history traits, such as food types and ability to retain a territory (Fritts and Sealander 1974, Conner et al. 1999). Age is a factor that contributes to the type of foods many predators consume. Young animals do not have the hunting skills possessed by adults and tend to consume easily captured prey (Fritts and Sealander 1974, Conner et al. 1999). Age also is known to affect the size of an animal's territory. For example, young bobcats cover a much larger area than established adults (Conner et al. 1999). Because these young animals do not have an established territory, they are forced to cover larger areas to find territories of their own.

My study focuses on the responses of predators after an intensive removal has taken place for 3 consecutive years. The results should allow for a better understanding of how predators function in the ecosystem. It also will add to the scientific knowledge of predators in the Southeast, which is limited in the current literature. This research also may help to provide a better understanding of how coyotes affect southeastern U.S. ecosystems, since they are a relatively new species to this area.

OBJECTIVES AND THESIS FORMAT

My study is a continuation of predator control research that began in 2001 on southeastern U.S. quail plantations. Other researchers (Staller 2001, Staller et al. 2005, Thornton

2003, S. Ellis-Felege, personal communication) documented quail population responses to these predator control treatments. Given that these predators were being lethally removed as a treatment for the quail research, there was an opportunity to determine population-level responses by predators to intensive predator removal. My study was designed to understand the impacts of an intensive predator removal on the diet, age, and reproduction of the target animals.

During the first year of treatment, trapping began 1 March 2001 and continued until 30 September 2001 on 2 separate study sites. The trapping continued for 3 years (2001, 2002, 2003) on the same 2 sites from March to September each year. Schoch (2003) analyzed the data for 2001 (i.e., "pre-removal") and 2002 (i.e., "1 year post-removal)". Trapping was continued in 2003 and data collected during that year were added to the data collected by Schoch (2003) for analysis. After 2003, trapping switched to 2 different sites. These sites were then trapped during 2004, 2005, and 2006 from 1 March to 30 September each year. Therefore, I analyzed data from 2001 through 2006 (i.e., 1 year "pre-removal" and 2 years "post-removal" on 4 different study sites). The objectives of my project were to quantify any shifts in diet, age structure, and reproductive output of targeted predators in response to 2 years of intensive removal.

My thesis is divided into 3 chapters. Chapter 1 is an introduction and gives the background of the project. Chapter 2 is the main body of my thesis, which is written in manuscript style. It contains the methods, results and discussion of the research, and will be submitted for publication. The third and final chapter contains conclusions and predator management implications for southeastern U.S. quail plantations.

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CHAPTER 2

THE EFFECTS OF INTENSIVE PREDATOR HARVEST DURING THE QUAIL NESTING SEASON ON DIET, AGE AND REPRODUCTION OF MESO-MAMMALIAN PREDATORS

Lang, M. C., R. J. Warren, L. M. Conner, and N. B. Schoch. To be submitted to the Human – Wildlife Conflicts Journal

ABSTRACT

Lethal control of predators has been used to promote game species for centuries. Recently, this method of game promotion has become a common part of intensive quail management on southwestern Georgia plantations. Predators targeted for removal include opossums (*Didelphis virginianus*), raccoons (*Procyon lotor*), bobcats (*Lynx rufus*), and coyotes (*Canis latrans*). During the last few decades much emphasis has been placed on the responses of quail populations to predator removal. However, little research has examined the responses of the predators and the potential impacts of predator reduction on the remaining wildlife community. To address some of these questions, meso-mammalian predators were removed from March to October for 3 years from 4 different study sites. Two sites were trapped from 2001 to 2003 (Pebble Hill Plantation and Pinebloom Front). In 2004, trapping switched to the remaining 2 sites (Pinebloom Back and Tall Timbers Research Station) and was continued through 2006. Lower canines from all species were removed and cementum annuli analysis was used to estimate age. Stomachs and reproductive tracts also were removed to obtain diet and reproductive indices. The results of the stomach analyses (n=638) for opossums, raccoons, bobcats and coyotes were consistent with current food habits literature, but there were no consistent changes evident in diets that could be related to the predator removal treatments. Despite the high densities of quail found on our study sites, only 3% (21 out of 638) of the predators we examined contained quail or quail eggs. Our age data revealed significant decreases in mean age in opossums; significant age decrease were not found for any other species. Litter sizes were consistent with current literature for all species; however, no trends in reproduction were related to the trapping removals. Thus, the predator removal treatments we

imposed did not appear to consistently alter diets, age, or reproduction of opossums, raccoons, bobcats, or coyotes.

INTRODUCTION

For years, predator removal has been considered an effective way to promote certain game species. Predator removal is used throughout the Southeast by quail managers in hopes of increasing northern bobwhite (*Colinus virginianus*) populations. Quail managers have targeted mammalian predators in removal efforts because these predators are thought to negatively influence quail populations and nesting success. However, the actual impact these animals place on quail populations is not well known. There have been several predator diet studies in the Southeast, but few have been conducted on areas that have been intensively managed for quail (Miller and Speake 1978). Furthermore, removing large numbers of predators from an ecosystem may have effects that extend beyond the managed prey species, and in some cases may lead to an increase in smaller predators, which in turn may lead to higher predation rates (Paine 1969, Estes and Palmisiano 1974). Therefore, this research will provide important information to quail plantation managers and wildlife biologists who may consider initiating predator management strategies.

The objective for this project was to identify any changes in diet, age, and reproduction of predators during 3 years of intensive removal efforts. We hypothesized that age structure in the targeted predator populations would shift toward younger age classes during the 3-year period because of the addition of more young individuals to the population in response to increased reproduction or immigration. We hypothesized that diets of targeted predators would shift during the 3-year period to a greater occurrence of preferred food items in response to a reduction in competition resulting from the intensive predator removal. Finally, we hypothesized that reproductive rates for targeted predator populations would increase during the 3-year period in response to lower population abundance resulting from the intensive predator removals.

STUDY AREAS

This study was conducted on 3 quail plantations--two located in southwestern Georgia and the other in northwestern Florida. All plantations were intensively managed for quail and had similar habitat types. Pinebloom Plantation is located in Baker County, Georgia and consists of approximately 4,800 ha. We divided Pinebloom into 2, ≈1,400-ha sites (front and back) for the predator removal treatments (see experimental design section below). Habitat types of Pinebloom are primarily southern pine forests with the main overstory component being slash pine (*Pinus elliottii*). The understory of Pinebloom consists of mainly old-field vegetation. There are a number of fallow fields that are interspersed throughout this landscape. Because of annual fall disking, ragweed (*Ambrosia artemisfolia*) is the most common vegetation found in these fields. Small pockets of hardwoods consisting of live oak (*Quercus virginiana*), southern red oak (*Q. falcata*), and water oak (*Q. nigra*) also are found scattered throughout the property. Occasional food plots are scattered about the plantation.

Pebble Hill Plantation covers approximately 1,200 ha located in Thomas and Grady counties, Georgia. The main habitat on Pebble Hill is southern upland forest with the main overstory component being longleaf pine (*P. palustris*) and loblolly pine (*P. teada*). Most of the understory consists of wire grass (*Aristida stricta*) and old-field vegetation. Hardwood pockets are scattered across the property. The pockets consist of live oak, water oak, southern red oak, white oak (*Quercus alba*), sweetgum (*Liquidamber styraciflua*) and blackgum (*Nyssa sylvatica*).

Tall Timbers Research Station is a 1,200-ha operational quail plantation located in Leon County, Florida. This area of northwestern Florida is known as the Red Hills region. The habitat of Tall Timbers consists of upland southern pines such as loblolly, longleaf and slash pine. A mixture of old field vegetation as well as some wiregrass in areas of longleaf pine are the main understory components found on Tall Timbers. There also is an intermixing of small hardwood pockets and drains made up of similar species as those found on Pinebloom.

All 3 quail plantations used in this project received annual burning to reduce hardwood encroachment and promote herbaceous ground cover. Each plantation also used commercial thinning, mid-story hardwood removal, discing, and brush mowing. There are other habitat management practices, such as food plot plantings, that may also take place under the direction of the plantation managers. Predator removal was not conducted on either site during the 8 years before the beginning of this project.

METHODS

Experimental Design

This experiment was conducted on 4 different study sites in Georgia (Pinebloom Plantation front and back; Pebble Hill Plantation) and Florida (Tall Timbers Research Station). Each study site covered approximately 1,200 to 1,400 ha. During the first 3 years of this project, predator removal was conducted on Pinebloom-Front (PBF) and Pebble Hill (PH), while the other 2 sites were not trapped. Pinebloom-Back (PBB) and Tall Timbers (TT) were trapped during the last 3 years of the project, while PBF and PH were not trapped. Trapping was conducting during the quail nesting season (1 March to 30 September), during 2001 through 2006. Within each 3-year period of predator removal, the individual animals removed during the first year were considered to reflect the “control” or pre-removal condition. The following 2 years were considered to reflect the “treatment” or post-removal condition. We compared data from the last 2 years of removal to those collected in the first year of removal as a basis for estimating the effects of removal on the predator community.

Schoch (2003) analyzed the data from 882 opossums, raccoons, bobcats, and coyotes trapped during 2001 (i.e., "pre-removal") and 2002 (i.e., "1 year post-removal)" from PBF and PH. Trapping was continued on these 2 study sites in 2003 and data collected during that year were added to the data collected by Schoch (2003) for analysis. After 2003, trapping switched to the other 2 sites—PBB and TT. These sites were then trapped during 2004, 2005, and 2006 from 1 March to 30 September each year. Therefore, we analyzed data from 2001 through 2006 (i.e., 1 year "pre-removal" and 2 years "post-removal") on 4 different study sites.

Predator Removal

Predator removal treatments for this project were performed by USDA Georgia Wildlife Services personnel, and were approved by the University of Georgia Institutional Animal Care and Use Committee (AUP # A2004-10109-0). Trapping was conducted during the quail nesting season (1 March - 30 September) during each year of the experiment. Animals were removed using foothold traps, conibear traps, live-catch cage traps, and night shooting. Once an animal was captured and dispatched, it was given an individual identification number specific to the site from which it was removed. The heads, stomachs, and female reproductive tracts were removed from each carcass, labeled with the identification number, and frozen for later analysis.

Another group of research biologists examined the responses of quail populations to the predator removal treatments on our 4 study sites. These researchers used standardized scent-station surveys to monitor changes in predator abundance during the 3-year trapping periods. They simultaneously conducted scent-station surveys on all 4 study sites for 1 year before trapping commenced (2000) and during all 6 years (i.e., 3 years trapped plus 3 years untrapped) of this experiment (2001-2006). Comparing the mean index of predator abundance during the 4 years that each study site was untrapped to the 3 years that it received the predator removal treatments, these researchers observed that predator abundance on these study sites during the trapped years ranged from 39 – 84% of the abundances observed during untrapped years (S. Ellis-Felege, personal communication). Thus, there is evidence that the 3-year trapping treatments imposed on our study sites reduced the abundance of these meso-mammalian predators.

Food Habits

After thawing, each stomach was incised and its contents were emptied into a 3-layered sieve (Schoch 2003). Each layer of the sieve contained a different size mesh (12, 18, 20 mesh size), with the top layer having the largest mesh and the bottom having the smallest mesh. Stomach contents of each individual were analyzed and separated into like categories (i.e., mammal, bird, reptile, etc.). The contents were identified with the help of reference guides of hair, bones, feathers, and seeds. The contents were washed with warm water to dissolve fats and oils and help filter contents through the layered sieves. Once separated, an estimate of percent gut content was recorded for each food category (mammal, bird, reptile, etc.). These data were pooled into taxonomic categories for statistical analyses. Percent frequency of occurrence for each food category was obtained by dividing the number of stomachs in which each food item occurred by the total number of individual stomachs examined for each predator species within each site and year (i.e., sorted by site and year).

Age Determinations

Cementum annuli analysis was conducted on the lower canine teeth of raccoons, opossums, bobcats, and coyotes to estimate mean age for each species (Schoch 2003). Heads were thawed and the mandible was removed and placed in a hot water bath for 2-3 hours to loosen the periodontal membrane around the canine teeth. The lower canines were then extracted, with the aid of needle-nosed pliers, wiped clean, and placed in individual paper coin envelopes labeled with the animal's identification number. The packaged canines where then sent to Matson's Laboratory, Milltown, Montana for sectioning and cementum age analysis. Cementum annuli are deposited annually on the root of the tooth and represent a proven method for accurate age estimation in carnivores (Schroeder and Robb 2005).

Reproduction

The reproductive tracts from female raccoons, bobcats, and coyotes were analyzed for uterine swellings, fetuses, corpora lutea, and placental scars. Placental scars are known to develop in several mammalian orders, including Carnivora (Harder 2005). These scars are pigmented areas of the uterus occurring at the attachment site of a previous placenta. The age of these scars can be determined by the amount of fading, with the newest scars being darker. Counts of placental scars, along with fetuses, can be used to derive an index for reproductive output. This method works well with animals that only have 1 or 2 litters per year (Harder 2005). Corpora lutea (CL) are formed from ovulated follicles. Counts of CLs provide accurate estimates of ovulation rates but only an index for number of young (Harder 2005).

Female reproductive tracts were thawed and examined separately to estimate litter size and reproductive history. If fetuses or uterine swelling were not evident, the uterine horns were sliced open and examined for the presence of placental scars. Both ovaries were examined immediately after the uterine horns. Each ovary was sliced in half, lengthwise, and examined for CLs. A dissecting microscope was used to help identify CLs. Fetuses and uterine swellings were recorded, if present. Some uteri contained evidence of recent parturition (i.e., fresh trauma to the uterine endometrium at the site of placenta attachment rather than placental scars). We recorded these instances as fetuses rather than placental scars because parturition had obviously occurred shortly before the female was trapped.

Sample Selection and Statistical Analyses

Given the large samples sizes analyzed by Schoch (2003) for opossums (n=349) and raccoons (n=428), we used the random number generator in Microsoft Excel to randomly select individuals from these 2 species to obtain a subset of data from 2001 and 2002. We then combined this subset of data with data collected from 2003-2006 for analysis so that sample sizes were more equitable among all 6 years of this project. We randomly selected 30 individuals per year (females, if available) of opossums and raccoons from Schoch's (2003) larger data set. We then selected 242 opossums and 147 raccoons from our dataset for 2003-2006 for analysis. These individuals were selected because they all had "complete sample sets" (i.e., canines, stomachs and female reproductive tracts). Therefore, most of the opossums and raccoons we analyzed were female, but we added males to the analysis of food habits and age data to maximize sample sizes as much as possible. Sample sizes for bobcats and coyotes were smaller than for opossums and raccoons. Therefore, we combined all bobcats (n=68) and coyotes (n=37) analyzed by Schoch (2003) with all bobcats (n=90) and coyotes (n= 46) we collected during 2003-2006.

We conducted our statistical analyses using SAS (SAS Institute Inc. 2002-2004) and considered statistical significance at $P \leq 0.05$. We used analysis of variance (PROC GLM) followed by Tukey's mean separation test to compare mean ages for each species within each study site and among years (i.e., site-by-year groupings). For statistical analysis, we assigned an age of 0.5 years to any animal that was aged as <1 year old. We ran 2 separate analyses on our random sample of age data—one analysis included juveniles and the other excluded them. To further examine the large sample sizes available on ages of opossums and raccoons collected during the first 3 years of trapping, we merged all of the 2001 and 2002 data analyzed by Schoch (2003) with the age data from 392 predators collected during 2003 on PBF and PH. We then conducted a separate analysis of variance on the complete age dataset for opossums and raccoons collected during 2001-2003.

We used a Chi-square test of independence to determine differences in diets among removal years within each study site. For reproductive data, we conducted 2 types of analyses. First, we calculated the mean numbers of placental scars, fetuses, and CLs for females that had these structures in their reproductive tracts, and used analysis of variance to compare these data among years within each study site. Second, we used Chi-square tests to determine if there were any differences in the occurrence of reproduction among removal years. For this analysis, we assigned each individual a "1" if it had placental scars, fetuses, or CLs; if no evidence of reproductive activity was present, then each individual was assigned a "0".

RESULTS

Food Habits

Opossums.—There were no significant differences or any consistent trends in the food items consumed by opossums within each of the 3-year trapping periods on our 4 study sites (Table 1). There were no stomach samples available from opossum on PH during 2003. In general, food consumption by opossums appeared to be variable among years and among sites, probably related to site- and year-specific differences in food item availability. Opossums consistently consumed insects (16.7 – 41.4%) and vegetation (3.4 – 30.6%) among all sites and years (Table 1). Occurrence of soft mast (0.0 – 28.6%), other mammals (0.0 – 36.7%), and herpetofauna (0.0 – 17.2%) in opossum stomachs displayed the greatest variability among years and sites (Table 1). Consumption of quail or quail eggs by opossums was relatively low in all sites and years (Table 1).

One pattern that appeared to be evident was differences in consumption of mammalian and avian (Passerine) food items among site-by-year groupings (Table 1). During the first 3 years of our research, opossums on PBF and PH consumed relatively high amounts of mammals (i.e., rodents plus other mammals = 28.6 – 41.7%) and relatively low amounts (0 – 2.8%) of avian (Passerine) food items (Table 1). In contrast, during the last 3 years of our research, opossums on PBB and TT consumed relatively low amounts of mammals (i.e., rodents plus other mammals = 3.4 – 21.4%), but relatively high amounts (3.6 – 13.8%) of avian food (Table 1). Obviously, potential site- and year-specific variations in the availability of these food items prevent us from making inferences as to shifts in consumption of mammalian and avian prey.

Raccoons.—Similar to our observations on opossum food habits, there were no significant differences or any consistent trends in the food items consumed by raccoons within each of the 3-year trapping periods on our 4 study sites (Table 2). There were no stomach samples available from raccoons on PH during 2003. On PBB, the occurrence of soft mast in raccoon stomachs increased each year, from 6.3% in 2004 to 35.7% in 2006 (Table 2), but we did not observe this increasing trend in any of our other site-by-year groupings.

Table 1. Frequency of occurrence (%) of food items for opossums collected during 2001 through 2006 on Pinebloom (PBF and PBB), Pebble Hill (PH) plantations, Georgia and Tall Timbers Research Station (TT), Florida

Site	Year	n	Grain	Soft Mast	Rod ent	Other[1] Mam	Herps[2]	Insect	Veg[3]	Avian	Quail	Quail Eggs
PBF	2001	30	20.0	20.0	3.3	36.7	10.0	36.7	6.7	0.0	0.0	3.3
	2002	30	6.7	13.3	20.0	20.0	16.7	33.3	10.0	0.0	0.0	0.0
	2003	21	0.0	28.6	23.8	4.8	4.8	23.8	9.5	0.0	0.0	0.0
PH	2001	36	25.0	25.0	13.9	27.8	2.8	38.9	30.6	2.8	2.8	2.8
	2002	30	0.0	10.0	20.0	10.0	6.7	16.7	6.7	0.0	0.0	0.0
PBB	2004	28	0.0	0.0	14.3	7.1	0.0	17.9	10.7	3.6	0.0	0.0
	2005	32	0.0	0.0	3.1	3.1	3.1	25.0	18.8	12.5	3.1	0.0
	2006	33	0.0	18.2	9.1	3.0	12.1	36.4	15.2	9.1	0.0	0.0
TT	2004	29	0.0	6.9	3.4	0.0	17.2	41.4	3.4	13.8	0.0	0.0
	2005	29	0.0	20.7	3.4	13.8	6.9	31.0	27.6	6.9	0.0	0.0
	2006	30	0.0	10.0	6.7	10.0	6.7	36.7	23.3	10.0	0.0	0.0

[1] Contains all mammals not included in the rodent category.

[2] Contains material from herpetofauna.

[3] Contains all vegetative material excluding grain and soft mast

Table 2. Frequency of occurrence (%) of food items for raccoons collected during 2001 through 2006 on Pinebloom (PBF and PBB), Pebble Hill (PH) plantations, Georgia and Tall Timbers Research Station (TT), Florida.

Site	Year	n	Grain	Soft Mast	Rodent	Other[1] Mam	Herps[2]	Insect	Veg[3]	Avian	Quail	Quail Eggs
PBF	2001	15	6.7	40.0	0.0	6.7	0.0	20.0	13.3	0.0	0.0	0.0
	2002	15	26.7	26.7	6.7	0.0	0.0	26.7	0.0	6.7	0.0	0.0
	2003	4	0.0	0.0	0.0	25.0	0.0	0.0	25.0	0.0	0.0	0.0
PH	2001	15	46.7	13.3	0.0	20.0	0.0	6.7	26.7	0.0	0.0	0.0
	2002	10	10	10	0.0	0.0	0.0	10	10	0.0	0.0	0.0
PBB	2004	16	6.3	6.3	6.3	6.3	0.0	18.8	18.8	0.0	0.0	0.0
	2005	15	0.0	13.3	0.0	6.7	0.0	13.3	20.0	0.0	0.0	0.0
	2006	28	0.0	35.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TT	2004	11	9.1	0.0	0.0	18.2	0.0	27.3	36.4	0.0	0.0	0.0
	2005	9	0.0	22.2	0.0	0.0	0.0	0.0	22.2	0.0	0.0	0.0
	2006	17	0.0	11.8	0.0	5.9	5.9	11.8	5.9	0.0	0.0	5.9

[1] Contains all mammals not included in the rodent category.
[2] Contains material from herpetofauna.
[3] Contains all vegetative material excluding grain and soft mast.

In general, food consumption by raccoons was highly variable among sites and years. Occurrence of soft mast (0.0 – 40.0%), other mammals (0.0 – 25.0%), insects (0.0 – 27.3%), and vegetation (0.0 – 36.4%) in raccoon stomachs displayed the greatest variability among years and sites (Table 2). The small sample size (n=4) for raccoons from PBF during 2003 may be a major contributing factor in this variability. Consumption of rodents, herpetofauna, and avian food items by raccoons (Table 2) generally was lower than observed for opossums (Table 1), but consumption of quail or quail eggs by raccoons was similarly low as was observed for opossums in all years and sites (tables 1 and 2).

Bobcats.—There were no significant differences or any consistent trends in the food items consumed by bobcats within each of the 3-year trapping periods on our 4 study sites (Table 3). There were no stomach samples available from bobcats on PH during 2003. The major food item consumed by bobcats (>50% in all study sites and years) was rodents (Table 3). Rabbits and deer were the next most commonly occurring food items for bobcats (Table 3). Consumption of other mammals by bobcats (Table 3) generally was lower than observed for opossums (Table 1) or raccoons (Table 2), but consumption of quail or quail eggs by bobcats was higher than observed for either opossums or raccoons in all years and sites (tables 1, 2, and 3).

Coyotes.—There were no statistical differences found in frequency of occurrence for food items consumed by coyotes within each of the 3-year trapping periods on our 4 study sites (Table 4). There were no stomach samples available from coyotes on PH during 2003. Similar to what we observed in bobcats, coyotes consumed high amounts of rodents; however, they consumed more vegetation than was observed for bobcats (tables 3 and 4). There also appeared to be an inverse relationship between consumption of vegetation and soft mast. During the first

Table 3. Frequency of occurrence (%) of food items for bobcats collected during 2001 through 2006 on Pinebloom (PBF and PBB), Pebble Hill (PH) plantations, Georgia and Tall Timbers Research Station (TT), Florida.

Site	Year	n	Rodent	Rabbit	Deer	Hog	Other[1] Mam	Quail	Quail Egg
PBF	2001	16	56.3	43.8	0.0	25.0	12.5	12.5	18.8
	2002	12	83.3	16.7	0.0	0.0	0.0	0.0	0.0
	2003	5	80.0	0.0	0.0	0.0	0.0	0.0	0.0
PH	2001	9	66.7	22.2	44.4	0.0	11.1	0.0	0.0
	2002	4	50	0	25	0	0	0	0
PBB	2004	11	81.8	0.0	0.0	0.0	0.0	9.1	0.0
	2005	4	50.0	25.0	25.0	0.0	0.0	25.0	0.0
	2006	9	66.7	11.1	0.0	0.0	11.1	0.0	0.0
TT	2004	10	80.0	10.0	0.0	0.0	0.0	0.0	0.0
	2005	6	100.0	0.0	0.0	0.0	0.0	16.7	0.0
	2006	11	81.8	0.0	0.0	0.0	0.0	18.2	0.0

[1] Contains all mammals not included in the rodent, rabbit, deer or hog categories.

Table 4. Frequency of occurrence (%) of food items for coyotes collected during 2001 through 2006 on Pinebloom (PBF and PBB), Pebble Hill (PH) plantations, Georgia and Tall Timbers Research Station (TT), Florida.

Site	Year	n	Veg[1]	Soft Mast	Rodent	Rabbit	Deer	Hog	Other[2] Mam	Quail	Quail Egg
PBF	2001	10	0.0	30.0	30.0	10.0	20.0	30.0	0.0	0.0	0.0
	2002	3	0.0	20.0	40.0	0.0	60.0	0.0	0.0	0.0	20.0
	2003	1	100	0.0	100	0.0	0.0	100	100	0.0	0.0
PH	2001	0	0	0	0	0	0	0	0	0	0
	2002	5	0.0	20.0	20.0	0.0	40.0	0.0	20.0	0.0	20.0
PBB	2004	1	100.0	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
	2005	4	50.0	0.0	50.0	0.0	0.0	0.0	25.0	0.0	0.0
	2006	13	53.8	0.0	69.2	0.0	0.0	15.4	0.0	0.0	7.7
TT	2004	8	12.5	12.5	12.5	12.5	0.0	0.0	37.5	0.0	0.0
	2005	4	25.0	0.0	50.0	0.0	0.0	0.0	25.0	0.0	0.0
	2006	9	22.2	0.0	55.6	0.0	0.0	0.0	22.2	0.0	0.0

[1] Contains all vegetative material excluding soft mast.

[2] Contains all mammals not included in the rodent, rabbit, deer or hog categories.

3 years of our study, coyotes consumed more soft mast than during the last 3 years (Table 4). Conversely, coyotes consumed less vegetation during the first 3 years compared to the last 3 years (Table 4). Of course, differences in study sites between the first and last 3 years of our study prohibit us from inferring a definitive inverse relationship between these 2 food items. Finally, we did not observe quail in the coyote stomachs we examined and the occurrence of quail eggs was relatively low (Table 4), however, we had few or no samples for some study sites and years.

Quail Use by All Predators.—We found no statistical differences for the consumption of quail by any species on either of the sites. Among all study sites and years, the greatest occurrence of quail or quail eggs in the stomachs of meso-mammalian predators was observed for bobcats on PBB in 2005 (25.0%; Table 3). However, the sample size for this study site and year was small (n=4), with 1 bobcat containing quail remains. During all 6 years and all 4 study sites, we observed a 3% occurrence of quail and quail eggs for all 4 predator species combined (n=638).

Age

Opossums.—We observed a decreasing trend in ages of opossums among the first 3 years of trapping on PBF and PH (Table 5). Mean ages of opossums were significantly (P=0.0001) older during first year (2001) of trapping when compared to the second (2002) or third (2003) year, whether we included or excluded juveniles from the analysis (Table 5). Our mean ages for opossums on PBF and PH during 2002 are identical both with and without juveniles, because we did not trap any juveniles on either of these study sites in 2002 (Table 5).

Table 5. Age data for opossums collected during 2001 through 2006 on Pinebloom (PBF and PBB), Pebble Hill (PH) plantations, Georgia and Tall Timbers Research Station (TT), Florida.

		Age, excluding juveniles			Age, including juveniles		
Site	Year	N	x	SE	n	x	SE
PBF	2001	18	5.3^{a}	0.56	24	4.2^{a}	0.61
	2002	19	3.2^{b}	0.42	19	3.2^{a}	0.42
	2003	22	2.3^{b}	0.24	37	1.6^{b}	0.21
PH	2001	18	4.8^{c}	0.41	20	4.4^{c}	0.47
	2002	20	2.2^{d}	0.15	20	2.2^{d}	0.15
	2003	6	2.2^{d}	0.30	7	1.9^{d}	0.35
PBB	2004	37	2.2	0.18	39	2.2	0.18
	2005	31	2.8	0.24	33	2.5	0.24
	2006	31	2.3	0.15	35	2.1	0.17
TT	2004	29	2.6	0.28	35	2.3	0.27
	2005	24	2.6	0.27	30	2.2	0.27
	2006	31	2.3	0.18	35	2.1	0.19

^{a,b} For PBF, means among years with dissimilar superscripts are significantly different ($P<0.05$).

^{c,d} For PH, means among years with dissimilar superscripts are significantly different ($P<0.05$).

In contrast, we did not observe any trends or significant differences for mean ages of opossums among the second 3 years of trapping on PBB and TT (Table 5). This lack of trends or significant differences was evident whether we included or excluded juveniles from the analysis (Table 5).

The analysis of all age data collected from opossums during the first 3 years on PBF and PH (Table 6) revealed identical trends to those seen in the analysis of our subsample (Table 5). On both PBF and PH, all opossums collected during 2001 were significantly older than those collected during 2002 and 2003 (Table 6). Thus, the results from our random subsample of data (Table 5) collected during the first 3 years were essentially identical to the results obtained from the complete sample (Table 6).

Raccoons.—There were no significant differences among years in mean ages of raccoons, whether we included or excluded juveniles from the analysis (Table 7). There appeared to be a decreasing trend in mean age of raccoons on PBF and TT; however, this trend was not evident on PH or PBB (Table 7). Among all study sites and years, mean ages for adult raccoons ranged from 1.5 – 3.1 years (Table 7).

The analysis of all raccoons removed during 2001 through 2003 revealed no significant differences on PBF whether juveniles were included or not (Table 6). However, unlike our subsample of age data, raccoons from PH in the complete sample set were significantly older in 2001 than in 2002, whether including or excluding juveniles (Table 6). When excluding juveniles this trend was not continued in 2003. However, when including juveniles, the decreasing trend in age, though not significant, was evident (Table 6).

Table 6. Age data for all opossums and raccoons collected during 2001 through 2003 on Pinebloom Front (PBF) and Pebble Hill (PH) plantations, Georgia.

			Age, excluding juveniles			Age, including juveniles		
Species	Site	Year	n	X	SE	n	x	SE
Opossums	PBF	2001	22	4.8[a]	0.54	29	3.7[a]	0.53
		2002	91	3.1[b]	0.14	93	3.0	0.15
		2003	133	2.8[b]	0.11	152	2.6[b]	0.12
	PH	2001	34	4.3[c]	0.3	44	3.5[c]	0.34
		2002	94	2.6[d]	0.09	96	2.6[d]	0.1
		2003	89	2.6[d]	0.14	98	2.5[d]	0.14
Raccoons	PBF	2001	73	2.4	0.18	87	2.1	0.17
		2002	167	2.0	0.15	169	1.9	0.14
		2003	40	1.9	0.23	59	1.5	0.18
	PH	2001	44	2.5[c]	0.29	45	2.5[c]	0.29
		2002	22	1.4[d]	0.18	22	1.4[d]	0.18
		2003	23	1.9	0.26	50	1.1[d]	0.15

[a,b] For PBF, means among years and within species that have dissimilar superscripts are significantly different ($P<0.05$).

[c,d] For PH, means among years and within species that have dissimilar superscripts are significantly different ($P<0.05$).

Table 7. Age data for raccoons collected during 2001 through 2006 on Pinebloom (PBF and PBB), Pebble Hill (PH) plantations, Georgia and Tall Timbers Research Station (TT), Florida.

		Age, excluding juveniles			Age, including juveniles		
Site	Year	n	x	SE	n	x	SE
PBF	2001	16	3.1	0.43	16	3.1	0.43
	2002	20	2.8	0.56	21	2.6	0.55
	2003	6	1.8	0.16	8	1.5	0.25
PH	2001	20	2.5	0.39	20	2.5	0.38
	2002	15	1.5	0.23	15	1.5	0.23
	2003	3	2.6	0.88	3	2.6	0.88
PBB	2004	11	1.6	0.28	22	1.1	0.18
	2005	11	1.8	0.40	20	1.2	0.26
	2006	15	2.5	0.51	23	1.8	0.38
TT	2004	13	2.5	0.39	15	2.3	0.38
	2005	7	3.1	0.96	14	1.8	0.58
	2006	11	1.6	0.27	18	1.2	0.21

Bobcats. — There were no significant differences among years in mean ages of bobcats, whether we included or excluded juveniles from the analysis (Table 8). There appeared to be a decreasing trend in mean age of bobcats on PBF and TT; however, this trend was not evident on PH or PBB (Table 8). Among all study sites and years, mean ages for adult bobcats ranged from 1.3 – 3.8 years (Table 8).

Coyotes. — No significant trends or differences were determined for mean ages of coyotes, whether we included or excluded juveniles from the analysis; however, we had small sample sizes for most site-by-year groupings (Table 9). Among all study sites and years, mean ages for adult coyotes ranged from 1.0 – 4.0 years (Table 9).

Reproduction

Raccoons.—There were no significant differences or any consistent trends in the analysis of female reproductive tracts of raccoons within each of the 3-year trapping periods on our 4 study sites (Table 10). Indeed, the trends in reproductive data collected increased among years on some study sites and decreased among years on other study sites (Table 10). Thus, there were no consistent trends observed to indicate an increase in reproduction for the current breeding season (as evidenced by fetus and CL counts) or previous breeding season (as evidenced by placental scar counts). Among all study sites and years, the average percent of females that were pregnant ranged from 0 – 35.7%, and the number of fetuses per pregnant female ranged from 2.0 – 3.3 (Table 10). No significant differences were detected in the means for CLs, fetuses, or placental scars from the analysis of variance for these data.

The Chi-square test revealed that a significantly higher proportion of female raccoons had placental scars compared to those without placental scars during 2004 on TT (12 out of 18 or 66.7%) and during 2006 on PBB (18 out of 28 or 64%) (Table 10). No significant differences

Table 8. Age data for bobcats collected during 2001 through 2006 on Pinebloom (PBF and PBB), Pebble Hill (PH) plantations, Georgia and Tall Timbers Research Station (TT), Florida.

		Age, excluding juveniles			Age, including juveniles		
Site	Year	n	x	SE	n	x	SE
PBF	2001	12	2.2	0.42	12	2.2	0.42
	2002	34	1.8	0.18	34	1.8	0.18
	2003	17	1.6	0.26	18	1.5	0.25
PH	2001	9	3.1	1.07	9	3.1	1.07
	2002	4	2.3	0.75	4	2.3	0.75
	2003	5	1.8	0.37	5	1.8	0.37
PBB	2004	17	2.5	0.84	21	2.3	0.70
	2005	6	1.3	0.21	6	1.3	0.21
	2006	7	1.9	0.45	8	1.8	0.41
TT	2004	13	3.8	0.78	13	3.8	0.78
	2005	5	2.8	0.20	5	2.8	0.20
	2006	13	1.8	0.46	14	1.8	0.43

Table 9. Age data for coyotes collected during 2001 through 2006 on Pinebloom (PBF and PBB), Pebble Hill (PH) plantations, Georgia and Tall Timbers Research Station (TT), Florida.

		Age, excluding juveniles			Age, including juveniles		
Site	Year	n	x	SE	n	x	SE
PBF	2001	7	1.3	0.29	9	1.1	0.25
	2002	15	2.5	0.5	15	2.5	0.5
	2003	4	1.0	0	4	1.0	0
PH	2001	0	0	0	0	0	0
	2002	7	2.0	0.38	8	1.8	0.38
	2003	0	0	0	0	0	0
PBB	2004	3	2.7	0.88	4	2.3	0.75
	2005	2	1.5	0.50	4	1.3	0.25
	2006	10	1.6	0.31	14	1.4	0.22
TT	2004	2	4.0	0	6	2.0	0.63
	2005	4	1.8	0.47	6	1.5	0.34
	2006	4	1.3	0.25	8	1.1	0.13

were found for the chi-square test on the proportion of female raccoons with CLs or fetuses any site during any year (Table 10).

Bobcats. — There were no significant differences or any consistent trends in the analysis of female reproductive tracts of bobcats within each of the 3-year trapping periods on our 4 study sites (Table 11). Thus, there were no consistent trends observed to indicate an increase in reproduction for the current breeding season (i.e., fetus and CL counts) or previous breeding season (i.e., placental scar counts). It did appear as though the mean number of CLs per female that ovulated was greater for bobcats collected on both study sites during the last 3 years compared to those collected on both study sites during the first 3 years (Table 11). However, given that study sites and years are confounded in our design, we are unable to attribute these differences to site-specific or annual variation. Among all study sites and years, the average percent of females that were pregnant ranged from 0 – 66.7%, and the number of fetuses per pregnant female ranged from 2.0 – 4.0 (Table 11).

Coyotes.—Our samples sizes for female coyotes were relatively low among all study sites and years (Table 12). In fact, we did not obtain any coyotes from PH during 2001-2003. Our low samples sizes or lack of samples prevent us from making any statements regarding trends in the analysis of female reproductive tracts of coyotes within each of the 3-year trapping periods on our 4 study sites. For PBF, the only study site on which we observed pregnant female coyotes, the average percent of females that were pregnant ranged from 0 – 100%, and the number of fetuses per pregnant female ranged from 2.0 – 3.5 (Table 12).

Table 10. Reproductive data from raccoons collected 2001 through 2006 on Pinebloom (PPF and PBB), Pebble Hill (PH) Plantations, Georgia and Tall Timber Research Station (TT), Florida.

			Fetuses per pregnant female			Placental scars per post parturition females			CLs per pre/post parturition females		
Site	Year	# examined	% with Fetuses	X	SE	% with P. scars	x	SE	% with CLs	x	SE
PB	2001	15	26.7	3.3	0.13	40.0	3.0	0.23	46.7	3.6	0.20
	2002	15	13.3	2.0	0.00	26.7	3.0	0.26	46.7	3.3	0.23
	2003	5	20.0	3.0	0.00	40.0	3.0	0.00	20.0	3.0	0.00
PH	2001	15	26.7	2.5	0.15	20.0	2.8	0.25	26.7	2.2	0.38
	2002	10	20.0	2.5	0.22	40.0	3.3	0.16	50.0	3.4	0.28
	2003	4	25.0	3.0	0.00	50.0	2.8	0.25	75.0	2.0	0.50
PBB	2004	14	35.7	3.2	0.35	25.6	3	0.22	50.0	2.9	0.24
	2005	13	0	0	0	30.7	2	0.23	30.7	2.3	0.14
	2006	28	0	0	0	64.2[a]	3.1	0.04	32.1	2.6	0.04
TT	2004	18	22.2	2.8	0.3	66.7[a]	3.3	0.23	38.8	2.4	0.3
	2005	16	35.3	2.4	0.29	18.7	4	0.66	37.5	2.5	0.26
	2006	21	14.3	2.7	0.03	42.3	3.6	0.04	14.3	2.6	0.04

[a] Proportion of raccoons with placental scars significantly different than those without placental scars (Chi-square, $P<0.05$, df=2).

Table 11. Reproductive data from bobcats collected 2001 through 2006 on Pinebloom (PPF and PBB), Pebble Hill (PH) Plantations, Georgia and Tall Timber Research Station (TT), Florida.

			Fetuses per pregnant females			Placental scars per post parturition females			CLs per pre/post parturition female		
Site	Year	# examined	% with Fetuses	x	SE	% with P. scars	x	SE	% with CLs	x	SE
PB	2001	8	12.5	2	0.00	50.0	2.5	0.53	62.5	3.2	0.30
	2002	12	16.7	3.0	0.00	50.0	3.2	0.22	83.3	3.1	0.21
	2003	0	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
PH	2001	3	66.7	2.5	0.88	33.3	2.0	0.00	100	2.3	0.33
	2002	4	50.0	3.5	0.40	0	0.0	0.00	75.0	3.3	0.21
	2003	1	100	2.0	0.00	0	0.0	0.00	100	3.0	0.00
PBB	2004	6	33.3	3.0	0.21	0	0.0	0.00	100	5.5	0.85
	2005	1	0	0.0	0.00	0	0.0	0.00	100	4	0.00
	2006	5	20.0	2.0	0.00	20.0	3.0	0.00	80.0	5.8	1.29
TT	2004	10	10.0	2.0	0.00	40.0	2.3	0.30	70.0	5.8	0.84
	2005	2	50.0	3.0	0.00	50.0	2.0	0.00	50.0	7	0.00
	2006	4	25.0	4.0	0.00	0	0.0	0.00	75.0	6.3	0.76

Table 12. Reproductive data from coyotes collected 2001 through 2006 on Pinebloom (PPF and PBB), Pebble Hill (PH) Plantations, Georgia and Tall Timber Research Station (TT), Florida.

			Fetuses per pregnant females			Placental scars per post parturition females			CLs per pre/post parturition females		
Site	Year	# examined	% with Fetuses	x	SE	% with P. scars	x	SE	% with CLs	x	SE
PBF	2001	6	16.7	2.0	0	50.0	4.7	1.03	33.3	3.0	0.58
	2002	0	0	0	0	0	0	0	0	0	0
	2003	2	100	3.5	0.50	0	0	0	100	3.5	0.50
PBB	2004	0	0	0	0	0	0	0	0	0	0
	2005	3	0	0	0	33.3	7.0	0	33.3	7.0	0
	2006	5	0	0	0	20.0	2.0	0	20.0	2.0	0
TT	2004	3	0	0	0	66.7	3.5	2.04	66.7	3.5	2.04
	2005	3	0	0	0	66.7	3.0	0.81	25.0	4	0
	2006	7	0	0	0	28.6	3.0	0.81	0	0	0

DISCUSSION

Food Habits

Opossums.—Opossum diets examined during this study seemed to be consistent with earlier literature (Dexter 1951, Hamilton 1951, Hume 1999). The opossum has been described as an omnivorous animal, feeding on a variety of food items. Insects and vegetation were common in opossum stomachs analyzed on all study sites and during all years (Table 1). It is likely that insects and vegetation are commonly available food items for opossums.

Soft mast also was found commonly in opossum stomachs, except on PBB during 2004 and 2005 (Table 1). These differences probably reflect variation in soft mast availability among years. Much of the soft mast found was muscadines (*Vitus rotundifolia*), persimmons (*Diospyros virginiana*), hawthorns (*Crataegus* spp.), pawpaw (*Asimina* spp.), American beautyberry (*Callicarpa americana*) and blackberries (*Rubus* spp.).

Rodents and other mammals, when combined, also were found commonly in opossum stomachs on our 2 study sites during 2001 – 2003, but were less common in opossum stomachs on our 2 study sites during 2004 – 2006 (Table 1). These differences may suggest rodents and other mammals were not as readily available on 2 of our sites. Conversely, avian material (excluding quail) was less common in opossum stomachs on our 2 study sites during 2001 – 2003, but was more common in opossum stomachs on our 2 study sites during 2004 – 2006 (Table 1). It seems unlikely that the opossum posses the predatory skills necessary to capture Passerine birds, and seems more likely that they scavenged birds that were killed by vehicles along the highways or other natural causes.

Raccoons.—Raccoon food habits from our study were consistent with findings of earlier research (Dexter 1951, Schoononver et al. 1951, Greenwood 1981, Schoch 2003). Raccoons from all study sites and all years tended to have omnivorous diets, consuming soft mast, vegetation, insects, birds and mammals (Table 2). On most study sites and in most years, soft mast was a commonly occurring food item; however, on PBB the occurrence of soft mast increased each year from 6.3% in 2004 to 35.7% in 2006 (Table 2). This trend may reflect increased availability of soft mast from year to year. However, PBB was experiencing a severe drought in 2006, during which soft mast was the primary food item eaten by raccoons on this site (Table 2). Furthermore, a considerable percentage of raccoon stomachs from PBB contained material from crayfish, which is probably a direct result of foraging around 325 ha cypress (*Taxodium spp*) pond located on this study site.

Bobcats.—Bobcat diets were consistent with other literature, with rodents and other small mammals being the primary food item (Young 1958, Miller and Speake 1978, Fritts and Sealander 1978, Maehr and Brady 1986, Cochrane 2003, Godbois 2003, Schoch 2003, Doughty 2004). Bobcat diets examined during this study consisted mostly of rodent remains, with more than 50% of stomachs examined containing rodents during each year of the study (Table 3). The cotton rat made up the vast majority of the rodent material found in bobcat stomachs on all sites and for all years. Remains from *Peromyscus* spp., *Sciurus* spp. and *Microtus* spp. also were found in bobcat stomachs. During some years, lagomorphs occurred commonly in bobcat stomachs, perhaps related to site and year-specific variations in availability (Table 3).

Bobcats occasionally consumed mature snakes: In 2002, a mature timber rattlesnake (*Crotalus horridus*) was found in the stomach of a bobcat from PBF. A gray rat snake (*Elaphe obsolete spiloides*), a known quail egg predator, was found in a bobcat collected on PH in 2001. A mature eastern diamondback rattlesnake (*Crotalus adamanteus*) was recovered in a 2001 bobcat. Bobcats collected from PBB contained the remains of a mature timber rattlesnake

(*Crotalis horridus*) in 2004 and gray rat snakes (*Elaphus obsolete spiliodes*) in 2006. No other predatory snakes were found in stomachs from opossums, raccoons and coyotes.

Miller and Speake (1978) reported that the bobcat is not a major quail predator. However, when combining data on quail and quail eggs consumed by bobcats (n=16) on PBF during 2001, we observed a 31.3% occurrence of quail as a food item for bobcats (Table 3). Yet, we observed no quail remains in bobcats collected during 2002 or 2003 on PBF (Table 3). In 2005 on PBB, quail remains were found in 25% of bobcats examined (n=4; Table 3). Quail were recorded in 16.7% and 18.2% of bobcats from 2005 and 2006 on TT (Table 3). These results may be an indication that bobcats are feeding on quail in an opportunistic manner, but that they are not specifically targeting quail as a food item.

Coyotes.—Coyotes have been classified in several studies as opportunistic omnivores, feeding on a variety of food items from vegetation to carrion (Sperry 1941, Litvaitis and Shaw 1980, Wooding et al. 1984, Andelt 1985, Blanton and Hill 1989). The coyotes analyzed in our study (Table 4) consumed a wide variety of mammals, including rodents, such as cotton rats, rabbits, deer, hogs, and armadillos, but they also consumed considerable amounts of vegetation and soft mast (mostly persimmons and blackberries during 2001 – 2003, and mostly muscadines during 2004 – 2006). Most of the vegetation consisted of grass leaves from the Poeacea family. There were 6 coyote stomachs that contained green peanuts. The remains of both juvenile and adult wild turkeys were found in coyote stomachs. Two coyote stomachs even contained commercial shop towels.

Quail Use by All Predators.—Opossums, raccoons, bobcats and coyotes have been documented as predators of ground-nesting birds and their eggs (Hamilton 1951, Greenwood 1981, Maehr and Brady 1986, Staller et al. 2005). In our research, quail remains (quail and/or quail eggs) were found in bobcats, coyotes, opossums, and raccoons. Schoch (2003) found quail remains in raccoons from PBF and PH in 2001 and 2002; however, in our research, we examined a randomly selected sub-sample of these raccoons, none which contained any quail material. Staller et al. (2005) also documented raccoons feeding on quail eggs through video surveillance of quail nests on our study sites before predator removal began. From 2004 – 2006, quail material (either eggs or actual birds) was documented in each species of predator (tables 1, 2, 3, and 4). Only 2 coyotes, throughout the entire study were documented containing quail eggs, and none was found to contain quail. However, this may be a result of a small sample size of only 60 coyotes for our entire study. We observed several coyotes contained the remains of armadillo (*Dasypus novemcinctus*), a known quail nest predator, in their stomachs. Bobcats had the highest frequencies of occurrence of quail material, both eggs and quail, with several years of >20% occurrence. However, there also were years in which no quail material was documented in any examined bobcat.

Its seems, from our research, that these predators may be feeding on quail in a opportunistic manner and not primarily focusing on quail and quail eggs as a major food resource. The sites where our predator removals were conducted are intensely managed for quail, containing high densities of this species. Even with the high densities found on these properties, quail were only found in 3% of predators (n=638) examined during our research. The amount of predation a quail population incurs is probably directly related to the availability of other food sources. Meaning, higher rodent populations and heavy mast crops may deter predators from quail as they shift to other food resources. With the wide variety of food items found on intensely managed southeastern U.S. quail plantations, it seems unlikely that meso-mammals would limit quail populations found on these plantations.

Age

Age distribution of animal populations can be affected by intensive harvest. Populations subjected to intensive harvest are often skewed towards younger animals (Trautman et al. 1974, Andelt 1985, Windberg et al. 1985, Gese et al. 1989, Windberg 1995). Unexploited populations (populations in which humans do not remove animals) typically have older age structures than those of exploited populations (Knowlton 1972, Trautman et al. 1974, Berg and Chesness 1978, Andelt 1985, Gese et al. 1989, Windberg 1995).

Opossums.—Age data from PBF and PH during 2001 through 2003 (Table 5), revealed decreasing trends for age structure of opossums, whether juveniles were included or not. Thus, it appears on PBF that our treatments were having an effect on the mean age of opossums. The analysis of all opossums collected during 2001 through 2003 (Table 6) revealed almost identical trends as our subset analysis. This analysis revealed decreasing trend in mean ages for opossums from all sites and years despite including or excluding juveniles.

Opossums from PBB and TT during 2004 through 2006 did not reveal any trends of decreasing age (Table 5). It appears that the age structures of opossums were not at all affected by our removal efforts. This result may show that perhaps our removal effort was not intense enough to shift the age structure of opossum populations on PBB and TT.

Raccoons.—No significant differences in mean ages were determined for raccoons on PBB and PH; however, a decreasing trend in mean age was evident on PBF and TT (Table 7). Perhaps this a reflection of our treatment efforts having a slight effect on the age structure of raccoons on these sites. The analysis of all raccoons removed during 2001 through 2003 (Table 6) revealed that raccoons on PH were significantly older in 2001 than in 2002. This trend is seen when juveniles are included in the analysis. Without juveniles in the sample, mean ages of adult raccoons seem to level off after 2002. However, when juveniles are added to the sample, a continuous decreasing trend in mean ages is seen from 2001 through 2003. Of the 50 total raccoons removed in 2003, over half (27 out of 50) were aged as juveniles.

Bobcats.—Bobcats from PBF and PH did show decreases in mean age, although none were significant (Table 8). A similar trend was seen after the juvenile component was added. On PBB and TT, from 2004 through 2006, no significant differences in mean age were determined. However, a clear trend in decreasing mean age was found on both of these sites.

Coyotes.—We found no significant differences in mean age for coyotes from PBF (Table 9). Our subset only contained one coyote from PBF in 2003. This coyotes was aged at 1 year old. On PBB, a decrease in mean age in adult coyotes was found between 2004 and 2005 (Table 9). Mean age for coyotes in 2006 was determined at 1.6 years of age, basically the same as 2005. A similar trend was found when juveniles were included. However, we have small sample sizes for 2004 (n=3) and 2005 (n=2). A trend in decreasing age was also found on TT. Again, this trend agreed when juveniles were added. Interestingly, of the 6 coyotes sampled in 2004, 4 were juveniles. However, because sample sizes are small, it is difficult to determine any trends.

Overall, it seems our removal effort was not significant enough to significantly decrease age structure of these animal populations. A continuation of our removal efforts for several more years may be necessary to see the results that we originally hypothesized. However, if surrounding areas are un-trapped, then it may be possible that animals from these areas moved onto trapped areas soon after an animal is removed.

Reproduction

Populations under heavy exploitation have greater yearling reproduction and increased litter size (Knowlton 1972, Berg and Chesness 1978). Increased litter size in response to a reduction in conspecific density is known as compensatory reproduction. Lower density leads to less competition for resources, often resulting in a decrease in emigration, and an increase in litter size (Gese et al. 1996a, 1996b). We would expect to see an increase in litter size in our study populations, due to the reduction in competition through the removal effort.

Raccoons.—Litter sizes of raccoons in this study are similar to litter sizes reported in earlier literature (Sanderson 1950, McKeever 1957, Ritke 1990). Schoch (2003) did not find any evidence to support compensatory reproduction in raccoons on PBF and PH. In continuing this research, we also did not find any evidence for compensatory reproduction. We found no definite trends suggesting an increase in reproductive activity. However, during the analysis of our data, the proportion of raccoons with placental scars was found to be significantly greater during 2004 on TT and during 2006 on PBB (Table 10).

For TT, 2004 was the first year that an intensive predator removal was conducted, yet it had the highest occurrence of reproductively active females. In 2002, TT experienced a massive distemper outbreak, which resulted in the deaths of many raccoons. Placental scars are representative of the previous breeding season. Because placental scars are indicative of previous year breeding, this high number of raccoons with placental scars in 2004 may reflect increased breeding in 2003 that may be a compensatory response to the disease outbreak. We also found a significantly higher proportion of raccoons with placental scars during 2006 on PBB. Because this was the last year our study was conducted, it is unlikely that this is a response to our removal efforts.

Bobcats.—The litter sizes we detected for bobcats from our study are similar to those reported by Fritts and Sealander, (1978). Even though our sample sizes were small, we did not observe a shift towards increased reproduction on any site. We did see the mean fetal counts increase from 2.0 fetuses in 2004 to 4.0 fetuses by 2006. Again, sample sizes were very small and it is difficult to draw any definite conclusions dealing with bobcat reproduction.

Coyotes.—Similar to bobcat reproduction, our sample sizes for coyotes were very small. However, no trends of any kind could be discerned. Interestingly, out of the 21 female coyotes we sampled from 2004 to 2006 on both PBB and TT, none contained fetuses. According to our age data, in several instances ≥50% of the coyotes we captured were juveniles. Perhaps this is the reason for limited reproductive activity seen in the coyotes we sampled. In certain coyote populations only the dominant females breed (Gese et al. 1996a, 1996b). It is quite possible that we did not remove dominant females, which may explain why the majority the coyotes we examined contained no evidence for reproductive activity.

SUMMARY, CONCLUSIONS, AND MANAGEMENT IMPLICATIONS

Summary and Conclusions

Overall, it seems our predator removal efforts were not significant enough to shift diets, decrease age structure, or increase reproduction of these meso-mammal populations. Diets were so variable across all sites and years, that it seems likely food habits were based on availability of food sources. Bobcats were the only species examined that consistently contained certain food items. The majority of bobcats examined contained cotton rats. Opossums, raccoons and coyotes contained a wide variety of food items, from soft mast to rodents. Even though some minor trends for decreased age or increased reproduction were seen, the overall significant effects we hypothesized were not found.

Schoch (2003) reported a significant decrease in age structures of opossums and raccoons during 2001 and 2002, but did not observe much evidence for increased reproduction. Therefore, he hypothesized that the decrease in age structure for these populations resulted from emigrating young animals that were dispersing from the surrounding landscape. However, when we compared additional age data collected during 2003 to Schoch's data from 2001 and 2002, the trend in age structure did not decrease further. The data we collected from 2 additional study sites and 3 additional years also were highly variable such that no definite trends could be found. In some instances, no apparent effect was seen and in other cases mean ages increased among removal years. Because of the large amount of variability, it seems that our removal treatments did not have much of an effect on the predator community as a whole. Furthermore our trapping success remained fairly consistent throughout our entire study. Thus, if our trapping was significantly affecting these meso-mammal predator populations, then our trapping success likely would have decreased among years.

Management Implications

Even though we found no definite trends in the predator community, the quail researchers observed that predator abundance on these study sites during the trapped years ranged from 39 – 84% of the abundances observed during untrapped years (S. Ellis-Felege, personal communication). Thus, there is evidence that the 3-year trapping treatments imposed on our study sites reduced the abundance of these meso-mammalian predators.

Trap numbers remained consistent throughout each trapping season. Our study incorporated an intense predator removal treatment conducted continuously from March to September during a 3-year period. It seems unlikely the quail managers would be able to implement a more intense trapping regime than that used in our study, while also running an operational plantation at the same.

Quail managers also may want to consider the number of rodents, snakes, and other animals posing a threat to quail. Unlike mammalian predators that tend to depredate a nest during early incubation, snakes and fire ants tend to depredate nests during later incubation (J. Burnam, pers. comm.). This is an important factor because quail may have time to re-nest after mammalian depredation that occurs early during incubation. Conversely, if a snake depredates a nest during late incubation, then the hen may not have time to re-nest or may be re-nesting at a depleted physical condition. Additionally, predator control is an expensive, time-consuming component of quail management with benefits that may not be justified by the high cost. However, the judgment of whether this expense is justified is up to each quail manager's discretion. Quail managers may want to consider that the southeastern ecosystems are very complex, and there may be many other factors affecting both meso-mammal and quail demographics, such as weather, alternative prey, and predator community composition.

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CHAPTER 3

SUMMARY AND IMPLICATIONS FOR PREDATOR MANAGEMENT

SUMMARY

Humans have used predator removal as a means of enhancing game populations for centuries. This has recently become a popular management practice on areas that are intensively managed for the northern bobwhite (*Colinus virginianus*). The bobwhite is a popular game bird in southern Georgia, generating about $55 million of revenue for quail plantations throughout the Southeast (Burger et al. 1999). To support this sport, many quail plantations spend substantial amounts on management efforts each year. The average cost of quail management practices implemented on plantations in the Southeast has been estimated at $140 per ha/year (Burger et al. 1999). Part of this management includes predator removal.

Game managers and quail hunters alike have long blamed meso-mammalian predators for local declines in quail numbers. Much research has been conducted on responses of quail to predator removal; however, little has been done on the ecology of predators on these quail plantations (Miller and Speake 1978) or to quantify the population-level effects of removal on the predator community. There also is a lack of research that quantifies diets of predators on lands specifically managed for quail in the Southeast (Miller and Speake 1978, Schoch 2003).

We conducted a 6-year study on meso-mammalian predators harvested in conjunction with a larger quail research project in hopes of understanding how the predator community would respond to intensive removal. These predator removals took place during the quail nesting season on quail plantations in southwestern Georgia and northern Florida. Two study sites where trapped intensely from 2001 to 2003. In 2004 the trapping was switched to 2 separate study sites and continued until 2006. In this study, we examined diet, age, and reproduction of harvested predators to quantify any changes that may have been linked to our removal treatments.

The food habits of raccoons, opossums, bobcats, and coyotes documented in this study were consistent with previous literature. No major shifts in predator diets were found in response to the removal. The diets of harvested predators varied by site and year. This variability was attributed to the availability of food items across the landscape. Despite the high densities of quail found on the removal areas, only 3% (21 out of 638) of examined predators contained any quail material. We concluded that predators on these sites likely do not target quail specifically as a food item, but feed on them in an opportunistic manner. Age distributions found during this study did not convey any major shifts in age structures that could be linked to the removal. Only opossums removed between 2001 and 2002 from 2 study sites showed a significant decrease in age. However, this significant decrease did not continue into 2003. Other comparisons revealed slight decreases in age from year to year, although none was significant. The reproductive indices for raccoons, bobcats, and coyotes we observed were consistent with other research. However, we were unable to discover any evidence for compensatory reproduction. Other research has shown that populations under heavy exploitation have increased breeding and litter sizes (Knowlton 1972, Windberg 1995). Our research did not find any trends leading to compensatory reproduction and, similar to the results of the age and food habits analysis, reproductive results varied by site and year.

Despite our intensive harvests, no shifts in diets, age, or reproduction were found. Trap numbers remained fairly consistent from year to year and it appeared that our treatments did not affect the predator community in a consistent or significant manner. Connolly and Longhurst (1975) developed a model that predicted a minimum of 75% of the breeding population of coyotes needed to be consistently removed to lower coyote densities (Connolly and Longhurst 1975). It seems unlikely that our removal efforts achieved this level of reduction. Perhaps continued removal over longer time periods would have achieved more significant results, but then one must question the cost-effectiveness of such prolonged trapping efforts.

IMPLICATIONS FOR PREDATOR MANAGEMENT

Predator control is a major concern of land and quail managers of southeastern U.S. quail plantations. Managers tend to believe the predators play an important role in limiting populations of quail. The research conducted during this study offers a different insight. In examining diets of predators removed, very little quail material was found. Only 3% of animals contained quail material of any kind.

In reviewing these findings, predator control may not be as important as many quail managers believe. In saying this, we understand that in other areas predators may be a limiting factor for quail populations. However, not only mammals prey on quail. Other animals such as birds of prey, snakes, fire ants, and rodents prey on quail and quail nests. These types of predators are very difficult to control. Many of these predators such as snakes and rodents are consumed by mammalian predators. Therefore, if mammalian predators are removed, then these smaller predators may increase, causing more damage to the quail population. The decision to use predator management would be up to each individual quail manager, depending on the specifics of the property he/she managed.

Quail management is a expensive, labor intensive, time-consuming management tool that is composed of many different activities. Predator management will add time and expense to quail management. The cost (money and time) may not be worth the benefits gained from this component of quail management. However, if quail managers decide to perform predator control, then it should be balanced with other important components of quail management, such as providing proper habitat for bobwhites and an understanding of the site-specific community composition.

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