THE EXPERIMENTAL EFFECT OF MESOMAMMAL PREDATOR REMOVAL ON NEST DEPREDATION OF NORTHERN BOBWHITE IN SOUTH GEORGIA AND NORTH FLORIDA

by

RYAN PATRICK THORNTON

(Under the Direction of John P. Carroll)

ABSTRACT

The use of predator management to maintain and improve northern bobwhite numbers is not well understood. I performed the first 3 years of a 7-year experiment to better understand the effects of mesomammal predator reduction on bobwhite nesting predation, success and production. It was performed on two separate randomized blocks in South Georgia and North Florida using infrared video cameras and telemetry to monitor nests. We found proportions of mesomammal nest predations varied among all treatment versus control sites. Overall nesting success did not significantly increase on any treatment site compared to control sites during treatment. Mesomammal predation decreased significantly on one removal site during only one year. Non-mesomammal predation was not significantly different among sites any year. Production indices varied during pretreatment, but increased on all sites during treatment years. At this time, I conclude that in certain situations predation management may be useful in improving bobwhite production

INDEX WORDS: Northern bobwhite, *Colinus virginianus*, Compensatory predation Infrared video camera, Mesomammal removal, Nest predation, Nest production indices, Predation management

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DEDICATION

I would like to dedicate this first and foremost to my Mother and Father who have always supported me in all of my endeavors, and who allowed me to run around in the woods of Michigan in the summers and the deserts and mountains of Arizona the rest of the year while growing up. Secondly, to my three brothers Eric, Chad and Nathan and all of my friends all over the map for having faith in me, and encouraging me while I was pursuing this and my previous degree. I couldn’t have done it without all of you.

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

Introduction

Northern bobwhite (*Colinus virginianus*) (hereafter bobwhite) is an important gamebird species which generates millions of dollars in revenues annually from hunting. In the 11 southeastern states, hunting produced an estimated $95 million dollars in economic activity in 1991, and maintained millions of acres of wildlife habitat (Burger et al. 1999). Since before the mid-1960s, bobwhite populations have declined steadily across their range (Sauer et al. 2000). This decline has been caused largely by the changes in land management and uses of quail habitat, particularly the reduction and fragmentation of bobwhite habitat through clean farming practices, intensive silviculture, and expanding urban development (Brennan 1991). In addition, certain mesomammalian predators (medium-sized omnivorous or carnivorous mammals), such as raccoon (*Procyon lotor*) and armadillo (*Dasypus novemcinctus*), have increased in density and range throughout the bobwhite's distribution (Rollins and Carroll 2001).

In recent years, some landowners, land managers and conservation groups have perceived a direct correlation between these two trends, believing that the increased presence of mesomammalian predators has caused the decline in bobwhite populations. This has lead to the illegal use of poisoned eggs during bobwhite nesting periods to reduce nest predators (Pinkston 1999), and the recent enactment of a law in Georgia that allows landowners to control predators if they do so as part of a management plan approved by the Georgia Department of Natural Resources (DNR) (Georgia state code 27-2-31).

While there have been studies on the effects of predator removal on the control of nest predation and increases in populations of bobwhite and other game birds in Europe and the United States, their results have ranged from negligible to significant (Cote and Sutherland 1997).

Literature Review

Landscape and community ecology

The term " natural ecosystem" is misused and misinterpreted. To most, the term is usually interpreted an ecosystem unaltered by humans. It is doubtful that there is any ecosystem in the world that has not been affected by humans in some way (J.P. Carroll, pers. comm). Humans have altered the environment since prehistoric times by farming, forestry and other practices such as burning to increase early successional plant growth. This is just as true in the United States as it is in Europe and Asia, not only by European settlers in America, but by the Native American tribes who preceded them (Burger 1978, Tapper 1999).

Human-induced changes are often irreversible as soils are depleted of nutrients and disturbance sensitive systems succeed into different communities than they were previously. As an example, in the Southeast the most noticeable effect on the landscape has been agriculture, and more increasingly, urbanization. From colonial times to the early part of the 20^{th} century woodlands were cleared to create farmlands. Following the depression many of these farms reverted to fallow fields and woodlots of second growth hardwoods, (Burger 1978). Today many of these areas have again been cleared of forest to make way for large-scale farms, and housing. These changes are an integral part of the ecosystems that exist today, affecting the contexts of many species including predator communities that prey upon bobwhite (Rollins and Carroll (2001).

Nest Depredation

Nest success and depredation have been studied by various means since the 1920's, with nest success rates ranging between 12% to 50% and losses due to predation ranging from 37% to 91% (Rollins and Carroll 2001). Known nest predators include mesomammals [raccoon, armadillo, opossum (*Didelphis virginiana*)], snakes, birds, rodents, and fire ants. Most studies considered mesomammals to be the most important group of predators affecting bobwhite (Rollins and Carroll 2001). Studies of nest predation performed on real bobwhite nests and simulated ground nests have reported that mesomammalian predators are responsible for 27% to 92% of nest depredations recorded (Stoddard 1931, Klimstra and Roseberry 1975, Simpson 1976, DeVos and Mueller 1993, Hernandez et al. 1997, Fies and Puckett 2000, Staller 2001). In the same studies, between 2% and 55% of bobwhite nest depredations were attributed to snakes (Simpson 1976, Peoples et al. 1996). Proper predator identification in these studies, particularly studies using anecdotal evidence such as nest remains, have been shown to be severely biased. Hernandez et al. (1997) noted that snakes are often implicated when no egg remains are found, possibly overestimating their predation rate (Lariviere 1999). Using infrared video cameras to determine nest predators, Staller (2001) predicted the correct nest predator (seen on tape following prediction) using nest remains only 61% of the time using experienced field crews and nest sign. This study visually attributed 45% of the nest predations to mesomammals (predominantly raccoon and armadillo), whereas snakes were responsible for 41% of the nest depredations. Depredations by birds, rodents and fire ants were far less frequent (Staller 2001). Using nest remains, Stoddard (1931) implicated birds in less than 5%, cotton rats in 3.5%, and fire ants for about 4% of bobwhite nest depredations in a northern Florida/southern Georgia study. In the most recent study in this area, only one bird (1%), 2 rodents (2%), and 8 fire ants (10%) depredations of bobwhite nests were reported from a total of 68 predation events (Staller 2001).

Predator control

The use of predator control to increase game populations became an important management tool during the 18th and 19th century, continuing through the present (Reynolds and Tapper 1996). In an extensive study in the upper midwest of the United States, Errington (1934) showed that habitat management was more influential on the survival of bobwhite than predator control. Habitat management practices offer bobwhite security by increasing the amount of cover, which hides both the birds and their nests, and increases the area predators must search for their prey (Errington 1934). It appears that only two recent studies have been performed to determine the effects of predator control on bobwhite. A two-year study in the Rio Grande Plain of Texas examined the effects of predator control on bobwhite, white-tailed deer (*Odocoileus virginianus*), and wild turkey (*Meleagris gallopavo*) (Beasom 1974). During the study, mammalian predators were intensively removed from a 5,760-acre experimental area from February through to June each year. In addition, “light” predator removal occurred during the late fall and winter at a separate 5760-acre control area. In the experimental area large increases in white-tailed deer and wild turkey productivity were observed, but there was only a moderate increase in bobwhite reproductive success in the treated area (Beasom 1974). However, the conclusions of Beasom's (1974) study are considered somewhat biased since the control site was also manipulated with predator control, albeit "light" predator control (J.P. Carroll, pers. comm.). A similar study was performed in south Texas, using a 225-ha treated (predators removed) area and a 201-ha control area (Guthrey and Beasom 1977). This two-year study found no significant increase in bobwhite productivity (Guthrey and Beasom 1977).

Nest predation studies have also been performed on other galliform birds. Kauhala et al. (2000) conducted a four-year study in Finland studying the effects of predator removal on four different species of grouse. Their data showed an increase in brood size for all four species. In a six-year study in England, a significant increase in gray partridge (*Perdix perdix*) breeding success and population densities were found when predators were specifically controlled during the partridge nesting period (Tapper et al. 1996). In Minnesota, a four-year study on pheasants (*Phasianus colchicus*) found that predator control significantly increased pheasant nest success. However, predator populations returned to pre-removal numbers within a year after the completion of the study (Chesness et al. 1968).

Rollins and Carroll (2001) noted "among those studies demonstrating a positive impact of predator control in one form or another on gamebird populations, most have occurred in simpler ecosystems and with simpler predator and prey communities than those found in the Southeast. How these results translate to more complex ecosystems remains to be seen." The ecosystems in Europe, particularly the United Kingdom, are typically intensively managed farmland with a less diverse predator and prey community than the southeastern United States (Rollins and Carroll 2001). The Southeast is characterized by a variety of ecosystems managed at different intensities from intensive farming to hunting plantations (Rollins and Carroll 2001). Predator reduction can have complex biological and political ramifications. In a more diverse ecosystem, there is a greater chance that the reduction in numbers of one or a few predator species will have little or no effect on the population of the target species to be improved while potentially reducing the diversity of the system as a whole (Rollins and Carroll 2001). In addition, predator control, when used only to increase gamebird populations primarily for the purpose of increasing hunting opportunities, may negate its conservation purpose due to increased predation by man (Rollins and Carroll 2001). However, it is possible that predator control designed to increase bobwhite populations may also benefit other currently declining species. Predator control may not adversely affect the predator population if practiced in a targeted manner (i.e., species-specific and/or temporally specific removals) (Rollins and Carroll 2001). This has lead some to view predation on a target species as a process rather than an event. Philosophically this changes the objectives of management from simple predator control to predation management. The former implies that the goal is to simply reduce numbers of species preying on the target species, which is accomplished by removal of some or all predators. The latter emphasizes predation management, which seeks to reduce predation on the target species at key times. Removal of predators may or may not be part of this management. Often overall reduction of predator numbers is not a goal, but rather simple removal of key species during critical time periods (J.P. Carroll, pers. comm.)

Compensatory Predation

The theory of compensatory predation suggests that the reduction in a predator population may "release" populations of lower predators that are normally preyed upon by the higher predator, thus potentially increasing the lower predators population(s). This would consequently increase the effects upon the populations of their prey species such as bobwhite and other ground-nesting birds (Terborgh and Winter 1980, Rogers and Caro 1998). Rollins and Carroll (2001) cite this effect as a possible explanation for the high quail and coyote densities in the Rolling Plains and Rio Grande Plain of Texas, compared with the low densities of each species in the Edwards Plateau Region of Texas, where coyote densities are low due to constant control for sheep and goat ranching (Nunley 1985). This is also supported in the northern United States by Savado et al. (1995), who found that the absence of coyotes in areas with otherwise similar predator communities had increased nest predation on duck nests in the Prairie Pothole Region. This could be an important factor in my study, since only mesomammals and feral mammal species [e.g. dogs (*Canis familiaris*) and cats (*Felis domesticus*)] will be removed from the treated sites. Removal of these may lead to a release of their prey, some of which are known bobwhite nest predators.

The most commonly removed species at my study areas are raccoon, opossum (*Didelphis virginiana*), armadillo, bobcat (*Lynx rufus*), and coyote (*Canis latrans*). The primary predators of my study area is the coyote and the bobcat. In a Florida study of bobcat stomach contents, cotton rats were the most common prey item by frequency

(26%) with snakes making up a minor part of their diet (< 1%) (Maehr and Brady 1986). Raccoons and opossums are both considered omnivorous with very broad diets, which include both rodents and reptiles (Johnson 1970, Hume 1999). Armadillos are also considered omnivores; their diets consists largely of insects, with no rodents and only 2% to 4% snakes by frequency based on stomach contents studies conducted in Florida and Alabama (Breece and Dusi 1985, Wirtz et al. 1985). Coyotes are considered opportunistic omnivores, consuming a variety of food items varying seasonally from various plant matter to wild and domestic animal prey (Andrews and Boggess 1978, Berg and Chesness 1978, Litvaitis and Shaw 1980, Wooding et al.1984, Schoch 2003). Cotton rats composed 46% of stomach contents in an Alabama and Mississippi food habit study (Wooding et al. 1984), while reptiles varied from 0% to 13% depending on season and location (Wooding et al. 1984, Litvaitis and Shaw 1980). Removal of these predators may release cotton rats, snakes, and other unknown nest predators from competitive andmortality factors, potentially allowing them to depredate bobwhite nests more frequently.

Study Description

Overall project

While it is understood that broad-scale habitat management is critical for bobwhite management throughout its range, predator management may also be a useful tool for land owners and managers to improve both bobwhite other wildlife numbers on their land. To determine the effects of predator removal on bobwhite, a 7-year research experiment has been initiated. This project is being conducted on private properties in the area of Albany and the Red Hills region of southern Georgia and northern Florida. This portion of the southeastern United States is typified by diverse and integrated forestry, agriculture, and wildlife management activities. It is characteristic of much of the land throughout the Coastal Plain physiographic region. To provide adequate spatial replication of experimental treatments and controls, 4 different study sites will be used in this project depending upon year.

Experimental design

The overall experimental design was a randomized block design using mesomammal predator removal during the spring and summer bobwhite breeding season as treatment, with a crossover of treatments after 3 years so that each replicate will be both treated and untreated during the 6 year-time after a one-year pretreatment. The design of this experiment involved paired replicates (i.e. experimental units), each 1,200 to 1,600 ha in size. Each set of replicates will included a mesomammalian predator removal treatment area and a " non-removal" area as a control. At treated sites mesomammals and feral mammal species were removed between March 1 and September 31 each year. Predator removal was performed by USDA-Georgia (USDA-GA) Wildlife Services employees in accordance with USDA-Wildlife Services procedures and directives including leg-hold traps, live traps, day shooting and night shooting with spotlight. Predator removal treatments were applied to the entire treatment replicate. For the first 3 years Pinebloom Plantation East in the Albany area, and Pebble Hill Plantation in the Red Hills region have been selected for predator removal with Pinebloom Plantation West and Tall Timbers Research Station as their respective control replicates.

Assessments for this project will focus primarily on the predator community and quail populations. The abundance and diversity of predator species are determined using the scent-station index method (Conner et al. 1983, Diefenbach et al. 1994, Wilson et al. 1996). Data on mammalian predator abundance and diversity were collected once per year in October after removal work ends (i.e., post-treatment). Snakes (gray rat snake (*Elaphe obsolete*), corn snake (*Elaphe guttata*), eastern king snake (*Lampropeltis getulus*), and black racer (*Coluber constrictor*) are important nest predators and might also be impacted by mammalian predator removals we monitored populations of key nest predators using mark-recapture and radio-telemetry, and infrared video camera methodology (Staller 2001).

The bobwhite population was thoroughly assessed within the study areas. This work required the use of radiotelemetry to determine survival of adults and chicks. Previous research with radiotelemetry-marked quail in this region has documented the significance of predation on quail mortality (Burger et al. 1998). Radiotelemetry and infrared video monitoring of nesting bobwhites provided data on nest success on all study areas. Recruitment of quail into the huntable fall population was determined by careful monitoring of early fall quadrat counts. Capture-mark-recapture procedures (Wilson et al. 1996) were used to assess the abundance of quail in October and March. These data were used to estimate over-winter survival on all subplots.

This Study

This study was a quasi-experiment to determine the preliminary effects of the overall predator control study. This study was conducted over 3 years from 2000-2003. Year One was a pretreatment year with no mesomammalian predator removal performed on any of the sites that were used in the overall predator removal project. During Year One Pinebloom Plantation was considered one contiguous experimental unit. Year Two and Three were the first two years of the overall predator project.

The main purpose of my study was to determine the preliminary effects of mesomammal predator control on the nesting productivity of bobwhite in southern Georgia and northern Florida. My objectives were to assess the preliminary: correlations between scent station camera monitored nest predation indices, proportional differences in predators between sites and treatments, effects of cameras on overall predation rates, effects of predation over time between treatments, and bobwhite reproductive responses to mesomammal reductions using simple methods of productivity.

To accomplish this I monitored a sample of bobwhite nests constantly using an infrared video camera system until the nest hatched, was completely depredated, or was abandoned. Visually identified predators were documented along with the type of predation they caused, either partial depredation, where incubation of eggs continued after the event, or complete depredation. To determine the influence of mesomammal predator reduction on nest predation dynamics, nest success between treatment sites was compared using an index of predations per hour of video. Analysis of overall predation, mesomammal and non-mesomammal predators depredations per hour were performed to determine the influence of each group. Further productivity analysis was performed using both chick per hen and nest initiation rates.

Objectives and thesis format

The objectives of my study are to assess the preliminary: correlations between scent station indices and video monitored nest depredation indices, proportional difference of bobwhite nest predators among sites and years, the effects of video cameras on overall predation rates, the effects of predator removal on nest predation over time between treatments, and bobwhite productivity responses to mesomammal removal using simple measures of productivity.

This thesis is organized into 5 chapters. Chapter 1 is an introduction and literature review of pertinent information pertaining to avian nest predation and predator control/ removal. Chapter 2 pertains to the correlations between scent station indices and video monitored nest depredation indices, proportional difference of bobwhite nest predators betweens sites and years, the effects of video cameras on overall predation rates. Chapter 3 pertains to the effects of predator removal on nest predation over time between treatments. Chapter 4 pertains to bobwhite productivity responses to mesomammal removal using simple measures of productivity. Chapter 5 summarizes my conclusions and implications of the research.

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CHAPTER 2

VIDEO DOCUMENTATION OF BOBWHITE NEST PREDATION IN SOUTH GEORGIA AND NORTH FLORIDA.

Introduction

Bobwhite nest depredation has been studied by various means since the 1920's with nest success rates ranging between 12% to 50% and losses due to predation ranging from 37% to 91% (Rollins and Carroll 2001). Known nest predators include mesomammals (medium-sized omnivorous or carnivorous mammals), snakes, birds, rodents, and fire ants. Most studies considered mesomammals the most important group of predators effecting bobwhite (Rollins and Carroll 2001). Studies of nest predation performed on real bobwhite nests and simulated ground nests have reported that mesomammalian predators are responsible for 28% to 92% of nest depredations recorded (Stoddard 1931, Klimstra and Roseberry 1975, Simpson 1976, DeVos and Mueller 1993, Hernandez, et al. 1997, Fies and Puckett 2000, Staller 2001). In the same studies, between 2% and 55% of bobwhite nest depredations were attributed to snakes (Simpson 1976, Peoples et al. 1996). Proper predator identification in these studies, particularly studies using anecdotal evidence such as nest remains, have been shown to be severely biased. Hernandez et al. (1997) noted that snakes are often implicated when no egg remains are found, possibly overestimating their predation rate (Lariviere 1999). Using infrared video cameras to determine nest predators, Staller (2001) attributed 45% of the nest predations to mesomammals [predominantly raccoon and armadillo (*Dasypus novemcinctus*)], and snakes were responsible for 41% of the nest depredations. Depredations by birds, rodents and fire ants were far less frequent, accounting for only one bird (1%), two rodents (2%), and eight fire ants (10%) depredations of bobwhite nests reported. This corresponds closely with Stoddard (1931), who implicated birds in less that 5%, cotton rats in 3.5%, and fire ants for about 4% of bobwhite nest depredations in the same region.

Predator removal has been used for more than 2000 years in some regions of Europe to reduce their competition with humans for both domestic and game species (Reynolds et al. 1996). Predator removal to specifically reduce their effects on small game populations came into effect in the 18th and 19th centuries in Europe on large hunting estates (Reynolds and Tapper 1996). Predator control to specifically increase game species in the United States appears to have begun in the late 19th or early 20th century (Stoddard 1931). While there have been studies on the effects of predator control on the control of nest predation and increases in populations of bobwhite and other game birds in Europe and the United States, their results have ranged from negligible to significant (Cote and Sutherland 1997). Rollins and Carroll (2001) noted, "among those studies demonstrating a positive impact of predator control in one form or another on gamebird populations, most have occurred in simpler ecosystems and with simpler predator and prey communities than those found in the Southeast. How these results translate to more complex ecosystems remains to be seen." The ecosystems in Europe, particularly the United Kingdom, are typically intensively managed farmland with a less diverse predator and prey community than the southeastern United States (Rollins and Carroll 2001). The Southeast is characterized by a variety of ecosystems managed at different intensities from intensive farming to hunting plantations (Rollins and Carroll 2001). Predator reduction has complex biological and political ramifications. In a more diverse system, there is a greater chance that reduction in one or a few predator species will have little or no effect on the population of the target species to be improved while potentially reducing the diversity of the system as a whole (Rollins and Carroll 2001). If predator control is used just to increase gamebird populations primarily for the purpose of increasing hunting opportunities, then its purpose for the conservation of the species is diminished since it's population as a whole may not significantly improve due to increased predation by man (Rollins and Carroll 2001). At the same time, it is possible that the predator control may not only increase bobwhite populations but other currently declining species. Predator control may not adversely affect the predator population if practiced in a targeted manner (i.e., species-specific and/or temporally specific removals) (Rollins and Carroll 2001).

Objective

The objective of this study was to assess the preliminary correlations between video monitored bobwhite nest depredation indices compared to scent station indices, asses the proportional differences of predator species preying upon bobwhite nests on each site, each year of my study and to determine the camera surveillance system effects nest predation rates.

Study Sites

Four study sites on three different plantations were used during the 2000, 2001, and 2002 field seasons. These were Tall Timbers Research Station (TTRS), Pebble Hill Plantation in the "Red Hills Region" of South Georgia and North Florida, and Pinebloom

Plantation in the Albany area of Southwest Georgia, which was divided into Pinebloom East and West sites for the purposes of this study. TTRS comprises approximately 1,500 ha, and Pebble Hill comprising 1,246 ha. Habitats at these sites are composed primarily of southern upland forests with overstories comprised primarily of longleaf pine (*Pinus palustris*) and Loblolly pine (*Pinus taeda*) as the dominant overstories, and understories varying from wiregrass (*Aristida stricta*) to old-field vegetation. Interspersed throughout these sites are hardwood drains/hammocks and fallow fields. Pinebloom Plantation, was divided into two sites of approximately 1,400 ha each. These sites are primarily upland slash pine (*Pinus elliottii*) forest with old-field understory vegetation, interspersed with fallow fields. At all sites, fallow fields were maintained by annual disking to encourage growth of preferred cover and forage plant species. Portions of the understory of all sites were burned and/or treated with herbicides annually to control hardwood encroachment and promote early successional herbaceous ground cover. Site habitat and game management practices also included supplemental feeding of grain, small food plots, chopping and mowing, and also the thinning of forests stands. All of these practices were performed in varying amounts depending on the management plans of the property managers and were considered uncontrollable factors, which may affect this study.

Methods

Study design and predator removal

This study involved a randomized complete block design with repeated measures. This study was conducted on two separate blocks, with each block composed of two treatment plots or sites. During 2000 no predator removal occurred on any plots as a pretreatment baseline for comparison with the second and third years. During 2001 and 2002 mesomammal predator removal treatment was applied to Pebble Hill Plantation and Pinebloom East, with TTRS and Pinebloom West as their respective control plots. At treated sites, mesomammals [raccoon (*Procyon lotor*), armadillo (*Dasypus novemcinctus*), opossum (*Didelphis virginiana*) bobcat (*Lynx rufus*)], coyote (*Canis latrans*), and feral mammal species [(dog (*Canis familiaris*) and cat (*Felis domesticus*)] were removed between March 1 and September 31 during 2001 and 2002. Predator removal was performed by Georgia-U.S. Department of Agriculture (GA-USDA) Wildlife Services employees in accordance with USDA Wildlife Services procedures and directives to include the use of foot hold traps, live traps, and shooting during the day and at night with spotlights. Predator removal was performed at Pebble Hill Plantation and Pinebloom East, with TTRS and Pinebloom West used as control sites.

Bobwhite monitoring

Bobwhite were captured between January and April each year using "walk in" funnel traps baited with cracked corn and/or milo (Smith et al. 1981). Trapping, handling, and marking procedures were consistent with the guidelines provided in the American Ornithologists' Union Report of the Committee on use of wild birds in research (American Ornithologists' Union 1988), and the University of Georgia (Institutional Animal Care and Use Committee Permit #A199-10028-N2)(Staller 2001). At least 70 bobwhite per site, weighing $\geq$150 g were fitted with 6.4-6.9 g pendant-style radio-transmitters (American Wildlife Enterprises, 493 Beaver Lake Rd. Tallahassee, FL. 32312), on each site, with an approximate sex ratio of radio tagged birds of 75% female and 25% male.

To locate nests, bobwhites were tracked daily using telemetry homing techniques during breeding season from April through October (White and Garrot 1990). Telemetry equipment consisted of a 3-element, directional hand-held antenna and receivers. Bobwhite were assumed to be nesting if a bird was observed in the same location for two consecutive telemetry locations >30 minutes apart. Nest areas were marked with 2 to 4 small marking tape flags placed around the nest, each approximately 2 to 3 m from the nest. Following the initial location of a nest, the nest was monitored hourly throughout the day until the incubating parent left the nest to forage, typically in the afternoon. After the parent left, the flagged area was searched for the nest, eggs were counted, and the nest's fate was monitored by either telemetry only, or using an infrared surveillance cameras and telemetry, if available. Nests to be monitored were randomly among the nesting birds on each site when a camera system or systems were available. Flagging was removed following placement of camera or positive nest identification to reduce bias by attracting or repelling predators. In 2000 19 camera systems were available between TTRS, Pebble Hill Plantation and Pinebloom Plantation. During 2001 and 2002 13 camera systems were used at the Pineboom Plantation sites, and 13 at the TTRS/Pebble Hill Plantation sites.

The surveillance video camera system consisted of a Model N9C2 FIELDCAM™ LRTV MICROCAM™ with a 3.7 mm wide-angle lens and a 6 Light Emitting Diode (LED) array at 950nm surrounding the lens. Illumination was provided by natural sunlight, the 6-LED array, and a 36-LED array illumination system at 950nm on an opposable arm, for low light situations (i.e. in inclement weather and at night). The FIELDCAM™ and illumination system are part of a camouflaged articulating arm which was clamped to a wooden stake. The camera was connected to a VHS time-lapse video recorder that recorded at 10 frames per second via a 30-m cord. A TOTE™ LCD 410 field and set-up monitor were used to view the camera picture during set-up of the system at nests (Furhman Diversified Inc., 2912 Bayport Blvd. Seabrook, TX 77586). A 225 volt-reserve capacity Marine Source™ deep-cycle battery powered the entire system.

On each camera-monitored nest, a camera was placed 1.5 to 2 m from the nest and camouflaged with supplemental vegetation similar to existing vegetation. Video cables were stretched from the camera to the VCR, located 20-30 meters away. Cables and the VCR were camouflaged with vegetation, and were not placed on or across likely predator travel routes (e.g., roads, paths, fire breaks). Camouflage vegetation was used to reduce notice by both nesting bobwhite and possible attraction or repulsion of predators. The nesting bobwhite was monitored at daybreak the morning after camera set-up to ensure that it had not been disturbed by the camera's presence, causing abandonment. If the parent was not on the nest, the camera armature angle was adjusted to place the camera farther from the nest. The nest was monitored hourly; and if the parent did not return within 4 hours, the camera was removed.

During normal monitoring, the previous day's videotape and battery were replaced every 24-hours until the nest hatched or was vacated due to depredation of the nest, death or abandonment of the incubating parent(s). The last 2 minutes of the VHS videotape were viewed to ensure that the nest had not been obscured by vegetation or moved by weather or animal contact. Nests were monitored daily by myself or a technician in charge of the area's bobwhite telemetry to determine the status of the nest (incubating, hatched, depredated, or abandoned). For nests found to have been depredated, the preceding day's videotape(s) were viewed to determine the predator. All tapes with suspected depredations were viewed to gather any pertinent data (e.g. undetected partial depredations).

Depredated nests were classified into two categories, partial or complete. A nest depredation was considered a complete depredation if the nest is abandoned permanently prior to hatching due to a depredation event of the eggs or the incubating parent(s). A depredation was considered partial when at least one egg was consumed or removed by a predator, but incubation of remaining eggs continued.

Predators were grouped into three broad categories of mesomammals, non-mesomammals, and other. Mesomammal included, but was not limited to armadillo, bobcat, opossum, and raccoon. Non-mesomammal denoted any other non-mesomammal species viewed (e.g., snake, ants) and other included unknown predators and birds killed off nest. "Unknown" was used if the predator was not seen, but a depredation was known to have occurred while camera was operating properly.

Scent station indices

I used scent stations to compare the relative abundance of nest predators within each site to their known video-monitored frequencies of mesomammal nest predation. Procedures were performed as per Staller et.al. (in press).

Data analysis

Scent station and camera indices

It was assumed that the rate of nest predations was a function of exposure time. Video time for each nest ended at the beginning of a known complete depredation or at the first sight of a chick if a hatch occurred. In case of an unseen hatching, video time was ended at 12:00 midnight the night before the hatching was determined by telemetry. Video time for each site, each year was tallied to the nearest hour for accuracy, and converted into camera/days for standardization for this analysis. To determine if there was a relationship between scent station visitation rates and video camera recorded predation rates, we performed regression analysis using each of these parameters, per site, per year. All rates were square root transformed.

Camera effects

Novel items and human scent may repel or attract certain predators, e.g. raccoons are thought to be attracted to unknown objects, while foxes (*Vulpes and Urocyon spp*.) are thought to shy away from them in their environment. Because of this we were concerned that the camera system, being in such close proximity to the nest, would cause a bias in the studies results.

Possible camera bias was determined using the Mayfield method (1961) of survival estimation by comparing the nest success rates of video-monitored birds to non video-monitored birds on each site. Data for 2000, 2001 and 2002 on TTRS, 2002 on Pebble Hill Plantation, and on Pinebloom West and East 2000 were used separately for this analysis. These data were not pooled due to both known and unknown differences in site and treatment effects each year, which might confound analysis. Data from Pebble Hill in 2000 and 2001, Pinebloom 2000, and Pinebloom West and East 2001 were not used due to very low sample size of either camera or non-camera monitored birds. For this analysis only known complete nest depredations of both camera-monitored and non-camera monitored nests were used since non-camera-monitored birds have no records of confirmed partial depredations.

All Mayfield method data analysis was performed using the Micromort© program, version 1.2 (Minnesota Department of Natural Resources/ Wildlife, NH Analytical Software, 801 West Iowa Ave., St. Paul, Minnesota USA).

Results

Camera and scent station indices

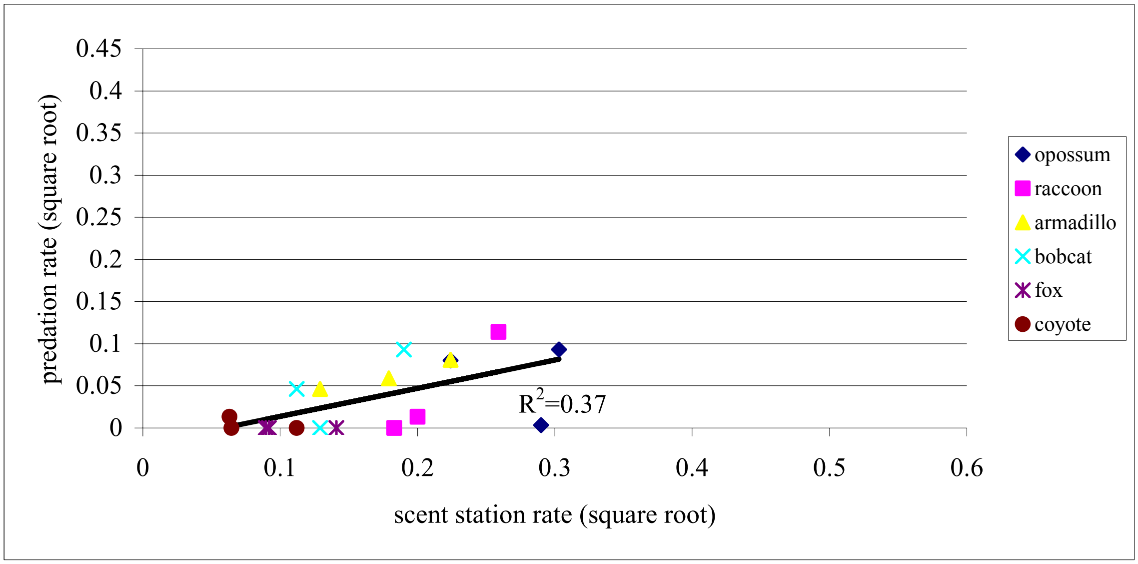
Scent station and camera indices regression analysis were summarized per site, and overall sites combined. Both sites without mesomammal removal showed a consistently higher coefficient of correlation compared to removal sites with TTRS and Pinebloom West having coefficients of correlation of 0.37 and 0.27 respectively compared to Pebble Hill and Pinebloom East coefficients of correlation of 0.02 each. Overall correlation between scent station and camera indices is again not significant with a coefficient of correlation of only .17 (Figure 2.1-2.3).

Video documentation of predators

With the exception of Pebble Hill 2002 mesomammal removal areas showed a lower proportion of mesomammal depredations compared to nonremoval areas. This was also true overall between removal and nonremoval sites (Figures 2.4 - 2.6). Identifiable snakes were grey rat snake (*Elaphe obsolete spiloides*), corn snake (*Elaphe guttata guttata*) eastern king snake (*Lampropeltis getula getula*) and black racer (*Coluber constrictor*). Cotton rat species in this region are *Sigmodon hispidus*. Known partial depredations accounted for 31% (n=14) and 17% (n=1) of predations on TTRS and Pebble Hill respectively in 2000. In 2001 partial predations decreased to 0% on all sites

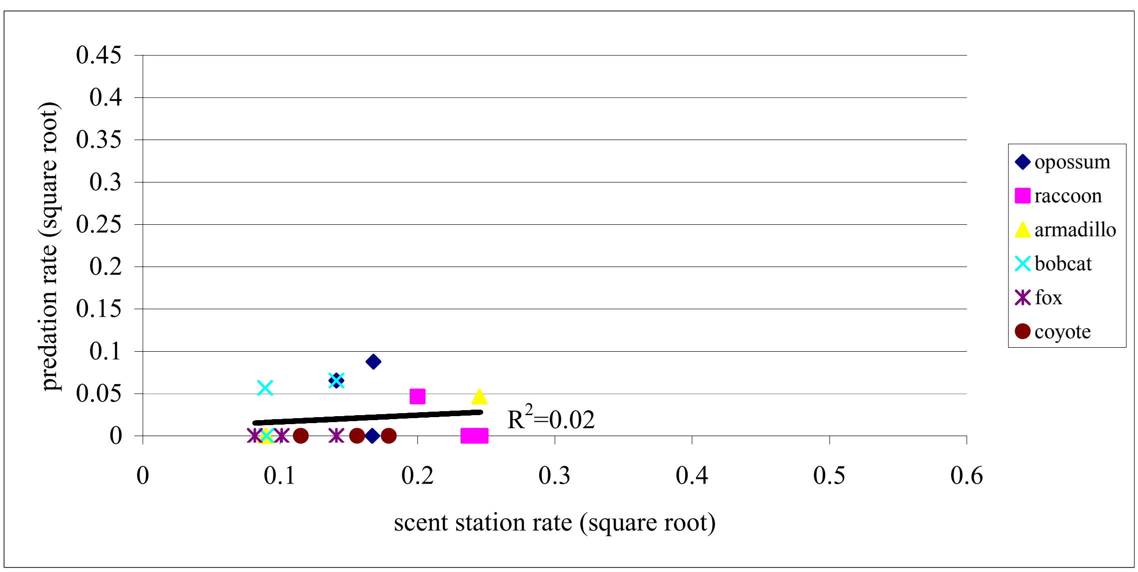
Figure 2.1 Scent station/ predation rate regression relations per site and year on field sites in South Georgia and North Florida, USA. 2000-2002. TTRS= Tall Timbers Research Station. NMR= No mesomammal removal, MR= mesomammal removal.

TTRS (NMR)



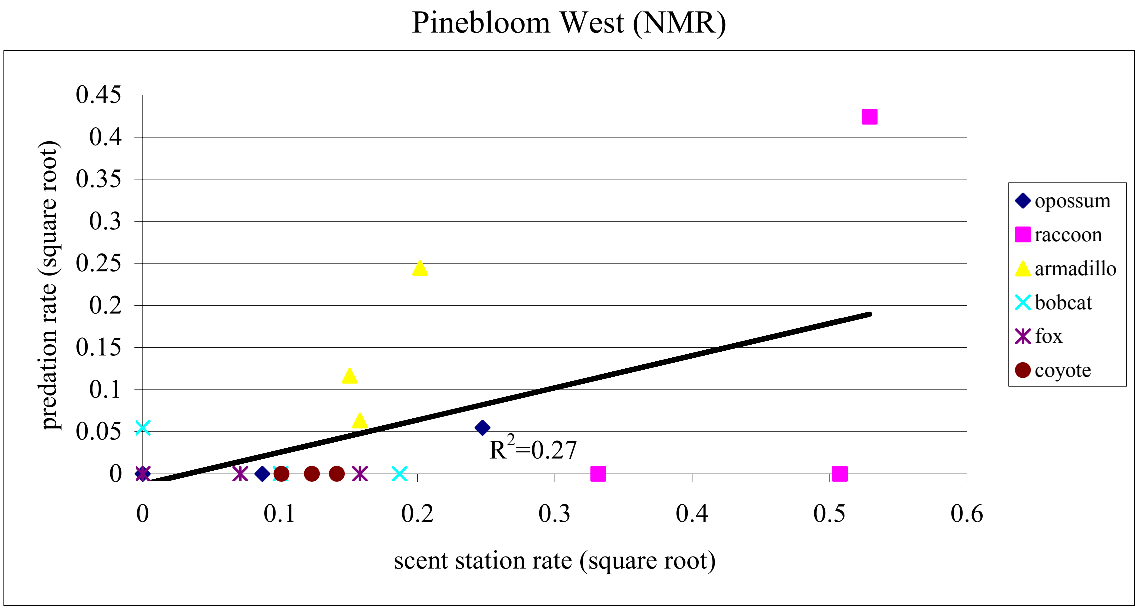
Scent station n=728 exposure days
Camera monitoring n= 158 nests, 1955.59 exposure days

Pebble Hill (MR)

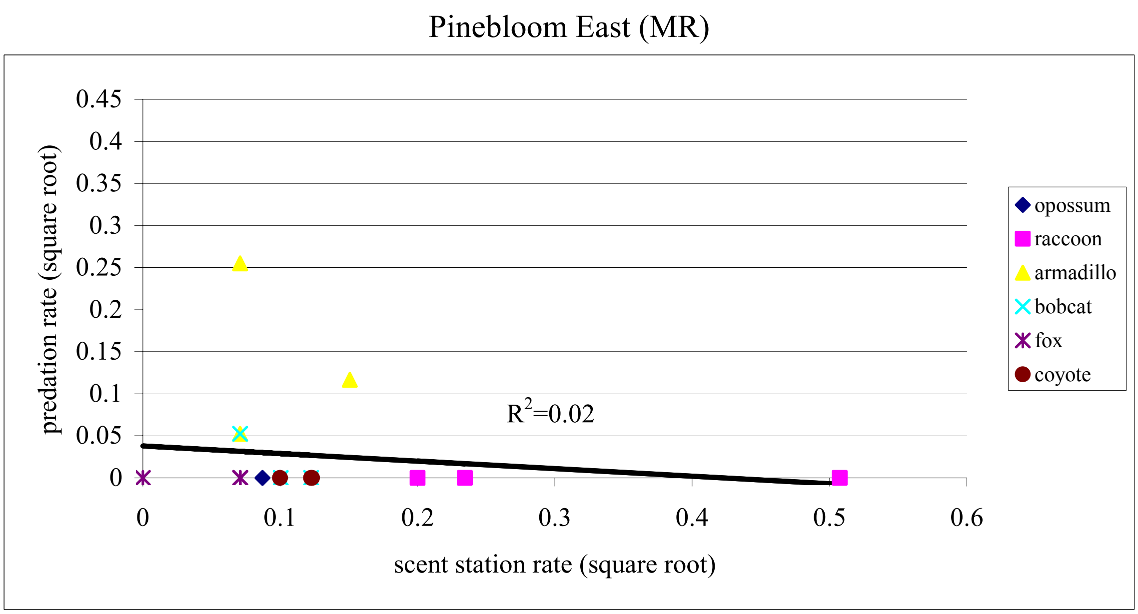


Scent station n=648 exposure days
Camera monitoring n=67 nests, 905.10 exposure days

Figure 2.2 Scent station/ predation rate regression relations per site and year on field sites in South Georgia and North Florida, USA. 2000-2002.

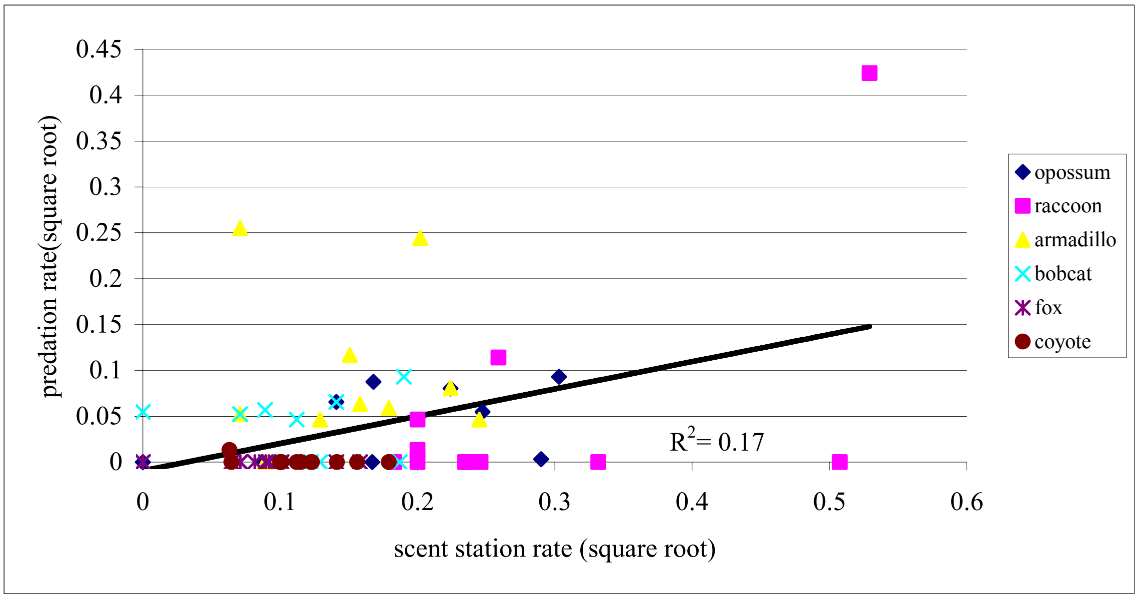


Scent station n=792 exposure days
Camera monitoring n=59 nests, 654.34 exposure days



Scent station n=796 exposure days
Camera monitoring n=64 nests, 742.83 exposure days

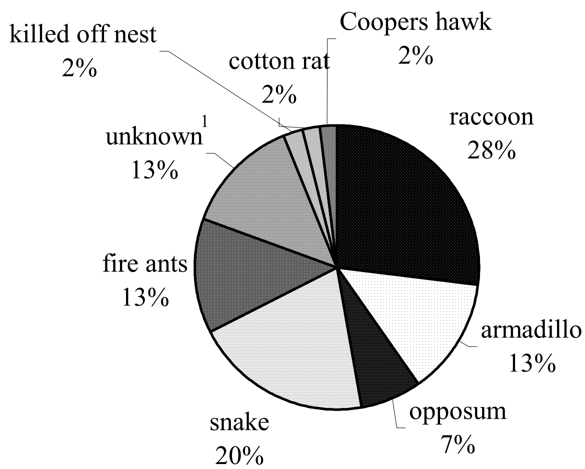
Figure 2.3 Overall scent station/ predation rate regression relations on field sites in South Georgia and North Florida, USA. 2000-2002.



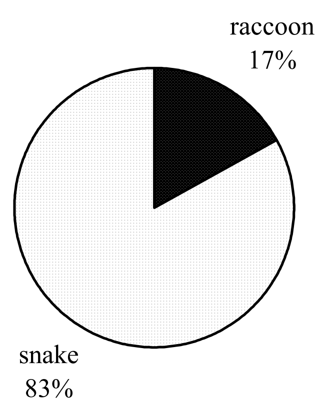
Scent station n=2568 exposure days
Camera monitoring n=345 nests, 4184.59 exposure days

Figure 2.4 Video monitored nest predators on field sites in South Georgia and North Florida, USA. 2001. TTRS= Tall Timbers Research Station. NMR=no mesomammal removal, MR= mesomammal removal. All unknown predators were suspected to be snakes based on Staller (2001), but were not visually confirmed.

TTRS (NMR)
(n=45)



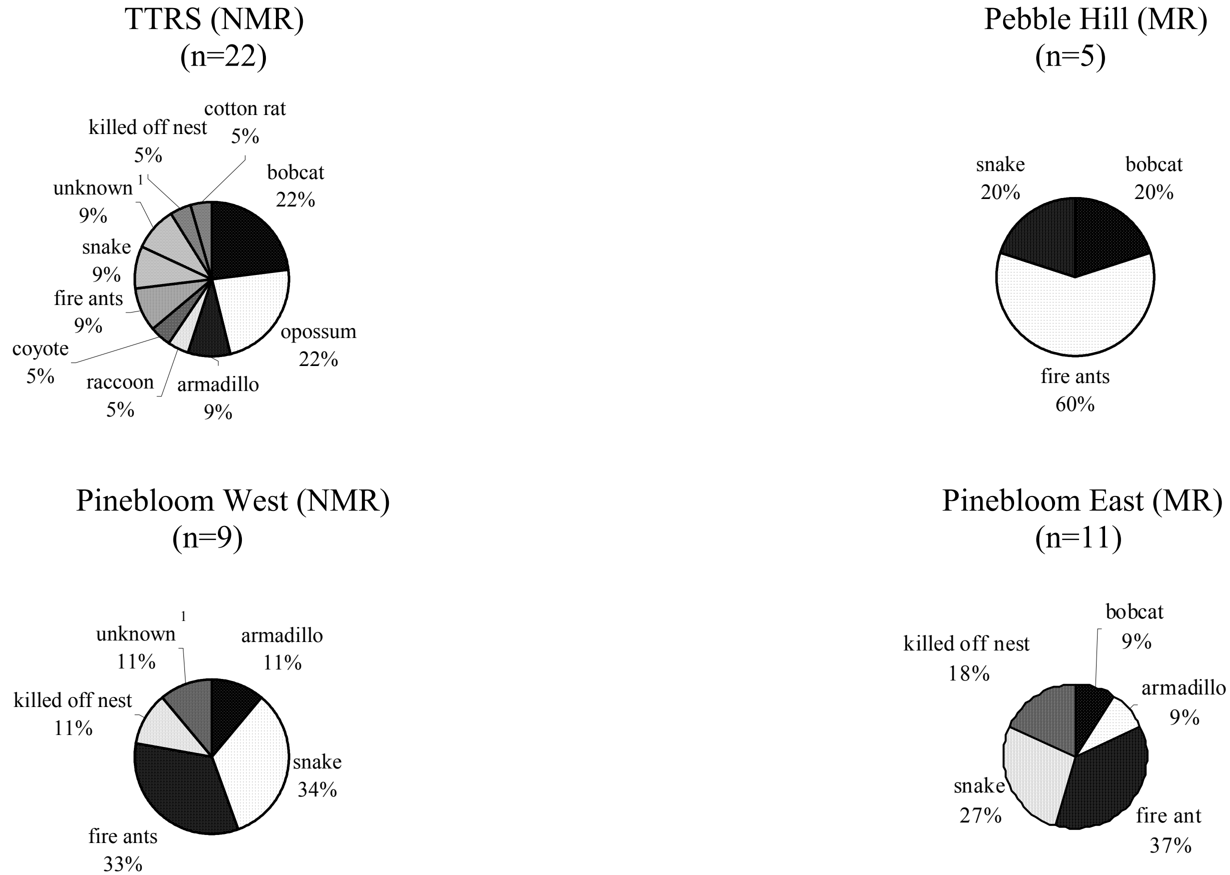
Pebble Hill (NMR)
(n=6)



[1] All unknown predators were suspected to be snakes based on Staller (2001), but were not visually confirmed.

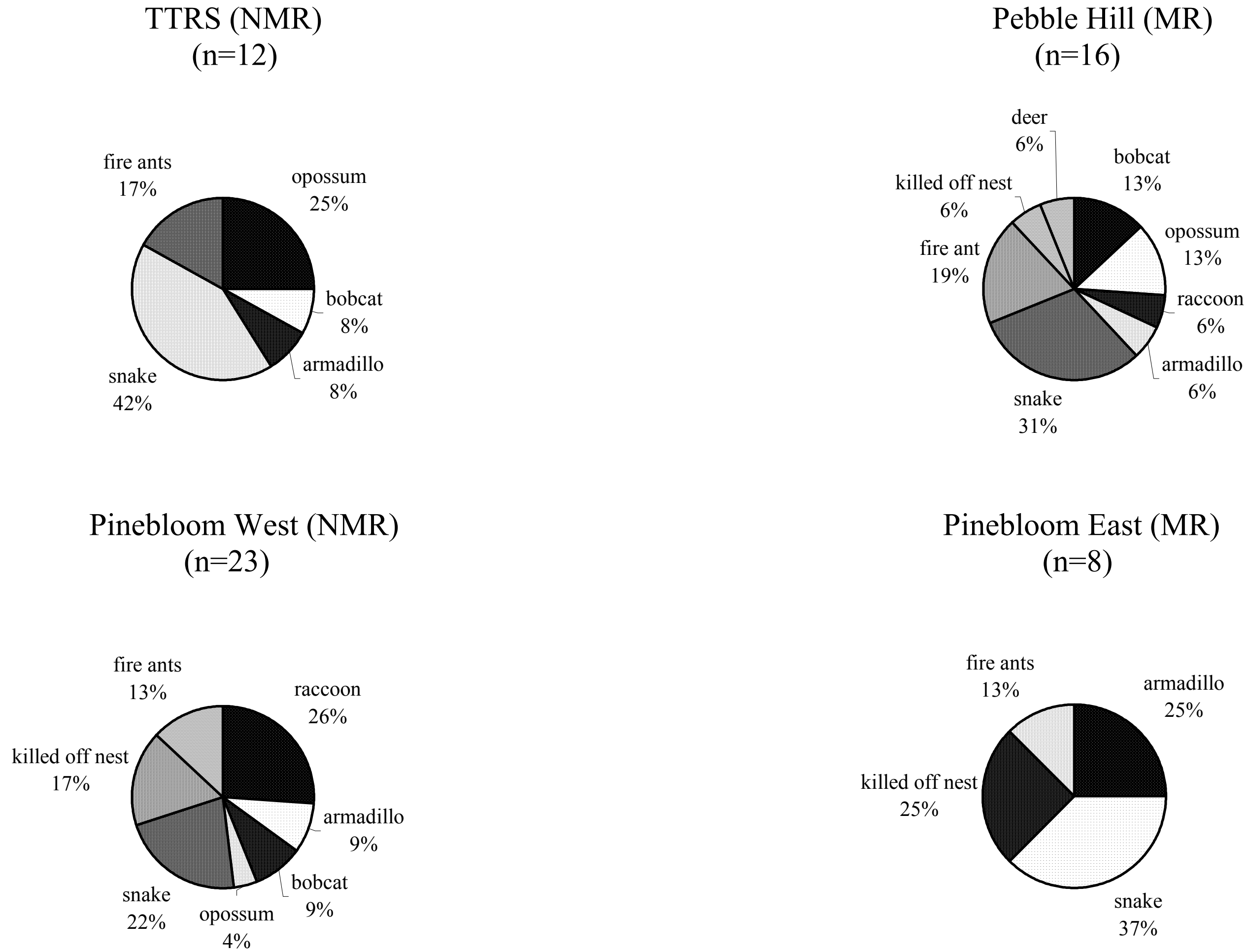
* Pinebloom Plantation (NMR) 2000 data not shown, n= 1: Armadillo

Figure 2.5 Video monitored nest predators on field sites in South Georgia and North Florida, USA. 2001. TTRS= Tall Timbers Research Station. NMR=no mesomammal removal, MR= mesomammal removal.



[1]All unknown predators were suspected to be snakes based on Staller (2001), but were not visually confirmed.

Figure 2.6 Video monitored nest predators on field sites in South Georgia and North Florida, USA. 2002. TTRS= Tall Timbers Research Station. NMR=no mesomammal removal, MR= mesomammal removal.



except Pinebloom West, where they composed 22% (n=2) of nest predations. In 2002 partial predations accounted for 25% (n=3), 13% (n=2), 9% (n=2), and 0% for TTRS, PebbleHill, Pinebloom West and Pinebloom East respectively. Partial predation predator species are summarized overall in Figure 2.7.

Camera effects

With the exception of Pinebloom West 2001, which showed the opposite trend, camera-monitored nests consistently showed a trend of higher mean success rates compared to noncamera monitored nests, though no comparison shows a significant difference (Mayfield adjusted) (Figure 2.8).

Predator removal

During 2001-2002 a total of 1,398 individuals were removed representing 9 species. The most common species removed were raccoon and opossum, making up 38% and 37% respectively, or 75% of all animals removed, while fox species (*Vulpes vulpes* and *Urocyon cinereoargenteus*) and feral cat and dogs consistently remained low to nonexistent each year (Table 2.1).

Discussion

Scent station and camera indices

Though low, coefficients of correlation were consistently higher on sites without predator removal. This coincides with results from previous studies that show that while predator removal does reduce their effects on bobwhite nests during the breeding season, predator species are constantly repopulating areas that have removal efforts, especially shortly after the removal effort ceases, when scent station indices were being performed

(Gillis, Tapper, et al.1996). Thus, if scent station indices are to be used to obtain correlative data on probable bobwhite nest predation they should be performed in areas either without predator removal, or at the same time as removal efforts if predator removal is occurring.

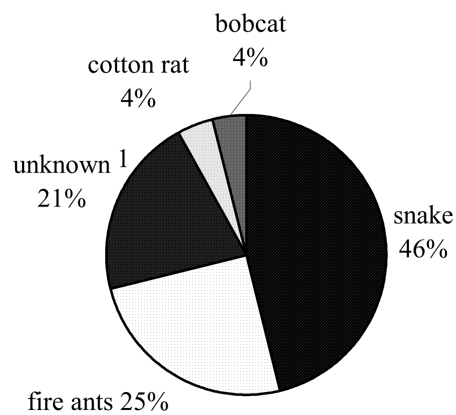
Video documentation of predators

In 2001 and 2002 we documented snakes, ants, bobcat, opossum, armadillo, raccoon, cotton rats, coyote, and deer preying upon nests. This is a greater diversity of predators than Staller's (2001) previous study using infrared video cameras in this area, seen partially in the 2000 TTRS and Pebble Hill data.

Predator context and variations

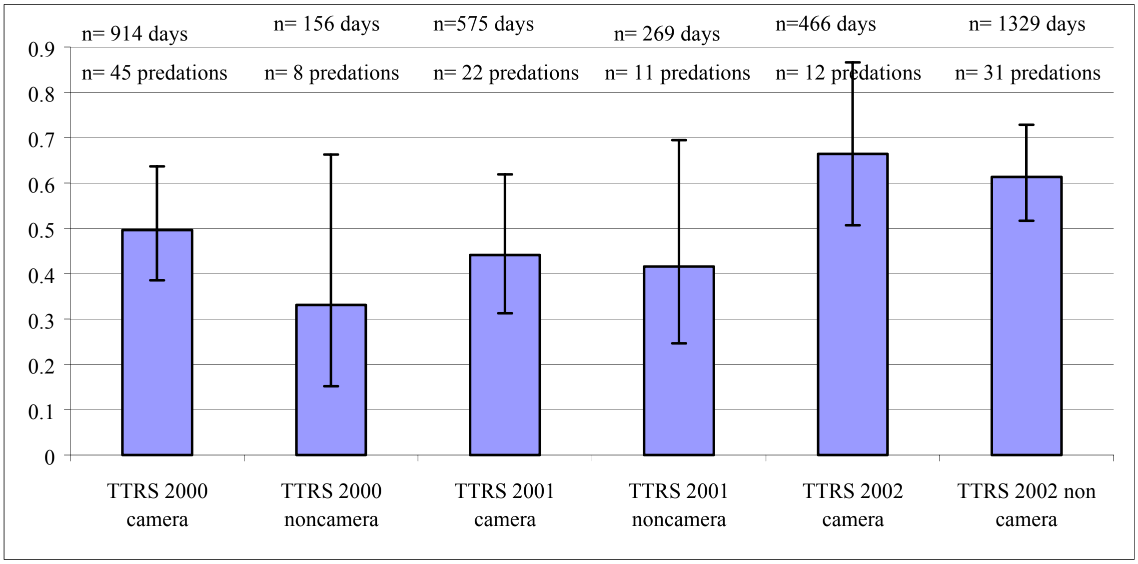
For comparison we used Staller's (2001) data from 2000, which was incorporated into this study as the "pretreatment" data. We documented much more variability concerning major mesomammalian predators. Staller (2001) found both raccoons and armadillos to be major nest predators while opossums and bobcats nonexistent on the same sites. Depending on site, our study found almost the opposite, with raccoons being a significant predator only in 2002 on Pinebloom West. Opossum and bobcat became more significant predators during both 2001 and 2002, especially in the Red Hills region, with a total of 11 and 12 predations overall. It is suspected that the lower incidences of raccoon depredations in 2001 were due to a larger than normal soft mast crop during that summer, particularly of blackberry (*Rubus* spp.) noted by many personnel at all study sites, including myself, in addition to standard analysis of stomach contents by Schoch (2003).

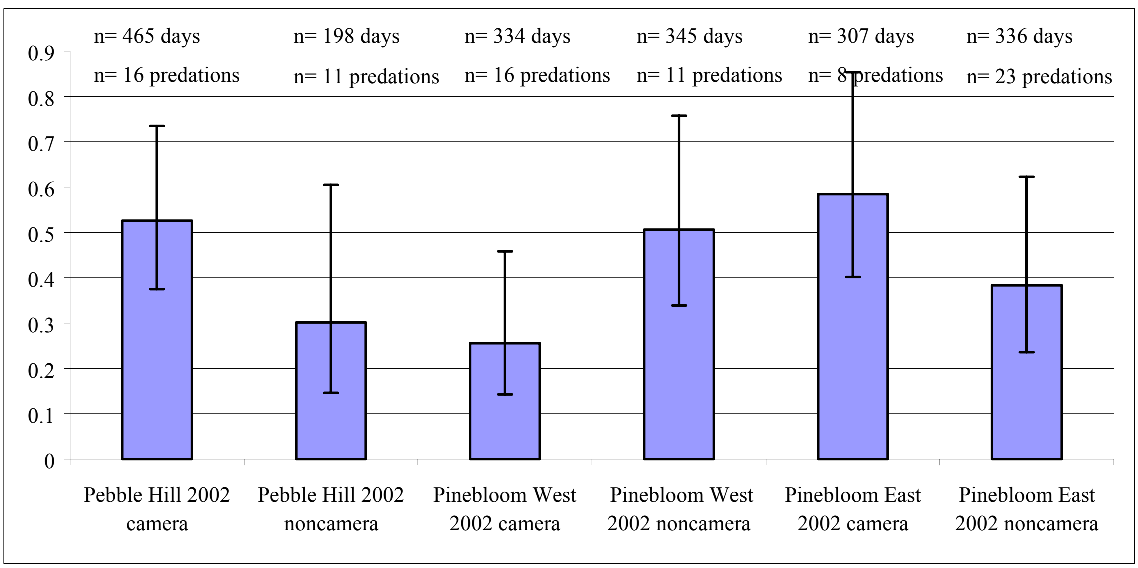
Figure 2.7 Overall proportions of video monitored partial nest predators in South Georgia and North Florida, USA, 2000-2002. n=24.



[1]All unknown predations are thought to be snakes based on Staller (2001), but were not visually confirmed.

Figure 2.8 Mayfield adjusted nesting success rates of camera vs. noncamera-monitored nests on field sites in South Georgia and North Florida. USA. 2000-2002.





* Pebble Hill 2000, Pinebloom 2000, Pinebloom West 2001 and Pinebloom East 2001 data was not used due to low sample size of either camera or noncamera monitored nests.

Table 2.1. Mesomammalian Predators removed by GA-USDA Wildlife Services from treatment sites in south Georgia, USA, 2001-2002.

Year 2001

Species	Pebble Hill	Pinebloom East
Raccoon	87	160
Opossum	104	50
Armadillo	61	39
Bobcat	14	17
Coyote	13	8
Gray Fox	6	1
Feral Cat	6	7
Total	291	282

Year 2002

Species	Pebble Hill	Pinebloom East
Raccoon	47	236
Opposum	186	179
Armadillo	44	45
Bobcat	5	40
Coyote	13	14
Gray Fox	0	6
Red Fox	0	2
Feral Cat	2	5
Feral Dog	0	1
Total	297	528

Though not quantified, it could be postulated that this ephemeral food source may have diverted feeding efforts of raccoons and other omnivores on all sites with a more easily obtained food source than bobwhite eggs during the bobwhite nesting season. This is further supported with an increase in raccoon depredations on Pinebloom West in 2002 compared to 2001, when soft mast crops were not as noticeably large as the previous year. The decrease in raccoon predations in 2002 on TTRS was probably due to a canine distemper outbreak in the TTRS area, which reduced the raccoon population. Approximately 12 raccoons were found dead on TTRS and surrounding properties in the winter of 2001 through spring of 2002. Two were sent to the Southeastern Cooperative Wildlife Disease Study (SCWDS) at the University of Georgia and confirmed infected with canine distemper (W.E. Palmer, person. comm.). This assumption is further supported by the fact that in 1999 and 2000 raccoons were found to be common nest predators in the TTRS area, and in 2001 there were no camera-monitored bobwhite nest predations by raccoons (Staller 2001). There was no indications this disease affected the raccoon population on Pebble Hill, or the Albany region sites, or any other species on all sites.

The final three predators, cotton rats, coyote, and white-tailed deer accounted for only 1% of depredations each overall. The frequency of cotton rat depredations coincides with Stoddard's (1931) anecdotally observed minor rate of cotton rat depredations. Though not quantified, the one nest failure due to cotton rat depredation coincided with the highest rodent densities seen by field technicians at TTRS during this and the preceding camera study. From the video footage, it appears that cotton rats do not have a large enough jaw gape to bite into a shell and rupture it, but must instead rely upon weak spots, such as cracks. The one complete depredation by cotton rats was due primarily to the rats constant badgering of the nesting adult, which eventually abandoned the nest, though only two eggs were consumed. One coyote was documented causing a depredation, but killed the parent at the nest, and never ate any eggs. This is of particular interest because a coyote was documented attempting to catch this same incubating hen the night prior to the actual event. In each case the coyote did not eat eggs from the nest. The most recent study of predators conducted on two of the four sites we performed our study (Pebble Hill and Pinebloom East) found only bobwhite egg remains in coyote stomachs (Shoch 2003). Although other past studies found both avian body and egg parts in coyote scat and stomach analysis, Sargeant et al. (1987) considered them to be poor predators of ground-nesting birds compared to other mesomammals (Berg and Chessness 1978, Litvaitis and Shaw 1980, Sooter 1946). At this time it is unclear why the coyote would ignore the eggs. White-tailed deer depredation nest has been documented by both video and motion-detecting still photography systems previously, with both eggs and chicks of various bird species, and artificial nest studies (Pietz and Granfor 2000, W.J. McShea, pers. comm). Due to their insignificant effect in this and Staller's (2001) study it is thought that these three predators are not serious nest predators of bobwhite in our study areas.

Five incubating adults were killed at the nest site during this study, all by mesomammals. In 2001 one opposum and one coyote killed nesting birds on TTRS, and one bobcat killed a nesting bird on Pebble Hill. In 2002 two separate bobcats killed nesting bobwhite, one on TTRS, and one on Pebble Hill plantation. Though the nest predation was only counted towards the first predator to cause the nest's failure, it should be noted that the opposum and the bobcat in 2001 and the bobcat on Pebble Hill in 2002 returned to the nest and consumed all eggs in the nest. The other two nests remained vacant, both being later eaten, by a raccoon on the TTRS "coyote-killed" nest, and an opposum on the TTRS "bobcat killed" nest. This is in contrast to Staller's (2001) study which only documented one incubating parent killed at the nest, by a Coopers hawk (*Accipiter cooperii*).

Known partial predations decreased substantially between the 2000, both 2001 and 2002. There were several possible reasons for these decreases. The first year of this study was the second year of drought in the region and this may have reduced the amounts of other available prey compared to eggs. Rainfall on all sites in 2001 was more typical for the study sites thereby possibly increasing typical, more accessible prey for these predators than in the previous years. Partial predations may have occurred on nests that were never suspected, as egg counts on many nests were often not taken more than once before a hatching or depredation to reduce any disturbance to the nest and incubating parent. From Staller's (2001) and my own personal observations, egg counts following hatchings are often unreliable because parents feed eggshells to chicks, and other animals remove eggshells and/or passing through the nest following hatch (e.g. armadillo, cotton rats). These egg counts were still used as an indication of possible partial egg depredation when no other egg count had occurred. On nests with unconfirmed, but suspected partial egg predations missing eggs may be caused by unseen partial predations due to the cryptic nature of bobwhite nests and certain predators such as snakes. Video observer bias, and poor camera view may be another reason for missed events. Incubating parents have also been seen removing eggs that had cracked or ruptured, as was seen on TTRS in 2001, but possibly missed on other nests. It is also possible that an incubating parent may merely eat the eggshells from a cracked egg to remove it, though this was never seen.

All unknown predations are suspected to be snakes, but because they were not confirmed visually were classified as unknown for data analysis. This is one limitation of this video camera system when used with bobwhite nests due to the cryptic nature of both bobwhite nests and snakes.

Predator reduction effects

A large quantity of predators were removed from the treatment sites each year, yet as we see in the second years trapping data and scent station indices from removal areas these species were again present in the second year. These data show that predator species are continually recolonizing areas where temporally specific removals are occurring thus maintaining biodiversity in the area.

Proportionally, a wide variation in specific predators was seen depredating nests per year and per site, in some cases apparently regardless of treatment. When comparing removal areas to nonremoval areas in the Red Hills in 2001 and the Albany sites in 2002. In the Albany Region in 2001 and the Red hills region in 2002 there appears to be less of an effect. It would appear that predator removal does have some effect on bobwhite nest predation, but that there are other significant factors involved. Some, but not all of this variation can be accounted for by known causes (e.g. disease, increased soft mast production). These known causes of variation are only part of the complex system in the study areas, which should be sorted out as the overall study continues.

Camera effects

According to my data, the infrared camera system does not appear to either attract or repel predators significantly (figure 2.8). With the exception of Pinebloom West in 2002, there does appear to be a trend of higher nesting success in camera-monitored birds. This leads me to believe that the camera system may be repelling individual predators but not necessarily specific species as a whole, thus reducing predation slightly. Though raccoons are considered very curious, and were documented noticing the camera system by looking into it and in at least one case pulling the armature down, none of the raccoons preying on nests appeared to notice the camera before the depredation event. Of their 11 video-documented depredations, bobcats appear to have noticed the camera 2 times, once prior to and the other following the nest depredation. In each case the bobcat only stopped briefly to inspect the camera before moving on. While coyotes are considered wary, the camera system did not appear to have been noticed during the one depredation due to coyotes. A coyote had in fact attempted to catch the same hen the night prior to the successful event, again never apparently noticing the camera. With only one predation due to coyotes it is unlikely that the camera system attracts this species either. While there have been no video-documented fox predations of bobwhite nests yet, I do not think foxes are avoiding camera-monitored bobwhite nests. I feel that it is more likely due to their low density in our study sites since foxes have not been trapped or hunted in recent history on our study sites, therefore probably do not relate human scent or the camera with harm. In all other nest predations, the camera appears to be completely ignored.

Management Implications

Infrared video camera surveillance is proving to be extremely useful in determining may aspects of bobwhite ecology. Though this study focused on aspects of predation, the same video footage can also be used for further analysis of behavior of both the predators and the bobwhite including interspecific and conspecific interactions that occur at the nest area. These systems could also prove very useful in the surveillance of many other species.

It should be remembered that these systems have limitations due to their expense, complexity, and limited viewing area, as was previously mentioned, and should not be solely relied upon to obtain data.

For general management practices scent station indices can be a useful tool to assess the predator community in an area and their likely effects on bobwhite nest predation. From my data it appears that the most consistent results would be obtained in areas that do not have predator removal. In areas where predator removal is occurring it is thought that scent station indices performed concurrently with predator removal will probably give a more accurate assessment, but research needs to be performed to confirm this. As indices, they should not be relied upon as the only sources of data upon which to base management actions.

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CHAPTER 3

BOBWHITE NEST PREDATION IN RELATION TO PREDATOR REDUCTION - DYNAMICS OVER TIME.

Introduction

Northern bobwhite (*Colinus virginianus*) (hereafter bobwhite) is an important gamebird species that generates millions of dollars in revenues annually from hunting. In the 11 southeastern United States, hunting produced an estimated $95 million dollars in economic activity in 1991 (Burger et al. 1999). Since the mid-1960s, bobwhite populations have declined steadily across their range (Sauer et al. 2000). This decline has been caused largely by the changes in land management and uses of quail habitat, particularly the reduction and fragmentation of quail habitat through clean farming practices, intensive silviculture, and expanding urban development (Brennan 1991). In addition, certain mesomammalian predators (medium-sized omnivorous or carnivorous mammals), such as raccoon (*Procyon lotor*) and armadillo (*Dasypus novemcinctus*) have increased in density and range throughout the bobwhite's distribution (Rollins and Carroll 2001). This may be due to many possible reasons including the decline in fur market trapping in the 1980's and increased supplemental wildlife feeding which is also fed on by some of these mammals (Rollins and Carroll 2001, Schoch 2003).

In recent years, some landowners, land managers, and conservation groups have perceived a direct correlation between these two trends, believing that the increased presence of mesomammalian predators has caused the decline in bobwhite populations. This has lead to the illegal use of poisoned eggs during bobwhite nesting periods to reduce nest predators (Pinkston 1999), and the recent enactment of a law in Georgia that allows landowners to control predators if they do so as part of a management plan approved by the Georgia Department of Natural Resources (DNR) (Georgia state code 27-2-31).

Predator removal has been used for more than 2,000 years in some regions of Europe to reduce their competition with humans for both domestic and game species (Reynolds and Tapper 1996). Predator removal to specifically reduce their effects on small game populations came into effect in the 18^{th} and 19^{th} centuries in Europe on large hunting estates (Reynolds and Tapper 1996). In North America deliberate predator control mirrored Europe, with a later timeline beginning in the 16^{th} century with the European settlers for protection of livestock, continuing in varying degrees, to the present (Reynolds and Tapper 1996). Predator control to specifically increase game species in the United States appears to have begun in the late 19^{th} or early 20^{th} century. Stoddard (1931) gives full details of procedures to control various quail predators on private quail hunting preserves in the South Georgia and North Florida region. While there have been studies on the effects of predator control on the control of nest predation and increases in populations of bobwhite and other game birds in Europe and the United States, their results have varied from negligible to significant (Cote and Sutherland 1997). Rollins and Carroll (2001) noted "Among those studies demonstrating a positive impact of predator control in one form or another on gamebird populations, most have occurred in simpler ecosystems and with simpler predator and prey communities than those found in the Southeast. How these results translate to more complex ecosystems remains to be seen." The ecosystems in Europe, particularly the United Kingdom, are typically intensively managed farmland with a less diverse predator and prey community than the southeastern United States (Rollins and Carroll 2001). The Southeast is characterized by a variety of ecosystems managed at different intensities from intensive farming to hunting plantations (Rollins and Carroll 2001). Predator reduction has complex biological and political ramifications. In a more diverse system, there is a greater chance that reduction in one or a few predator species will have little or no effect on the population of the target species to be improved while potentially reducing the diversity of the system as a whole (Rollins and Carroll 2001). If predator control is used just to increase gamebird populations primarily for the purpose of increasing hunting opportunities, then its purpose for the conservation of the species is diminished since it's population as a whole may not significantly improve due to increased predation by humans (Rollins and Carroll 2001). At the same time, it is possible that the predator control may not only increase bobwhite populations but other currently declining species. Predator control may not adversely affect the predator population if practiced in a targeted manner (i.e., species-specific and/or temporally specific removals) (Rollins and Carroll 2001).

Objective

The objective of this study was to assess the preliminary correlations between treatment and control sites during the bobwhite nesting season pertaining to overall, mesomammal, and non-mesomammal bobwhite nest predation.

Study Sites

4 study sites on 3 different plantations were used during the 2000, 2001, and 2002 field seasons. These were Tall Timbers Research Station (TTRS), Pebble Hill Plantation

in the "Red Hills Region" of South Georgia and North Florida, and Pinebloom Plantation in the Albany area of southwest Georgia, which was divided into Pinebloom East and West sites for the purposes of this study. TTRS comprises approximately 1,500 ha, and Pebble Hill comprising 1,246 ha. Habitats at these sites are composed primarily of southern upland forests with overstories comprised primarily of longleaf pine (*Pinus palustris*) and Loblolly pine (*Pinus taeda*) as the dominant overstories, and understories varying from wiregrass (*Aristida stricta*) to old-field vegetation. Interspersed throughout these sites are hardwood drains/hammocks and fallow fields. Pinebloom Plantation, is divided into two sites of approximately 1,400 ha each. These sites are primarily upland slash pine (*Pinus elliottii*) forest with old-field understory vegetation, interspersed with fallow fields. At all sites, fallow fields are maintained by annual disking to encourage growth of preferred cover and forage plant species. Portions of the understory of all sites will be burned and/or treated with herbicides annually to control hardwood encroachment and promote early successional herbaceous ground cover. Site habitat and game management practices may also include supplemental feeding of grain, small food plots, chopping and mowing, and also the thinning of forests stands. All of these practices were performed in varying amounts depending on the management plans of the property managers and were considered uncontrollable factors, which may affect this study.

Methods

Study design and predator removal

This study involved a randomized complete block design with repeated measures. This study was conducted on two separate blocks, one in each region, with each block composed of two treatment plots or sites. During 2000, no predator removal occurred on any plots as a pretreatment baseline of comparison with the second and third years. During the second and third years predator removal treatment was applied to Pebble Hill Plantation and Pinebloom East, with TTRS and Pinebloom West as their respective control plots. At treated sites mesomammals [raccoon (*Procyon lotor*), armadillo (*Dasypus novemcinctus*), opossum (*Didelphis virginiana*) bobcat (*Lynx rufus*), and coyote (*Canis latrans*)], and feral mammal species [(dog (*Canis familiaris*) and cat (*Felis domesticus*)] were removed between March 1 and September 31 during 2001 and 2002. Predator removal was performed by USDA-Georgia (USDA-GA) Wildlife Services employees in accordance with USDA Wildlife Services procedures and directives to include the use of foot hold traps, live traps, and shooting during the day and at night with spotlights. Predator removal was performed at Pebble Hill Plantation and Pinebloom East, with TTRS and Pinebloom West used as control sites.

Bobwhite monitoring

Bobwhites were captured between January and April each year using "walk in" funnel traps baited with cracked corn and/or milo (Smith et al. 1981). Individuals were classified by sex and age, weighed and leg-banded, then released at the capture site. Trapping, handling, and marking procedures were consistent with the guidelines provided in the American Ornithologists' Union Report of the Committee on use of wild birds in research (American Ornithologists' Union 1988), and the University of Georgia (Institional Animal Care and Use Committee Permit #A3437-01) (Staller 2001). At least 70 bobwhite per site, weighing $\geq$150 g were fitted with 6.4-6.9 g pendant-style radio-transmitters (American Wildlife Enterprises, 493 Beaver Lake Rd. Tallahassee, FL.

32312), on each site, with an approximate sex ratio of radio tagged birds of 75% female and 25% male.

To locate nests, bobwhite were tracked daily using telemetry homing techniques during breeding season from April through October (White and Garrot 1990). Telemetry equipment consisted of a 3-element, directional hand-held antenna and receivers. Bobwhite were assumed to be nesting if a bird was observed in the same location for two consecutive telemetry locations >30 minutes apart. Nest areas were marked with 2 to 4 small marking tape flags placed around the nest, each approximately 2 to 3 m from the nest. Following the initial location of a nest, the nest was monitored hourly throughout the day until the incubating parent left the nest to forage, typically in the afternoon. After the parent left, the flagged area was searched for the nest, eggs were counted and the nest's fate was monitored by either telemetry only, or using an infrared surveillance cameras and telemetry, if available. Nests to be video monitored were selected randomly among the nesting birds on each site when a camera system or systems were available. Flagging was removed following placement of camera or positive nest identification to reduce bias by attracting or repelling predators. nineteen camera systems were available in 2000 between TTRS, Pebble Hill Plantation and Pinebloom Plantation. 13 were used at the Pineboom Plantation sites, and 13 at the TTRS/Pebble Hill Plantation sites during 2001 and 2002.

The surveillance video camera system consisted of a Model N9C2 FIELDCAM™ LRTV MICROCAM™ with a 3.7-mm wide-angle lens and a 6-Light Emitting Diode (LED) array at 950nm surrounding the lens. Illumination was provided by natural sunlight, the 6-LED array, and a 36-LED array illumination system at 950nm on an opposable arm, for low light situations (i.e. in inclement weather and at night). The FIELDCAM™ and illumination system are part of a camouflaged articulating arm, which was clamped to a wooden stake. The camera was connected to a VHS time-lapse video recorder, which recorded 10 frames per second via a 30-m cord. A TOTE™ LCD 410 field and set-up monitor was used to view the camera picture during set-up of the system at nests (Furhman Diversified Inc., 2912 Bayport Blvd. Seabrook, TX 77586). A 225 volt-reserve capacity Marine Source™ deep-cycle battery powered the entire system.

On camera monitored nests, a camera was placed 1.5 to 2 m from the nest and camouflaged with supplemental vegetation similar to existing vegetation. Cameras were placed so as to provide the best possible view of the nest, usually pointing to the entrance, and to include the best possible view of surroundings so that predators approaching or leaving the nest may be seen. Camera cables were stretched from the camera to the VCR, located 20-30 m away. Cables and VCR were camouflaged with vegetation, and were not placed on or across likely predator travel routes (e.g., roads, paths, fire breaks). Camouflage vegetation was used to reduce notice by both nesting bobwhite and possible attraction or repulsion of predators. The nesting bobwhite was monitored at daybreak the morning after camera set-up to ensure that it had not been disturbed by the camera's presence causing abandonment. If the parent was not on the nest, the camera armature angle was adjusted to place the camera farther from the nest. The nest was monitored hourly; and if the parent did not return within 4 hours, the camera was removed.

During normal monitoring, the previous day's videotape and battery were replaced every 24 hours until the nest hatched or was vacated due to depredation of the nest or death or abandonment of the incubating parent(s). The last 2 minutes of the VHS videotape was viewed to ensure that the nest had not been obscured by vegetation or moved by weather or animal contact. Nests were monitored daily by myself or a technician in charge of the area's bobwhite telemetry to determine the status of the nest (incubating, hatched, depredated, or abandoned). For nests found to have been depredated, the preceding day's videotape(s) were viewed to determine the predator(s).

Data Analysis

Depredated nests were classified into two categories, partial or complete. A nest depredation was considered a complete depredation if the nest was abandoned permanently prior to hatching due to loss of the eggs or the incubating parent(s). A depredation was considered partial when an at least one egg was consumed or removed by a predator, but incubation of remaining eggs continued. Predators were grouped into three broad categories of mesomammals, non-mesomammals, and other. Mesomammals included, but was not limited to armadillo, bobcat, opossum, and raccoon, coyote, gray fox, and feral dogs, and cats. Non-mesomammal denoted any other non-mesomammal species viewed (e.g. snake, ants) and other included unknown predators and birds killed off nest. "Unknown" was used if the predator was not seen, but a depredation was known to have occurred while camera was operating properly.

Each nest monitored was considered a subsample of each experimental plot, each year. It was assumed that the rate of nest predations was a function of exposure time. Video time for each nest ended at the beginning of a known complete depredation or at the first sight of a chick after a hatch. In case of an unseen hatching, video time was ended at 12:00 midnight the night before the hatching was determined by telemetry.

Nest predation rates were determined using the Mayfield method. Predation rates were determined for the effects of overall, mesomammal only, and non-mesomammal predations affecting each site, each year. For the analysis of each category the combined totals of complete and partial depredation events were used.

Mayfield method data analysis was performed using the Micromort© program, version 1.2 (Minnesota department of Natural Resources/ Wildlife, NH Analytical Software, 801 West Iowa Ave., St. Paul Minnesota USA).

Results

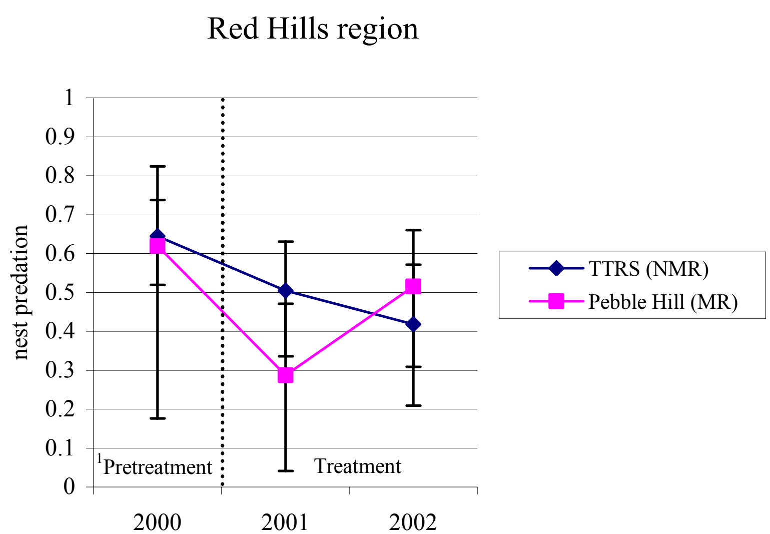
Overall predation rates show large variability year to year on each site, with no significant difference between removal and nonremoval areas. Albany region sites showed more consistent overall trends, but again, not significant (Figure 3.1). In terms of mesomammal only predation rates there was a significant difference between Red Hill sites, with predation rates on Pebble Hill 2001 significantly lower than TTRS, but this trend did not continue into the second year of removal (Figure 3.2). Non-mesomammal predation trends mirrored each other between sites in both blocks over the course of this study, never showing a significant difference between sites in any year (Figures 3.3)

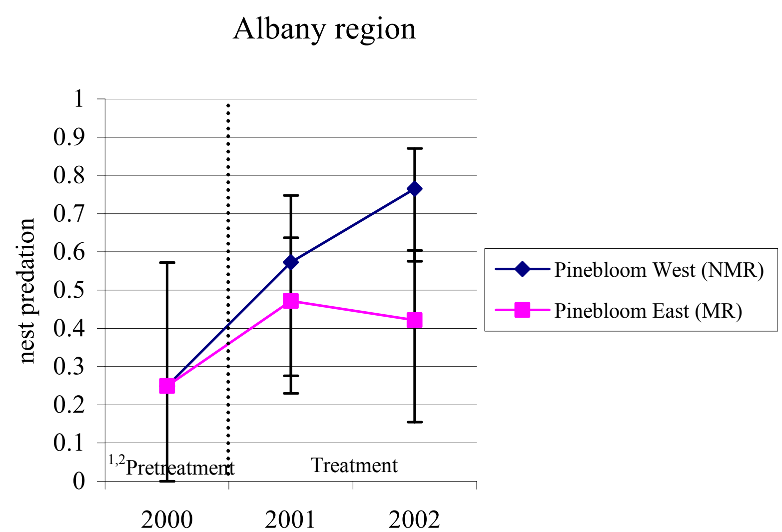
Discussion

Effects of predator control on target species

Though there was a decrease in nest predation in 2001 on the Red Hills region treatment area compared to its control area this did not continue into the second year of the experiment in this region. There was no significant difference in nest predation

Figure 3.1. Overall predation rate of camera monitored bobwhite nest predations and 95% CI (Mayfield adjusted) during a nesting period (21 days) on study sites in South Georgia and North Florida, USA, 2000 to 2002. TTRS= Tall Timbers Research Station. NMR= no mesomammal removal, MR=mesomammal removal.

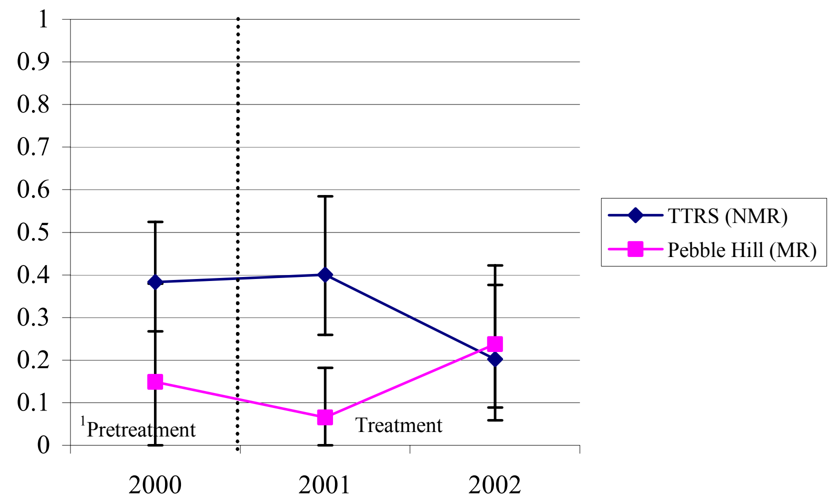




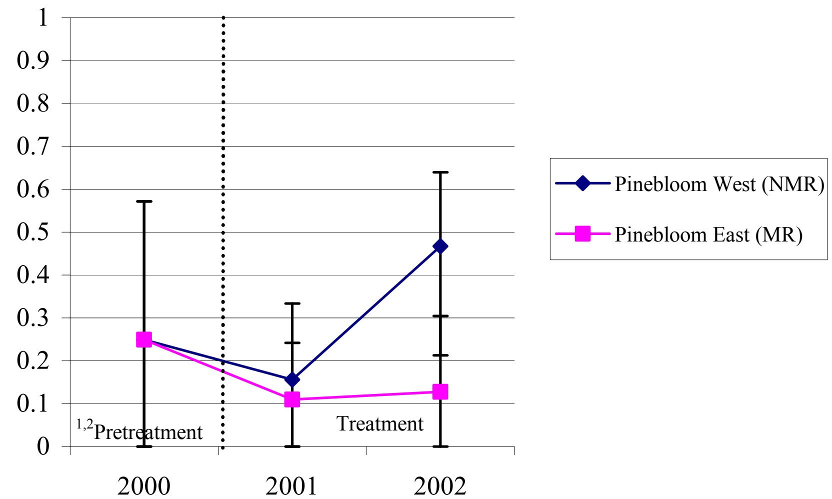
Nesting period sample sizes by plantation and year.
TTRS: 2000 n=43.5, 2001n=31.4, 2002 n= 22.2
Pebble Hill: 2000 n=6.2, 2001n=14.8, 2002 n=22.1
[2]Pinebloom Plantation 2000 n= 3.5
Pinebloom West; 2001n=11.8, 2002 n=15.9
Pinebloom East; 2001n=17.3, 2002 n=14.6
[1] No mesomammal removal occurred on any sites during the pretreatment year (2000).
[2] Pinebloom Plantation has only one data point in 2000 because it was not divided into two study sites until 2001.

Figure 3.2. Mesomammal predation rate of camera monitored bobwhite nest predation and 95% CI (Mayfield adjusted) during a nesting period (21 days) on study sites in South Georgia and North Florida, USA, 2000 to 2002. TTRS= Tall Timbers Research Station. NMR= no mesomammal removal, MR=mesomammal removal.

Red Hills region



Albany region



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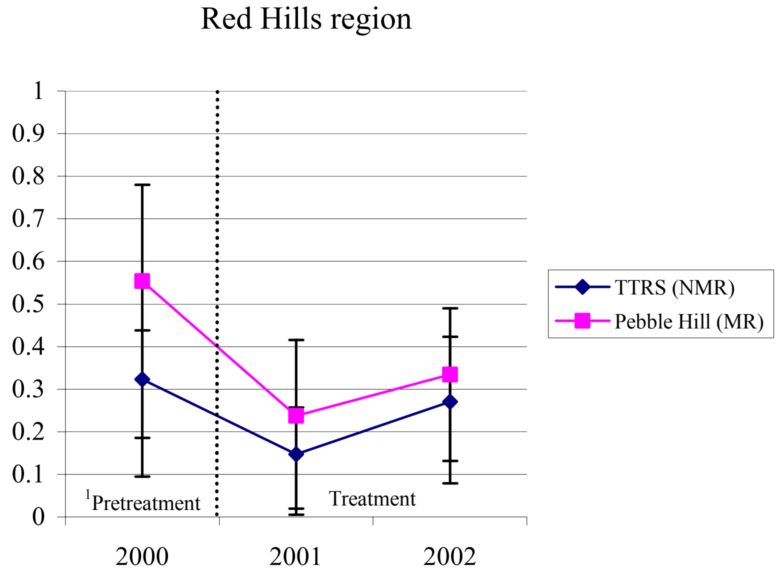
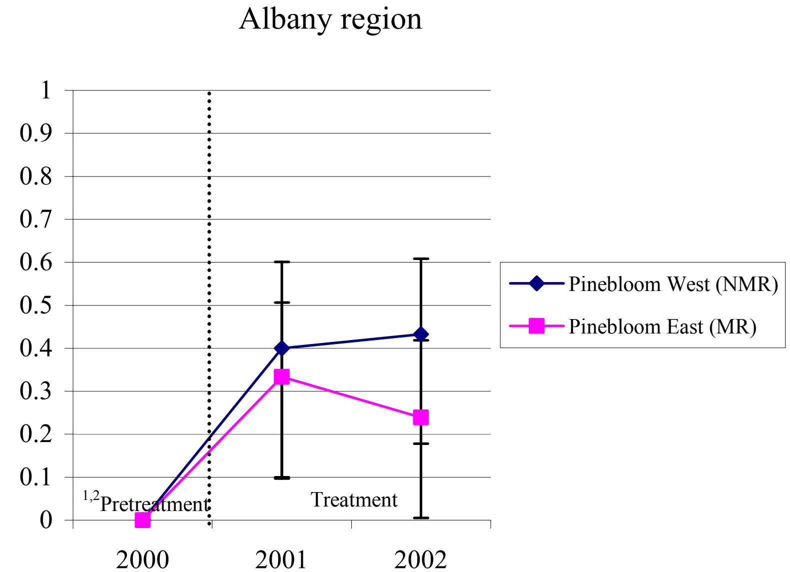
Pinebloom East; 2001n=17.3, 2002 n=14.6
[1] No mesomammal removal occurred on any sites during the pretreatment year (2000).
[2] Pinebloom Plantation has only one data point in 2000 because it was not divided into two study sites until 2001.

Figure 3.3. Non-mesomammal predation rate of camera monitored bobwhite nest depredation and 95% CI (Mayfield adjusted) during a nesting period (21 days) on study sites in South Georgia and North Florida, USA, 2000 to 2002. TTRS= Tall Timbers Research Station. NMR= no mesomammal removal, MR=mesomammal removal.





Nesting period sample sizes by plantation and year.
TTRS: 2000 n=43.5, 2001n=31.4, 2002 n= 22.2
Pebble Hill: 2000 n=6.2, 2001n=14.8, 2002 n=22.1
[2]Pinebloom Plantation 2000 n= 3.5
Pinebloom West; 2001n=11.8, 2002 n=15.9
Pinebloom East; 2001n=17.3, 2002 n=14.6
[1] No mesomammal removal occurred on any sites during the pretreatment year (2000).
[2] Pinebloom Plantation has only one data point in 2000 because it was not divided into two study sites until 2001.

between sites in the Albany Area though there was an increase in the second year of treatment in the non-treated site compared to the treatment area, but it was not statistically significant. While there does appear to be a possible trend at the Albany sites, due to the variability seen in just these 3 years on both blocks it cannot be said with any certainty that this trend will continue.

Mesomammalian predation rates showed a more distinct differences in the Red Hills Region in the first year of treatment, but because this trend did not continue into the second year I can not say that this difference between sites was due to the effects of predator removal. Mesomammalian predations rates on Pinebloom sites showed similar trends compared to overall predation rates, but again, not significantly and without consistency at this time.

It is suspected that the lower predations rates on all sites in 2001 were due to a larger than normal soft mast crop during that summer, particularly of blackberry (*Rubus* spp.) as was noted by other personnel at all study sites (Shoch 2003). Though not quantified, it could be postulated that this ephemeral food source may have diverted feeding efforts of raccoons and other omnivores on all sites with a more abundant food source than bobwhite eggs during the bobwhite nesting season. This is further supported with an increase in raccoon depredations on Pinebloom West in 2002 compared to 2001, when soft mast crops were not as noticeably large as the previous year.

The decrease in raccoon predations in 2002 on TTRS is probably due to a canine distemper outbreak in the TTRS area, which probably reduced the area's raccoon population. Approximately 12 raccoons were found dead on TTRS and surrounding properties in winter of 2001 through spring 2002. Two raccoons were sent to the

Southeastern Cooperative Wildlife Disease Study (SCWDS) at the University of Georgia and confirmed infected with canine distemper (W.E. Palmer, personal comm.). This assumption is further backed by the fact that in 1999 and 2000 raccoons were found to be common nest predators in the TTRS area, and in 2001 there were no camera monitored bobwhite nest predations by raccoons (Staller 2001). There was no indications that this disease affected the raccoon population in either Pebble Hill, or the Pinebloom sites, or any other species on all sites because no infected animals were found on these sites.

Effects of predator control on non-target species

At this time there appears to be no compensatory predation by non-mesomammalian bobwhite nest predators. During each year, each regional blocks nest predation related to non-mesomammalian predators was almost identical between its removal and non-removal sites (Figure 3.3). Site and variability is the probable reason for the minor differences in the mean rates of predation between removal and nonremoval sites in each area, as the Red Hills sites showed consistently lower mean predation rates in its mesomammal removal sites compared to its nonremoval site, while the opposite is seen in the Albany region. In this case the effects of a release of non-mesomammalian predators could be reduced as these species are continually preyed upon by avian predators, which are not removed from the areas, and by mesomammalian predators that have been found to repopulate these areas in the fall and winter when trapping ceases (Tapper et al. 1996). Or the release may occur with a greater time lag than 2 years for certain predators to increase enough to significantly impact bobwhite nest success. This has it's greatest validity with snake species, such as the grey rat (*Elaphe oboleta spiloides*) and corn snake (*Elaphe guttata guttata*) which may require more than 3 years to mature to >1 m size, the size more commonly seen depredating bobwhite nests [83% (n=24) of completed depredations, 66% (n=25) of overall depredations]. Though there is no known scientific literature on the growth rates of these snakes species, a captive-raised grey rat snake at TTRS was still < 1 m after two years (S.P. Stapleton, pers. comm.). Though not quantified, the one complete nest predation due to cotton rat(s) coincided with the highest seen rodent densities by field technicians at TTRS during this and Staller's (2001) preceding camera study.

Management Implications

So far the results of this study concerning the effectiveness of predator reduction and bobwhite nest predation are variable. The study does show that this ecosystem has many complexities (e.g., variable yearly weather patterns, disease, and soft mast crop) that can become significant factors in the system besides the factor that we manipulate.

If predators are considered a factor that must be reduced in order to improve the success of another species, then predation management, not just predator control should be the primary consideration. Predation management does not always require the lethal removal of predators, but may involve habitat management to reduce the attraction of the site to certain predator species.

If managers feel the need to perform predator management through reductions in mesomammal or other predators, then efforts should be focused on specific species, and at certain critical times, such as nesting periods to be most efficient for the intended goal, while maintaining both species in the ecosystem. Our data show that the removed species will persist in the area, never being completely extirpated as some hope, or fear.

With the allowance for the repopulation of these predators, possible compensatory predation by lower order predators appears to be negated as they are continually preyed upon and thus probably never "released".

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CHAPTER 4

NORTHERN BOBWHITE BREEDING SEASON PRODUCTIVITY RESPONSES TO MESOMAMMAL PREDATOR REDUCTION

Introduction

Northern bobwhite (*Colinus virginianus*) (hereafter bobwhite) is an important gamebird species which generates millions of dollars in revenues annually from hunting. In the 11 southeastern United States, hunting produced an estimated $95 million dollars in economic activity in 1991 (Burger et al. 1999). Since the mid-1960s, bobwhite populations have declined steadily across their range (Sauer et al. 2000). This decline has been caused largely by the changes in land management and uses of quail habitat, particularly the reduction and fragmentation of bobwhite habitat through clean farming practices, intensive silviculture, and expanding urban development (Brennan 1991). In addition, certain mesomammalian predators (medium-sized omnivorous or carnivorous mammals), such as raccoon (*Procyon lotor*) and armadillo (*Daypus novemcinctus*) have increased in density and range throughout the bobwhite's distribution (Rollins and Carroll 2001).

In recent years, some landowners, land managers, and conservation groups have perceived a direct correlation between these two trends, believing that the increased presence of mesomammalian predators has caused the decline in bobwhite populations. This has lead to the illegal use of poisoned eggs during bobwhite nesting periods to reduce nest predators (Pinkston 1999), and the recent enactment of a law in Georgia that allows landowners to control predators if they do so as part of a management plan approved by the Georgia Department of Natural Resources (DNR) (Georgia state code 27-2-31).

While there have been studies on the effects of predator removal on the control of nest predation and increases in populations of bobwhite and other game birds in Europe and the United States, their results have varied from negligible to significant (Cote and Sutherland 1997).

Study Sites

Four study sites on three different plantations were used during the 2000, 2001, and 2002 field seasons. These were Tall Timbers Research Station (TTRS), Pebble Hill Plantation in the "Red Hills Region" of South Georgia and North Florida, and Pinebloom Plantation in the Albany area of Southwest Georgia, which is divided into Pinebloom East and West sites for the purposes of this study. TTRS comprises approximately 1,500 ha, and Pebble Hill comprising 1,246 ha. Habitats at these sites are composed primarily of southern upland forests with overstories comprised primarily of longleaf pine (*Pinus palustris*) and Loblolly pine (*Pinus taeda*) as the dominant overstories, and understories varying from wiregrass (*Aristida stricta*) to old-field vegetation. Interspersed throughout these sites are hardwood drains/hammocks and fallow fields. Pinebloom Plantation, is divided into two sites of approximately 1,400 ha each. These sites are primarily upland slash pine (*Pinus elliottii*) forest with old-field understory vegetation, interspersed with fallow fields. At all sites, fallow fields are maintained by annual disking to encourage growth of preferred cover and forage plant species. Portions of the understory of all sites will be burned and/or treated with herbicides annually to control hardwood encroachment and promote early successional herbaceous ground cover. Site habitat and game management practices may also include supplemental feeding of grain, small food plots, chopping and mowing, and also the thinning of forests stands. All of these practices were performed in varying amounts depending on the management plans of the property managers and were considered uncontrollable factors, which may affect this study.

Objectives

The objective of this study was to assess the bobwhite productivity responses using simple measures of productivity.

Methods

Study design and predator removal

This study involved a randomized complete block design with repeated measures. This study was conducted over 3 years between 2000 and 2002 on two separate blocks, one in each region, with each block composed of two treatment plots or sites. The first year had no treatment on any plots as a baseline of comparison with the second and third years. During the second and third years predator removal treatment was applied to Pebble Hill Plantation and Pinebloom East, with TTRS and Pinebloom West as their respective control plots. At treated sites, mesomammals [raccoon, armadillo, opossum (*Didelphis virginiana*) bobcat (*Lynx rufus*), and coyote (*Canis latrans*)], and feral mammal species [(dogs (*Canis familiaris*) and cats (*Felis domesticus*)] were removed between March 1 and September 31, during 2001 and 2002. Predator removal was performed by USDA-Georgia (USDA-GA) Wildlife Services employees in accordance with USDA Wildlife Services procedures and directives to include the use of foot hold traps, live traps, and shooting during the day and at night with spotlights. Predator removal was performed at Pebble Hill Plantation and Pinebloom East, with TTRS and Pinebloom West used as control sites.

Bobwhite monitoring

Bobwhites were captured between January and April each year using "walk in" funnel traps baited with cracked corn and/or milo (Smith et al. 1981). Individuals were classified by sex and age, weighed and leg-banded, then released at the capture site. Trapping, handling, and marking procedures were consistent with the guidelines provided in the American Ornithologists' Union Report of the Committee on use of wild birds in research (American Ornithologists' Union 1988), and the University of Georgia (Institional Animal Care and Use Committee Permit #A3437-01) (Staller 2001). At least 70 bobwhite per site, weighing $\geq$150 g were fitted with 6.4-6.9 g pendant-style radio-transmitters (American Wildlife Enterprises, 493 Beaver Lake Rd. Tallahassee, FL. 32312), on each site, with an approximate sex ratio of radio tagged birds of 75% female and 25% male.

To locate nests, bobwhites were tracked daily using telemetry homing techniques during breeding season from April through October (White and Garrot 1990). Telemetry equipment consisted of a 3-element, directional hand-held antenna and receivers. Bobwhites were assumed to be nesting if a bird was observed in the same location for two consecutive telemetry locations >30 minutes apart. Nest fate was monitored by either telemetry only, or using an infrared surveillance cameras and telemetry, if available. Egg remains following a hatch were used to determine number eggs hatched. Nesting data were recorded and maintained for all birds radio tagged in each site.

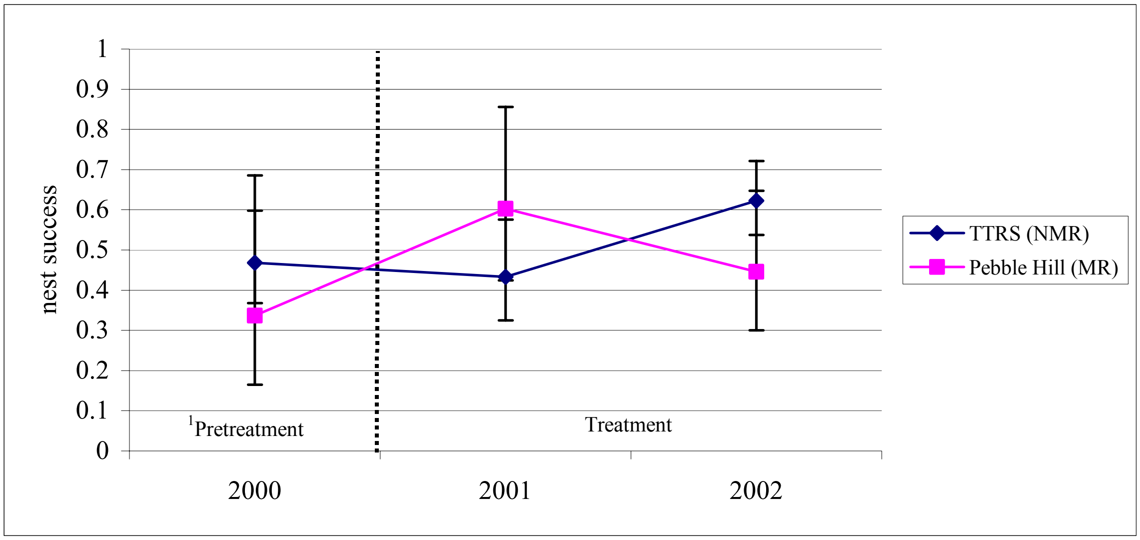
Data analysis

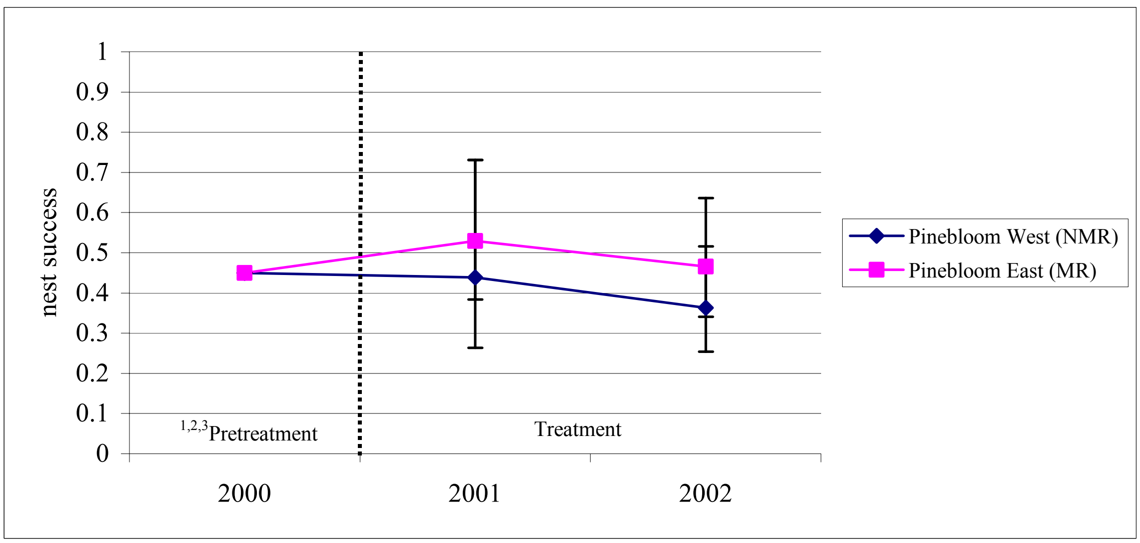
Each bird and nest monitored was considered a subsample of each experimental plot, each year. Overall nest success was determined using nest success of all radio telemetry monitored bobwhite each year and Mayfield (1961) adjusted. It was assumed that the number of nests and subsequently chicks produced per hen was a function of predation. Therefore, as predation increases hens will be able to initiate fewer nests resulting in fewer hatched clutches and lower chick per hen production. Nest per hen rate was determined by the total number of nests initiated by all birds monitored throughout the breeding season divided by the number of monitored hens alive at the beginning of the season. Nests were not considered initiated until incubation began. Chick per hen production was determined by the number of hatched egg remains at a nest site following a hatching divided by the number of hens monitored at the beginning of the breeding season. Variances for both nests and chick per hen production were analyzed using 95% CI where possible.

Results

Overall production showed no statistically significant difference between pretreatment and treatment years or between treated sites and control sites at either regional block, but Pebble Hill did show an almost 2 fold nesting success improvement in the first year of treatment and continued in the second year of treatment with a higher than pretreatment nesting success rate. Pinebloom East showed a consistently higher mean nest success compared to Pinebloom West, but this appeared to be due to natural variations between sites and birds sampled (Figure 4.1). Nests per hen production increased each year of treatment on Pebble Hill from a significantly lower rate in pretreatment years compared to treatment years to a rate of nest initiation consistent with TTRS in each of the treatment years. Pebble Hill nest production improves in each year of treatment to a mean nest production per hen of more than double compared to the pretreatment by the second year of treatment whereas TTRS production decreases each year of the study compared to the pretreatment. Both Albany sites showed increases in nest production each year of treatment compared to the pretreatment, but no significant difference are seen in either year of treatment nor are the increase of a significantly large magnitude compare to pretreatment (Figure 4.2). Chicks per hen rate trends were very similar to nest production trends for each of the blocks respectively. In the Red Hills region, Pebble Hills chick production consistently improved in each treatment year to an almost 5 fold increase in chick production by the second year of treatment compared to the pretreatment, while TTRS shows far more variability with no noticeable increase throughout the study. Pinebloom East showed a significant difference in chick production during the first year of treatment, but dropped to almost half of its first treatment year production in the second year of treatment, whereas Pinebloom West chick production remains relatively equal between treatment years (Figure 4.3). Unfortunately due to an incomplete pretreatment data set we did not have pretreatment chick data to compare with treatment data on Albany sites.

Figure 4.1 Overall nest success rate of camera monitored bobwhite nest predations and 95% CI (Mayfield adjusted) during a nesting period (21 days) on study sites in South Georgia and North Florida, USA. 2000 to 2002. TTRS = Tall Timbers Research Station. NMR= no mesomammal removal, MR=mesomammal removal.

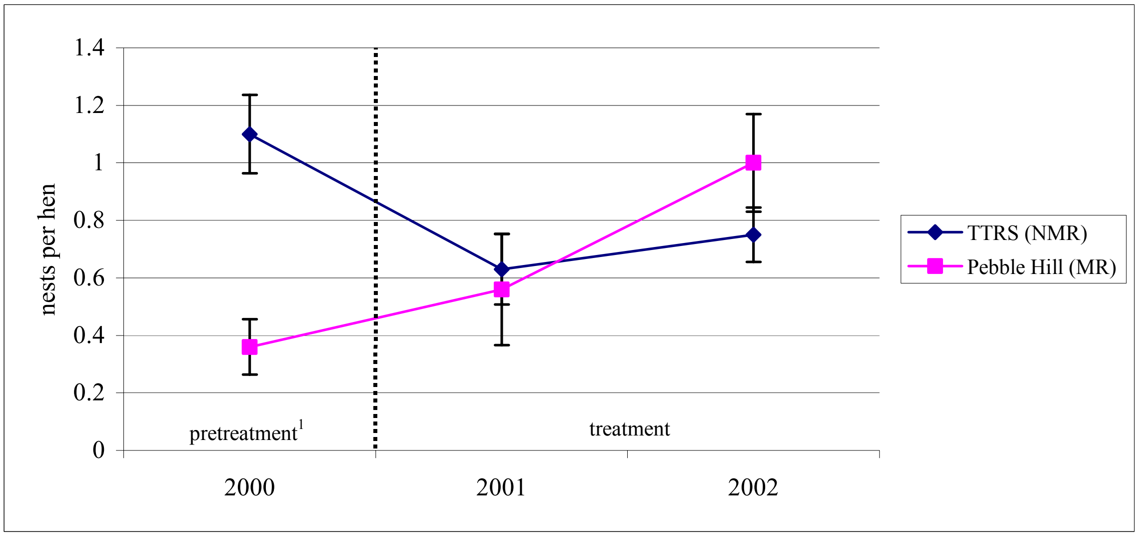




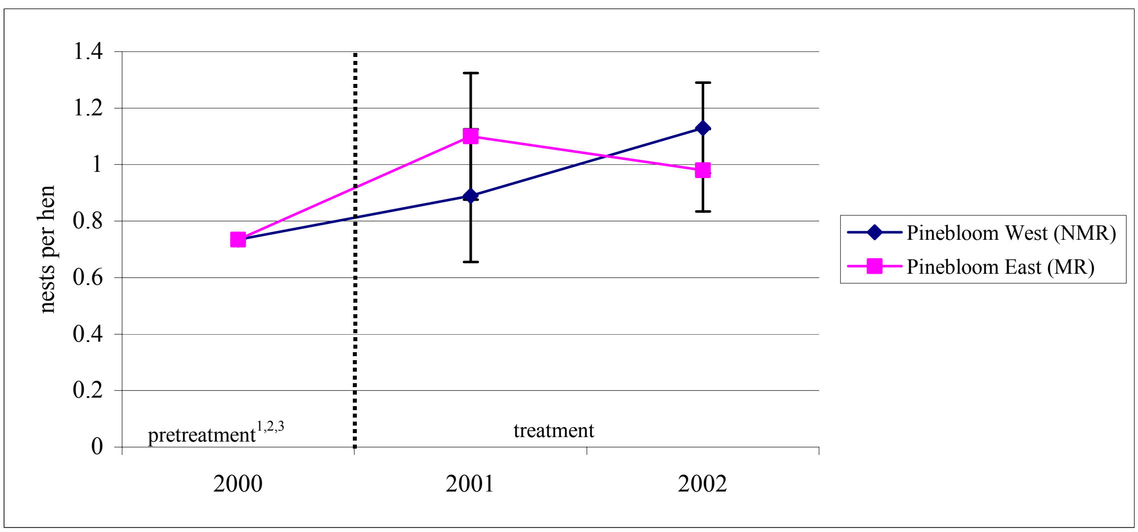
Nesting days monitored sample sizes by plantation and year.
TTRS (2000 n=1070, 2001 n=844, 2002 n= 1792)
Pebble Hill (2000 n=178, 2001 n=336, 2002 n=663)
[2] Pinebloom Plantation 2000, incomplete data set.
Pinebloom West (2001 n=260, 2002 n=679)
Pinebloom East (2001 n=503, 2002 n=643)
[1] No mesomammal removal occurred on any sites during the pretreatment year (2000).
[2] Pinebloom Plantation has only one data point in 2000 because it was not divided into two study sites until 2001.
[3] Pinebloom Plantation 2000 has no confidence intervals due to incomplete nest data set.

Figure 4.2 Nests per hen capita production (±95% CI) by bobwhite on sites in South Georgia and North Florida, USA, 2000-2001. TTRS= Tall Timbers Research Station. NMR= no mesomammal removal, MR=mesomammal removal.

Red Hills Region



Albany Region



Nesting sample size by plantation and year

TTRS (2000 n=76 hens, 80 nests; 2001 n=62 hens, 39 nests; 2002 n= 144 hens, 108 nests)

Pebble Hill (2000 n=39 hens, 14 nests; 2001 n= 36 hens, 20 nests; 2002 n=46 hens, 46 nests)

[2] Pinebloom Plantation 2000 188 hens, 138 nests. incomplete data set.

Pinebloom West (2001 n=28 hens, 25 nests; 2002 n=50 hens, 62 nests)

Pinebloom East (2001 n= 40 hens, 44 nests, 2002 n=52 hens, 51 nests)

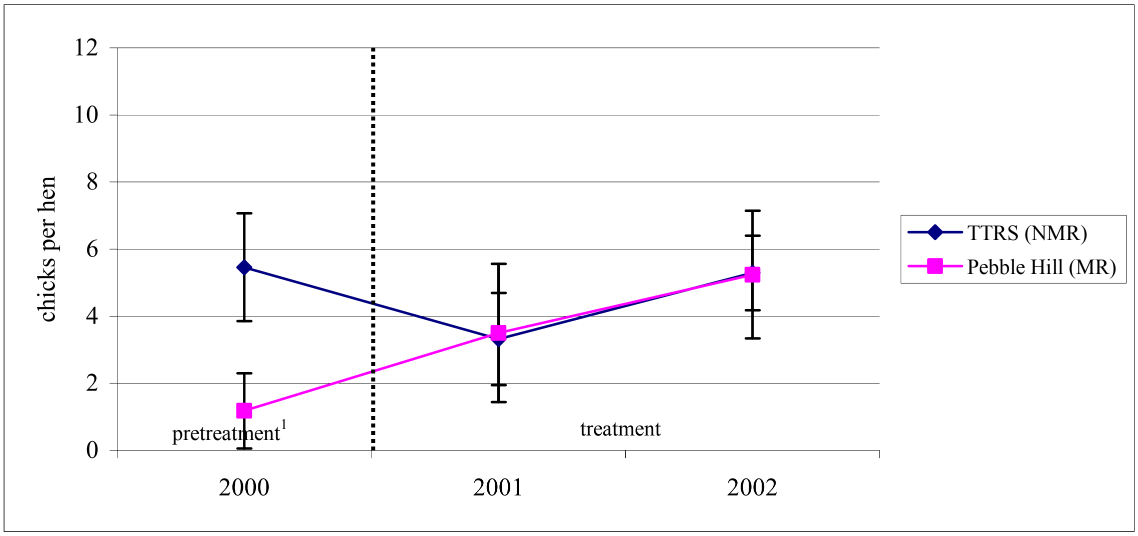
[1] No mesomammal removal occurred on any sites during the pretreatment year (2000).

[2]Pinebloom Plantation has only one data point in 2000 because it was not divided into two study sites until 2001.

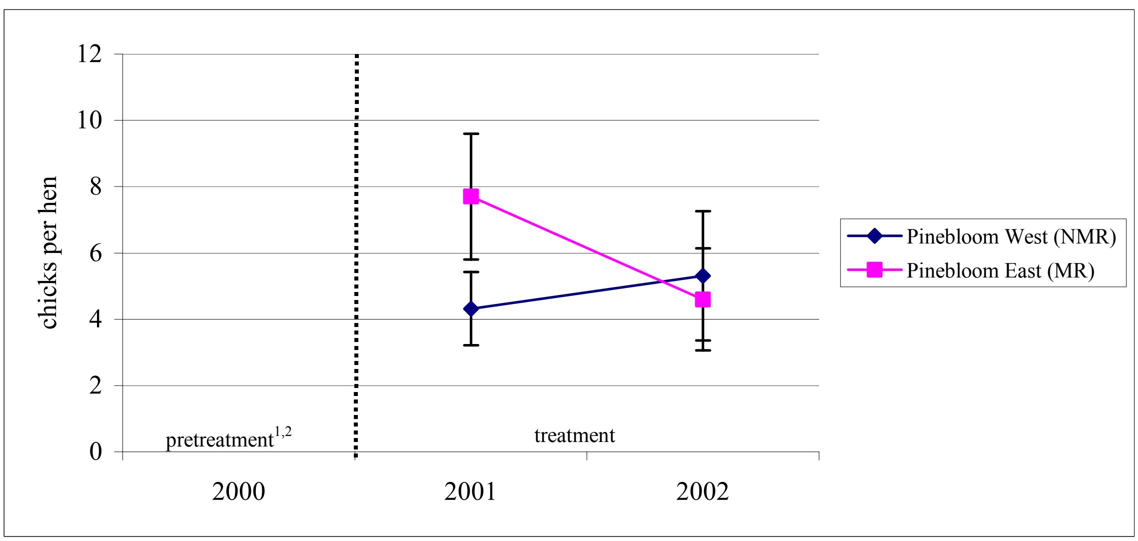
[3] Pinebloom 2000 has no confidence interval data not used due to an incomplete data set.

Figure 4.3 Chicks per hen capita production (±95% CI) by bobwhite on sites in South Georgia and North Florida, USA, 2000-2001. TTRS= Tall Timbers Research Station. NMR= no mesomammal removal, MR=mesomammal removal.

Red Hills Region



Albany Region



Chick per hen capita sample size by plantation and year
TTRS (2000 n=76 hens, 415 chicks; 2001 n=62 hens, 206 chicks; 2002 n= 144 hens, 108 chicks)
Pebble Hill (2000 n=39 hens, 46 chicks; 2001 n=36 hens, 119 chicks; 2002 n= 46 hens, 46 chicks)
[2] Pinebloom Plantation 2000, 188 hens, unknown chicks (incomplete data set).
Pinebloom West (2001 n=28 hens, 21 chicks; 2002 n=55 hens, 292 chicks)
Pinebloom East (2001 n= 40 hens, 308 chicks; 2002 n= 52 hens, 239 chicks)
[1] No mesomammal removal occurred on any sites during the pretreatment year (2000).
[2] Pinebloom 2000 data not used due to an incomplete data set.

Discussion

Overall success

It would appear that predator removal may have had some effect on mean nest success in the Red Hills at this time. Though not statistically significant, Pebble Hill did show a trend of improvement between the pretreatment and both years of treatment. The improved success of TTRS in 2002 was probably related to an outbreak of canine distemper affecting raccoons locally in and around TTRS. Approximately 12 raccoons were found dead on TTRS and surrounding properties during winter 2001 through spring 2002. Two were sent to the Southeastern Cooperative Wildlife Disease Study (SCWDS) at the University of Georgia and confirmed infected with canine distemper (W.E. Palmer, personal comm.). This assumption is further supported by the fact that in 1999 and 2000 raccoons were found to be common nest predators in the TTRS area, and in 2001 there were no camera monitored bobwhite nest predations by raccoons (Staller 2001). There was no indications that the disease affected the raccoon population in either Pebble Hill, or the Pinebloom sites, or any other species on all sites. Pinebloom sites showed little effects of predator removal throughout the study period as mean overall production mirrored each other between sites in both years of treatment. Such consistency was probably due more to differences in sampling and site variations than any manipulation.

Chicks per hen and nest per hen production

The most noticeable trends occurred on the Red Hills sites with Pebble Hill's nest per hen and chicks per hen production increasing each year of treatment compared to pretreatment. While nest per hen production at Pebble Hill is statistically significant in both treatment years compared to the treatment year, chicks per hen production was not until the second year of treatment. With the magnitude of increase each year of treatment seen on Pebble hill I believe both the nest per hen increase and particularly chicks per hen production increases during treatment years is biologically significant irregardless of their statistical significance. During this same time TTRS showed no noticeable improvements in either treatment year compared to pretreatment further supporting my belief that predator removal had a positive effect on these two factors of production in this region. Both Pinebloom sites nest production increased in the treatment years compared to the pretreatment years. While there was an increase in mean nest production on Pinebloom East compared to Pinebloom West and the pretreatment year, the trend did not continue into the second year of treatment. Due to this and the large variances among both sites during the first year of treatment, predator removal did not have much affect on nest production in the Albany area during that time period. Between Pinebloom sites, chick production was higher in the first year of treatment on the treatment site, but this did not continue into the second year. Without the pretreatment years chick per hen production data for comparison, or a consistent trend during both treatment years there was not sufficient data to support a correlation between predator removal and any improvement concerning chick production of bobwhite on these sites.

While nests per hen and chicks per hen production appears to be a relatively accurate indices of bobwhite chick production is should be noted that there is a great deal of variability in determining the amount of nest produces and chicks hatched. Because of bobwhite ability to initiate nests multiple times in a season, particularly if early attempts are depredated, nest per hen capita may not be a good indication of quail production. Both Staller (2001) and I noted rodents, other mammals, and on occasion the incubating parent and chicks removing eggshells following a hatch, lowering the number suspected to have hatched from a nest. Heavy rain may also wash egg remains from a nest site before a hatched egg count can occur. Though rare, depredations may also be misinterpreted as hatches as one video documented fire ant depredation was considered because the ants removed all chick remains from the shells before the technician viewed the nest.

Possible other indices of production could include number of successfully hatched nests per hen, chicks per hen at brood capture, typically performed at 9-12 days following hatch, or at an earlier day.

Management Implications

While the use of new technology such as the infrared system previously mentioned has proven very useful in more accurately determining exact predators for specific comparisons of manipulations and other factors, it is also very expensive to use and maintain. If a study does not have the funding for this equipment, or the need for exact causes of events these indices, particularly overall success rates, and chicks per hen capita rates appear to be useful in showing the general effects of manipulations or other factors affecting nest success and productivity.

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CHAPTER 5

CONCLUSIONS AND IMPLICATIONS

At this time only 3 of the 7 years overall project have been completed. So far we have already seen some of the uncontrollable factors that can and have affected this study, but there may be others including some which have a longer time-lag than two years. Yet, while this is less than half of the overall study, this is also longer than many studies that have been performed in the past, some of which have been used as the basis of management decisions.

From this study I can say that predation rates appear to be related to the combination of predator abundance and some site-specific effects. Measures of productivity of bobwhite improved on some site and in some years as a result of predator removal. But, productivity was also affected by many other site and year factors, creating highly variable predator removal effectiveness. Therefore, these results suggest that long term studies, such as the overall study that my project is part of, are needed to separate the effects of predator removal and the many confounding factors that impact bobwhite productivity.

Predator management has shown its use in Europe, particularly Britain, where it is understood to be an accepted and in some cases necessary practice in light of the changes that humans have made to the landscape (Tapper et al. 1996). Though the United States typically has more complex ecosystems than Europe, especially Britain, all of its ecosystems are affected by human activities, which affect many species, including predators. Under certain circumstances predation management by lethal and non-lethal means should be viewed as a viable tool for the management of both the predator and its prey species. In our study, where lethal removal was performed in a focused manner the predator population did not appear to be adversely affected overall. This allowed the targeted predator species to remain in the ecosystem, retaining its necessary role, including maintaining and possibly preventing lower order predator species from taking its place, while reducing predatory pressures on certain prey species at critical times and places.

Although the primary focus of this study was with its effects on a game species, predation management can and is also considered useful for the management of non-game species. Currently predation management of feral hogs and native raccoons focused on the beaches and dunes of Cumberland Island, Georgia during the sea turtle nesting season has resulted in a reduction of nest predations from 66% pretreatment to 15% in the first year, and as of this year, the fourth season, less than 1%. Although not quantified, populations of raccoons on the island as a whole have not dropped noticeably, if at all (D. Hoffman pers. comm.). Although this example is useful, it should be remembered that the effectiveness and use of predation management should be determined on a case by case basis as results from a study on the Canaveral National Seashores, Florida found removal of approximately 50% of raccoons depredating sea turtle nests had no significant effect on sea turtle nest predation rates (Ratnaswamy et al. 1997).

In conclusion, predation is a process affected by numerous factors relative to the prey species and the predators. At the completion of the full study we should be able to tease apart some of those factors and develop better management programs as a result.

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