DIET, AGE, AND REPRODUCTION OF MESOMAMMALIAN PREDATORS IN RESPONSE TO INTENSIVE REMOVAL DURING THE QUAIL NESTING SEASON

by

BRIAN NORMAN SCHOCH

(Under the Direction of ROBERT J. WARREN)

ABSTRACT

While much emphasis has been placed on documenting the response of game populations to predator removal efforts, less thought has been afforded to the effects of removal upon the predator communities. We hypothesized that intensive removal during the quail nesting season would alter diets, decrease the mean age, and increase reproductive performance within the predator community. Mesomammalian predators were removed during 1 March to 1 September 2001 and were considered “pre-removal” samples. Removal treatments were repeated during 1 March to 1 September 2002 and were considered “post-removal” samples. Dietary items contained in stomachs from captured raccoons (*Procyon lotor*), opossums (*Didelphis virginiana*), bobcats (*Lynx rufus*), and coyotes (*Canis latrans*) were consistent with findings from previously published research. Food habits data in 2002 were similar to those in 2001. Mean age of captured predators decreased in 2002 as compared to 2001. Reproductive indices for 2002 were similar to those for 2001.

INDEX WORDS: Age, Bobcat, Coyote, Diet, Opossum, Predator, Raccoon, Removal, Reproduction

DIET, AGE, AND REPRODUCTION OF MESOMAMMALIAN PREDATORS IN RESPONSE TO INTENSIVE REMOVAL DURING THE QUAIL NESTING SEASON

by

BRIAN NORMAN SCHOCH

B.S.F.R., The University of Georgia, 2001

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

2003

DIET, AGE, AND REPRODUCTION OF MESOMAMMALIAN PREDATORS IN RESPONSE TO INTENSIVE REMOVAL DURING THE QUAIL NESTING SEASON

by

BRIAN NORMAN SCHOCH

Approved:

Major Professor:	Robert J. Warren
Committee:	L. Michael Conner Steven B. Castleberry Jay Shelton

Electronic Version Approved:

Maureen Grasso
Dean of the Graduate School
The University of Georgia
May 2003

DEDICATION

My thesis is dedicated to my family. Mom and Dad, I could never be thankful enough for everything that you provided for me in my youth. Mom, thanks for always being willing to endure my so many, “One more casts.” Thanks for reading to me as a child, and creating a love of learning and adventure in me. Dad, I cannot imagine what I would have become without you instilling your love of the woods and waters in me. Thank you for taking the time to teach me about fishing, hunting, and respect and love for nature. Thanks to you both for always being there for me. I love you both. Brett and Brandi, may God bless you both as He has blessed me, you both certainly deserve it.

Jenn, you complete me. I cannot imagine life without you. Thank you for loving me for who I am, and enduring all of my varied outdoor pursuits. Thank you for seeing me through my darkest hours. I know that was frightening for you, but still you gave me strength. We are so fortunate to be blessed with our two beautiful children. Hunter and Brooke, I thank God for giving me the pleasure of being your dad. I only hope that through my efforts, and those of my colleagues, wild places will continue to exist for you both to enjoy growing up, and for your children to enjoy. I love you both, and will always give you my best.

ACKNOWLEDGMENTS

I'd like to sincerely thank my "co-major" professors, Dr. Bob Warren and Dr. Mike Conner for allowing me the pleasure of working with them. I feel quite fortunate to have had such esteemed supervision. Dr. Warren, thanks for always having an "open door", and listening to my questions and problems. I would also like to thank Drs. Steven Castleberry, and Jay Shelton for their time and advice while serving as members of my committee. Much gratitude is due to Doug Hall for thinking of me at the inception of this project, and for assembling such a fine field crew in south Georgia.

I am grateful to the Daniel B. Warnell School of Forest Resources at the University of Georgia, the Joseph W. Jones Ecological Research Center, the Robert W. Woodruff Foundation, and USDA-Georgia Wildlife Services for financial support.

A great deal of thanks to the south Georgia Wildlife Services crew. Thanks to Shane Drew, J. C. Griffin, Daymond Hughes, and Bubba White for their help in the field. Bubba, Shane, and J.C., thanks for housing me on my many trips south, and always doing your best to keep me entertained. I surely enjoyed all of the hunting and fishing that we were able to squeeze into those trips. Thanks to both the White family and the Drew family, for opening up their homes to me, and feeding me on more than one occasion.

Thanks to all of those who served as my second set of hands in the laboratory. Jenn, Mom, Dad, Brett, Brandi, and Bubba, I know that you probably could have found something to do that was less offensive to the olfactory system, but you helped me, nonetheless. I am eternally grateful to you all for significantly boosting my productivity.

Once again, you proved that my family and friends will always be there for me. Thanks also to Ronnie, Pat, and Sarah Cail, my "other" family, for always offering to take care of the babies so Jenn could help me.

Jenn, thanks for being the most beautiful, understanding, wonderful, helpful woman in the world. I could not have done this without your help and support. I'll never know what I did to deserve a wife who is as wonderful as you are!

Mom and Dad, thanks for always supporting me, assuming whatever role was necessary to ensure my success. Ronnie and Pat, thank you for all of your support, thank you for raising the strong, brilliant, beautiful woman who is now my wife. I am so grateful to my cousin, Jeff Teeple, for enduring my rantings, and guiding me in statistics (as well as calculus, in an earlier life). Thanks for your time and patience, you are a wonderful teacher. I am evermore fortunate to have a plethora of loving, caring, helpful people in my life.

Thanks is also due to Gary Matson and the fine folks at Matson's Laboratory for their advice on teeth-pulling, and timely cementum age analysis.

Finally, I thank God, ceaselessly, for all of my blessings. I am thankful for all of the opportunities and experiences that You have chosen to show me. You have seen me through difficult times, and have always been there for me in times of despair. I thank You, Lord, for all of the good things in my life. I thank You for showing me how precious, fragile, and finite this life is, and I thank You for allowing me to live it.

TABLE OF CONTENTS

Page

LIST OF TABLES

CHAPTER 1

INTRODUCTION, LITERATURE REVIEW, AND THESIS FORMAT

Introduction

Land managers on southern U.S. plantations have long considered all mammalian predators to be a threat to the northern bobwhite quail (*Colinus virginianus*). Managers, therefore, have often targeted predators such as raccoons (*Procyon lotor*), opossums (*Didelphis virginianus*), bobcats (*Lynx rufus*), and coyotes (*Canis latrans*) in removal efforts. While there have been a number of predator diet studies conducted in the Southeast, relatively few studies have occurred on lands managed specifically for quail (Miller and Speake 1978). Therefore, research is needed to document the diets of mammalian predators on areas managed intensively for quail, and to assess the potential impacts each predator species may have upon the quail population. If predator removal efforts are being conducted, then the population-scale response of the targeted animals also needs to be quantified. This is an important issue because removal of predators from an ecosystem can have secondary effects that extend beyond effects on the prey species of concern (Paine 1969, Estes and Palmisiano 1974, Palomares et al. 1995, Henke and Bryant 1999).

Predator control and predation

Predator control efforts attempt to suppress predator populations to alleviate predation impacts on specific prey species (Reynolds and Tapper 1996). For centuries, lethal removal of predators has been a popular way to increase recruitment of game species and protect domestic livestock (Reynolds and Tapper 1996). The USDA-Georgia Wildlife Services' Wildlife Management and Gamebird Restoration Project, from which this project descends, involves the removal of mammalian carnivores, yet other species (e.g., rat snakes, cotton rats, etc.) are also reported to depredate nests (Stoddard 1931, Simpson 1976, Hawthorne 1983, Aldrich and Endicott 1984, Wheeler 1984, Farnsworth and Simons 2000, Staller 2001). There is evidence that top carnivores suppress smaller predators, which results in increased faunal diversity (Palomares et al. 1995, Rogers and Caro 1998, Courchamp et al. 1999). In southwestern Georgia, apex predators such as bobcats and coyotes may actually play a role in reducing nest predation on quail by suppressing smaller predators (Sovada et al. 1995, Rogers and Caro 1998, Courchamp et al. 1999). Implicit in the aim of predator control is a belief that predators ordinarily limit the productivity, juvenile survival and/or breeding density of the prey species, so that prey availability to humans is reduced (Reynolds and Tapper 1996).

Age distribution and reproductive output of predators can be affected by intensive harvest. Populations subjected to intensive harvest are often skewed toward younger animals (Trautman et al. 1974, Andelt 1985, Windberg et al. 1985, Gese et al. 1989, Windberg 1995). Animal age is known to influence movement patterns (Conner et al. 1999) and diet (Fritts and Sealander 1978). Younger predators generally cover more territory and consume prey that is more easily captured. Many predator populations are self-regulating (Sandell 1989). In high-quality habitat, a decline in predator numbers is generally followed by increased reproduction (Sandell 1989). Therefore, assessment of age structure and reproductive output of predators in response to a removal effort is important for assessing the overall value of such an effort and may well prove useful in explaining responses of prey populations to predator removal.

Many studies have identified the raccoon as an opportunistic omnivore (Dexter 1951, Schoonever and Marshall 1951, Johnson 1970, Greenwood 1981). Raccoons also have been identified as a significant nest predator of gamebirds such as wild turkey

(*Meleagris gallopavo*) and quail (Cook 1972, Baker 1978, Miller and Leopold 1992, Peoples et al. 1995).

The opossum is another opportunistic omnivore (Hamilton 1951, Dexter 1951, Hume 1999). While considered more a scavenger than predator, recent evidence has shown that the opossum can prey not only upon eggs contained within a quail nest, but can successfully prey upon the incubating hen as well (R. Thornton, Tall Timbers Research Station, pers. comm.).

Food habits of bobcats have been studied in some parts of their range, and regional differences are reported (Young 1958). It is accepted that the bobcat is highly carnivorous, and in the southeastern U.S., should be considered an apex predator (Rogers and Caro 1998). Bobcats exhibit a difference in prey selection between sexes (Fritts and Sealander 1978). Rats and mice appear more frequently in female bobcat diets than in males, while deer remains are found more frequently in males than in females (Fritts and Sealander 1978). Bobcats most frequently prey upon rodents and lagomorphs found within their range (Beasom and Moore 1977, Fritts and Sealander 1978, Miller and Speake 1978). Miller and Speake (1978) reported that the bobcat is not an important predator of the northern bobwhite on managed quail lands. However, Maehr and Brady (1986) found that quail made up a significant portion of the winter diet in Florida bobcats.

Coyotes are seasonally omnivorous, opportunistic predators and scavengers (Sperry 1941, Litvaitis and Shaw 1980, Wooding et al. 1984, Blanton and Hill 1989). They are documented to take a variety of animal prey, including lagomorphs, rodents, birds, ungulates, and domestic livestock (Sperry 1941, Litvaitis and Shaw 1980, Wooding et al. 1984, Blanton and Hill 1989). Once considered an animal of the western plains, coyotes have increased dramatically in the southeastern U.S. since 1972 and now occur in every southeastern state (Gipson 1978, Hill et al. 1987). “Exotic” predators are known to be particularly devastating to their introduced ecosystems (Estes 1996, Cote and Sutherland 1997).

Detailed studies comparing unexploited (populations in which humans do not remove animals) to exploited predator populations are few. For coyotes, some demographic differences are apparent (Andelt 1985, Windberg 1995, Windberg et al. 1997). Unexploited coyote populations typically have older age structures, high adult survival rates, low reproductive rates (particularly among yearlings), and low rates of recruitment into the adult population (Andelt 1985, Windberg et al. 1985, Gese et al. 1989, Windberg 1995). Populations under heavy exploitation have younger age structures, lower adult survival rates, greater yearling reproduction, and increased litter size (Knowlton 1972, Berg and Chesness 1978). When food availability is high, emigration decreases, litter size increases, and pack size increases (Gese et al 1996a, 1996b). This increase in litter size in response to lower coyote density is known as compensatory reproduction. Compensatory reproduction may occur in other species being exploited on the study area. Connolly and Longhurst (1975) developed a simulation model and determined that a minimum annual removal of 75% of the breeding population of coyotes was needed to consistently lower coyote density.

In recent years, populations of bobwhite quail have dwindled (Brennan 1991). Since the 1960’s, northern bobwhite populations have declined as much as 70% over the southeastern U.S., which has led some biologists to predict that quail populations may decline to unhuntable levels by the year 2005 (Brennan 1991). Land use changes that have eliminated large areas of bobwhite habitat are largely to blame (Brennan 1991). Many believe that predators also play a role in this decline, and have targeted predators for removal, particularly on lands that are managed for quail.

Traditionally, mammalian predators (raccoon, opossum, bobcat, etc.) were harvested during the winter trapping season. This was done in order to provide the highest quality furs. As fur markets have declined during the last 20 years, the use of trapping as a management tool also has declined. In Georgia alone, the number of licensed trappers has declined from 3,560 during the 1979-80 trapping season to only 352 during 1999-2000 (Todd Holbrook, Georgia Wildlife Resource Division, pers. comm.). Lower harvest pressure and continued land use changes have allowed predator populations to increase and, in some cases, attain historically high densities (Peoples et al. 1995). Cases involving the illegal use of poisoned eggs to kill these overabundant predators demonstrate the extreme desperation felt by some landowners (as evidenced in a Wall Street Journal article, October 27, 1999). Therefore, research in this area is needed because we currently do not understand all of the interactions among gamebirds, nongame species, and their predators.

Objectives and thesis format

If predator control is being utilized, it is crucial that predator populations be monitored to quantify the population-scale response of the targeted predators. Much emphasis has been placed upon the response of quail populations to large-scale predator removal, but very little has been focused upon the response of the predator populations.

Additionally, research is lacking about predator diets on lands managed intensively for quail (Miller and Speake 1978).

This study was developed to examine the impacts that predator-removal has on a select predator community. We examined diet composition of the mammalian predator community present on 2 study sites, and determined the utilization of quail and quail eggs. We scrutinized predator diet, community age-structure, and reproduction in response to intensive removal during the quail nesting season. We considered samples from predators removed during 2001 to represent "pre-removal" data. We compared these data to those obtained during 2002 (i.e., "post-removal"), because it would potentially reflect the effect of the removal treatment. These comparisons allowed me to make inferences regarding the effects of predator removal on the predator community present on the study sites. This information was used to make recommendations regarding predator management on intensely managed quail plantations.

This thesis is organized in 3 chapters. Chapter 1 provides background information concerning predation management, information concerning the predators that will be examined in this study, and published data on the parameters that we examined. Chapter 2 is in manuscript form (to be submitted to Wildlife Society Bulletin), and is the main body of the thesis. Chapter 3 summarizes my findings, and presents management recommendations to those considering predation management.

Literature cited

Aldrich, J. W., and C. G. Endicott. 1984. Black rat snake predation on giant Canada goose eggs. Wildlife Society Bulletin 12:263-264.

Andelt, W. F. 1985. Behavioral ecology of coyotes in south Texas. Wildlife Monographs 94:145.

Baker, B. W. 1978. Ecological factors affecting wild turkeys nest predation on South Texas rangelands. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 32:126-136.

Beasom, S. L. and R. A. Moore. 1977. Bobcat food habit response to a change in prey abundance. Southwest Naturalist 21:451-457

Berg, W. E. and R. A. Chesness. 1978. Ecology of coyotes in northern Minnesota, pages 229-247 *in* M. Bekoff, editor. Coyotes: biology, behavior and management. Academic Press, New York, N.Y.

Blanton, K. M. and E. P. Hill. 1989. Coyote use of white-tailed deer fawns in relation to deer density. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 43:470-478.

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:544-555.

Conner, L. M., B. Plowman, B. D. Leopold, and C. Lovell. 1999. Influence of time-in-residence on home range and habitat use of bobcats. Journal of Wildlife Management 63:261-269.

Connolly, G. E., and W. M. Longhurst. 1975. The effects of control on coyote populations: a simulation model. University of California Division of Agricultural Science Bulletin 1872:1-37.

Cook, R. L. 1972. A study of nesting turkeys in the Edwards Plateau of Texas. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commission 26:236-244.

Cote, I. M., and W. J. Sutherland. 1997. The effectiveness of removing predators to protect bird populations. Conservation Biology 11:395-405.

Courchamp, F., M. Langlais, and G. Sugihara. 1999. Cats protecting birds: modeling the mesopredator release effect. Journal of Animal Ecology 68:282-292.

Dexter, R. W. 1951. Earthworms in the winter diet of the opossum and raccoon. Journal of Mammalogy 32:464.

Estes, J. A., and J. F. Palmisano. 1974. Sea otters: their role in structuring nearshore communities. Science 185:1058-1060.

Estes, J. A. 1996. Predators and ecosystem management. Wildlife Society Bulletin 24:390-396.

Farnsworth, G. L., and T. R. Simons. 2000. Observations of wood thrush nest predators in a large contiguous forest. Wilson Bulletin 112:82-87.

Fritts, S. H., and J. A. Sealander. 1978. Diets of bobcats in Arkansas with special reference to age and sex differences. Journal of Wildlife Management 42:533-539.

Gese, E. M., O. J. Rongstad, and W. R. Mytton. 1989. Population dynamics of coyotes in southeastern Colorado. Journal of Wildlife Management 53:174-181.

Gese, E. M., R. L. Ruff, and R. L. Crabtree. 1996a. Social and nutritional factors influencing the dispersal of resident coyotes. Animal Behavior 52:1025-1043.

Gese, E. M., R. L. Ruff, and R. L. Crabtree. 1996b. Foraging ecology of coyotes (*Canis latrans*): the influence of extrinsic factors and a dominance hierarchy. Canadian Journal of Zoology 74:769-783.

Gipson, P. S. 1978. Coyotes and related *Canis* in the southeastern United States with a comment on Mexican and Central American *Canis*. Pages 191-208 *in* M. Bekoff, ed. Coyotes: biology, behavior, and management. Academic Press, New York, N.Y. 384pp.

Greenwood, R. J. 1981. Foods of prairie raccoons during the waterfowl nesting season. Journal of Wildlife Management 45:754-760.

Hamilton, W. J. 1951. The food of the opossum in New York state. Journal of Wildlife Management 15:258-264.

Hawthorne, D. W. 1983. Cotton rats. Pp. B 85-87 *in* R. A. Timm, Editor. Prevention and control of wildlife damage. Institute of Agriculture and Natural Resources, University of Nebraska, Lincoln.

Henke, S. E. and F. C. Bryant. 1999. Effects of coyote removal on the faunal community in western Texas. Journal of Wildlife Management 63:1066-1081.

Hill, E. P., P. W. Sumner and J. B. Wooding. 1987. Human influences on range expansion of coyotes in the southeast. Wildlife Society Bulletin 15:521-524.

Hume, I. D. 1999. Marsupial Nutrition. Cambridge University Press. Cambridge, UK.

Johnson, S. A. 1970. Biology of the raccoon in Alabama. Alabama Cooperative Wildlife Research Unit. Department of Conservation. Alabama. USA.

Knowlton, F. F. 1972. Preliminary interpretations of coyote population mechanics with some management implications. Journal of Wildlife Management 36:369-382.

Litvaitis, J. A., and J. H. Shaw. 1980. Coyote movements, habitat use, and food habits in southwestern Oklahoma. Journal of Wildlife Management 44:62-68.

Maehr, D. S, and J. R. Brady. 1986. Food habits of the bobcat in Florida. Journal of Mammalogy 67:133-138.

Miller, J. E., and B. D. Leopold. 1992. Population influences: Predators. Pages 119-128 *in* J. D. Dickson, editor. The wild turkey: biology and management. Stackpole, Mechanicsburg, Pennsylvania, USA.

Miller, S. D., and D. W. Speake. 1978. Prey utilization by bobcats on quail plantations in southern Alabama. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 32:100-111.

Paine, R. T. 1969. A note on trophic complexity and community stability. American Naturalist. 103:91-93.

Palomares, F. P. Gaona, P. Ferreras, and M. Delibes. 1995. Positive effects on game species of top predators by controlling small predator populations: an example with lynx, mongooses and rabbits. Conservation Biology 9:295-305.

Peoples, J. C., D. C. Sisson, and D. W. Speake. 1995. Mortality of wild turkey poults in coastal plain pine forests. Proceeding of the Annual Conference of Southeastern Associations of Fish and Wildlife Agencies 49:448-453.

Reynolds, J. C., and S. C. Tapper. 1996. Control of mammalian predators in game management and conservation. Mammal Review 26:127-156.

Rogers, C. M. and M. J. Caro. 1998. Song sparrows, top carnivores, and nest predation: a test of the mesopredator release hypothesis. Oecologia 116:227-233.

Sandell, M. 1989. The mating tactics and spacing patterns of solitary carnivores. Pages 164-182 *in* J.L. Gittleman, editor. Carnivore Behavior, Ecology, and Evolution. Cornell University Press, Ithaca, New York.

Schoonover, L. J., and W. H. Marshall. 1951. Food habits of the raccoon in north-central Minnesota. Journal of Mammalogy 32:422-428.

Simpson, R. C. 1976. Certain aspects of the bobwhite quail's life history and population dynamics in southwest Georgia. Georgia Department of Natural Resources, Game and Fish Division. Technical bulletin WL1. Social Circle, Georgia.

Sovada, M. A., A. B. Sargeant, and J. W. Grier. 1995. Differential effects of coyotes and red foxes on duck nest success. Journal of Wildlife Management 59:1-9.

Sperry, C. C. 1941. Food habits of the coyote. U. S. Department of the Interior, Fish and Wildlife Service Wildlife Resource Bulletin 4:1-70.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation and increase. C. Scribner's Sons, New York, NY.

Staller, E. L. 2001. Identifying predators and fates of northern bobwhite nests using miniature video camera. M. S. Thesis. UGA.

Trautman, C. G., L. F. Fredrickson, and A. V. Carter. 1974. Relationship of red foxes and other predators to populations of ring-neck pheasants and other prey, South Dakota. Thirty-Ninth North American Wildlife Conference. Pages 241-253.

Wheeler, W. E. 1984. Duck egg predation by fox snakes in Wisconsin. Wildlife Society Bulletin 12:77-78.

Windberg, L. A. 1995. Demography of a high-density coyote population. Canadian Journal of Zoology 73:942-954.

Windberg, L. A., H. L. Anderson, and R. M. Engeman. 1985. Survival of coyotes in southern Texas. Journal of Wildlife Management 49:301-307.

Windberg, L. A., S. M. Ebbert, and B. T. Delly. 1997. Population characteristics of coyotes in the northern Chihuahuan desert. American Midland Naturalist 138:197-207.

Wooding, J. B., E. P. Hill, and P. W. Sumner. 1984. Coyote food habits in Mississippi and Alabama. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 38:182-188.

Young, S. P. 1958. The bobcat of North America. The Stackpole Co., Harrisburg, Pa. 193pp.

CHAPTER 2

DIET, AGE, AND REPRODUCTION OF MESOMAMMALIAN PREDATORS IN RESPONSE TO INTENSIVE REMOVAL DURING THE QUAIL NESTING SEASON[1]

---

[1] Schoch, N. B., R. J. Warren, L. M. Conner, and D. I. Hall. To be submitted to Wildlife Society Bulletin.

Abstract

Many landowners in southwestern Georgia believe that intensive removal efforts to control mesomammalian predators will enhance wildlife production on their lands. Our study was designed to assess the effects of intensive removal treatments on the mesomammalian predator community of 2 plantations ranging in size from 1,200-1,400 ha. We hypothesized that intensive removal treatments during the quail nesting season would alter diets, decrease the mean age, and increase reproductive performance within the predator community. Mesomammalian predators were removed during 1 March to 1 September 2001 and were considered "pre-removal" samples. Removal treatments were repeated during 1 March to 1 September 2002 and were considered "post-removal" samples. We removed 882 animals during the 2-year period, most of which were raccoons (*n*=428) and opossums (*n*=349). Dietary items contained in stomachs from captured raccoons (*Procyon lotor*), opossums (*Didelphis virginiana*), bobcats (*Lynx rufus*), and coyotes (*Canis latrans*) were consistent with findings from previously published research. Food habits data in 2002 were similar to those in 2001. There was a trend for decreasing use of the quail resource (quail and quail eggs) in 2002 vs. 2001. Mean ages of collected raccoons and opossums were younger ($P<0.05$; t-test) in 2002 (1.9 years and 2.9 years, respectively) than in 2001 (2.5 years and 4.4 years, respectively). Number of corpora lutea, fetuses, and placental scars observed in mesomammalian predators collected in 2002 were not different from those observed in 2001. Thus, we noted no evidence for a dietary shift or compensatory reproduction in response to the removal treatments. We believe the decrease in mean age of the raccoon and opossum populations resulted from increased sub-adult immigration into the removal areas.

Introduction

For centuries, lethal control of predators has been a popular way to increase recruitment of game species and protect domestic livestock (Reynolds and Tapper 1996). Due to the drastic declines that northern bobwhite (*Colinus virginianus*) populations have undergone (Brennan 1991), managers of northern bobwhite (hereafter, quail) plantations have often targeted mammalian predators for removal. While predators often shoulder the blame for the decline in quail populations, little research exists on predator diets and demographics on areas managed specifically for quail (Miller and Speake 1978). Much emphasis has been placed on documenting quail population response to predator removal efforts, but less concern has been afforded to the effects upon the predator communities and the potential impacts upon the ecosystem. Manipulation of predator populations can create secondary impacts that extend beyond effects on the prey species of concern (Paine 1969, Estes and Palmisano 1974, Palomares et al. 1995, Henke and Bryant 1999).

In this study, we examined the predators harvested in conjunction with a larger study of quail population responses to predator removal. The objectives of our project were to provide a descriptive analysis of predator diet during the quail nesting season, quantify predator usage of the quail resource (both quail and quail eggs), and examine the dietary changes of predators in response to intensive predator removal. Additionally, we assessed changes in the demographics and fecundity of selected predator populations in response to predator removal. Predator removal occurred during 2 years—2001 and 2002. We considered samples from predators removed during 2001 to represent "pre-removal" data. We compared these data to those obtained during 2002 (i.e., "post-removal"), because it would potentially reflect the effect of the removal treatment.

Study Areas

This study was conducted on 2 plantations in southwestern Georgia: Pebble Hill Plantation, and Pinebloom Plantation. Pebble Hill Plantation consists of approximately 1,246 ha, and is located in Thomas and Grady counties, Georgia. Habitat consists primarily of southern upland forest with the main overstory component being longleaf pine (*Pinus palustris*) and loblolly pine (*Pinus taeda*). Dominant understory components are wiregrass (*Aristida stricta*) and old-field vegetation. The hardwood component consists primarily of live oak (*Quercus virginiana*), southern red oak (*Quercus falcata*), water oak (*Quercus nigra*), white oak (*Quercus alba*), sweetgum (*Liquidambar styraciflua*), and blackgum (*Nyssa sylvatica*). The bulk of the hardwood component lies within the riparian areas interspersed throughout the property. Pinebloom Plantation is located in Baker County, Georgia. The portion on which this study was conducted was approximately 1,400 ha. Habitat consists primarily of slash pine (*Pinus elliottii*) overstory with an understory component of old-field vegetation. Fallow fields are interspersed across the property, and are dominated by ragweed (*Ambrosia* spp.), due to a regime of fall disking. Forests on both sites may undergo commercial thinning, annual fire, hardwood mid-story removal, brush mowing, and disking. Additionally, game management practices such as supplemental feeding of grain and planting of food plots occur in varying amounts on both properties according to the direction of the property managers. Intensive predator removal was not practiced on either of these sites prior to initiation of this study.

Methods

Predator collection

Personnel from USDA-Georgia Wildlife Services removed mid-sized mammalian predators from 1 March to 1 September during 2001 and 2002. Predators were harvested using foothold traps, live-catch traps, conibear traps, and spotlighting at night with firearms.

Sacrificed predators were processed and samples collected were frozen on the day of capture for later analysis. Processing included recording the sex of animals, date of removal, and method of removal. Stomachs and lower mandibles were removed from the carcasses, as were female reproductive tracts. These materials were placed in freezer bags, tagged with a unique, identifying number, and frozen.

Food habits

After thawing, stomachs were incised and contents were emptied into 3 nested sieves: U.S. standard 12, 18, and 20 mesh, respectively. Contents were washed through the sieves with hot water to facilitate segregation and degreasing (Korschgen 1969, Litvaitis et al. 1996). Prey remains were identified with aid of reference collections of hair, seeds, feathers, and bones obtained from species inhabiting the study areas. Additionally, mammalian hair keys (Spiers 1973, Moore et al. 1974), reference hair slides, and microscopic hair photos were used to identify mammalian remains. To aid in identifying quail remains, a reference collection of quail feathers, body parts, and egg shells was assembled. Upon identification of contents, like items were separated and an ocular estimate of percent gut content was recorded for each item. To reduce potential observer bias, all stomach analyses were performed by the lead author.

All food habits data were entered into an Excel spreadsheet and frequency of occurrence for all food items was calculated. Species were pooled into taxonomic or abundance groupings to facilitate statistical analyses. Items occurring in greatest frequency of occurrence were examined using Chi-square (Bishop et al., 1975) to examine differences in proportion of prey usage between years on each site.

To assess overall predator utilization of the quail resource, predator species were pooled, and frequency of occurrence of quail, quail eggs, and combined quail resource (quail and quail eggs) between years was also examined using Chi-square.

Age determination

Cementum annuli analysis has proven to be an accurate indicator of age in carnivores (Dimmick and Pelton 1994). For raccoons, opossums, bobcats, and coyotes, lower canine teeth are considered optimum for obtaining an accurate age through cementum age analysis (G. Matson, Matson's Lab, pers. comm.). Processing entailed soaking labeled jawbones in a hot water bath at 75^0 C for 2-3 hours to soften the periodontal membrane (G. Matson, Matson's Lab, pers. comm.). Lower canine teeth were then removed manually with aid of needle-nosed vise grips, taking care not to damage the root tip. Cleaning of the extracted tooth was done with a firm and thorough wiping of the tooth with a nylon mesh material. Teeth were individually packaged, labeled, and shipped to Matson's Laboratory, Milltown, Montana, for sectioning and cementum age analysis.

Age data were analyzed in SAS (SAS 1999) using t-tests. I calculated mean ages for each predator species on both study sites in both years. For raccoons and opossums, 2 means were calculated. One mean was calculated to determine the average age of the adult population (animals = 1 year old). Another mean was calculated including the juveniles removed from the population. Because an accurate approximation of age was not available for juvenile animals, all removed juveniles were considered to be 0.3 years of age. Data were log transformed to adjust for a non-normal distribution, and means were compared using t-tests, comparing 2001 data to 2002 data. Predator species were then pooled between sites to increase sample size, and again t-tests were performed, comparing the means of 2001 to those of 2002.

Among 120 known-age, land mammal teeth (12 species) processed at Matson's Laboratory, exact agreement occurred between known age and cementum age in 94 individuals; 21 were within 1 year of known age, and 5 were incorrect by more than 1 year (G. Matson, pers. comm.). To assess reliability of the cementum aging procedure in our study animals, a random blind sample of matching lower canine teeth was sent to Matson's Laboratory for cementum aging. Ages from this sample were compared to the match to determine the accuracy of the age data generated.

Reproduction

A placental scar is a pigmented area of the uterus occurring at the attachment site of a previous placenta (Harder and Kirkpatrick 1994). Placental scars from different pregnancies can easily be differentiated by color, with more recent scars being darker (Sanderson and Nalbandov 1973, Junge and Sanderson 1982, Fritzell et al. 1985, Harder and Kirkpatrick 1994). Placental scars and fetal counts can be used to estimate the number of young produced and reproductive history (Davis and Emlen 1948, Johnson 1970, Sanderson and Nalbandov 1973, Junge and Sanderson 1982, Fritzell et al. 1985, Harder and Kirkpatrick 1994). The corpus luteum (CL) is formed from ovulated follicles

(Sanderson and Nalbandov 1973, Harder and Kirkpatrick 1994). Number of CL provide an indication of ovulation rate, which is a primary indicator of reproductive success in mammalian species (Harder and Kirkpatrick 1994).

Female reproductive tracts from raccoons, bobcats, and coyotes were examined for evidence of uterine swellings, fetuses, CL, and placental scars. Fetuses were removed and examined to determine sex. If no evident uterine swellings were observed, the uterine horns were scrutinized for the presence of placental scars. Ovaries were either examined immediately for the presence of CL, or placed in a 10% formalin solution and processed after 7 days (Harder and Kirkpatrick, 1994).

An estimation of litter size was made based on counts of CL, placental scars, and fetal counts (Johnson 1970, Sanderson and Nalbandov 1973, Kramer 1996). Predator-specific and site-specific comparisons of these indices were made using t-tests, comparing 2001 data to 2002 data. Predator-specific data were then pooled between sites to increase sample size, and again t-tests were performed, comparing 2001 and 2002 data.

Results

Sample collections

We collected 882 animals for analysis during the 2-year period, 428 raccoons, 349 opossums, 68 bobcats, and 37 coyotes. Capture effort was constant from 1 March 2001 until 1 September 2001 for the first year of removal. Constant capture effort was applied from 1 March 2002 until 1 September 2002 for the second year removal effort. Capture success between years may have differed due to increased experience of trappers in 2002, as well as increased familiarity with the treatment areas.

Food habits

Raccoons. On Pinebloom Plantation, no differences (*P*>0.05) were found in frequency of occurrence between years for the following food items: grain, insects, quail, and quail eggs (Table 1). Raccoons on the PB site ate more acorns (*P*=.001) and rodents (*P*=.001), but less soft mast (*P*=.026), “other mammals” (*P*=.011), and vegetation (*P*=.001) in 2002 vs. 2001 (Table 1).

On Pebble Hill Plantation, no differences (*P*>0.05) were found in frequency of occurrence between years for the following food items: rodents, and insects (Table 1). Due to limited consumption, Chi-square analysis for quail and quail eggs was inappropriate. Raccoons on the PH site ate more acorns (*P*=.01), but less grain (*P*=.02), soft mast (*P*=.041), “other mammals” (*P*=.049) and vegetation (*P*=.018) in 2002 vs. 2001 (Table 1).

Opossums. On Pinebloom plantation, no differences (*P*>0.05) were found in frequency of occurrence between years of the following food items: soft mast, reptile/amphibians, insects, vegetation, quail and quail eggs (Table 2). Opossums ate more rodents (*P*=.026), but less grain (*P*=.048) and “other mammals” (*P*=.041) in 2002 vs. 2001.

On Pebble Hill Plantation, no differences (*P*>0.05) were found in frequency of occurrence between years of the following food items: soft mast, rodents, reptile/amphibians, insects, vegetation, quail and quail eggs (Table 2). Opossums on Pebble Hill ate less grain (P=.001) and “other mammals” (P=.005) in 2002 vs. 2001. There were no significant statistical increases in frequency of occurrence from 2001 to 2002.

Table 1. Frequency of occurrence (%) of food items for raccoons collected during 2001 and 2002 on Pinebloom (PB) and Pebble Hill (PH) Plantations, Georgia.

Site	Year	n	Grain	Acorn	Soft mast	Rodent	Other mammal	Insect	Vegetation	Quail	Quail eggs
PB	2001	122	26.2	7.4[a]	30.3[a]	4.1[a]	16.4[a]	19.7	18.9[a]	0.0	4.9
	2002	214	23.4	36.0[a]	19.6[a]	15.9[a]	7.0[a]	17.8	4.7[a]	2.8	2.3
PH	2001	60	36.7[b]	1.7[b]	25.0[b]	6.7	21.7[b]	10.0	21.7[b]	1.7	1.7
	2002	32	6.3[b]	21.9[b]	18.8[b]	6.3	9.4[b]	9.4	3.1[b]	0.0	0.0

[a] For the Pinebloom site, means between years differ significantly (*P*<0.05; Chi-square test, d.f.=1)

[b] For the Pebble Hill site, means between years differ significantly (*P*<0.05; Chi-square test, d.f.=1)

Table 2. Frequency of occurrence (%) of food items for opossums collected during 2001 and 2002 on Pinebloom (PB) and Pebble Hill (PH) Plantations, Georgia.

Site	Year	n	Grain	Soft mast	Rodent	Other mammal	Reptile/ amphibian	Insect	Vegetation	Quail	Quail eggs
PB	2001	37	18.9[a]	21.6	2.7[a]	37.8[a]	13.5	32.4	10.8	0.0	2.7
	2002	129	7.8[a]	19.4	17.1[a]	27.1[a]	12.4	30.2	12.4	3.9	2.3
PH	2001	64	23.4[b]	20.3	17.2	28.1[b]	6.3	39.1	24.7	1.6	1.6
	2002	119	3.4[b]	13.5	20.2	11.8[b]	9.2	31.9	18.5	0.8	0.8

[a] For the Pinebloom site, means between years differ significantly ($P<0.05$; Chi-square test, d.f.=1)

[b] For the Pebble Hill site, means between years differ significantly ($P<0.05$; Chi-square test, d.f.=1)

Bobcats. On Pinebloom Plantation, no differences (P>0.05) were found in frequency of occurrence between years of the following prey items: rodents, rabbits, feral hogs, “other mammals” and quail (Table 3). Due to limited sample sizes, and limited consumption, Chi-square analysis for deer and quail eggs was inappropriate. Deer were not present in stomach contents of bobcats from Pinebloom, and while there were 3 separate instances of quail eggs found in 2001, no egg particles were found in stomach samples in 2002. One gray rat snake (*Elaphe obsoleta spiloides*), a known quail egg predator, was found in a 2001 stomach sample from a bobcat. A mature timber rattlesnake (*Crotalus horridus*) was found in a 2002 stomach sample from a bobcat.

On Pebble Hill Plantation, no differences (P>0.05) were found in frequency of occurrence between years for rodents or deer (Table 3). Due to limited sample sizes, and limited consumption, Chi-square analysis for rabbits, quail, and quail eggs was inappropriate. No test was performed on usage of feral hogs, as hogs were not present on the PH site. A mature Eastern diamondback rattlesnake (*Crotalus adamanteus*) was found in a 2001 stomach sample from a bobcat.

Coyotes. On Pinebloom Plantation, no differences (P>0.05) were found in frequency of occurrence between years for the following food items: rodents, rabbits, deer, hog, and soft mast (Table 4). Due to limited sample sizes, and limited consumption, Chi-square analysis for quail eggs was inappropriate. While no quail usage was documented for either year, remains from an adult Eastern wild turkey (*Meleagris gallopavo*) were found in a 2002 stomach sample from a coyote.

Table 3. Frequency of occurrence (%) of prey items for bobcats collected during 2001 and 2002 on Pinebloom (PB) and Pebble Hill (PH) Plantations, Georgia.

Site	Year	n	Rodent	Rabbit	Deer	Hog	Other mammal	Quail	Quail eggs
PB	2001	16	56.3	43.8	0.0	25.0	12.5	12.5	18.8
	2002	36	65.8	26.3	0.0	7.9	5.3	5.3	0.0
PH	2001	9	66.7	22.2	44.4	0.0	11.1	0.0	0.0
	2002	5	40.0	0.0	40.0	0.0	0.0	0.0	0.0

On Pebble Hill Plantation, Chi-square analyses for all food items were inappropriate due to small sample sizes. While we found no evidence of quail consumption from either year, Eastern wild turkey poults were found in 2 separate stomach samples from Pebble Hill coyotes in 2002.

Use of quail by all predators. On Pinebloom Plantation, no differences (*P*>0.05) were found between years when predator species were pooled and frequency of occurrence for quail, and combined quail resource (quail and quail eggs) were analyzed (Table 5). Overall, predators on the PB site ate less quail eggs (*P*=0.05) in 2002 vs. 2001.

On Pebble Hill Plantation, no differences (*P*>0.05) were found between years when predator species were pooled and frequency of occurrence for quail, quail eggs, and combined quail resource were analyzed (Table 5). While not found to be statistically significant, there was a trend for frequency of occurrence in all of these categories to decrease in 2002 vs. 2001.

Pooling the 2 sites, no differences were found between years in frequency of occurrence of quail, quail eggs, and combined quail resource (Table 5). While not statistically significant, frequency of occurrence of quail in predator diets appeared to increase in 2002 vs. 2001, while there appeared to be a decrease in frequency of occurrence of quail eggs and combined quail resource.

Table 4. Frequency of occurrence (%) of food items for coyotes collected during 2001 and 2002 on Pinebloom (PB) and Pebble Hill (PH) Plantations, Georgia.

Site	Year	n	Rodent	Rabbit	Deer	Hog	Other mammal	Soft mast	Quail	Quail eggs
PB	2001	8	37.5	12.5	12.5	37.5	0.0	37.5	0.0	0.0
	2002	14	50.0	14.3	28.6	14.3	0.0	7.1	0.0	14.3
PH	2001	2	0.0	0.0	50.0	0.0	0.0	0.0	0.0	0.0
	2002	13	30.8	7.7	15.4	0.0	23.1	15.4	0.0	7.7

Table 5. Frequency of occurrence (%) of quail and quail eggs pooling all predators collected during 2001 and 2002 on Pinebloom (PB) and Pebble Hill (PH) Plantations, Georgia.

Site	Year	n	Quail	Quail eggs	Quail & quail eggs
PB	2001	183	1.1	5.5[a]	6.5
	2002	395	3.3	2.5[a]	5.8
PH	2001	135	1.5	1.5	3.0
	2002	169	0.6	1.2	1.8
Pooled	2001	318	1.3	3.8	5.0
	2002	564	2.5	2.1	4.6

[a] For the Pinebloom site, means between years differ significantly ($P<0.05$; Chi-square test, d.f.=1)

Age

Reliability of the cementum aging procedure. Cementum age data from the corresponding lower canine tooth matched that returned from the blind sample in 25 of 26 cases. If this ratio was maintained throughout the samples, an accuracy rate of 96% was accomplished in the estimation of age from removed predators.

Raccoons. On Pinebloom Plantation, a difference (*P*=0.001) was found when comparing mean age of adult raccoons removed in 2002 vs. 2001 (Table 6). Mean age of the adult population decreased from 2.4 years in 2001, to 2.0 years in 2002. When juveniles were included in the comparison, there was no difference in age.

On Pebble Hill Plantation, a difference (*P*=0.007) was found when comparing mean age of adult raccoons removed in 2002 vs. 2001 (Table 6). Mean age of the adult population decreased from 2.6 years in 2001, to 1.4 years in 2002. When juveniles were included in the comparison, ages remained different (*P*=0.001).

After pooling the raccoon age data from both sites, a difference (*P*=0.001) was found when comparing mean age of adult raccoons removed in 2002 vs. 2001 (Table 6). Mean age of the adult population decreased from 2.5 years in 2001, to 1.9 years in 2002. When juveniles were included in the comparison, a difference (*P*=0.001) was again noted.

Opossums. On Pinebloom Plantation, a difference (*P*=.006) was found when comparing the mean age of adult opossums removed in 2002 vs. 2001 (Table 6). Mean age of the adult population decreased from 4.8 years in 2001, to 3.1 years in 2002. When juveniles were included in the comparison, no difference (*P*>0.05) was observed.

Table 6. Age data from raccoons and opossums collected during 2001 and 2002 on Pinebloom (PB) and Pebble Hill (PH) Plantations, Georgia.

			Adult-age			Adult-age with juveniles		
Species	Site	Year	n	x	SE	n	x	SE
Raccoons	PB	2001	83	2.4[a]	0.17	102	2.0	0.16
		2002	170	2.0[a]	0.15	194	1.8	0.14
	PH	2001	52	2.6[b]	0.28	52	2.6[b]	0.28
		2002	19	1.4[b]	0.19	23	1.2[b]	0.18
	Pooled	2001	135	2.5[c]	0.15	154	2.2[c]	0.14
		2002	189	1.9[c]	0.14	217	1.7[c]	0.12
Opossums	PB	2001	23	4.8[a]	0.52	29	3.8	0.54
		2002	92	3.1[a]	0.14	124	2.4	0.15
	PH	2001	38	4.2[b]	0.29	49	3.3	0.33
		2002	93	2.6[b]	0.10	112	2.2	0.12
	Pooled	2001	61	4.4[c]	0.27	78	3.5[c]	0.29
		2002	185	2.9[c]	0.09	236	2.3[c]	0.10

---

[a] For the Pineblooom site, means between years differ significantly ($P<0.05$; t-test, log transformation, d.f. = $(n_1+n_2)-2$)

[b] For the Pebble Hill site, means between years differ significantly ($P<0.05$; t-test, log transformation, d.f. = $(n_1+n_2)-2$)

[c] Pooling data from both PB and PH sites, means between years differ significantly ($P<0.05$; t-test, log transformation, d.f. = $(n_1+n_2)-2$)

On Pebble Hill Plantation, a difference (*P*=0.001) was found when comparing the mean age of adult opossums removed in 2002 vs. 2001 (Table 6). Mean age of the adult population decreased from 4.2 years in 2001, to 2.6 years in 2002. When juveniles were included in the comparison, no difference (*P*>0.05) was noted.

After pooling the opossum age data from both sites, a difference (*P*=0.001) was found when comparing the mean age of adult opossums removed in 2002 vs. 2001 (Table 6). Mean age of the adult population decreased from 4.4 years in 2001, to 2.9 years in 2002. When juveniles were included in the comparison, a difference (*P*=0.027) was again noted.

Bobcats. On Pinebloom Plantation, no significant differences (*P*>0.05) were found in the mean age of adult bobcats removed in 2002 vs. 2001 (Table 7). Only 2 juvenile bobcats were captured on the PB site during the duration of the study, so no comparison was made with juveniles included.

On Pebble Hill Plantation, no significant differences (*P*>0.05) were found in the mean age of adult bobcats removed in 2002 vs. 2001 (Table 7). No juvenile bobcats were captured on the PH site during the duration of the study.

Coyotes. On Pinebloom Plantation, no significant differences (*P*>0.05) were found in the mean age of adult coyotes removed in 2002 vs. 2001 (Table 7). Only 2 juvenile coyotes were captured on the PB site during the duration of the study, therefore no comparison was made with juveniles included.

On Pebble Hill Plantation, no significant differences were found in the mean age of adult coyotes removed in 2002 vs. 2001 (Table 7).

Table 7. Age data from bobcats and coyotes collected during 2001 and 2002 on Pinebloom (PB) and Pebble Hill (PH) Plantations, Georgia.

Species	Site	Year	n	x	SE
Bobcats	PB	2001	12	2.2	0.42
		2002	34	1.8	0.18
	PH	2001	10	2.9	0.98
		2002	5	2.0	0.63
	Pooled	2001	22	2.5	0.49
		2002	39	1.8	0.18
Coyotes	PB	2001	5	1.4	0.40
		2002	13	2.4	0.54
	PH	2001	2	1.0	0.00
		2002	7	2.0	0.38
	Pooled	2001	7	1.3	0.29
		2002	20	2.3	0.37

Reproduction

Raccoons. Examination of pregnant female raccoons from Pinebloom Plantation resulted in a greater (*P*=0.036) number of fetuses per female in 2001 (3.4) versus 2002 (2.6) (Table 8). Current year (dark) placental scars were found in 15 raccoons in 2001. The mean number of placental scars per female did not differ between 2001 and 2002 (Table 8). Potential litter size per female (obtained from CL counts) also did not differ between years (Table 8).

On Pebble Hill Plantation, examination of pregnant female raccoons revealed no differences in number of fetuses per female between years (Table 8). Current year placental scars and potential litter sizes obtained from CL counts also did not differ between years (Table 8). Pooling the data from both sites also revealed no differences between years in any of the 3 reproductive indices (Table 8).

Bobcats. One pregnant bobcat carrying 2 fetal young was captured on Pinebloom Plantation in 2001. Two pregnant bobcats were captured in 2002, both carrying 3 fetuses. Current year placental scars were identified in 4 bobcats in 2001, with a placental scar count of 2.5 ± 0.29 (x ± SE) per female. Current year placental scars were found on 6 bobcats in 2002, with a placental scar count of 3.2 ± 0.31 per female. In 2001, a potential litter size of 3.2 ± 0.37 per female was obtained from CL counts of 5 females. In 2002, the potential litter size obtained from corpora lutea counts was 3.1 ± 0.23 (*n*=10). There were no statistical differences (*P*>0.05) found in these reproductive indices.

Table 8. Reproductive data from raccoons collected during 2001 and 2002 on Pinebloom (PB) and Pebble Hill (PH) Plantations, Georgia.

			Fetuses per pregnant female			Placental scars per post-partuition female			CL per pregnant and/or post-partuition female		
Site	Year	# examined	n	x	SE	n	x	SE	n	x	SE
PB	2001	33	7	3.4[a]	0.30	15	2.9	0.15	11	3.5	0.25
	2002	67	11	2.6[a]	0.20	22	3.0	0.17	34	3.2	0.12
PH	2001	18	6	2.7	0.21	5	2.6	0.40	7	2.7	0.29
	2002	11	2	2.5	0.50	4	3.3	0.25	5	3.4	0.40
Pooled	2001	51	13	3.1	0.21	20	2.9	0.15	18	3.2	0.20
	2002	78	13	2.6	0.18	26	3.0	0.15	39	3.3	0.11

[a] For the Pineblooom site, means between years differ significantly ($P<0.05$; t-test, log transformation, d.f. = 16)

Two pregnant bobcats were captured on Pebble Hill Plantation in 2001, carrying 2 and 3 fetuses, respectively. In 2002, again 2 pregnant bobcats were captured, carrying 3 and 4 fetal young. Current year placental scars were found on only 1 bobcat from Pebble Hill in 2001, with 2 dark placental scars identified. In 2002, of the 3 female bobcats captured with reproductive characteristics, none had evidence of current year placental scars. In 2001, a potential litter size of 2.3 ± 0.33 per female was obtained from CL counts of 3 females. In 2002, the potential litter size obtained from CL counts was 3.3 ± 0.66 (*n*=3). No differences (*P*>0.05) were found in any of these reproductive indices.

Pooling the bobcat data from both sites, average fetal count was 2.3 ± 0.33 in 2001 (*n*=3) and 3.3 ± 0.25 in 2002 (*n*=4). Current year placental scars averaged 2.4 ± 0.25 per female (*n*=5) in 2001, compared to 3.2 ± 0.31 (*n*=6) in 2002. The potential litter size obtained from CL counts was 2.9 ± 0.29 per female (*n*=8) in 2001, compared to 3.2 ± 0.22 (*n*=13) in 2002. After pooling the data, no differences (*P*>0.05) were found in any of these reproductive indices.

Coyotes. One pregnant coyote was captured on Pinebloom Plantation in 2001, carrying 2 fetuses. In 2002, 2 pregnant coyotes were captured, carrying 3, and 7 fetuses, respectively. Current year placental scars were found on 3 coyotes in 2001, with an average of 4.7 per female. In 2002, of the 2 reproductively active female coyotes captured, none had evidence of dark placental scars. In 2001, a potential litter size of 3.0 per female was obtained from CL counts of 2 females. In 2002, the potential litter size obtained from CL counts was 6.0 (*n*=2).

No female coyotes with reproductive characteristics were captured on Pebble Hill Plantation in 2001. In 2002, 1 female coyote with reproductive characteristics was captured. This female had 4 CLs, and 4 current year placental scars.

Discussion

Food habits

Raccoons. Food habits for raccoons in this study were consistent with that of earlier literature (Dexter 1951, Schoonever and Marshall 1951, Johnson 1970, Cook 1972, Baker 1978, Greenwood 1981, Miller and Leopold 1992, Peoples et al. 1995). Raccoons tend to be opportunistic omnivores, making use of available resources.

The decrease in grain consumption observed on the PH site likely is due to a decrease in the practice of pre-baiting sites with grain. Grain usage on the Pinebloom site was stable in 2002 vs. 2001, and this grain usage we believe stemmed primarily from the use of supplemental feed spread for gamebirds. Acorn consumption by raccoons increased on both sites in 2002 vs. 2001. This was likely the result of availability differences between years. We noted a considerable increase in acorn production for 2002. The decrease in soft mast consumption on both sites again may be linked to availability. In 2002, there was a marked decrease in soft mast production, particularly blackberries (*Rubus* spp.) which made up the bulk of raccoon soft mast consumption in 2001. These abundance differences were noted during trapping excursions on the sites, as well as through communication with wildlife technicians present on the study areas.

No explanation can be offered for the increase of rodent consumption on the PB site in 2002 vs. 2001, nor the decrease in consumption of “other mammals” and vegetation on both sites. We can only assume that there was an increase in rodent availability in 2002 on the PB site, and a decrease in the availability of “other mammals” and vegetation on both sites. With no measurements to provide support, this is only conjecture.

Opossums. The diet of opossums examined in this study was consistent with previous work conducted on the species (Hamilton 1951, Dexter 1951, Hume 1999). The opossum is indeed a highly opportunistic omnivore that is rather unselective in its feeding habits. Insects were consistently prevalent in opossum diets on both sites, in both years.

Grain consumption decreased in 2002 on both sites, perhaps due to a decrease in the practice of pre-baiting sites with grain. Opossums utilize grain to a much lesser extent than raccoons (Hamilton 1951). Unlike data observed for raccoons, soft mast consumption remained constant for opossums on both sites. While there indeed was a decrease in the soft mast crop in 2002 vs. 2001, the opossums consumed a wider variety of soft mast, including muscadines (*Vitis rotundifolia*), persimmons (*Diospyros virginiana*), hawthornes (*Crataegus* spp.), pawpaw (*Asimina* spp.), American beautyberry (*Callicarpa americana*), and blackberries. We assume that the increases in consumption of rodents, and decreases in consumption of “other mammals” are linked to availability on the given sites.

Bobcats. Our analysis concurs with literature, that rodents and lagomorphs are the primary food item for the bobcat (Beasom and Moore 1977, Fritts and Sealander 1978, Miller and Speake 1978, Maehr and Brady 1986). While frequency of occurrence of deer was relatively high on the PH site (40-44%), no deer usage was documented on the PB site, despite larger sample sizes from this site. This could potentially be explained by the high incidence of hog consumption on the PB site, with hogs being absent on the

PH site. Deer abundance was similar between sites, based on cursory observation during predator spotlight collections.

Miller and Speake (1978) reported that the bobcat is not a significant quail predator on managed quail lands. While our findings on the PH site seem to support this, our findings on the PB site are more consistent with Maehr and Brady (1986) who consistently found quail in the diet of the bobcat in Florida. Of additional interest was the relatively high frequency of occurrence of quail eggs (19%) for bobcats captured on PB in 2001. Jones and Smith (1979) reported finding egg fragments in bobcat scats, but did not identify eggs to species.

Coyotes. The coyote has been identified in a number of studies as a highly versatile scavanger and predator (Sperry 1941, Litvaitis and Shaw 1980, Wooding et al. 1984, Lee and Kennedy 1986, Blanton and Hill 1989, Stratman and Pelton 1997). In our study, coyotes consumed large quantities of rodents, rabbits, deer, hogs, and soft mast. Persimmons and blackberries were the primary soft mast utilized by coyotes. Quail were not present in the remains sorted from coyote stomachs, but remains of both juvenile and adult wild turkeys were found. Incidence of quail eggs in the coyote diet appeared to increase on both sites in 2002, as there was no usage of quail eggs by coyotes documented on either site in 2001.

Use of quail by all predators. Past research has shown that raccoons, opossums, bobcats, and coyotes prey on ground-nesting birds (adults and juveniles) and their eggs (Yeagar and Elder 1945, Hamilton 1951, Jones and Smith 1979, Greenwood 1981, Maehr and Brady 1986, Wagner and Hill 1994, Staller 2001). In our research, we found presence of quail eggs in all of the predator species examined, and quail remains in raccoon, opossum, and bobcat stomach samples, but absent from coyote stomach samples. This absence of quail in coyote stomach samples could be due to the relatively low number of coyotes captured during the study (10 examined in 2001, 27 examined in 2002). The pooled predator utilization of quail eggs decreased significantly on the PB site in 2002 vs. 2001. Utilization of quail, quail eggs, and combined quail resource (quail and quail eggs) remained statistically constant, but with an overall downward trend in 2002 vs. 2001. This seemingly constant level of resource usage may be linked to availability of the quail resource. The removal treatment appeared to have the desired effect of increasing quail survival and recruitment (W. E. Palmer, Tall Timbers Research Station, pers.comm.). Therefore, the remaining predators could exploit this increase in availability of the quail resource. While the frequency of occurrence of quail, quail eggs, and combined quail resource may remain constant in predator diets, the collective amount of quail resource consumed by these targeted predators may actually be decreasing, due to a decrease in the overall size of this select predator population. Scent station data collected during the study showed a decreasing population trend of predators on the removal areas (W. E. Palmer, pers. comm.). If indeed the removal effort is reducing the population of this select predator community on the given sites, then the overall food intake of the select predator community would be decreasing, theoretically decreasing consumption of the quail population by these predator species.

Age

Age distribution of animal populations can be affected by intensive harvest. Populations subjected to intensive harvest are often skewed towards younger animals (Trautman et al. 1974, Andelt 1985, Windberg et al. 1985, Gese et al. 1989, Windberg

1995). Unexploited populations (populations in which humans do not remove animals) typically have older age structures than those of exploited populations (Knowlton 1972, Trautman et al. 1974, Berg and Chesness 1978, Andelt 1985, Windberg et al. 1985, Gese et al. 1989, Windberg 1995).

Raccoons. Age data generated from raccoons collected in this study followed the pattern established in the literature. We observed an older age structure for animals removed in 2001 ("pre-removal", or "unexploited" population) as compared to the age structure the raccoon community data generated from animals captured in 2002 ("post-removal", or "exploited" population). This trend was consistent on both sites, with or without the inclusion of the juvenile component of the population. This result leads us to believe that indeed the removals were having an effect on the raccoon population demographics on the two sites.

Opossums. Considering the adult portion of the opossum population present on the 2 sites, the age data generated followed the pattern established in the literature. On both sites separately, as well as pooled, we saw a significant decrease in the mean age of the adult portion of the opossum population in 2002 vs. 2001. The "pre-removal" population was significantly older than the "post-removal" population. With the inclusion of the juvenile component of the population, only after pooling both sites did a significant decrease in the mean age occur between 2002 and 2001. Again, particularly considering the significant decrease in the mean age of the adult component of the opossum population, we are led to believe that the removal effort was indeed affecting the opossum population. This effect was apparent in the shift to a population skewed towards younger animals, as illustrated by Trautman et al. (1974).

Bobcats. While no significant differences were noted when comparing the mean ages of bobcats removed in 2001 to those removed during 2002, the trend was for decreasing mean age in the "exploited" population. We would surmise that lack of statistical significance stems from the relatively small number of bobcats removed from the population during the first year (12 on the PB site, and 10 on the PH site). It would be of interest to determine the mean age of the removed bobcat population in 2003 on the PB site, where 34 animals were removed in 2002. Younger bobcats have a greater home range, and consume prey that are more easily captured (Fritts and Sealander 1978).

Coyotes. Unexploited coyote populations typically have older age structures, high adult survival rate, and low rates of recruitment into the adult population (Andelt 1985, Windberg et al. 1985, Gese et al. 1989, Windberg 1995). While no significant differences were noted when comparing the mean ages of coyotes removed in 2001 to those removed during 2002, the trend was opposite of what we expected. The trend was toward an increase in mean age in the "exploited" population. However, when we examined the removal data for coyotes captured in 2001, one could hardly conclude that the population had been "exploited". Eight coyotes were captured on the PB site in 2001, while only 2 were captured on the PH site. Connolly and Longhurst (1975) developed a simulation model and determined that a minimum annual removal of 75% of the breeding population of coyotes was needed to consistently affect coyote density. Perhaps if more animals had been removed, a trend towards decreasing mean age would be realized.

Reproduction

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

Raccoons. Litter sizes of raccoons in this study were similar to other raccoon studies in the Southeast (Sanderson 1950, McKeever 1957, Cunningham 1962, Johnson 1970, Kramer 1996). There was no evidence to support compensatory reproduction in raccoons on the study areas. The significant decrease in observed litter size on the PB site in the exploited population argues against any compensatory reproduction in raccoons. Overall, the reproductive data collected in 2002 were consistent with that collected in 2001. Perhaps more time and continued removal would be needed to document compensatory reproduction in raccoons.

Bobcats. Litter sizes of bobcats in this study were similar to other bobcat studies (Gashwiler et al. 1961, Crowe 1975, Fritts and Sealander 1978). While small sample size made it difficult to provide a definitive conclusion, the trend was toward increased reproductive indices in 2002 vs. 2001. However, no definitive evidence for compensatory reproduction in bobcats was provided by this study.

Coyotes. The potential for compensatory reproduction is well documented in wild canids (Knowlton 1972, Connolly and Longhurst 1975, Berg and Chesness 1978, Andelt 1985, Windberg 1995, Gese et al. 1996a, 1996b, Windberg et al. 1997). While our sample size was small, reproductive indices of coyotes in this study were consistent with other coyote studies (Knowlton 1972, Gipson et al. 1975, Gese et al. 1989,Green et al.

2002). Compensatory reproduction typically occurs when a previously "unexploited" population is exploited, or some other occurrence creates an abundant supply of previously scarce resources. One could argue that the coyote populations on these sites were not exploited by the removal treatments conducted in 2001, as very few coyotes were captured. If indeed the number of coyotes removed increases, we would expect to see an increase in litter size through compensatory reproduction.

Conclusions and management recommendations

Predation management is a valid concern for landowners and managers of southern plantations. While I do not believe that predators can be implicated on a landscape scale for the declines in quail numbers, they can be a limiting factor on lands managed specifically for quail. On lands where appreciable efforts are made to manage for quail, these same efforts may in turn foster artificially high predator populations, which then negatively impact quail and quail productivity.

My research on food habits offers insight to quail management practices fostering predator populations, particularly mesomammalian predators such as raccoons and opossums. Both raccoons and opossums utilized small grains in their diets. Grain, such as sorghum and corn, are often broadcasted over the landscape for supplemental feeding of quail. From my research, it is evident that the birds are not the only animals utilizing "supplemental feed". Nutrition is linked to reproduction. In deer, high energy diets significantly raised ovulation rates (Abler et al 1976). Adding corn to the diet boosts ovulation in deer by increasing the energy content of the diet (Vogelsang 1977). Reproductive rates of raccoons and opossums may be influenced by high-energy supplemental feed. This may allow a consistently high rate of reproduction, even with high population levels, which would normally lead to increased competition and decreased reproduction. In this fashion, supplemental feeding may actually be detrimental to quail populations.

The goal of predator removal efforts should not be extirpation, but predation management. Habitat management practices and absence of fur-trapping have allowed furbearer populations to increase under little exploitation. Efforts should be made to reduce predators to a more "tolerable" level (a level consistent with the resource management goals), but not eliminate the predator component as a whole. Errington (1956) reported that some vertebrate populations can increase up to the limits of their food supply in the absence of significant predation. One must consider the number of rodents consumed by the raccoons, opossums, bobcats, and coyotes present in these communities to realize their benefit to the ecosystem, and, potentially, to quail managers.

In today's highly political environment, lethal predation management is often treated as a "hot potato", particularly by the uninformed. Due to this, many have proposed alternative, non-lethal measures to limit predation. These measures include: excluding predators with physical or electrical barriers, diversionary feeding, conditioned taste aversion, and fertility control. Exclusion can be dismissed, as it is considered feasible only for small areas (Reynolds and Tapper 1996). Diversionary feeding has proven unsatisfactory in decreasing predation of ground-nesting birds (Jones et al. 2002), and may actually increase predation by fostering artificially high mesomammalian predator populations (i.e., supplemental feeding practices). Conditioned taste aversion had no significant affect on reducing raccoon depredation of sea turtle nests in Florida (Ratnaswamy et al. 1997), and if it were used, could only affect nest depredation, and not predator utilization of either juvenile or adult gamebirds. Fertility control could theoretically reduce predator productivity, but was determined to be infeasible for use in free-ranging predator populations on Canaveral National Seashore, Florida, for a variety of health, ecological and regulatory reasons (Kramer 1996).

Efforts to reduce predator numbers should concentrate on seasons when the predators removed add to natural mortality (Reynolds and Tapper 1996). Harvesting predators at this time (spring and summer) adds another benefit: predator numbers are being reduced while ground-nesting birds are most vulnerable. This strategy should benefit nest productivity. Recognizing this, the Georgia Department of Natural Resources has implemented a spring-summer trapping season on lands whose conservation goals include gamebird management. Mammalian-caused mortality peaks during the height of the northern bobwhite nesting period (Burger et al. 1995). However, predator harvest at this time is of little economic benefit to the trapper concerned with the sale of fur, as furs are "unprime". This has the unfortunate consequence of reducing species that were once a valuable commodity through the sale of their furs, to nuisance status. Hopefully, fur markets will rebound, trappers concerned with the harvest of marketable fur will reappear, and predator populations will again be subject to control via hunting and fur trapping in the traditional season. Until that time, predator harvest in the spring and summer may be necessary to control predator populations on lands managed for quail.

Acknowledgements. We thank the Daniel B. Warnell School of Forest Resources at the University of Georgia, Robert W. Woodruff Foundation, Joseph W. Jones Ecological Research Center, and USDA-Georgia Wildlife Services for supporting our research. H. S. Drew, J. C. Griffin, D. Hughes, and O. B. White, Jr., provided help in the field. Housing was provided by H. S. Drew, J. C. Griffin, and O. B. White, Jr. J. L. Teeple provided assistance on statistical analysis. J. E. Schoch provided laboratory assistance.

Literature cited

Abler, W. A., D. E. Buckland, R. L. Kirkpatrick, and P. F. Scanlon. 1976. Plasma progestins and puberty in fawns as influenced by energy and protein. Journal of Wildlife Management 40:442-446.

Aldrich, J. W., and C. G. Endicott. 1984. Black rat snake predation on giant Canada goose eggs. Wildlife Society Bulletin 12:263-264.

Andelt, W. F. 1985. Behavioral ecology of coyotes in south Texas. Wildlife Monographs 94:145.

Baker, B. W. 1978. Ecological factors affecting wild turkeys nest predation on South Texas rangelands. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 32:126-136.

Beasom, S. L. and R. A. Moore. 1977. Bobcat food habit response to a change in prey abundance. Southwest Naturalist 21:451-457

Berg, W. E. and R. A. Chesness. 1978. Ecology of coyotes in northern Minnesota, pages 229-247 *in* M. Bekoff, editor. Coyotes: biology, behavior and management. Academic Press, New York, N.Y.

Bishop, Y. M., S. E. Fienberg, and P. W. Holland. 1975. Discrete multivariate analyses: theory and practice. The MIT press, Cambridge, 557 pp.

Blanton, K. M. and E. P. Hill. 1989. Coyote use of white-tailed deer fawns in relation to deer density. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 43:470-478.

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:544-555.

Burger, L. W., Jr., T. V. Dailey, E. W. Kurzejeski, and M. R. Ryan. 1995. Seasonal and annual survival and cause-specific mortality of northern bobwhite in Missouri. Journal of Wildlife Management 59:401-410.

Conner, L. M., B. Plowman, B. D. Leopold, and C. Lovell. 1999. Influence of time-in-residence on home range and habitat use of bobcats. Journal of Wildlife Management 63:261-269.

Connolly, G. E., and W. M. Longhurst. 1975. The effects of control on coyote populations: a simulation model. University of California Division of Agricultural Science Bulletin 1872:1-37.

Cook, R. L. 1972. A study of nesting turkeys in the Edwards Plateau of Texas. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commission 26:236-244.

Cote, I. M., and W. J. Sutherland. 1997. The effectiveness of removing predators to protect bird populations. Conservation Biology 11:395-405.

Courchamp, F., M. Langlais, and G. Sugihara. 1999. Cats protecting birds: modeling the mesopredator release effect. Journal of Animal Ecology 68:282-292.

Crowe, D. M. 1975. Aspects of ageing, growth, and reproduction of bobcats from Wyoming. Journal of Mammalogy 56:177-198.

Cunningham, E. R. 1962. A study of the Eastern Raccoon (*Procyon lotor*) on the Atomic Energy Commission Savannah River Plant. M. S. Thesis. University of Georgia, Athens, Georgia. 55pp.

Davis, D. E., and J. T. Emlen, Jr. 1948. The placental scar as a measure of fertility in rats. Journal of Wildlife Management 12:162-166.

Dexter, R. W. 1951. Earthworms in the winter diet of the opossum and raccoon. Journal of Mammalogy 32:464.

Dimmick, R. W. and M. R. Pelton. 1994. Criteria of sex and age. Pages 169-214 *in* T.A. Bookhout, editor. Research and management techniques for wildlife and habitats. The Wildlife Society, Bethesda, Maryland, USA.

Errington, P. L. 1956. Factors limiting higher vertebrate populations. Science 124:304-307.

Estes, J. A., and J. F. Palmisano. 1974. Sea otters: their role in structuring nearshore communities. Science 185:1058-1060.

Estes, J. A. 1996. Predators and ecosystem management. Wildlife Society Bulletin 24:390-396.

Farnsworth, G. L., and T. R. Simons. 2000. Observations of wood thrush nest predators in a large contiguous forest. Wilson Bulletin 112:82-87.

Fritts, S. H., and J. A. Sealander. 1978. Diets of bobcats in Arkansas with special reference to age and sex differences. Journal of Wildlife Management 42:533-539.

Fritzell, E. K., G. F. Hubert, Jr., B. E. Metzer, and G. C. Sanderson. 1985. Age-specific reproduction in Illinois and Missouri Raccoons. Journal of Wildlife Management 49:901-905.

Gashwiler, J. S., W. L. Robinette, and O. W. Morris. 1961. Breeding habits of bobcats in Utah. Journal of Mammalogy 42:76-84.

Gese, E. M., O. J. Rongstad, and W. R. Mytton. 1989. Population dynamics of coyotes in southeastern Colorado. Journal of Wildlife Management 53:174-181.

Gese, E. M., R. L. Ruff, and R. L. Crabtree. 1996a. Social and nutritional factors influencing the dispersal of resident coyotes. Animal Behavior 52:1025-1043.

Gese, E. M., R. L. Ruff, and R. L. Crabtree. 1996b. Foraging ecology of coyotes (*Canis latrans*): the influence of extrinsic factors and a dominance hierarchy. Canadian Journal of Zoology 74:769-783.

Gipson, P. S., I. K. Gipson, and J. A. Sealander. 1975. Reproductive biology of wild *Canis* in Arkansas. Journal of Mammalogy 56:605-612.

Green, J. S., F. F. Knowlton, and W. C. Pitt. 2002. Reproduction in captive wild-caught coyotes (*Canis latrans*). Journal of Mammalogy 83:501-506.

Greenwood, R. J. 1981. Foods of prairie raccoons during the waterfowl nesting season. Journal of Wildlife Management 45:754-760.

Hamilton, W. J. 1951. The food of the opossum in New York state. Journal of Wildlife Management 15:258-264.

Harder, J. D. and R. L. Kirkpatrick. 1994. Physiological methods in wildlife research. Pages 275-306 *in* T.A. Bookhout, editor. Research and management techniques for wildlife and habitats. The Wildlife Society, Bethesda, Maryland, USA.

Hawthorne, D. W. 1983. Cotton rats. Pp. B 85-87 *in* R. A. Timm, Editor. Prevention and control of wildlife damage. Institute of Agriculture and Natural Resources, University of Nebraska, Lincoln.

Henke, S. E. and F. C. Bryant. 1999. Effects of coyote removal on the faunal community in western Texas. Journal of Wildlife Management 63:1066-1081.

Hume, I. D. 1999. Marsupial Nutrition. Cambridge University Press. Cambridge, UK.

Johnson, S. A. 1970. Biology of the raccoon in Alabama. Alabama Cooperative Wildlife Research Unit. Department of Conservation. Alabama. USA.

Jones, R. H., and N. S. Smith. 1979. Bobcat density and prey selection in central Arizona. Journal of Wildlife Management 43:666-672.

Jones, D. J., L. M. Conner, R. J. Warren, and G. O. Ware. 2002. The effect of supplemental prey and prescribed fire on success of artificial nests. Journal of Wildlife Management 66:1112-1117.

Junge, R. E., and G. C. Sanderson. 1982. Age related reproductive success of female raccoons. Journal of Wildlife Management. 46:527-529.

Kirkpatrick, R. L. 1980. Physiological indices in wildlife management. Pages 99-112 *in* S. D. Schemnitz, editor. Wildlife management techniques manual, 4th ed. Wildlife Society, Washington, D. C., USA.

Knowlton, F. F. 1972. Preliminary interpretations of coyote population mechanics with some management implications. Journal of Wildlife Management 36:369-382.

Korschgen, L. J. 1969. Procedures for food habits analysis. Pages 233-250 *in* R. H. Giles, editor. Wildlife Management Techniques, 3rd Ed. The Wildlife Society.

Kramer, M. T., R. J. Warren, M. J. Ratnaswamy, and B. T. Bond. 1999. Determining sexual maturity of raccoons by external versus internal aging criteria. Wildlife Society Bulletin 27:231-234.

Lee, R. M., III, and M. L. Kennedy. 1986. Food habits of the coyote in Tennessee. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 40:364-372.

Litvaitis, J. A., K. Titus, and E. M. Anderson. 1996. Measuring vertebrate use of terrestrial habitats and foods. Pages 254-274 *in* T. A. Bookhout, editor. Research and management techniques for wildlife and habitats. The Wildlife Society, Bethesda, Maryland, USA.

Litvaitis, J. A., and J. H. Shaw. 1980. Coyote movements, habitat use, and food habits in southwestern Oklahoma. Journal of Wildlife Management 44:62-68.

Maehr, D. S, and J. R. Brady. 1986. Food habits of the bobcat in Florida. Journal of Mammalogy 67:133-138.

McKeever, S. 1957. Reproduction in the raccoon in the southeastern United States. Journal of Wildlife Management 22:211.

Miller, J. E., and B. D. Leopold. 1992. Population influences: Predators. Pages 119-128 *in* J. D. Dickson, editor. The wild turkey: biology and management. Stackpole, Mechanicsburg, Pennsylvania, USA.

Miller, S. D., and D. W. Speake. 1978. Prey utilization by bobcats on quail plantations in southern Alabama. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 32:100-111.

Moore, T. D., L. W. Spence, and C. E. Dugnolle. 1974. Identification of the dorsal guard hairs of some mammals of Wyoming. Wyoming Game and Fish Dept. Bull. No. 14, 177 pp.

Paine, R. T. 1969. A note on trophic complexity and community stability. American Naturalist. 103:91-93.

Palomares, F. P. Gaona, P. Ferreras, and M. Delibes. 1995. Positive effects on game species of top predators by controlling small predator populations: an example with lynx, mongooses and rabbits. Conservation Biology 9:295-305.

Peoples, J. C., D. C. Sisson, and D. W. Speake. 1995. Mortality of wild turkey poults in coastal plain pine forests. Proceeding of the Annual Conference of Southeastern Associations of Fish and Wildlife Agencies 49:448-453.

Ratnaswamy, M. J., R. J. Warren, M. T. Kramer, and M. D. Adam. 1997. Comparisons of lethal and non-lethal techniques to reduce raccoon depredation of sea turtle nests. Journal of Wildlife Management 61:368-376.

Reynolds, J. C., and S. C. Tapper. 1996. Control of mammalian predators in game management and conservation. Mammal Review 26:127-156.

Rogers, C. M. and M. J. Caro. 1998. Song sparrows, top carnivores, and nest predation: a test of the mesopredator release hypothesis. Oecologia 116:227-233.

Sandell, M. 1989. The mating tactics and spacing patterns of solitary carnivores. Pages 164-182 *in* J.L. Gittleman, editor. Carnivore Behavior, Ecology, and Evolution. Cornell University Press, Ithaca, New York.

Sanderson, G. C., and A. V. Nalbandov. 1973. The reproductive cycle of the raccoon in Illinois. Illinois Nat. Hist. Sur. Bull. 31:29-85.

Sanderson, G. C. 1950. Methods of measuring productivity in raccoons. Journal of Wildlife Management 14:389-402.

SAS Institute. 1999. SAS/STAT User's Guide, Version 8. SAS Institute, Cary, North Carolina, USA.

Schoonover, L. J., and W. H. Marshall. 1951. Food habits of the raccoon in north-central Minnesota. Journal of Mammalogy 32:422-428.

Simpson, R. C. 1976. Certain aspects of the bobwhite quail's life history and population dynamics in southwest Georgia. Georgia Department of Natural Resources, Game and Fish Division. Technical bulletin WL1. Social Circle, Georgia.

Sovada, M. A., A. B. Sargeant, and J. W. Grier. 1995. Differential effects of coyotes and red foxes on duck nest success. Journal of Wildlife Management 59:1-9.

Sperry, C. C. 1941. Food habits of the coyote. U. S. Department of the Interior, Fish and Wildlife Service Wildlife Resource Bulletin 4:1-70.

Spiers, J. E. 1973. A microscopic key to the hairs of Virginia land mammals. M. S. Thesis, Virginia Polytech. Inst. 106 pp.

Stoddard, H. L. 1931. The bobwhite quail: its habits, preservation and increase. C. Scribner's Sons, New York, NY.

Staller, E. L. 2001. Identifying predators and fates of northern bobwhite nests using miniature video camera. M. S. Thesis. UGA.

Stratman, M. R., and M. R. Pelton. 1997. Food habits of coyotes in northwestern Florida. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 51:269-275.

Trautman, C. G., L. F. Fredrickson, and A. V. Carter. 1974. Relationship of red foxes and other predators to populations of ring-neck pheasants and other prey, South Dakota. Thirty-Ninth North American Wildlife Conference. Pages 241-253.

Vogelsang, R. W. 1977. The effect of energy intake and reproductive state on blood urea nitrogen, cholesterol, and progestin levels in captive and free-ranging white-tailed deer. M.S. Thesis. Virginia Polytechnic Institute and State University, Blacksburg. 100pp.

Wagner, G. D., and E. P. Hill. 1994. Evaluation of southeastern coyote diets during the wild turkey reproductive season. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 48:173-181.

Windberg, L. A. 1995. Demography of a high-density coyote population. Canadian Journal of Zoology 73:942-954.

Windberg, L. A., H. L. Anderson, and R. M. Engeman. 1985. Survival of coyotes in southern Texas. Journal of Wildlife Management 49:301-307.

Windberg, L. A., S. M. Ebbert, and B. T. Delly. 1997. Population characteristics of coyotes in the northern Chihuahuan desert. American Midland Naturalist 138:197-207.

Wheeler, W. E. 1984. Duck egg predation by fox snakes in Wisconsin. Wildlife Society Bulletin 12:77-78.

Wooding, J. B., E. P. Hill, and P. W. Sumner. 1984. Coyote food habits in Mississippi and Alabama. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 38:182-188.

Yeagar, L. E., and W. H. Elder. 1945. Pre- and post-hunting season foods of raccoons on an Illinois goose refuge. Journal of Wildlife Management 9:48-56.

Young, S. P. 1958. The bobcat of North America. The Stackpole Co., Harrisburg, Pa. 193pp.

CHAPTER 3

SUMMARY AND IMPLICATIONS FOR PREDATOR MANAGEMENT

Summary

As fur markets have declined during the last 20 years, the use of trapping as a management tool also has declined. In Georgia alone, the number of licensed trappers has declined from 3,560 during the 1979-1980 trapping season to only 352 during 1999-2000 (Todd Holbrook, Georgia Department of Natural Resources, pers.comm.). Lower harvest pressure and land use changes have allowed predator populations to increase dramatically (Peoples et al. 1995). During this same time, populations of bobwhite quail have dwindled (Brennan 1991). Land managers on southern U.S. plantations have recognized this increase in predator abundance, and perceive these predators as a threat to quail populations. Cases involving the illegal use of poisoned eggs to kill these overabundant predators demonstrate the extreme desperation felt by some landowners. With the virtual abandonment of fur-trapping as a practiced trade, especially in the South, a new predator management alternative was desired by landowners. The Wildlife Management and Gamebird Restoration Project (WMGBRP) was conceived to provide landowners this alternative. The goal of the WMGBRP was to determine whether intensive removal efforts to control mammalian predators will provide landowners a means of enhancing wildlife production and populations on their land.

I conducted a study on the animals harvested in conjunction with the WMGBRP to ascertain the population-scale response of the targeted predators. In this study, I analyzed predator diets, and quantified changes in diet, age, and reproduction of predators in response to intensive removal efforts during the quail nesting season on 2 quail plantations in southwestern Georgia.

Food habits of raccoons, opossums, bobcats, and coyotes collected during the study were consistent with earlier studies. There were no appreciable shifts in predator diets that could be definitively linked to the removals. Any changes in prey or food item intake we documented were likely due to changes in prey or food item availability. Predators that have proven successful and become abundant in modern environments are versatile generalists, capable of exploiting a wide variety of food resources (Reynolds and Tapper 1996). The overall pattern of age distribution declined during the course of the study. In general, mean ages of captured predators decreased in year 2 versus year 1. Populations subjected to intensive harvest are often skewed towards younger animals (Trautman et al. 1974, Andelt 1985, Windberg et al. 1985, Gese et al. 1989, Windberg 1995). Reproductive indices for raccoons, bobcats, and coyotes were studied. These reproductive indices did not differ from reproductive indices found in supporting literature for the species. We noted no compensatory reproduction in response to the removal efforts, contrary to what we expected. Populations under heavy exploitation have increased litter size (Knowlton 1972, Berg and Chesness 1978). Reproductive output remained relatively constant in both years of my research.

This study represents relatively short-term results. Continued removal pressure on the predator community could indeed lead to changes in food habits, an exacerbated shift to a younger population, and an increase in the reproductive rate, or compensatory reproduction. Populations of certain predators, such as coyotes, may not have been altered whatsoever by the removal efforts. A minimum annual removal of 75% of the breeding population of coyotes is necessary to consistently lower coyote density

(Connolly and Longhurst 1975). Only continued monitoring of this type can provide conclusive data.

Implications for predator management

Predation management is a valid concern for landowners and managers of southern plantations. While I do not believe that predators can be implicated on a landscape scale for the declines in quail numbers, they can be a limiting factor on lands managed specifically for quail. On lands where appreciable efforts are made to manage for quail, these same efforts may in turn foster artificially high predator populations, which then negatively impact quail and quail productivity.

My research on food habits offers insight to quail management practices fostering predator populations, particularly mesomammalian predators such as raccoons and opossums. Both raccoons and opossums utilized small grains in their diets. Grain, such as sorghum and corn, are often broadcasted over the landscape for supplemental feeding of quail. From my research, it is evident that the birds are not the only animals utilizing "supplemental feed". Nutrition is linked to reproduction. In deer, high energy diets significantly raised ovulation rates (Abler et al. 1976). Adding corn to the diet boosts ovulation in deer by increasing the energy content of the diet (Vogelsang 1977). Reproductive rates of raccoons and opossums may be influenced by high-energy supplemental feed. This may allow a consistently high rate of reproduction, even with high population levels, which would normally lead to increased competition and decreased reproduction. In this fashion, supplemental feeding may actually be detrimental to quail populations.

The goal of these removal efforts should not be extirpation, but predation management. Habitat management practices and absence of fur-trapping have allowed furbearer populations to increase under little or no persecution. Efforts should be made to reduce predators to a more “tolerable” level (a level consistent with the resource management goals), but not eliminate the predator component as a whole. Errington (1956) reported that some vertebrate populations can increase up to the limits of their food supply in the absence of significant predation. One must consider the number of rodents consumed by the raccoons, opossums, bobcats, and coyotes present in these communities to realize their benefit to the ecosystem, and, potentially, to quail managers.

In today’s highly political environment, lethal predation management is often treated as a “hot potato”, particularly by the uninformed. Due to this, many have proposed alternative, non-lethal measures to limit predation. These measures include: excluding predators with physical or electrical barriers, diversionary feeding, conditioned taste aversion, and fertility control. Exclusion can be dismissed, as it is considered feasible only for small areas (Reynolds and Tapper 1996). Diversionary feeding has proven unsatisfactory in decreasing predation of ground-nesting birds (Jones et al. 2002), and may actually increase predation by fostering artificially high mesomammalian predator populations (i.e., supplemental feeding practices). Conditioned taste aversion had no significant affect on reducing raccoon depredation of sea turtle nests in Florida (Ratnaswamy et al. 1997), and if it were used, could only affect nest depredation, and not predator utilization of either juvenile or adult gamebirds. Fertility control could theoretically reduce predator productivity, but was determined to be infeasible for use in free-ranging predator populations on Canaveral National Seashore, Florida, for a variety of health, ecological and regulatory reasons (Kramer 1996).

Efforts to reduce predator numbers should concentrate on seasons when the predators removed add to natural mortality (Reynolds and Tapper 1996). Harvesting predators at this time (spring and summer) adds another benefit: predator numbers are being reduced while ground-nesting birds are most vulnerable. This strategy should benefit nest productivity. Recognizing this, the Georgia Department of Natural Resources has implemented a spring-summer trapping season on lands whose conservation goals include gamebird management. Mammalian-caused mortality peaks during the height of the northern bobwhite nesting period (Burger et al. 1995). However, predator harvest at this time is of little economic benefit to the trapper concerned with the sale of fur, as furs are “unprime”. This has the unfortunate consequence of reducing species that were once a valuable commodity through the sale of their furs, to nuisance status. Hopefully, fur markets will rebound, trappers concerned with the harvest of marketable fur will reappear, and predator populations will again be subject to control via hunting and fur trapping in the traditional season. Until that time, predator harvest in the spring and summer may be necessary to control predator populations on lands managed for quail.

Literature cited

Abler, W. A., D. E. Buckland, R. L. Kirkpatrick, and P. F. Scanlon. 1976. Plasma progestins and puberty in fawns as influenced by energy and protein. Journal of Wildlife Management 40:442-446.

Andelt, W. F. 1985. Behavioral ecology of coyotes in south Texas. Wildlife Monographs 94:145.

Berg, W. E. and R. A. Chesness. 1978. Ecology of coyotes in northern Minnesota, pages 229-247 *in* M. Bekoff, editor. Coyotes: biology, behavior and management. Academic Press, New York, N.Y.

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:544-555.

Burger, L. W., T. V. Dailey, E. W. Kurzejeski, and M. R. Ryan. 1995. Survival and cause-specific mortality of northern bobwhite in Missouri. Journal of Wildlife Management 59:401-410.

Connolly, G. E., and W. M. Longhurst. 1975. The effects of control on coyote populations: a simulation model. University of California Division of Agricultural Science Bulletin 1872:1-37.

Errington, P. L. 1956. Factors limiting higher vertebrate populations. Science 124:304-307.

Gese, E. M., O. J. Rongstad, and W. R. Mytton. 1989. Population dynamics of coyotes in southeastern Colorado. Journal of Wildlife Management 53:174-181.

Jones, D. D., L. M. Conner, R. J. Warren, and G. O. Ware. 2002. The effect of supplemental prey and prescribed fire on success of artificial nests. Journal of Wildlife Management 66:1112-1117.

Knowlton, F. F. 1972. Preliminary interpretations of coyote population mechanics with some management implications. Journal of Wildlife Management 36:369-382.

Kramer, M. T. 1996. Reproductive biology and preliminary investigations of levonorgestrel as a contraceptive for managing raccoons at Canaveral National Seashore, Florida. M. S. Thesis. University of Georgia, Athens, Georgia. 89pp.

Peoples, J. C., D. C. Sisson, and D. W. Speake. 1995. Mortality of wild turkey poults in coastal plain pine forests. Proceeding of the Annual Conference of Southeastern Associations of Fish and Wildlife Agencies 49:448-453.

Ratnaswamy, M. J., R. J. Warren, M. T. Kramer, and M. D. Adam. 1997. Comparisons of lethal and non-lethal techniques to reduce raccoon depredation of sea turtle nests. Journal of Wildlife Management 61:368-376.

Reynolds, J. C., and S. C. Tapper. 1996. Control of mammalian predators in game management and conservation. Mammal Review 26:127-156.

Trautman, C. G., L. F. Fredrickson, and A. V. Carter. 1974. Relationship of red foxes and other predators to populations of ring-neck pheasants and other prey, South Dakota. Thirty-Ninth North American Wildlife Conference. Pages 241-253.

Vogelsang, R. W. 1977. The effect of energy intake and reproductive state on blood urea nitrogen, cholesterol, and progestin levels in captive and free-ranging white-tailed deer. M.S. Thesis. Virginia Polytechnic Institute and State University, Blacksburg. 100pp.

Windberg, L. A., H. L. Anderson, and R. M. Engeman. 1985. Survival of coyotes in southern Texas. Journal of Wildlife Management 49:301-307.

Windberg, L. A. 1995. Demography of a high-density coyote population. Canadian Journal of Zoology 73:942-954.