THE EFFECT OF PREDATION ON WHITE-TAILED DEER RECRUITMENT AT THE JOSEPH W. JONES ECOLOGICAL RESEARCH CENTER

by

M. BRENT HOWZE

(Under the Direction of Robert J. Warren)

ABSTRACT

This project investigated the effect of predation on white-tailed deer (*Odocoileus virginianus*) recruitment in southwestern Georgia during 2007 and 2008. I removed coyotes (*Canis latrans*) and bobcats (*Lynx rufus*) from a 4,200-ha portion of the Joseph W. Jones Ecological Research Center in Baker County, Georgia and compared recruitment rates to those in a 2,800-ha non-removal portion of the property. Fawn:doe ratios were higher in the predator removal zone than the non-removal zone as indicated by pre and post-hunting season camera surveys and hunter observations. Analysis of coyote (n=312) and bobcat (n=171) scat indicated that both predators consumed deer. However, deer remains occurred more frequently in coyote scat than in bobcat scat. Furthermore, predation on radio-collared fawns during the 2-year study indicated coyotes are the primary predator of white-tailed deer fawns. The collective data suggests that predation (primarily coyote) is limiting white-tailed deer recruitment in on this property.

INDEX WORDS: Bobcat, *Canis latrans*, Coyote, Fawn, *Lynx rufus*, *Odocoileus virginianus*, Predation, Predator removal, White-tailed deer,

THE EFFECT OF PREDATION ON WHITE-TAILED DEER RECRUITMENT AT THE JOSEPH W. JONES ECOLOGICAL RESEARCH CENTER

by

M. BRENT HOWZE

B.S.F.R., University of Georgia, 2002

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

2009

© 2009

Michael Brentley Howze

All Rights Reserved

THE EFFECT OF PREDATION ON WHITE-TAILED DEER RECRUITMENT AT THE

JOSEPH W. JONES ECOLOGICAL RESEARCH CENTER

by

M. BRENT HOWZE

Major Professor: Robert J. Warren

Committee: L. Mike Conner
Karl V. Miller

Electronic Version Approved:

Maureen Grasso
Dean of the Graduate School
The University of Georgia
August 2009

DEDICATION

This thesis is dedicated to my parents, Ken and Patti Howze. Your guidance has led me to where I am today. You have instilled in me the virtues of education and hard work as well as a love of nature. Without your support and understanding, none of this would have been possible. I love you both.

ACKNOWLEDGEMENTS

I would first like to thank Dr. Mike Conner. Not only have you been a mentor, but also a friend. You have put in countless hours to make sure this project is a success and always made sure that I was on track. For that, I will be forever grateful. To Dr. Bob Warren, thank you for all of the time and effort you have put into this project and for always having an open door for my endless questions and concerns. Thanks also to Dr. Karl Miller, you have been an invaluable asset to this project. I am honored to have had the privilege to work with all of you.

Thank you to my parents, Ken and Patti Howze, as well as my brother Lon and sister-in-law Heather. Without your support, I would not be where I am today. I am lucky to have such a wonderful and loving family. I would also like to thank Jen Linehan. You are my inspiration. Your love and encouragement made all of this possible. Thanks also to Biscuit, Charlie, and Abbey, you were always there to greet me with a smile.

It would be impossible to list everyone who has helped out with this project, but special thanks go out to Gail Morris, Cat Eddins, Sean Sterrett, Jessica Rutledge and the Wildlife Lab for help with trapping, camera surveys and putting up with all of my junk around the lab. I also thank David Osborn for making sure I had everything I needed. Thanks to Jonathan Stober, Bobby Bass, Scott Smith, Jimmy Atkinson, Joel Rackley, as well as the rest of the staff at the Jones Center for equipment and logistical needs. I would also like to thank Liz Cox whose library service were invaluable and Jean Brock who was always there to help with GIS questions. Finally, I would also like to thank the Joseph W. Jones Ecological Research Center and the Daniel B. Warnell School of Forestry and Natural Resources for financial support.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION, LITERATURE REVIEW, OBJECTIVES AND THESIS FORMAT

Introduction

The white-tailed deer (*Odocoileus virginianus*) herd at the Joseph W. Jones Ecological Research Center (Ichauway) has remained at a relatively constant density of 3.8 – 5.8 deer/km^2 (10 – 15 deer/mile^2) with an even sex ratio since the mid-1990s. However, the number of harvested deer, lactation rates of harvested deer, and observed fawn:doe ratios all appear to have declined since 2001, while hunter effort has remained constant (J. W. Jones Ecological Research Center, 2008). Concurrently, coyote (*Canis latrans*) densities have increased during this period (J. Stober, Joseph. W. Jones Ecological Research Center, Pers. Comm.). Because coyotes and bobcats (*Lynx rufus*) are known predators of white-tailed deer fawns, research is needed to understand the impact these predators may be having on deer recruitment. The importance of predation on white-tailed deer recruitment has been demonstrated in numerous studies (Cook et al. 1971, Beasom 1974, Stout 1982, Vreeland et al. 2004, Roberts 2007), but only VanGilder (2008) has investigated the direct impacts of predation on recruitment rates of white-tailed deer in the Southeast. The purpose of this study was to evaluate the impacts of these predators on white-tailed deer recruitment on a study site in southwestern Georgia. Data derived from this research will allow for improved management decisions based on a better understanding of the interactions of white-tailed deer, bobcats and coyotes.

Literature Review

Food habits of coyotes and bobcats—Coyotes are generalist predators and usually have a more diverse diet than bobcats (Litvaitis and Harrsion 1989). Small mammals (rats and mice) and rabbits are common prey items of coyotes in the United States. The occurrence of white-tailed deer in coyote diet studies is variable, but coyotes are known to prey on fawns (Beasom 1974, Blanton and Hill 1989, Ballard et al. 2001, Schrecengost et al. 2008, and VanGilder 2008). In Mississippi, Chamberlain and Leopold (1999) found deer in 31.9% of coyote scat collected from 1991-1997. In a study encompassing several Southeastern states, Blanton and Hill (1989) reported that deer remains occurred in 31% of the coyote scat collected in summer, of which 77% of these occurrences were identified as fawns. The highest reported frequency of occurrence of white-tailed deer in coyote scat in the Southeast (37.6%) is from a study in west central Alabama (Hoerth and Causey 1991).

Although consumption of white-tailed deer by bobcats varies regionally and seasonally, most studies in the southern U.S. have reported relatively low occurrence of deer. In Florida, Maehr and Brady (1986) reported that deer occurred in 2% of bobcat scat, whereas Wassmer et al. (1988) did not find any deer remains. A 2-year study in Texas indicated low amounts of white-tailed deer occurring in bobcat diets, 6% in the first year and no deer in the second year (Beasom and Moore 1977). Doughty (2004) found annual occurrences of deer in scat to be <10% during 2001-2004 on Ichauway.

Griffin (2001) reported greater frequency of occurrence of white-tailed deer in bobcat scat on Kiawah Island, South Carolina, relative to other studies in the Southeast. Similarly, Baker et al. (2001) and Epstein et al. (1983) both found extensive use of white-tailed deer by bobcats on barrier islands off the coasts of Georgia and South Carolina. In all of these studies, coyotes did not occur on the study areas. It has been suggested that in areas where Coyotes and Bobcats are sympatric, Bobcats consume more rabbits and rodents while coyotes consume more ungulates (Chamberlain and Leopold 1999, Neale and Sacks 2001). Thornton et al. (2004) reported similar diet partitioning between predators in Florida.

Collectively, these studies indicate that coyotes and bobcats may be important predators of white-tailed deer. However, diet studies do not quantify the impact that predators have on white-tailed deer. They merely suggest that predators could be influencing recruitment due to the occurrence of deer in their diet.

Fawn mortality—Several studies have investigated fawn mortality (Cook et al. 1971, Garner et al. 1976, Nelson and Woolf 1987, Vreeland et al 2004, Pusateri Burroughs et al. 2006), but until recently, these studies have taken place outside of the southeastern U. S. (Saalfeld and Ditchkoff 2006, Kilgo et al. 2009, Roberts 2007). Fawn mortality rates are highly variable throughout their range. Pusateri Burroughs et al. (2006) found mortality rates as low as 23% in Michigan. In contrast, Bartush and Lewis (1981) reported fawn mortality as high as 90% in Oklahoma, the majority of which was due to coyote predation. Garner et al. (1976) found predation was responsible for 28 of 29 mortalities in Oklahoma and coyotes were responsible for up to 71% of the total predation events in this study. In the Southeast, Kilgo et al. (2009) found that coyotes were responsible for up to 84% of all mortalities of radio-collared fawns in a South Carolina study. Similarly, Saalfeld and Ditchkoff (2007) reported coyotes as the most common cause of mortality in an exurban area of Alabama.

Coyotes and bobcats are the most common white-tailed deer predators in the Southeast, but because they exhibit such variability in their diets, site-specific data is needed determine the role of predation in the population dynamics of white-tailed deer.

Impacts of predator removal—Few studies have investigated the effects of predator removal on white-tailed deer recruitment, but all have indicated a positive response. Beasom (1974) reported a 72% increase in recruitment following predator removal in south Texas and Stout (1982) found a 154% increase in recruitment in Oklahoma. A recent study in northern Alabama examined the effects of an intensive removal effort on white-tailed deer recruitment (VanGilder 2008) and found a 189% increase in recruitment rate one year after the removal.

Predation is often the primary cause of mortality in studies of neonate survival. In a research review on neonatal mortality of temperate ungulates, Linnell et al. (1995) reported that mortality rates averaged 47% on areas where predators occurred and predation accounted for an average for 67% of the overall mortalities. However, mortality rates averaged only 19% in studies where predators did not occur. Increasing numbers of coyotes in the Southeast coupled with declining numbers of deer has led to speculation regarding the potential impacts of these predators on white-tailed deer.

Study Area

The Joseph W. Jones Ecological Research Center (Ichauway) in Baker County, Georgia, is an 11,736-ha, privately owned research center in the Upper Gulf Coastal Plain. The landscape is dominated by a longleaf pine (*Pinus palustris*) overstory with a wiregrass (*Aristida stricta*) understory. Limesink and cypress-gum (*Taxodium ascendens-Nyssa biflora*) wetlands are interspersed within the riparian hardwood hammocks along Ichawaynochaway Creek that bisects the property longitudinally and the Flint River that forms the eastern property boundary. Ichauway is managed on a 2-year prescribed fire rotation with approximately 10% of the property consisting of agricultural fields and food plots planted with winter wheat (*Triticum aestivum)*, Egyptian wheat (*Sorghum* spp.), grain sorghum (*Sorghum vulgare*), browntop millet

(*Brachiaria ramosa*), and cowpeas (*Vigna* spp.). Most of the private lands surrounding Ichauway consists of agricultural fields and plantation-style timber tracts.

Ichauway lies in Georgia's Deer Management Unit 6, which consists of 31 counties in the Upper Gulf Coastal Plain where deer densities average 8.1 deer/km^2 (21 deer/mile^2, Bowers et al. 2005). The deer management goal for Ichauway is to maintain a herd density that maximizes herd health while minimizing negative ecological impacts of the herd on its forest ecosystem. Past data indicate that Ichauway's white-tailed deer herd has remained at a constant density of 3.8 – 5.8 deer/km^2 (10 – 15 deer/mile^2) and a relatively even sex ratio since the early 1990s. The site-wide fawn:doe ratio averaged 0.53 from 2001 – 2008 (J. W. Jones Ecological Research Center 2008).

Objectives and Format

The objectives of this research were to determine survival rates and causes of fawn mortality, and to describe the diets of the primary predators of white-tailed deer at the Joseph W. Jones Ecological Research Center. An additional objective was to determine the effect of an intensive predator removal program on deer recruitment by comparing fawn:doe ratios within a predator removal zone to those within a non-removal zone

This thesis was written in manuscript format. Chapter 1 is an introductory chapter that provides details regarding the study area as well as past research on predator (coyote and bobcat) removal, food habits of coyotes and bobcats, and survival of white-tailed deer fawns. Chapter 2 presents the results of a study examining the effects of predator removal on white-tailed deer recruitment in a longleaf pine-wiregrass ecosystem. Chapter 3 is an investigation of the food habits of coyotes and bobcats based on scat analyses. Chapter 4 reports on the survival and cause-specific mortality of white-tailed deer fawns based on a sample of radio-collared fawns.

Chapter 5 is a summary chapter consisting of conclusions and management implications of this research.

Literature Cited

Baker, L.A., R.J. Warren, D.R. Diefenbach, W.E. James, and M.J. Conroy. 2001. Prey selection by reintroduced bobcats (*Lynx rufus*) on Cumberland Island, Georgia. American Midland Naturalist 145:80-93.

Ballard, W. B., D. Lutz, T. W. Keegan, L. H. Carpenter, and J. C. deVos, Jr. 2001. Deer-predator relationships: a review of recent North American studies with emphasis on mule and black-tailed deer. Wildlife Society Bulletin 29:99-115.

Bartush, W. S. and J. C. Lewis. 1981. Mortality of white-tailed deer fawns in the Wichita Mountains. Proceedings of the Oklahoma Academy of Science 61:23-27.

Beasom, S. L. 1974. Relationships between predator removal and white-tailed deer net productivity. Journal of Wildlife Management 38:854-859.

Beasom, S. L. and R. A. Moore. 1977. Bobcat habitat response to prey abundance. Southwestern Naturalist 21:451-457.

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.

Bowers, J. W., A. Hammond, K. Kammermeyer, C. Martin, S. McDonald, N. Nicholson, J. Robbins, T. Touchstone, and G. Waters. 2005. Georgia's deer management plan 2005–2014. Georgia Department of Natural Resources. Social Circle, GA.

Chamberlain, M. J. and B. D. Leopold. 1999. Dietary patterns of sympatric bobcats and coyotes in central Mississippi. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 53:204-219.

Cook, R. S., M. White, D. O. Trainer, and W. C. Glazener. 1971. Mortality of young white-tailed deer fawns in south Texas. Journal of Wildlife Management 35:47-56.

Doughty, J. 2004. Bobcat (*Lynx rufus*) ecology in a longleaf pine ecosystem in southwestern Georgia. M.S. Thesis. University of Georgia, Athens.

Epstein, M. B., G. A. Feldhammer, and R. L. Joyner. 1983. Predation on white-tailed deer fawns by bobcats, foxes, and alligators: predator assessment. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 37:161-172.

Garner, G. W., J. A. Morrison, and J. C. Lewis. 1976. Mortality of white-tailed deer fawns in the Wichita Mountains, Oklahoma. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 30:493-506.

Griffin, J.C. 2001. Bobcat ecology on developed and less-developed portions of Kiawah Island, South Carolina. M.S. Thesis. University of Georgia, Athens, GA.

Hoerth, J. D. and M. K. Causey. 1991. Seasonal diets of coyotes in western central Alabama. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 45:91-96.

Joseph W. Jones Ecological Research Center. 2008. White-tailed deer management summary 1993-2008. Joseph W. Jones Ecological Research Center, Newton, GA.

Kilgo, J. C., H. S. Ray, M. J. Goode, M. A. Vukovich, and C. Ruth. 2009. Impact of coyotes on fawn survival in South Carolina. Annual Southeast Deer Study Group Meeting 32:48 (abstract).

Linnel, J. D., C., R. Aanes, and R. Anderson. 1995. Who killed Bambi? The role of predation in the neonatal mortality of temperate ungulates. Wildlife Biology 1:209-223.

Litvaitis, J. A. and D. J. Harrison. 1989. Bobcat-coyote niche relationships during a period of coyote population increase. Canadian Journal of Zoology 67:1180-1888.

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

Neale, J. C. C. and B. N. Sacks. 2001. Food habits and space use of gray foxes in relation to sympatric coyotes and bobcats. Canadian Journal of Zoology 79:1794-1800.

Nelson, T. A. and A. Woolf. 1987. Mortality of white-tailed deer fawns in southern Illinois. Journal of Wildlife Management 51:326-329.

Pusateri Burrughs, J., H. Campa, III, S. R. Winterstein, B. A. Rudolph, and W. E. Mortiz. 2006. Cause-specific mortality and survival of white-tailed deer fawns in southwestern lower Michigan. Journal of Wildlife Management 70:743-751.

Roberts, S. B. 2007. Ecology of white-tailed deer and bobcats on Kiawah Island, South Carolina: Implications for suburban habitat preservation. Ph.D. Dissertation. University of Georgia, Athens.

Saalfeld, S. T. and S. S. Ditchkoff. 2007. Survival of neonatal white-tailed deer in an exurban population. Journal of Wildlife Management 71:940-944.

Schrecengost, J. D., J. C. Kilgo, D. Mallard, H. S. Ray, and K. V. Miller. 2008. Seasonal food habits of the coyote in the South Carolina Coastal Plain. Southeastern Naturalist 7:135-144.

Stout, G. G. 1982. Effects of coyote reduction on white-tailed deer productivity on Fort Sill, Oklahoma. Wildlife Society Bulletin 10:329-332.

Thornton, D. H., M. E. Sunquist, and M. B. Main. 2004. Ecological separation within newly sympatric populations of coyotes and bobcats in south-central Florida. Journal of Mammalogy 85: 973-982.

VanGilder, C. L. 2008. Examination of coyote and bobcat food habits and the effects of an intensive predator removal on white-tailed deer recruitment in northeast Alabama. M.S. Thesis, University of Georgia, Athens.

Vreeland J. K., D. R. Diefenbach, and B. D. Wallingford. 2004. Survival rates, mortality causes, and habitats of Pennsylvania white-tailed deer fawns. Wildlife Society Bulletin 32:542-553.

Wassmer, D. A., D. D. Guenther, and J. N. Layne. 1988. Ecology of the bobcat in south-central Florida. Florida State Museum, Biological Science Bulletin 33:159-228.

CHAPTER 2

PREDATOR REMOVAL AND WHITE-TAILED DEER RECRUITMENT IN SOUTHWESTERN GEORGIA[1]

---

[1]Howze, M. B., L. M. Conner, R. J. Warren, and K. V. Miller. Submitted to *the Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies*.

Abstract: We assessed the efficacy of predator removal as a tool for increasing fawn recruitment at the Joseph W. Jones Ecological Research Center in southwestern Georgia, an area with a low-density (2 - 6 deer/km^2) deer herd. We partitioned our 11,736-ha study area into predator removal (approximately 4,200 ha) and non-removal (approximately 2,800 ha) zones with a 4,500-ha buffer between them. We removed 23 coyotes (*Canis latrans*) and 3 bobcats (*Lynx rufus*) from the removal zone between January and August 2008. Most of these (14 coyotes and 1 bobcat) were removed during the fawning period (June – August 2008). Pre-hunting season camera surveys conducted during September 2008 indicated a difference in fawn:doe ratios between the 2 zones (0.68 in the removal zone; 0.07 in the non-removal zone). Post-hunting season surveys conducted during February suggested a fawn:doe ratio of 0.97 in the removal zone and 0.45 in the non-removal zone. Our study provides further evidence that predator management may be an effective tool for increasing fawn recruitment in low-density deer herds.

Key words: *Canis latrans*, coyote, fawn recruitment, *Odocoileus virginianus*, predation, white-tailed deer

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies ___:___-___

White-tailed deer are one of the most economically important game species in Georgia and throughout the Southeast. Many wildlife managers in Georgia are now managing their herds under Quality Deer Management guidelines, which advocates socially and biologically balanced deer herds (Bowers et al. 2005). This management strategy protects younger bucks ($\leq$2.5yrs.) and encourages doe harvests to promote a healthy herd.

Natural resource managers often want to minimize the impact of deer on the landscape, while simultaneously promoting a healthy deer herd. This is accomplished by keeping the population below habitat carrying capacity (*K*). Without some sort of predation (including sport hunting), white-tailed deer populations can increase to levels which can lead to destruction of vegetation by overbrowsing, ultimately reducing carrying capacity, and lowering reproductive rates (Kie et al. 1979, Kie and White 1985, Ballard et al. 2001).

The potential impact of predation on a deer population is dependent upon the population's density relative to the carrying capacity (*K*) of the habitat. When deer density approaches *K*, predation is often compensatory because it does not cause an increase in overall mortality; rather, it replaces another mortality factor such as starvation or disease (Ballard et al. 2001). Alternatively, in low-density herds, predation can limit population growth because it can cause a reduction in recruitment. In these herds, predation may be additive, resulting in an increase in overall mortality (Ballard et al. 2001). Individual mortalities have a greater impact on populations when a deer herd is managed well below *K* (Ballard et al. 2001).

Herd monitoring efforts on the Joseph W. Jones Ecological Research Center (since 1993) suggest that although deer abundance, has remained relatively stable, the number of harvested deer, lactation rates of harvested deer, and observed fawn:doe ratios have declined since 2001. There has also been an increase in coyote density during this same period. Because the long-term data indicated a decline in recruitment, we initiated a predator removal experiment to determine if predation was limiting recruitment on our study area. Specifically, we investigated the impacts of an intensive predator removal during fawning season on fall and winter fawn:doe ratios. Based on research conducted in Alabama (VanGilder 2008), Oklahoma (Stout 1982) and Texas (Beasom 1974), we predicted significantly greater recruitment rates on the predator removal area relative to the non-removal site.

STUDY AREA

The Joseph W. Jones Ecological Research Center (Ichauway) in Baker County, Georgia is an 11,736-ha, privately owned research center in the Upper Gulf Coastal Plain. The landscape is dominated by a longleaf pine (*Pinus palustris*) overstory with a wiregrass (*Aristida stricta*) understory. Limesink and cypress-gum (*Taxodium ascendens-Nyssa biflora*) wetlands are interspersed within the riparian hardwood hammocks along the Ichawaynochaway Creek that bisects the property longitudinally and the Flint River that forms the eastern property boundary.

The site is characterized by relatively flat, karst topography with hot, humid summers and short, mild winters. The average daily temperature ranges from 11.1 °C in the winter to 27.2 °C in summer with an average precipitation of 132 cm per year (Boring 2001). Ichauway is managed on a 2-year prescribed fire rotation. Private lands surrounding Ichauway are comprised mainly of agricultural fields and plantation-style timber tracts. Just over ten percent of the property consists of agricultural fields and food plots planted with winter wheat (*Triticum aestivum)*, Egyptian wheat (*Sorghum* spp.), grain sorghum (*Sorghum vulgare*), browntop millet (*Brachiaria ramosa*), and cowpeas (*Vigna* spp.).

Ichauway lies in Georgia's Deer Management Unit 6, which consists of 31 counties in the Upper Gulf Coastal Plain where deer densities average 8.1 deer/km^2 (21 deer/mile^2, Bowers et al.

2005). The deer management goal for Ichauway is to maintain a herd density that maximizes herd health while minimizing negative ecological impacts of the herd on its forest ecosystem. Past data indicate that Ichauway's white-tailed deer herd has remained at a constant density of 3.8 – 5.8 deer/km^2 (10 – 15 deer/mile^2) and a relatively even sex ratio since the early 1990s. The site-wide fawn:doe ratio averaged 0.53 from 2001 – 2008 (J. W. Jones Ecological Research Center 2008).

METHODS

For this study, we divided the property into three zones. The southern portion of Ichauway (4,200-ha) was designated as the predator removal zone (Fig. 2.1). A 2,800-ha area on the northern portion of the property served as a control area with no predator removal. Between the experimental and control zones, there were two major highways and a 4,500-ha buffer area to minimize impacts of the predator removal on the control area. Limited predator removal occurred within this buffer zone, but focused on predators that do not prey on deer fawns (e.g., raccoons, *Procyon lotor* and opossums, *Didelphis virginiana*).

We trapped predators from January 2008 through August 2008, but most trapping efforts were concentrated during May – August 2008. All predators were trapped using #1.75 offset, laminated leg-hold traps (Woodstream Corp., Lititz, PA). Captured predators were dispatched using a .22 caliber rifle. All predators were handled under Georgia Department of Natural Resources' Scientific Collecting Permit #29-WTN-07-103 and University of Georgia's Institutional Animal Care and Use Committee Proposal #A2006-10093.

We used Cuddeback (Non Typical inc., Park Falls, WI) digital trail cameras to survey two, 608-ha blocks in the predator removal and two blocks of the same size in the non-removal zones. Camera surveys occurred during September 2008 and February 2009 following protocols from Jacobson et al. (1997) and Demarais et al. (2000). Camera surveys in the removal zone and in the non-removal site were conducted simultaneously. Survey sites used a camera density of 1 camera per 67.5 ha. Cameras were placed on trees 50-90 cm above the ground, set on a 5-minute delay, and positioned such that they faced either northward or southward to avoid glare from the sun, which could reduce our ability to identify animals. We placed bait piles consisting of whole corn ~4.5 m from the camera and replenished corn as needed. Pre-baiting occurred for 7 days prior to beginning camera surveys and survey periods lasted for 14 days. Since the 2001-2002 deer hunting season, a subset of hunters have systematically recorded number of deer, sex, and age (fawn or adult) observed while deer hunting. Therefore, we obtained annual fawn:doe ratios from 15-18 hunters who recorded deer observation data.

We used a χ^2 test of independence (Dowdy and Wearden 1991) in SAS (SAS Institute, Inc. 2003) to determine if camera observations of fawns and does were independent of predator removal and non-removal zones. We then used a similar approach to determine if there were differences between the average hunter-observed fawn:doe ratios during 2001 – 2008 versus the hunter-observed fawn:doe ratios during the 2008 – 2009 hunting season within both predator removal and non-removal zones (i.e., we performed a before [2001-2008] vs. after [2008-2009] test within each zone). Finally, we applied the same statistical test to determine if hunter-observed fawn:doe ratios were independent between the two zones during the 2008-2009 hunting season. For all hypotheses tests, we set $\alpha = 0.05$.

RESULTS

We removed 23 coyotes and 3 bobcats from the removal zone between January and August 2008. Most (14 coyotes, 1 bobcat) were removed during the fawning season (June-August).

Pre-hunting season camera surveys conducted during September 2008 revealed a fawn:doe ratio of 0.68 in the removal zone compared to 0.07 in the non-removal zone (Table 2.1; χ^2_1 = 99.8291, $P < 0.0001$). Post-hunting season camera surveys in February 2009 indicated a fawn:doe ratio of 0.97 in the removal zone and 0.45 in the non-removal zone (χ^2_1 = 104.6503, $P < 0.0001$). The pre-hunting season fawn:doe ratios were 9.71 times higher in the removal zone than the non-removal zone; whereas post-hunting season ratios were 2.15 times higher in the removal zone.

The hunter-observed fawn:doe ratio in the removal zone during the 2008-2009 hunting season (0.96) was greater (χ^2_1 = 4.6116, P = 0.0318) than the average hunter-observed fawn:doe ratio during the 2001-2008 hunting seasons (0.61). However, the hunter-observed fawn:doe ratio in non-removal zone during the 2008-2009 hunting season (0.44) was similar (χ^2_1 = 0.0182, P = 0.8927) to the average for the 2001-2008 hunting season fawn:doe ratio (0.47) observed in this area. Finally, the hunter-observed fawn:doe ratio in the removal zone (0.96) during the 2008-2009 hunting season was greater (χ^2_1 =3.8923, P = 0.0485) than the fawn:doe ratio observed in the non-removal zone (0.44) during the same period.

DISCUSSION

We removed fewer animals per unit area than previous studies reported in the literature (Table 2.2). However, monitoring efforts suggest that our removal efforts were equivalent to removing 1 coyote for every 8.5 deer based on the 2008-2009 white-tailed deer thermal camera survey data (deer density estimate = 4.6 deer/km^2; J. W. Jones Ecological Research Center 2008). Although coyote populations can withstand annual harvests of 70% in some areas (Connolly and Longhurst 1975), we only removed 34-43% of the estimated coyote population in our predator removal zone based on track count estimates of 1.44 $\pm$ 0.16 coyotes/km^2 (3.72 $\pm$

0.42 coyote/mile^2; J. Stober, Joseph. W. Jones Ecological Research Center, Pers. Commun). This reduction was apparently sufficient to result in an increase in fawn recruitment.

During the pre-hunting season camera survey, fawn:doe ratios between the removal and the non-removal zone differed by an order of magnitude. This is the greatest response to predator reduction reported in the literature to date. However, we are unsure as to what caused this large difference, and suggest that our pre-season camera survey estimates may not provide a reliable representation of the true impact of predator reduction on fawn recruitment. Peak fawning on our study area occurred from June – August and fawns were likely less mobile during the September surveys and therefore less likely to be photographed. Nevertheless, the fawn:doe ratio differed substantially between the removal and non-removal zones.

The post-season fawn:doe ratio in the removal zone was 2.15 times greater than the non-removal zone, and we suggest that these estimates are more representative of the true effect of predator reduction on fawn:doe ratios. Does were killed during the 2008-2009 hunting season, but the harvest was approximately equal between the two zones (9 in the non-removal zone and 11 in the removal zone). Hunter-observed fawn:doe ratios from 2008-2009 for both the removal (0.96) and non-removal zone (0.44) were remarkably similar to our post–season camera survey results for the removal (0.97) and non-removal zone (0.45). The congruence of these different survey methods provides evidence that our post-hunting season camera surveys are more representative of the population than our pre-hunting season survey. Moreover, both the hunter observations and our post-hunting season survey suggest a positive impact of predator reduction on fawn:doe ratios.

Our increase in fawn:doe ratios in the predator removal zone is in agreement with increases reported by other studies examining the effects of predator management in relation to recruitment rates of white-tailed deer. Coyote removal efforts on Fort Sill, Oklahoma resulted in an overall 154% increase in the doe:fawn ratio during a 4-year study (Stout 1982). Predator removal in northern Alabama resulted in an increase in fawn recruitment of 189% (VanGilder 2008). Beasom (1974) also found a 74% greater net productivity of deer in predator removal areas than in control areas.

A study of both predator and deer densities on a small temporal scale (i.e., every few days) relative to predator harvest would be beneficial to gain additional insight into predator-deer dynamics. This would permit quantification of predator recolonization rates and ultimately allow managers to better focus predator removal efforts to provide greater impacts on fawn recruitment.

MANAGEMENT IMPLICATIONS

Increasing coyote populations coupled with management strategies that manage for lower density white-tailed deer herds are creating new challenges for natural resource managers. Predation can have detrimental impacts on these deer herds if not accounted for when setting harvest goals. Removing coyotes and bobcats can have a positive impact on fawn recruitment in low-density deer herds when removal efforts are conducted properly. However, the timing of removal efforts can be as important as the intensity of removal efforts (Hamlin 1997, Ballard et al. 2001). Previous research has suggested that trapping efforts should be concentrated just prior to and throughout the fawning season (Hamlin 1997, Ballard et al. 2001) so that the area from which predators were removed does not become immediately repopulated while fawns are still in their first 30-60 days of life, when they are most susceptible to predation. Because of the reproductive capacity of white-tailed deer, it is also recommended predator control programs stop before populations increase to a level that harvest by hunters would not be able to stabilize the population.

LITERATURE CITED

Ballard, W.B., D. Lutz, T.W. Keegan, L.H. Carpenter, and J.C. deVos, Jr. 2001. Deer-predator relationships: a review of recent North American studies with emphasis on mule and black-tailed deer. Wildlife Society Bulletin 29:99-115.

Beasom, S.L. 1974. Relationships between predator removal and white-tailed deer net productivity. Journal of Wildlife Management 38:854-859.

Boring, L.R. 2001. The Joseph W. Jones Research Center: Co-directed applied and basic research in the private sector. Pages 233-258 in G. W. Barrett and T. L. Barrett, eds. Holistic science: the evolution of the Georgia Institute of Ecology (1940-2000). Taylor and Francis, New York, NY.

Bowers, J.W., A. Hammond, K. Kammermeyer, C. Martin, S. McDonald, N. Nicholson, J. Robbins, T. Touchstone, and G. Waters. 2005. Georgia's deer management plan 2005–2014. Georgia Department of Natural Resources. Social Circle, GA.

Connolly, G.E., and W.M. Longhurst. 1975. The effect of control on coyote populations. University of California, Division of Agricultural Science, Bulletin 1872, Davis, CA.

Demarais, S., S.W. McKinley, and H.A. Jacobson. 2000. Using infrared-triggered cameras to survey white-tailed deer in Mississippi. Forest and Wildlife Research Center, Research Advances 5, Mississippi State University.

Dowdy, S., and S. Wearden. 1991. Statistics for Research. John Wiley and Sons, New York, NY.

Hamlin, K.L. 1997. Survival and home range fidelity of coyotes in Montana: implications for control. Intermountain Journal of Sciences 3:62-72.

Jacobson, H.A., J.C. Kroll, R.W. Browning, B.H. Koerth, and M.H. Conway. 1997. Infrared-triggered cameras for censusing white-tailed deer. Wildlife Society Bulletin 25:547-556.

Joseph W. Jones Ecological Research Center. 2008. White-tailed deer management summary 1993-2008. Joseph W. Jones Ecological Research Center. Newton, GA.

Kie, J.G., M. White, and F.F. Knowlton. 1979. Effects of coyote predation on population dynamics of white-tailed deer. Proceedings of the Welder Wildlife Foundation Symposium 1:65-82.

Kie J.G., and M. White. 1985. Population dynamics of white-tailed deer (*Odocoileus virginianus*) on the Welder Wildlife Refuge, Texas. Southwestern Naturalist 30:105-118.

Schrecengost, J.D. 2007. Home range and food habits of the coyote (*Canis latrans*) at the Savannah River site, South Carolina. M.S. Thesis. University of Georgia, Athens.

Stout, G.G. 1982. Effects of coyote reduction on white-tailed deer productivity on Fort Sill, Oklahoma. Wildlife Society Bulletin 10:329-332.

VanGilder, C.L. 2008. Examination of coyote and bobcat food habits and the effects of an intensive predator removal on white-tailed deer recruitment in northeast Alabama. M.S. Thesis. University of Georgia, Athens.

Table 2.1. Number of white-tailed deer does and fawns detected during pre-hunting season and post-hunting season camera surveys within predator removal and non-removal zones at the Joseph W. Jones Ecological Research Center, Baker County, Georgia, 2008 – 2009.

	Predator Removal Zone			Non-Removal Zone		
Month	Adult Does[a]	Fawns[a]	Fawn:Doe[a]	Adult Does[a]	Fawns[a]	Fawn:Doe[a]
September	288	197	0.68	260	19	0.07
February	514	497	0.97	1705	759	0.45

[a] Excludes animals that could not be positively identified.

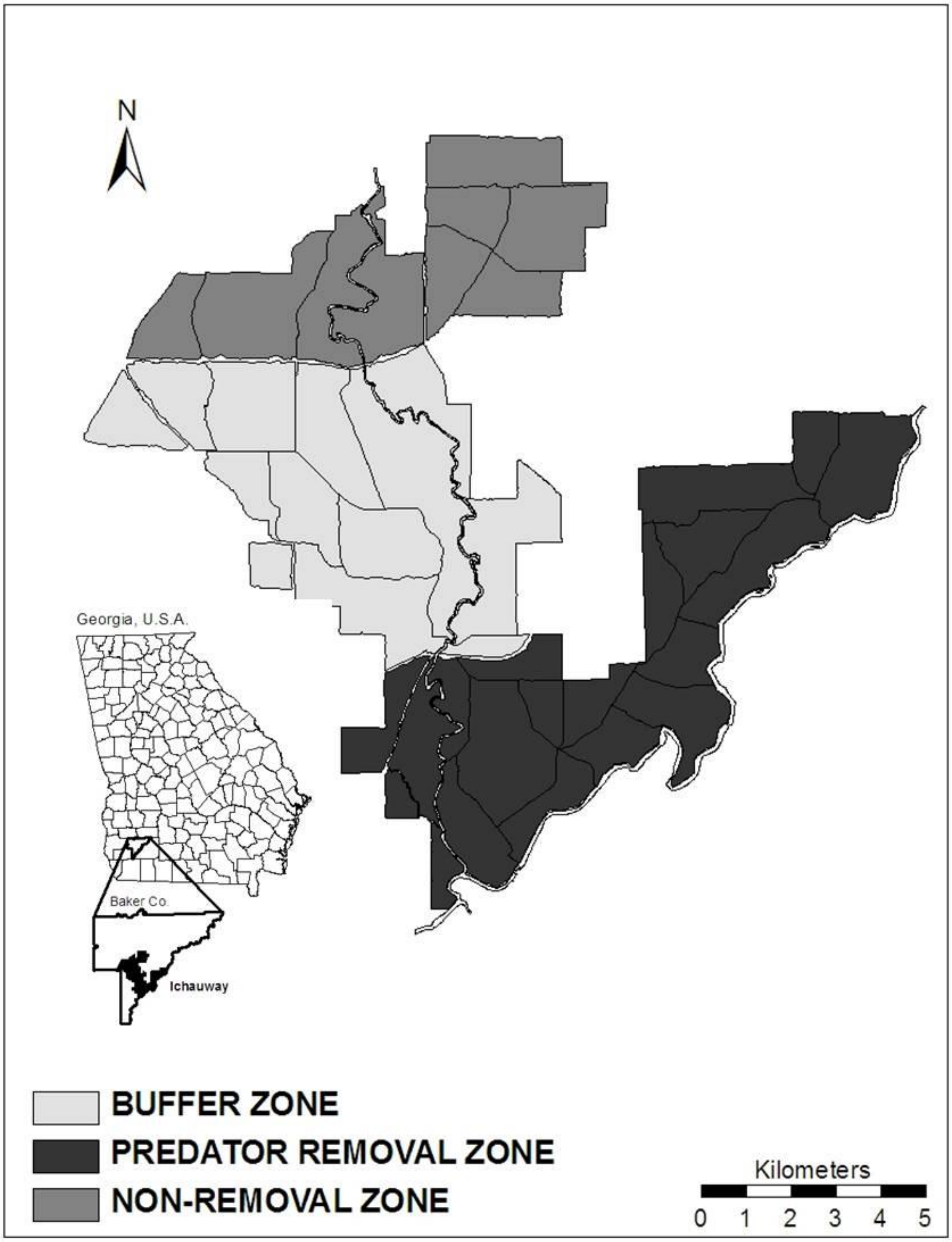


Figure 2.1. Predator management zones on the Joseph W. Jones Ecological Research Center (Ichauway), Baker County, GA 2008.

Table 2.2. Duration of removal effort, number of predators removed and study area size of predator-removal studies that address effects of predator removal on white-tailed deer fawn:doe ratios.

Study	Removal length	Coyotes removed	Bobcats removed	removal area size (ha)
Beasom 1974	2 years (Feb-June)	188	120	2,186
Stout 1982	4 years (Jan-April)	398	0	38,099
VanGilder 2008	6 months	22	10	810
This study	8 months	23	3	4,500

CHAPTER 3

FOOD HABITS OF COYOTES AND BOBCATS IN SOUTHWESTERN GEORGIA WITH EMPHASIS ON DEER PREDATION[1]

[1]Howze, M.B., L. M. Conner, R. J. Warren, and K. V. Miller. To be submitted to *The Southeastern Naturalist*.

ABSTRACT

Canis latrans (Coyotes) and *Lynx rufus* (Bobcats) are known predators of *Odocoileus virginianus* (White-tailed Deer), but their impact on herds varies regionally as well as seasonally. We collected scat from Coyotes (n = 312) and Bobcats (n = 171) during 2007 and summer 2008 in southwestern Georgia, and analyzed them for food item content. Vegetation (79.5%) and rodents (55.4%) were the most common items in coyote scat throughout the study, while rodents (70.8%) and *Sylvilagus* spp. (rabbits) were the most common items bobcat scat. Deer remains occurred in 13% of Coyote scat during the pre-fawning season 2007 (Feb. – May), 46% during the fawning season 2007 (June – August), 18.2% during the post-fawning season 2007 (Sept. – Oct.), 30.2% during the hunting season 2007 (Nov. – Dec.), and 32.5% during the fawning season 2008 (June – August). Deer remains occurred in 3.6% of Bobcat scat during the pre-fawning season, 14.7% during the 2007 fawning season, 8.7 % during the post-fawning season 19.0% during the hunting season, and 11.1% during the 2008 fawning season. Deer occurred more frequently in Coyote scat than in Bobcat scat during the fawning season 2007 (Fisher's exact P = 0.0015) and fawning season 2008 (Fisher's exact P = 0.0423), but not during the hunting season (Fisher's exact P = 0.3858), pre-fawning season (Fisher's exact P = 0.1094), or the post-fawning season (Fisher's exact P = 0.4490). The greater occurrence of deer in Coyote scat, especially during the fawning season, suggests that white-tailed deer are a more commonly utilized prey item in the diet of Coyotes than Bobcats, and as a result, Coyotes may be having a greater impact on White-tailed Deer recruitment.

INTRODUCTION

Canis latrans Say (Coyotes) and *Lynx rufus* Schreber (Bobcats) are two of the most widely distributed carnivores in North America (Chapman and Feldhammer 1982). In the southeastern United States, several studies have investigated the food habits of these predators (Blanton and Hill 1989, Chamberlain and Leopold 1999, VanGilder 2008). However, only investigations into Bobcat food habits have occurred in Georgia (Baker et al. 2001, Cochrane 2003, Godbois 2003, Doughty 2004). Furthermore, few studies have investigated diets of sympatric Bobcats and Coyotes in the Southeast (Chamberlain and Leopold 1999, Thornton et al. 2004).

Coyotes are generalist predators with a more diverse diet than Bobcats (Litvaitis and Harrsion 1989). While small mammals and *Sylvilagus* spp. (rabbits) are common prey items in Coyote diets (Gipson 1974, Hall 1979), the occurrence of *Odocoileus virginianus* Zimmerman (White-tailed Deer) in Coyote diets is variable, although they are known predators of fawns (Ballard et al. 2001, Beasom 1974, Blanton and Hill 1989, Schrecengost et al. 2008, and VanGilder 2008). In Mississippi, Chamberlain and Leopold (1999) found deer in 31.9% of Coyote scat collected throughout all seasons. In a study encompassing several southeastern states, Blanton and Hill (1989) reported that deer remains occurred in 31% of Coyote scat collected during the summer; 77% of these occurrences were identified as containing fawn remains.

Although the frequency of White-tailed Deer reported in Bobcat diets varies regionally and seasonally, most studies in the Southeast have reported relatively low occurrences. In Florida, Maehr and Brady (1986) reported that deer occurred in 2% of Bobcat scat, whereas, Wassmer et al. (1988) did not find any deer remains in another study in Florida. A 2-year study in Texas also indicated low amounts of White-tailed Deer in Bobcat diets: 6% in the first year and none in the second year (Beasom and Moore 1977). Doughty (2004) found annual occurrences of deer in scat to be <10% during 2001 – 2004 in Georgia. It has been suggested that in areas where Coyotes and Bobcats are sympatric, Bobcats consume more rabbits and rodents while Coyotes consume more ungulates (Chamberlain and Leopold 1999, Neale and Sacks 2001, Thornton et al. 2004).

Herd monitoring efforts on the Joseph W. Jones Ecological Research Center (since 1993) suggest that although deer abundance has remained relatively stable, the number of harvested deer, lactation rates of harvested deer, and observed fawn:doe ratios have declined since 2001 (J. W. Jones Ecological Research Center 2008). Concurrently, coyote abundance has increased (J. Stober, Joseph W. Jones Ecological Research Center, Pers. Commun). Increasing numbers of Coyotes coupled with decreasing recruitment rates on our study area has led to speculation regarding potential impacts of these predators on White-tailed Deer.

To understand the potential impacts of predator consumption of deer on recruitment rates in the Southeast, we designed a study to examine predator diets, with an emphasis on quantifying consumption of White-tailed Deer. Our objective was to quantify the consumption of White-tailed Deer by Bobcats and Coyotes during the fawning season compared to the rest of the year in a *Pinus palustris* Miller-*Aristida stricta* Michx. (Longleaf Pine-Wiregrass) ecosystem in southwestern Georgia.

STUDY AREA

The Joseph W. Jones Ecological Research Center (Ichauway) in Baker County, Georgia is an 11,736-ha, privately owned research center in the Upper Gulf Coastal Plain. The landscape is dominated by a Longleaf Pine overstory with a Wiregrass understory, managed on a two-year prescribed fire regime. Limesink and *Taxodium ascendens* Brongn. - *Nyssa biflora* Walt.

(Cypress-Gum) wetlands are interspersed within the riparian hardwood hammocks along Ichawaynochaway Creek that bisects the property longitudinally and the Flint River that forms the eastern property boundary.

The site is characterized by relatively flat, karst topography with hot, humid summers and short, mild winters. The average daily temperature ranges from 11.1 °C in the winter to 27.2 °C in summer with an average precipitation of 132 cm per year (Boring 2001). Private lands surrounding Ichauway are comprised mainly of agricultural fields and plantation-style timber tracts. Approximately 10% of the property consists of agricultural fields and food plots planted with *Triticum aestivum* Linneaus, (winter wheat), *Sorghum* spp. (Egyptian wheat), *Sorghum vulgare* Pers. (grain sorghum), *Brachiaria ramosa* (L.) Stapf (browntop millet), and *Vigna* spp. (cowpeas).

Ichauway lies in Georgia's Deer Management Unit 6, which consists of 31 counties in the Upper Gulf Coastal Plain where deer densities average 8.1 deer/km^2 (21 deer/mile^2, Bowers et al. 2005). Past data indicate that Ichauway's white-tailed deer herd has remained at a constant density of 3.8 – 5.8 deer/km^2 (10 – 15 deer/mile^2) and a relatively even sex ratio since the early 1990s. The site-wide fawn:doe ratio averaged 0.53 from 2001 – 2008 (J. W. Jones Ecological Research Center 2008).

METHODS

We collected Bobcat and Coyote scat opportunistically from roads and firebreaks across the study site during February – December 2007 and during June – August 2008. We only collected fresh scat for analysis (Godbois et al. 2005) to ensure accurate identification of the predator. Scat was identified as Bobcat or Coyote based on a combination of size, shape, odor and tracks around fresh scat (Bowyer et al. 1983, Danner and Dodd 1982). We discarded scat of questionable origin. We placed individual scats in labeled paper bags and froze them to prevent further decomposition before processing.

Samples were placed in a drying oven for 72 hours at 60°C before processing to kill bacteria or parasites (Baker et al. 1993, Griffin 2001). Each scat was separated and contents were examined macroscopically. Individual prey items were identified to species whenever possible from hair (Stains 1958), teeth, hoof, claw, and plant matter. Hair samples that could not be identified macroscopically were compared microscopically to guard hair reference samples in the University of Georgia's Warnell School of Forestry and Natural Resources collection. Vegetation (primarily seeds) was compared to known reference samples from the Joseph W. Jones Ecological Research Center herbarium and seed collection. Fawn remains were identified based on size, color and texture of hair (Blanton 1988), as well as the presence of bones, and teeth. All deer remains were categorized as adult unless fawn remains could be positively identified. We grouped individual prey items into six prey categories (rodent, bird, deer, rabbit, other, and vegetation) and report frequency of occurrence (%) for each category. We determined frequency of occurrence for each food item by dividing the number of scats in which each food item occurred by the total number of individual scats examined for each predator species within each season.

We partitioned the year into five seasons: pre-fawning season 2007 (February – May), fawning season 2007 (June – August), post-fawning season 2007 (September – October), hunting season 2007 (November – December), and fawning season 2008 (June – August). Due to lack of hunter participation during the archery season (Sept. – Oct.), we partitioned it into the post-fawning season instead of including it in the hunting season.

For statistical analysis, we grouped individual food items into six categories (rodent, bird, deer, rabbit, other, and vegetation) and report frequency of occurrence for each category. We used a Fisher's exact test of independence (Fisher 1973) in SAS (SAS Institute, Inc. 2003) to compare white-tailed deer occurrence among the aforementioned seasons within predator species, as well as between predator species for a particular season. We then applied the same statistical test to determine if the occurrence of deer was greater in scat from Coyotes than Bobcats during the fawning season, hunting season, pre-fawning season, and the post-fawning season. For all hypotheses tests, we set $\alpha = 0.10$.

RESULTS

We collected 312 Coyote and 171 Bobcat scats from February – December 2007 and from June – August 2008. We identified 43 prey items in Coyote scat (Table 3.1). Vegetation was the most common item (79.5%) in Coyote scat collected throughout the study. Rodents were the most common prey item in Coyote scat during the pre-fawning season (78.3%) and occurred in approximately half of all scats in the remaining seasons. Insects (primarily Orthoptera and Coleoptera) occurred throughout the year, but occurrence peaked during the fawning seasons (Table 3.1). Rabbits were common primarily in the pre-fawning season (30.4%), post-fawning season (21.2%) and the hunting season (30.2%). Bird occurrence in scat (14.9%) was highest during the fawning season 2007.

We identified 25 food items from Bobcat scat (Table 3.2). Rodent (70.8%) occurred most frequently in Bobcat scat and *Sigmodon hispidus* Say and Ord (Cotton Rat) was detected in 40.4% of these. Rodent occurrence peaked during the pre-fawning season (80.4%). Bird remains were observed in 21.1% of all scat, while vegetation was found in 15.2% of Bobcat scat. Occurrences of bird remains in Bobcat scat was greatest in the post-fawning season (30.4%) and the fawning season 2008 (29.7%). Occurrences of rabbit was most common during the pre-fawning season (35.7%) and the fawning season 2007 (35.3%). Snakes comprised the largest percentage of the other category with the greatest occurrence in the post-fawning season (13%). Grass (Poaceae) was the only vegetation found in bobcat scat.

Deer remains occurred in 13% of Coyote scat during the pre-fawning season 2007 (Feb. – May), 46% during the fawning season 2007 (June – August), 18.2% during the post-fawning season 2007 (Sept. – Oct.), 30.2% during the hunting season 2007 (Nov. – Dec.), and 32.5% during the fawning season 2008 (June – August). White-tailed Deer occurrence during the fawning season 2007 (46%) was greater (Fisher's exact $P = 0.0833$) than during the fawning season 2008 (32.5%). Frequency of occurrence was also greater during the fawning season 2007 than both the pre-fawning season (Fisher's exact $P < 0.0001$), the post-fawning season (Fisher's exact $P = 0.0060$), and the hunting season (Fisher's exact $P = 0.0922$). Frequency of occurrence during the fawning season 2008 was greater than the pre-fawning season (Fisher's exact $P = 0.0064$), but was similar during the post-fawning season (Fisher's exact $P = 0.1689$) and the hunting season (Fisher's exact $P = 0.8415$). Deer occurrences in coyote scat during the hunting season were similar during the post-fawning season (Fisher's exact $P = 0.2900$), but were greater during pre-fawning season (Fisher's exact $P = 0.0306$). Occurrences of Deer in Coyote scat were also similar during the pre-fawning and post-fawning seasons (Fisher's exact $P = 0.5547$). Deer occurred more frequently in Coyote scat than in Bobcat scat during the fawning season 2007 (Fisher's exact $P = 0.0015$) and fawning season 2008 (Fisher's exact $P = 0.0423$), but not during the hunting season (Fisher's exact $P = 0.3858$), pre-fawning season (Fisher's exact $P = 0.1094$), or the post-fawning season (Fisher's exact $P = 0.4490$).

Deer remains occurred in 3.6% of Bobcat scat during the pre-fawning season, 14.7% of scat during the fawning season 2007, 8.7% during the post-fawning season, 19.0% during the hunting season, and 16.2% in the fawning season 2008. Deer remains were encountered in 11.1% of all Bobcat scat. During the fawning season 2007, 14.7% of Bobcat scat contained deer with most (80%) of these containing fawn remains. Frequency of occurrence during the fawning season 2007 was similar to that of the fawning season 2008 (Fisher's exact P = 1.0000), post-fawning season (Fisher's exact P = 0.6893), hunting season (Fisher's exact P = 0.7187), but was greater than the pre-fawning season (Fisher's exact P = 0.0922). Deer occurrences in scat during the fawning season 2008 were greater than the pre-fawning season (Fisher's exact P = 0.0551), but were similar during hunting season (Fisher's exact P = 1.000), and the post-fawning season (Fisher's exact P = 0.6983). Frequency of occurrence was higher during the hunting season than the pre-fawning season (Fisher's exact P = 0.0439), but not the post-fawning season (Fisher's exact P=0.4029). Occurrences of Deer in Bobcat scat were also similar during the pre-fawning and post-fawning seasons (Fisher's exact P = 0.5757).

DISCUSSION

White-tailed Deer occurred more frequently in the diets of Coyotes in our study than has been reported in Florida (Stratman and Pelton 1997, Thornton et al. 2004), Alabama (VanGilder 2008), and South Carolina (Schrecengost 2008), but similar to other studies in Alabama (Hoerath and Causey 1991) and Mississippi (Chamberlain and Leopold 1999). The frequent occurrence of deer hair in scat during the fawning period is also consistent with previous studies (Chamberlain and Leopold 1999, Thornton et al. 2004, Schrecengost et al. 2008, VanGilder 2008). Deer remains in Coyote scat were also common during the hunting season (Fig. 3.1), and likely are the result of scavenging unrecovered hunter kills (Wooding 1984, Schrecengost 2008). Although we designated June – August as the fawning season, we found occasional fawn remains in Coyote scat outside of this period, due to predation of fawns born before or after the peak of parturition.

Previous studies have suggested that seasonally available soft mast may buffer Coyote predation on fawns by providing a readily available alternative food source (Andelt et al. 1987, Shrecengost et al. 2008). Vegetation in Coyote scat during the fawning seasons (2007 and 2008) was largely blackberry (*Rubus* spp.) and wild plum (*Prunus* spp.), while vegetation during the post-fawning season was primarily *Diospyros virginiana* Linneaus (Persimmon), similar to research in South Carolina (Schrecengost et al. 2008). The increased prevalence of soft mast in Coyote scat during the fawning season 2008, coupled with a the decrease in deer detected in scat compared to the fawning season 2007, suggests that soft mast may also serve as a buffer on Ichauway. We also noted a large percentage of *Arachis hypogaea* Linneaus (Peanuts) during the post-fawning season (30.3%) and the hunting season (39.5%). This was likely due to coyotes utilizing food sources from agricultural fields surrounding Ichauway.

Overall, occurrence of Deer in Bobcat scat was similar to other studies on our research area (Cochrane 2003, Doughty 2004, Godbois 2003) as well as elsewhere in Georgia (Lang, 2008, Schoch 2003) and Alabama (Miller and Speake 1978, VanGilder 2008). However, the occurrence of deer in Bobcat scat was lower than in several other studies (Baker et al. 2001, Epstein et al.1983, Griffin 2001) conducted on barrier islands off the coasts of Georgia and South Carolina. However, in all of these studies, Coyotes did not occur on the study areas.

Occurrence of rodents and rabbits in Coyote scat was similar to several studies in the Southeast (Blanton and Hill 1989, Chamberlain and Leopold 1999, VanGilder 2008), but higher than previous research in South Carolina (Schrecengost et al. 2008) and Florida (Stratman and Pelton 1997). Occurrence of birds in Bobcat scat was similar to previous studies on Ichauway

(Doughty 2004) as well as other studies in the Southeast (Fritts andSealander 1978, Maehr and Brady 1986).

The increased occurrence of deer in Coyote scat during the fawning seasons coincided with a decreased occurrence of rodents and rabbits in scat, while the least occurrence of deer coincided with the greastest occurrence of rodents. Our results concur with Blanton and Hill (1989) and Shrecengost et al. (2008), who suggest that coyotes may be selecting fawns over less beneficial prey items. Moreover, the increased occurrence of deer in Bobcat scat during the hunting season coincided with a decreased use of rodents, while the greatest occurrences of deer (hunting season and fawning season 2008) coincided with the least occurrences of rabbit.

It has been suggested that in areas where Coyotes and Bobcats are sympatric, Bobcats consume more rabbits and rodents while coyotes consume more ungulates (Chamberlain and Leopold 1999, Neale and Sacks 2001). Thornton et al. (2004) reported similar diet partitioning between predators in Florida. Although Bobcats and Coyotes consumed White-tailed Deer during our study period, Coyotes consumed significantly more deer during the fawning seasons than Bobcats. The prevalence of deer remains in Coyote and Bobcat scat, especially during the fawning season, coupled with declining fawn:doe ratios based on hunter observations (J. W. Jones Ecological Research Center 2008), suggest that these predators may be reducing deer recruitment on Ichauway.

Future studies should incorporate coyote and bobcat densities relative to each other as well as to deer to more accurately make inferences regarding the consumption of deer and the impact(s) of these predators on deer herd dynamics. Research could also include genetic sampling of prey items for predator DNA (Kilgo et al. 2009) and scat (Onorato et al. 2006) for identification of numbers of individual predators. These data could be useful in determining how many individual predators were identifiable when analyzing diet data and verify if deer consumption was equal among individual predators.

LITERATURE CITED

Andelt, W.F., J.G. Kie, F.F. Knowlton, and K. Cardwell. 1987. Variation in coyote diet associated with season and successional changes in vegetation. Journal of Wildlife Management 51:273-277.

Baker, L.A., R.J. Warren, D.R. Diefenbach, W.E. James, and M.J. Conroy. 2001. Prey selection by reintroduced bobcats (*Lynx rufus*) on Cumberland Island, Georgia. American Midland Naturalist 145:80-93.

Baker, L.A., R.J. Warren, and W.E. James. 1993. Bobcat prey digestibility and representations in scats. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 47:71-79.

Ballard, W.B., D. Lutz, T.W. Keegan, L.H. Carpenter, and J.C. deVos, Jr. 2001. Deer-predator relationships: a review of recent North American studies with emphasis on mule and black-tailed deer. Wildlife Society Bulletin 29:99-115.

Beasom, S.L. 1974. Relationships between predator removal and white-tailed deer net productivity. Journal of Wildlife Management 38: 854-859.

Beasom, S.L., and R.A. Moore. 1977. Bobcat habitat response to prey abundance. Southwestern Naturalist 21:451-457.

Blanton, K.M. 1988. Summer diets of coyotes in the Southeast, and the response of coyotes to siren surveys. M.S. Thesis. Mississippi State University, Mississippi State, MS.

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.

Boring, L.R. 2001. The Joseph W. Jones Research Center: Co-directed applied and basic research in the private sector. Pages 233-258 in G.W. Barrett and T.L. Barrett, eds. Holistic Science: The Evolution of the Georgia Institute of Ecology (1940-2000). Taylor and Francis, New York, NY.

Bowers, J.W., A. Hammond, K. Kammermeyer, C. Martin, S. McDonald, N. Nicholson, J. Robbins, T. Touchstone, and G. Waters. 2005. Georgia's deer management plan 2005–2014. Georgia Department of Natural Resources. Social Circle, GA.

Bowyer, T.R., S.A. McKenna, and M.E. Shea. 1983. Seasonal changes in coyote food habits determined by fecal analysis. American Midland Naturalist 109:266-273.

Chamberlain, M.J., and B.D. Leopold. 1999. Dietary patterns of sympatric bobcats and coyotes in central Mississippi. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 53:204-219.

Chapman, J.E., and G.A. Feldhammer. 1982. Wild Mammals of North America. The Johns Hopkins University Press, Baltimore, MD.

Cochrane, J.C. 2003. Ecology of bobcats in a longleaf pine forest in southwestern Georgia. M.S. Thesis. University of Georgia, Athens, GA.

Danner, D.A., and N. Dodd. 1982. Comparison of coyote and gray fox scat diameters. Journal of Wildlife Management 46:240-241.

Doughty, J. 2004. Bobcat (*Lynx rufus*) ecology in a longleaf pine ecosystem in southwestern Georgia. M.S. Thesis. University of Georgia, Athens, GA.

Epstein, M. B., G. A. Feldhammer, and R. L. Joyner. 1983. Predation on white-tailed deer fawns by bobcats, foxes, and alligators: predator assessment. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 37:161-172.

Fisher, R.A. 1973. Statistical Methods for Research Workers, 14th ed. Hafner, New York, NY.

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.

Gipson, P.S. 1974. Food habits of coyotes in Arkansas. Journal of Wildlife Management 38:848-853.

Godbois, I.A. 2003. Ecology of bobcats on land managed for northern bobwhite in southwestern Georgia. M.S. Thesis, University of Georgia, Athens, GA.

Godbois, I.A., L.M. Conner, B.D. Leopold, and R.J. Warren. 2005. Effect of diet on mass loss of bobcat scat after exposure to field conditions. Wildlife Society Bulletin 33:149-153.

Griffin, J.C. 2001. Bobcat ecology on developed and less-developed portions of Kiawah Island, South Carolina. M.S. Thesis, University of Georgia, Athens, GA.

Hall, D.I. 1979. An ecological study of the coyote-like canid in Louisiana. M.S. Thesis. Louisiana State University, Baton Rouge, LA.

Hoerth, J.D., and M.K. Causey. 1991. Seasonal diets of coyotes in western central Alabama. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 45:91-96.

Joseph W. Jones Ecological Research Center. 2008. White-tailed deer management summary 1993-2008. Joseph W. Jones Ecological Research Center. Newton, GA.

Kilgo, J.C., H.S. Ray, M.J. Goode, M.A. Vukovich, and C. Ruth. 2009. Impact of coyotes on fawn survival in South Carolina. Annual Southeast Deer Study Group Meeting 32:48 (abstract).

Lang, M.C. 2008. The effects of intensive predator harvest during the quail nesting season on diet, age, and reproduction of meso-mammalian predators. M.S. Thesis. University of Georgia, Athens, GA.

Litvaitis, J.A., and D.J. Harrison. 1989. Bobcat-coyote niche relationships during a period of coyote population increase. Canadian Journal of Zoology 67:1180-1188.

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

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.

Neale, J.C.C., and B.N. Sacks. 2001. Food habits and space use of gray foxes in relation to sympatric coyotes and bobcats. Canadian Journal of Zoology 79:1794-1800.

Onorato, D., C. White, P. Zager, and L.P. Waits. 2006. Detection of predator presence at elk mortality sites using mtDNA analysis of hair and scat samples. Wildlife Society Bulletin 34(3):815-820.

SAS Institute, Inc. 2003. SAS User's Guide: Statistics, 2003 edition. SAS Inst. Inc., Cary, NC.

Schoch, B.N. 2003. Diet, age, and reproduction of mesomammalian predators in response to intensive removal during the quail nesting season. M.S. Thesis, University of Georgia, Athens, GA.

Schrecengost, J.D., J.C. Kilgo, D. Mallard, H.S. Ray, and K.V. Miller. 2008. Seasonal food habits of the coyote in the South Carolina coastal plain. Southeastern Naturalist 7:135-144.

Stains, H.J. 1958. Field key to guard hair of middle western furbearers. Journal of Wildlife Management. 22:95-97.

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.

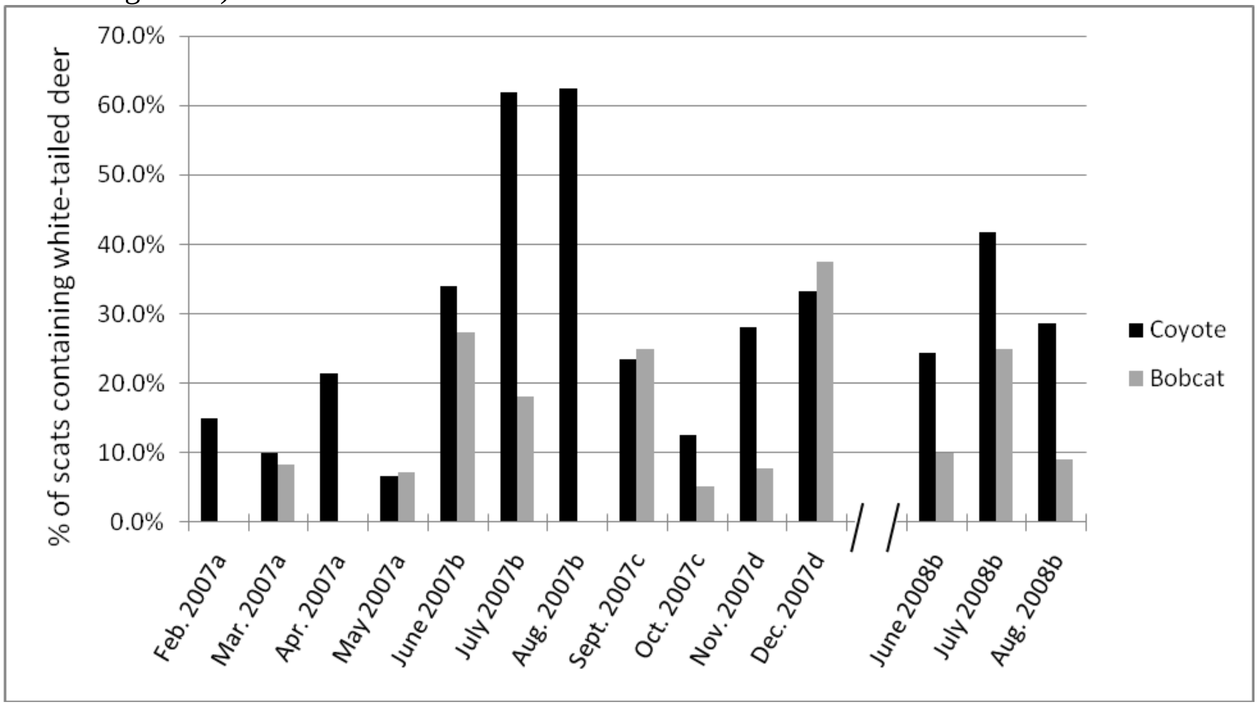
Thornton, D.H., M.E. Sunquist, and M.B. Main. 2004. Ecological separation within newly sympatric populations of coyotes and bobcats in south-central Florida. Journal of Mammalogy 85:973-982.

VanGilder, C.L. 2008. Examination of coyote and bobcat food habits and the effects of an intensive predator removal on white-tailed deer recruitment in northeast Alabama. M.S. Thesis, University of Georgia, Athens, GA.

Wassmer, D.A., D.D. Guenther, and J.N. Layne. 1988. Ecology of the bobcat in south-central Florida. Florida State Museum, Biological Science Bulletin 33:159-228.

Wooding, J.B. 1984. Coyote food habits and the spatial relationship of coyotes and foxes in Mississippi and Alabama. M.S. Thesis. Mississippi State University, Mississippi State, MS.

Figure 3.1. Monthly occurrence of White-tailed Deer in Coyote and Bobcat scat at the Joseph W. Jones Ecological Research Center (Ichauway), Baker County, Georgia (Feb. – Dec. 2007 and Jan. – Aug. 2008).



a = Pre-fawning season
b = Fawning season
c = Post-fawning season
d = Hunting season

Table 3.1. Percent occurrence of prey items found in coyote scat on the Joseph W. Jones Ecological Research Center (Ichauway), Baker County, Georgia (February – December 2007 and June – August 2008).

	Pre-fawning season 2007[a] (n=69)	Fawning season 2007[b] (n=87)	Post-fawning season 2007[c] (n=33)	Hunting season 2007[d] (n=43)	Fawning season 2008[b] (n=80)	Total (n=312)
White-tailed Deer	13.0	46.0	18.2	30.2	32.5	30.1
Odocoileus virginianus						
Adult	11.6	23.0	15.2	30.2	15.0	18.6
Fawn	1.4	23.0	3.0	—	17.5	11.5
Rodent	78.3	49.4	45.5	53.5	47.5	55.4
Cotton rat	37.7	29.9	21.2	25.6	22.5	28.2
Sigmodon hispidus						
Peromyscus spp.	2.9	—	—	2.3	—	1.0
Eastern woodrat	—	—	3.0	2.3	2.5	1.3
Neotoma floridana (Ord)						
Southeastern pocket gopher	—	1.1	—	—	—	0.3
Geomys pinetis (Rafinesque)						
Fox squirrel	—	1.1	3.0	—	—	0.6
Sciurus niger (L.)						
Eastern chipmunk	—	1.1	—	—	—	0.3
Tamais striatus (L.)						
Eastern gray squirrel	—	1.1	3.0	—	1.3	1.0
Sciurus carolinensis (Gmelin)						
Rabbit	30.4	10.3	21.2	30.2	10.0	18.6
(*Sylvilagus* spp.)						
Bird (Aves)	10.1	14.9	12.1	2.3	10.0	10.6
Northern bobwhite	—	—	—	—	1.3	0.3
Colinus virginianus (L.)						
Eastern wild turkey	1.4	2.3	—	—	—	1.0
Meleagris gallopavo (L.)						
Other	39.1	23.0	27.3	37.2	35.0	32.1
Bobcat	1.4	—	—	4.7	—	1.0
Lynx rufus						
Coyote	1.4	1.1	—	—	—	1.0
Canis latrans						
Domestic dog	2.9	—	—	—	—	0.6
Canis familiaris (L.)						
Nine-banded armadillo	7.2	1.1	3.0	2.3	5.0	3.8
Dasypus novemcinctus (L.)						
Raccoon	11.6	—	—	2.3	6.3	4.5
Procyon lotor (L.)						
Virginia opossum	1.4	—	6.1	2.3	1.3	1.6
Didelphis virginiana (Kerr)						
Wild hog	—	—	—	—	1.3	0.3
Sus scrofa (L.)						
Shrew	1.4	—	—	—	—	0.3
(*Sorex* spp.)						
Grasshopper	4.3	4.6	12.1	7.0	12.5	7.7
(Orthoptera)						
Beetle	5.8	6.9	12.1	2.3	5.0	6.1
(Coleoptera)						

Millipede (Diplopoda)	—	—	—	7.0	—	1.0
Crayfish (Cambaridae)	1.4	1.1	—	2.3	2.5	1.6
Fish (Osteichthyes)	2.9	3.4	—	—	—	1.6
Unidentified snake (Serpentes)	4.3	2.3	—	4.7	5.0	3.5
Reptile egg	—	1.1	—	—	—	0.3
Sand	—	—	—	—	1.3	0.6
Rocks	—	—	—	2.3	—	0.3
Vegetation	59.4	88.5	87.9	60.5	93.8	79.5
grass (Poaceae)	30.4	20.7	9.1	7.0	18.8	19.2
Peanut *Arachis hypogaea* (L.)	17.4	12.6	30.3	39.5	3.8	17.0
Corn *Zea mays* (L.)	10.1	12.6	12.1	14.0	5.0	10.3
Blackberry *Rubus* spp.	1.4	40.2	—	—	10.0	14.1
Plum *Prunus* spp.	8.7	31.0	—	—	66.3	27.6
Persimmon *Diospyros virginiana* (L.)	—	2.3	51.5	4.7	—	6.7
Muscadine *Vitis rotundifolia* (Michx.)	—	12.6	9.1	—	2.5	5.1
Black Cherry *Prunus serotina* (Ehrh.)	—	11.5	—	—	22.5	9.0
Blueberry *Vaccinium* spp.	—	1.1	—	—	—	0.3
American Beautyberry *Phytolacca americana* (L.)	—	—	3.0	2.3	—	1.0
Oak leaves and sticks *Quercus* spp.	7.2	—	—	2.3	—	1.3
Acorns *Quercus* spp.	1.4	—	12.1	—	—	1.6
Milo *Sorghum* spp.	5.8	—	—	—	1.3	1.9

[a] Feb. – May
[b] June – Aug.
[c] Sept. – Oct.
[d] Nov. – Dec.

Table 3.2. Percent occurrence of prey items found in bobcat scat on the Joseph W. Jones Ecological Research Center (Ichauway), Baker County, Georgia (February – December 2007 and June – August 2008).

	Pre-fawning season 2007[a] (n=56)	Fawning season 2007[b] (n=34)	Post-fawning season 2007[c] (n=23)	Hunting season 2007[d] (n=21)	Fawning season 2008[b] (n=37)	Total (n=171)
White-tailed Deer	3.6	14.7	8.7	19.0	16.2	11.1
Odocoileus virginianus						
Adult	3.6	2.9	8.7	19.0	2.7	5.8
Fawn	—	11.8	—	—	13.5	5.3
Rodent	80.4	73.5	65.2	57.1	64.9	70.8
Cotton rat	44.6	55.9	17.4	47.6	29.7	40.4
Sigmodon hispidus						
Peromyscus spp	12.5	—	17.4	14.3	—	8.2
Eastern woodrat	5.4	—	—	4.8	—	2.3
Neotoma floridana (Ord)						
Southeastern pocket gopher	5.4	—	4.3	9.5	—	3.5
Geomys pinetis (Rafinesque)						
Fox squirrel	3.6	—	—	—	—	1.2
Sciurus niger (L.)						
Rabbit	35.7	35.3	30.4	23.8	24.3	31.6
Sylvilagus spp.						
Birds (Aves)	16.1	17.6	30.4	14.3	29.7	21.1
Northern bobwhite	1.8	—	—	—	2.7	1.2
Colinus virginianus (L.)						
Northern cardinal	—	2.9	—	—	—	0.6
Cardinalis cardinalis (L.)						
Other	21.4	29.5	30.4	28.0	21.6	25.1
Nine-banded armadillo	5.0	5.9	—	4.8	5.4	4.7
Dasypus novemcinctus (L.)						
Raccoon	3.6	2.9	8.7	9.5	—	4.1
Procyon lotor (L.)						
Virginia opossum	1.8	2.9	—	9.5	2.7	2.9
Didelphis virginiana (Kerr)						
Striped skunk	1.8	—	—	—	5.4	1.8
Mephitis mephitis (Schreber)						
Crayfish	—	2.9	4.3	4.8	2.7	2.3
(Cambaridae)						
Grasshopper	—	5.9	—	—	—	1.2
(Orthoptera)						
Beetle	3.6	—	—	—	—	1.2
(Coleoptera)						
Fish	1.8	—	—	4.8	—	1.2
(Osteichthyes)						
Snail	1.8	—	—	—	—	0.6
(Gastropoda)						
Unidentified snake	—	8.8	13.0	4.8	10.8	6.4
(Serpentes)						
Canebrake rattlesnake	—	—	4.3	4.8	—	1.2
Crotalus horridus (L.)						
Coachwhip	—	2.9	—	—	—	0.6
Masticophis flagellum (Shaw)						

Bird egg	—	2.9	—	—	2.7	1.2
Vegetation	10.7	26.5	4.3	14.3	18.9	15.2
Grass (Poaceae)	3.6	8.8	4.3	14.3	21.6	9.9

[a] Feb. – May
[b] June – Aug.
[c] Sept. – Oct.
[d] Nov. – Dec.

CHAPTER 4

SURVIVAL OF WHITE-TAILED DEER FAWNS IN A SOUTHWESTERN GEORGIA LONGLEAF PINE ECOSYSTEM

[1]Howze, M. B., L. M. Conner, R. J. Warren, and K. V. Miller. To be submitted to *the Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies.*

Abstract: We investigated survival of neonate white-tailed deer (*Odocoileus virginianus*) at the Joseph W. Jones Ecological Research Center in southwestern Georgia. We captured and radio-collared 8 fawns in 2007 and 13 in 2008 during June – August. Two fawns shed their collars prematurely in 2007 and, therefore, excluded from analysis. Three predation events occurred each year and three additional fawns died of unknown causes in 2008. Predation accounted for 100% of mortalities in 2007 and ≥50% in 2008. Mortality rates from date of capture until hunting season were 50% for 2007 and 46.2% in 2008 ($\bar{x}$ = 47.4%). Kaplan-Meier survival estimates for this period were 17% (SE = 5%) for all fawns captured in 2007 and 2008. Coyotes (*Canis latrans*) accounted for 44.4% of the total mortalities and 66.7% of predator-related mortalities. Our study provides further evidence that predators (primarily coyotes) may be inhibiting survival of white-tailed deer fawns in southwestern Georgia.

Key words: *Canis latrans*, coyote, fawn, mortality, *Odocoileus virginianus*, predation, white-tailed deer

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies ___:___-___

Several studies have investigated white-tailed deer (*Odocoileus virginianus*) neonate mortality (eg., Cook et al. 1971, Garner et al. 1976, Nelson and Woolf 1987, Vreeland et al 2004, Pusateri Burroughs et al. 2006, Saalfeld and Ditchkoff 2007). In the southeastern United States, most studies have been restricted to areas where coyotes (*Canis latrans*) were absent (Epstein et al. 1983, Boulay 1992, Roberts 2007). Fawn mortality rates vary throughout their range, but the primary source of mortality is typically predation (Linnell et al. 1995). Garner and Morrison (1980) reported that predation was responsible for 97% of the mortalities observed for radio-collared fawns in Oklahoma, almost all of which were caused by coyotes or bobcats (*Lynx rufus*).

Both coyotes and bobcats are effective predators of white-tailed deer fawns (Cook et al. 1971, Beasom 1974, Bartush and Lewis 1981, Stout 1982, Ballard et al 1999, Whittaker and Lindzey 1999, Vreeland et al. 2004, Saalfeld and Ditchkoff 2007), although coyotes are likely the dominant cause of fawn mortality across the United States. Whitaker and Lindzey (1999) recorded high predation rates (79%) on neonate fawns by coyotes in Colorado. Bartush and Lewis (1981) reported predation rates as high as 90% in Oklahoma, where the majority of predations were coyote kills. In the Southeast, Kilgo et al. (2009) found that coyotes were responsible for up to 84% of all mortalities of radio-collared fawns in a South Carolina study. Similarly, Saalfeld and Ditchkoff (2007) reported coyotes as the most common cause of mortality in an exurban area of Alabama.

Although herd monitoring at the Joseph W. Jones Ecological Research Center (Ichauway) suggests that deer abundance has remained relatively stable, the number of harvested deer, lactation rates of harvested deer, and observed fawn:doe ratios have declined since 2001 (Joseph W. Jones Ecological Research Center 2008). Concurrently, coyote abundance has increased (J. Stober, Joseph W. Jones Ecological Research Center, Pers. Commun). Because long-term data indicated a decline in recruitment, we initiated a radio-telemetry study to investigate survival of white-tailed deer fawns on Ichauway. Based on previous research in Alabama (Saalfeld and Ditchkoff 2006) and South Carolina (Kilgo et al. 2009), we predicted that coyotes would be the primary source of mortality among radio-collared fawns, with bobcats playing a secondary role in predation.

STUDY AREA

The Joseph W. Jones Ecological Research Center (Ichauway) in Baker County, Georgia is an 11,736-ha, privately owned research center in the Upper Gulf Coastal Plain. The landscape is dominated by a longleaf pine (*Pinus palustris*) overstory and wiregrass (*Aristida stricta*) understory managed on a 2-year prescribed fire regime, while private lands surrounding Ichauway consist of mainly agricultural fields and plantation-style timber tracts. Approximately 10% of the property consists of agricultural fields and food plots planted with winter wheat (*Triticum aestivum),* Egyptian wheat (*Sorghum* spp.), grain sorghum (*Sorghum vulgare*), browntop millet (*Brachiaria ramosa*), and cowpeas (*Vigna* spp.).

The site is characterized by relatively flat, karst topography with hot, humid summers and short, mild winters. The average daily temperature ranges from 11.1 °C in the winter to 27.2 °C in summer with an average precipitation of 132 cm per year (Boring 2001). Interspersed limesink and cypress-gum (*Taxodium ascendens-Nyssa biflora*) wetlands are established in the riparian hardwood hammocks along Ichawaynochaway Creek that bisects the property longitudinally and the Flint River that forms the eastern property boundary.

Ichauway lies in Georgia's Deer Management Unit 6, which consists of 31 counties in the Upper Gulf Coastal Plain where deer densities average 8.1 deer/km^2 (21 deer/mile^2, Bowers et al.

2005). Past data indicate that Ichauway's white-tailed deer herd has remained at a constant density of 3.8 – 5.8 deer/km^2 (10 – 15 deer/mile^2) and a relatively even sex ratio since the early 1990s. The site-wide fawn:doe ratio averaged 0.53 from 2001 – 2008 (J. W. Jones Ecological Research Center 2008).

METHODS

We used a Raytheon Palm IR 250 thermal imaging camera (Raytheon Commercial Infrared, Dallas, TX) to locate white-tailed deer fawns. The camera was mounted on an adjustable tripod located in the back of a pick-up truck. Monitors were connected to the camera such that both driver and camera operator could view the camera display.

We searched for fawns at night during May – August of 2007 and 2008. After locating a fawn, we attempted to capture the fawn with a long-handled landing net while the camera operator directed the other person(s) to the animal’s location via handheld radio. Once captured, fawns were fitted with elastic, breakaway radio-collar transmitters designed to fall off after approximately one year (M4210, Advanced Telemetry Systems, Isanti, MN; Diefenbach et al. 2003). Collars were equipped with a motion-activated mortality sensor and a precise event timer (PET) that allowed the time of death to be estimated $\leq$ 30 minutes using a binary coding scheme (Advanced Telemetry Systems, Isanti, MN). After radio-collaring, each fawn was weighed, given a unique numerical ear tattoo, and age was estimated by hoof growth characteristics (Haugen and Speake 1958) as well as body condition and behavior.

Fawns were monitored $\geq$3 times per day to maximize the likelihood of identifying causes of mortality. Predation was assessed by signs of trauma, external hemorrhaging, scattering of remains, and caching behavior in the case of bobcats (Garner et al 1976, Anderson and Lovallo 2003). We pooled capture data from 2007 and 2008 to estimate survival using the Kaplan-Meier method for staggered entry (Pollock et al. 1989). We estimated survival from time of capture until the beginning of hunting season (October 25th). All deer were handled under Joseph W. Jones Scientific Collecting Permit #29-WTN-07-103 and UGA Institutional Animal Care and Use Committee Proposal #A2006-10093.

RESULTS

We captured and radio-collared eight fawns (3M, 5F) in 2007 and 13 fawns (8M, 5F) in 2008. Of the 21 fawns radio-collared, two were censored from 2007 due to premature collar release and, therefore, excluded from analysis. Average age at capture for neonates in both 2007 and 2008 was 4 days ($\bar{x}$ = 4.1, S.E. = 0.35) and no deaths were attributable to capture or abandonment. Pre-hunting season observed mortality rates were 50.0% for 2007 and 46.2% for 2008 ($\bar{x}$ = 47.4%).

Six predation events occurred during the study period: three in 2007 and three in 2008. Predation accounted for 100% of all mortalities in 2007 and $\geq$ 50% of the total observed mortalities in 2008. Coyote predation accounted for 44.4% of all fawn mortality and 66.7% of all predator related mortalities. A bobcat and an unknown predator were responsible for one predation event each. All predation events occurred within the first 30 days of life. All fawns were in good condition at capture in 2007, however, four fawns captured in 2008 exhibited signs of red imported fire ant (*Solenopsis* spp.) bites. Three fawns died of unknown causes in 2008, but it is unknown if fire ants could be implicated in any of these deaths. Samples were sent to the University of Georgia's Veterinary Diagnostic Laboratory, but results were inconclusive. Therefore, we listed the cause of death as unknown. Kaplan–Meier survival estimate from capture until the beginning of hunting season was 17% (S.E. = 5%; Fig. 4.1).

DISCUSSION

Most of the fawn deaths in our study were due to predation, primarily by coyotes, which is consistent with other studies conducted in the southern U.S. (Cook et al 1971, Garner et al 1976, Carroll and Brown 1977, Saalfeld and Ditchkoff 2006, Kilgo et al. 2009). Our observed fawn mortality rate (47.4%) is similar to the average mortality rate among temperate ungulates (45%) as calculated by Linnell et al. (1995) and the average of previous studies on fawn mortality rates (Table 4.1). All mortalities occurred within the first 30 days and 88.9% of all mortalities occurred within the first two weeks of life. Because our average age at capture was four days, we could not account for mortality occurring within the first few days of life, which may have increased our observed mortality rates (Roberts 2007).

Bobcats and an unknown predator played a minor role in fawn mortality relative to coyotes during our study, similar to other studies where coyotes and bobcats were sympatric (Cook et al 1971, Garner et al. 1976, Carroll and Brown 1977, Ballard et al. 1999, Vreeland et al. 2004). Moreover, previous research has suggested that white-tailed deer were not a major component of bobcat diets on Ichauway (Cochrane 2003, Godbois 2003, Doughty 2004). In 2008, a bobcat was observed attacking a fawn, but its dam attacked the bobcat immediately before capture crews captured the fawn. Once captured, we noticed a puncture wound in the lower ear toward the base of the skull, but the fawn was not mortally wounded. A coyote subsequently killed this fawn three days later.

Four of the fawns captured in 2008 had fire ant bites or fire ants on their body and two mortalities may have been attributed to fire ants. Red imported fire ants have been implicated as a possible contributing factor to fawn mortality in the southern U.S. Allen et al. (1997) found white-tailed deer recruitment was 2X higher in areas subjected to fire ant control. Previous research suggests that fire ants may cause young fawns to move more than normal, thereby reducing their natural instinct to lie perfectly still and making them more susceptible to predation (Allen et al. 1997).

Our Kaplan-Meier survival estimates from capture until the beginning of hunting season (17%) were lower than 12-week post-capture estimates reported in an intensively farmed region of Minnesota (84%, Brinkman et al. 2004), possibly due to low predator density on their study area. Survival of fawns to six months was much higher (72%) on an island in Mississippi (Bowman et al. 1998) than reported in our study. This high survival rate may have been attributed to the seasonal flooding of the island. Pusateri Burroughs et al. (2006) reported survival estimates from capture until hunting season for white-tailed fawns to be as high as 91% in Michigan and reported only one predation event during the study. Caution should be used when comparing survival and mortality rates from other studies due to different capture methodology, study period, methods used to estimate survival, predator and prey populations, as well as site-specific differences (Roberts 2007).

MANAGEMENT IMPLICATIONS

Fawn survival is critical to understanding white-tailed deer population dynamics and making sound management decisions. When we compare our results with the declining trends in hunter harvests and fawn:doe ratios, it appears that predation (primarily attributed to coyotes) is limiting fawn recruitment on our study area. Coyotes are recent additions to the ecosystems of the southeastern U. S., largely due to human intervention, (Gipson 1974, Hill et al. 1987) and density estimates on Ichauway have been increasing since 2001 (J. Stober, Joseph. W. Jones Ecological Research Center, Pers. Commun). Red imported fire ants may have been responsible for 2 mortalities in 2008. Further research in needed to understand their impacts on deer recruitment. A bobcat also killed one fawn in this study, but we suggest that bobcats play a lesser role in predation of white-tailed fawns. Managers should be aware of the potential that predation can have on fawn survival, especially in areas of low-density deer herds. Future research should continue investigating predator-deer interactions and fawn survival due to their variability across landscapes.

LITERATURE CITED

Allen, C.R., S. Demarais, and R.S. Lutz. 1997. Effect of red imported fire ants on recruitment of white-tailed deer fawns. Journal of Wildlife Management 61:911-916.

Anderson, E.M., and M.J. Lovallo. 2003. Bobcat and lynx. Pages 758-786 *in* G. A. Feldhammer, B.C. Thompson, and J.A. Chapman, editors. Wild Mammals of North America. Johns Hopkins University Press, Baltimore, Maryland.

Ballard, W.B., H.A. Whitlaw, S.J. Young, R.A. Jenkins, and G.J. Forbes. 1999. Predation and survival of white-tailed deer fawns in north-central New Brunswick. Journal of Wildlife Management 63:574-579.

Ballard, W.B., D. Lutz, T.W. Keegan, L.H. Carpenter, and J.C. deVos, Jr. 2001. Deer-predator relationships: a review of recent North American studies with emphasis on mule and black-tailed deer. Wildlife Society Bulletin 29:99-115.

Bartush, W.S., and J.C. Lewis. 1981. Mortality of white-tailed deer fawns in the Wichita Mountains. Proceedings of the Oklahoma Academy of Science 61:23-27.

Beasom, S.L. 1974. Relationships between predator removal and white-tailed deer net productivity. Journal of Wildlife Management 38:854-859.

Boring, L.R. 2001. The Joseph W. Jones Research Center: Co-directed applied and basic research in the private sector. Pages 233-258 *in* G.W. Barrett and T.L. Barrett, eds.

Holistic science: the evolution of the Georgia Institute of Ecology (1940-2000). Taylor and Francis, New York, New York.

Boulay, M.C. 1992. Mortality and recruitment of white-tailed deer fawns in the wet prairie/tree island habitat of the everglades. M.S. Thesis, University of Florida, Gainesville.

Bowers, J.W., A. Hammond, K. Kammermeyer, C. Martin, S. McDonald, N. Nicholson, J. Robbins, T. Touchstone, and G. Waters. 2005. Georgia's deer management plan 2005–2014. Georgia Department of Natural Resources. Social Circle, GA.

Bowman, J.L., H.A. Jacobson, and B.D. Leopold. 1998. Fawn survival on Davis Island, Mississippi, after an early summer flood. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 52:397-402.

Brinkman, T.J., J.A. Jenks, C.S. DePerno, B.S. Haroldson, and R.G. Osborn. Survival of white-tailed deer in an intensively farmed region of Minnesota. Wildlife Society Bulletin 32:726-731.

Carroll B.K., and D.L. Brown. 1977. Factors affecting neonatal fawn survival in southern-central Texas. Journal of Wildlife Management 41:63-69.

Cochrane, J.C. 2003. Ecology of bobcats in a longleaf pine forest in southwestern Georgia. M.S. Thesis. University of Georgia, Athens.

Cook, R.S., M. White, D.O. Trainer, and W.C. Glazener. 1971. Mortality of white-tailed deer fawns in south Texas. Journal of Wildlife Management 35:47-56

Diefenbach, D.R., C.O. Kochanny, J.K. Vreeland, and B.D. Wallingford. 2003. Evaluation of an expandable, breakaway radiocollar for white-tailed deer fawns. Wildlife Society Bulletin 31:756-761.

Doughty, J. 2004. Bobcat (*Lynx rufus*) ecology in a longleaf pine ecosystem in southwestern Georgia. M.S. Thesis. University of Georgia, Athens.

Epstein, M.B., G.A. Feldhammer, and R.L. Joyner. 1983. Predation on white-tailed deer fawns by bobcats, foxes, and alligators: predator assessment. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 37:161-172.

Garner, G.W., and J.A. Morrison. 1980. Observations of interspecific behavior between predators and white-tailed deer in southwestern Oklahoma. Journal of Mammalogy 61:126-130.

Garner, G.W., J.A. Morrison, and J.C. Lewis. 1976. Mortality of white-tailed deer fawns in the Wichita Mountains, Oklahoma. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 30:493-506.

Gipson, P.S. 1974. Food habits of coyotes in Arkansas. Journal of Wildlife Management 38:848-853.

Godbois, I.A. 2003. Ecology of bobcats on land managed for northern bobwhite in southwestern Georgia. M.S. Thesis. University of Georgia, Athens.

Haugen, A.O., and D.W. Speake. 1958. Determining age of white-tailed deer fawns. Journal of Wildlife Management 22:319-321.

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

Huegel, C.N., R.B. Dahlgren, and H.L. Gladfelter. 1985. Mortality of white-tailed deer fawns in south-central Iowa. Journal of Wildlife Management 49:377-380.

Joseph W. Jones Ecological Research Center. 2008. White-tailed deer management summary 1993-2008. Joseph W. Jones Ecological Research Center. Newton, GA.

Kilgo, J.C., H.S. Ray, M.J. Goode, M.A. Vukovich, and C. Ruth. 2009. Impact of coyotes on fawn survival in South Carolina. Annual Southeast Deer Study Group Meeting 32:48 (abstract).

Linnell, J.D.C., R. Aanes, and R. Anderson. 1995. Who killed Bambi? The role of predation in the neonatal mortality of temperate ungulates. Wildlife Biology 1:209-223.

Nelson, T.A., and A. Woolf. 1987. Mortality of white-tailed deer fawns in southern Illlinois. Journal of Wildlife Management 51:326-329.

Pollock, K.H., S.R. Winterstein, C.M. Bunck, and P.D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry design. Journal of Wildlife Management 53:7-15.

Pusateri Burroughs, J., H. Campa, III, S.R. Winterstein, B.A. Rudolphm, and W. E. Mortiz. 2006. Cause-specific mortality and survival of white-tailed deer fawns in southwestern lower Michigan. Journal of Wildlife Management 70:743-751.

Roberts, S.B. 2007. Ecology of white-tailed deer and bobcats on Kiawah Island, South Carolina: Implications for suburban habitat preservation. Ph.D. dissertation. University of Georgia, Athens.

Saalfeld, S.T., and S.S. Ditchkoff. 2007. Survival of neonatal white-tailed deer in an exurban population. Journal of Wildlife Management 71:940-944.

Sams, M.G., R.L. Lochmiller, C.W. Qualls, Jr., D.M. Leslie, Jr., and M.E. Payton. 1996. Physiological correlates of neonatal mortality in an overpopulated herd of white-tailed deer. Journal of Mammalogy 77:179-190.

Stout, G.G. 1982. Effects of coyote reduction on white-tailed deer productivity on Fort Sill, Oklahoma. Wildlife Society Bulletin 10:329-332.

Vreeland J.K., D.R. Diefenbach, and B.D. Wallingford. 2004. Survival rates, mortality causes, and habitats of Pennsylvania white-tailed deer fawns. Wildlife Society Bulletin 32:542-553.

Whittaker, D.G., and G.G. Lindzey. 1999. Effect of coyote predation on early fawn survival in sympatric deer species. Wildlife Society Bulletin 27:256-262.

Table 4.1. Observed mortality rates from previous fawn mortality studies in North America (1971 – 2009).

Study	year	Location	# of fawns	Mortality rate
Cook et al.	1971	TX	81	71.6%
Garner et al.	1976	OK	35	82.9%
Carroll and Brown	1977	TX	120	40.8%
Bartush and Lewis	1981	OK	48	90.0%
Epstein et al.	1985	SC	45	84.4%
Huegel et al.	1985	IA	55	23.6%
Nelson and Woolf	1987	IL	54	30.0%
Sams et al.	1996	OK	76	38.2%
Whitaker and Lindzey	1999	CO	37	64.9%
Brinkman et al.	2004	MN	39	15.4%
Vreeland et al.	2004	PA	218	48.6%
Pusateri Burroughs et al.	2006	MI	75	22.6%
Roberts	2007	SC	134	78.4%
Saalfeld and Ditchkoff	2007	AL	36	66.7%
		mean		54.2%
This study	2009	GA	19	47.4%

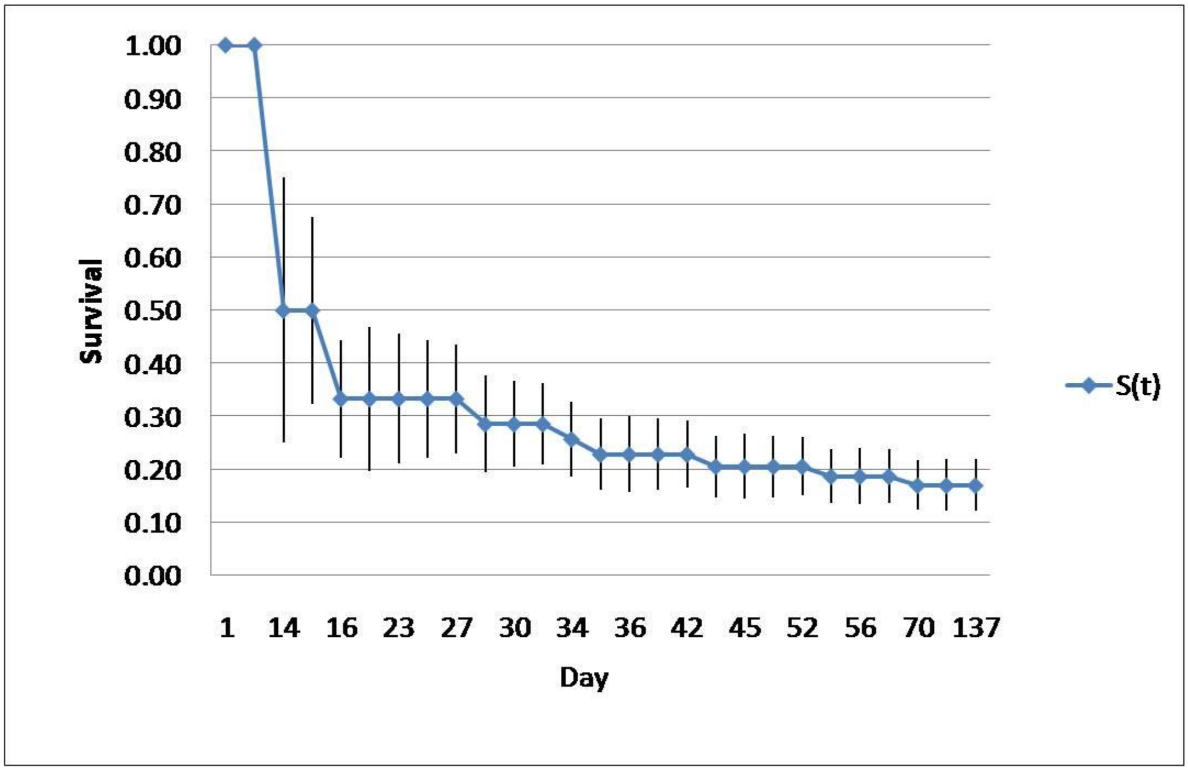


Figure 4.1. Pooled survival rates (2007 and 2008) of radio-collared white-tailed deer fawns from capture until the beginning of hunting season at the Joseph W. Jones Ecological Research Center (Ichauway), Baker County, Georgia.

CHAPTER 5

SUMMARY AND MANAGEMENT IMPICATIONS

Summary and Management Implications

This project was implemented to better understand the complex interactions of coyotes (*Canis latrans*), bobcats (*Lynx rufus*) and white-tailed deer (*Odocoileus virginianus*) in a southwestern Georgia longleaf pine forest. I assessed the efficacy of predator removal as a tool for increasing fawn recruitment at the Joseph W. Jones Ecological Research Center (Ichauway) in southwestern Georgia, an area with a low-density (2 - 6 deer/km^2) deer herd.

A predator removal program occurred during Jan. – Aug. 2008 on a 4,200-ha portion of Ichauway. Fawn:doe ratios increased dramatically following the removal of approximately 34-43% of the coyote population. Winter camera survey and hunter observed fawn:doe ratios were 2.15 times greater in the predator removal zone than the non-removal zone.

Both coyotes and bobcats consumed white-tailed deer in our study, but deer remains were detected more often in coyote scat than in bobcat scat. The occurrence of white-tailed deer in coyote scat was greater than many studies in the Southeast, despite our low density of deer. Occurrence of deer remains in coyote and bobcat scat was greatest during the fawning season and the hunting season. Occurrences of deer in scat during the fawning season indicate that predators are preying on deer when they are most vulnerable. Although white-tailed deer occurred commonly in both coyote and bobcat scat during the hunting season, it is likely that they are feeding on wounded or unrecovered hunter-killed deer (Schrecengost et al. 2008).

Mortality rates of fawns on Ichauway were similar to those of temperate ungulates, as calculated by Linnell et al. (1995). All predation events as well as all other mortalities of radio-collared fawns occurred within the first 30 days of life, consistent with the majority of fawn mortality studies. Kaplan-Meier survival rates from capture until the beginning of hunting season were lower than most reported in published literature.

Predation can impact white-tailed deer recruitment, but the degree of impact is site-specific. Previous research has suggested that coyotes and bobcats are the primary predators of white-tailed deer fawns (Cook et al 1971, Garner et al. 1976, Carroll and Brown 1977, Ballard et al. 1999, Vreeland et al. 2004). Removal programs directed at these predators can increase white-tailed deer recruitment when conducted properly (Beasom 1974, Stout 1982, Ballard et al. 2001, VanGilder 2008). Trapping should be concentrated before and throughout the fawning season (Hamlin 1997, Ballard et al. 2001) so that the area does not become repopulated while fawns are still in their critical first 30-60 days of life. Removal efforts should only be set in motion when sound data indicates predation is causing a decrease in recruitment. Because of the reproductive capacity of white-tailed deer, intensive predator control programs should stop before populations increase to a level that harvest by hunters would not be able to stabilize the population.

The increase in recruitment (fawn:doe ratio) following predator removal, along with our survival data from radiocollared fawns and predator-diet analysis collectively supports the hypothesis that predators (primarily coyotes and bobcats) are limiting white-tailed deer recruitment on our study area. Moreover, our results suggest that predator control can be an effective tool at increasing fawn recruitment. Connolly and Longhurst (1975) found that coyote populations can withstand annual harvests of 70%, but despite our removal efforts of 34-43% of the estimated coyote population, fawn:doe ratios dramatically increased following the removal of predators. However, our removal rate was one coyote for every 8.5 deer in our predator removal zone, data that is often unaccounted for in previous studies.

Increasing coyote populations coupled with management strategies that manage for lower density white-tailed deer herds are creating new challenges for natural resource managers. Management strategies such as habitat manipulation (i.e., planting soft mast fruits) can affect the influence that coyotes have on recruitment by directly decreasing consumption of deer (Andelt et al. 1987). Soft mast fruits, such as blackberries and wild plums, were available and widely used by coyotes during the peak of fawning seasons (especially fawning season 2008) in our study and it has been suggested that alternative food sources such as these may buffer coyote predation of white-tailed fawns (Andelt et al. 1987, Schrecengost et al. 2008, VanGilder 2008). Although we experienced high occurrence of deer in scat during fawning seasons, coyotes on our study site heavily utilized vegetation during the fawning seasons. Therefore, we suggest that predation rates on fawns by coyotes may be higher in years where soft mast failure.

Literature Cited

Andelt, W. F., J. G. Kie, F. F. Knowlton, and K. Cardwell. 1987. Variation in coyote diet associated with season and successional changes in vegetation. Journal of Wildlife Management 51:273-277.

Ballard, W. B., H. A. Whitlaw, S. J. Young, R. A. Jenkins, and G. J. Forbes. 1999. Predation and survival of white-tailed deer fawns in north-central New Brunswick. Journal of Wildlife Management 63:574-579.

Ballard, W. B., D. Lutz, T. W. Keegan, L. H. Carpenter, and J. C. deVos, Jr. 2001. Deer-predator relationships: a review of recent North American studies with emphasis on mule and black-tailed deer. Wildlife Society Bulletin 29:99-115.

Beasom, S. L. 1974. Relationships between predator removal and white-tailed deer net productivity. Journal of Wildlife Management 38:854-859.

Carroll B. K. and D. L. Brown. 1977. Factors affecting neonatal fawn survival in southern-central Texas. Journal of Wildlife Management 41:63-69.

Cochrane, J. C. 2003. Ecology of bobcats in a longleaf pine forest in southwestern Georgia. M.S. Thesis. University of Georgia, Athens.

Connolly, G. E. and W. M. Longhurst. 1975. The effect of control on coyote populations. University of California, Division of Agricultural Science, Bulletin 1872, Davis, CA.

Cook, R. S., M. White, D. O. Trainer, and W. C. Glazener. 1971. Mortality of young white-tailed deer fawns in south Texas. Journal of Wildlife Management 35:47-56.

Doughty, J. 2004. Bobcat (*Lynx rufus*) ecology in a longleaf pine ecosystem in southwestern Georgia. M.S. Thesis. University of Georgia, Athens.

Garner, G. W., J. A. Morrison, and J. C. Lewis. 1976. Mortality of white-tailed deer fawns in the Wichita Mountains, Oklahoma. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 30:493-506.

Godbois, I. A. 2003. Ecology of bobcats on land managed for northern bobwhite in southwestern Georgia. M.S. Thesis. University of Georgia, Athens.

Hamlin, K. L. 1997. Survival and home range fidelity of coyotes in Montana: Implications for control. Intermountain Journal of Sciences 3:62-72.

Linnell, J. D. C., R. Aanes, and R. Anderson. 1995. Who killed Bambi? The role of predation in the neonatal mortality of temperate ungulates. Wildlife Biology 1:209-223.

Schrecengost, J. D., J. C. Kilgo, D. Mallard, H. S. Ray, and K. V. Miller. 2008. Seasonal food habits of the coyote in the South Carolina Coastal Plain. Southeastern Naturalist 7:135-144.

Stout, G. G. 1982. Effects of coyote reduction on white-tailed deer productivity on Fort Sill, Oklahoma. Wildlife Society Bulletin 10:329-332.

VanGilder, C. L. 2008. Examination of coyote and bobcat food habits and the effects of an intensive predator removal on white-tailed deer recruitment in northeast Alabama. M.S. Thesis. University of Georgia, Athens.

Vreeland J. K., D. R. Diefenbach, and B. D. Wallingford. 2004. Survival rates, mortality causes, and habitats of Pennsylvania white-tailed deer fawns. Wildlife Society Bulletin 32:542-553.