5-2002

Winter Ecology of Cooper's Hawks on Ames Plantation, Tennessee

Laura A. Lake
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Laura A. Lake entitled "Winter Ecology of Cooper's Hawks on Ames Plantation, Tennessee." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

David Buehler, Major Professor

We have read this thesis and recommend its acceptance:

Allan Houston, Judy Grizzle

Accepted for the Council:
Dixie L. Thompson

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

I am submitting herewith a thesis written by Laura A. Lake entitled "Winter Ecology of Cooper's Hawks on Ames Plantation, Tennessee." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

David Buehler
Major Professor

We have read this thesis
And recommend its acceptance:

Allan Houston

Judy Grizzle

Accepted for the Council:

Dr. Anne Mayhew
Vice Provost and
Dean of The Graduate School

(Original signatures are on file in the Graduate Student Services Office.)

WINTER ECOLOGY OF COOPER'S HAWKS (*Accipiter cooperii*) ON AMES PLANTATION, TENNESSEE

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Laura A. Lake
May 2002

DEDICATION

This thesis is dedicated to my husband

Raymond Lake

For all his love and support.

AKNOWLEDGEMENTS

There are many people who deserve to be recognized for making this project possible. First of all, I want to express my thanks to the Ames staff and the families of the plantation workers for all their support during my time there, especially Steve Page, James Morrow, Larry Teague, Rachel Chambers, Shelton Whittington, Corinne Wilkerson, and Danny Haynes. The financial support from the Hobart Ames Foundation was also greatly appreciated. A special thanks is needed for Dr. Allan Houston who was by my side through all the trials of this project and who provided considerable mentoring when I needed it the most. Thank you!

I would like to also thank the other members of my committee, Billy Minser and Dr. Judy Grizzle, for guiding me in the right direction over and over again. I appreciate the encouragement and financial support received from the U.T. Department of Forestry, Wildlife, and Fisheries as well as the invaluable education I received. Dr. Arnold Saxton, Dr. Eric Linder, and Daniel Moss need to be recognized for their statistical support. My thanks also go to Jennifer Fettinger, Allison Mains, Jim Giocomo, Vijak Chimchome, Jenny Fiedler, and Dr. Daniel Kim.

The person most deserving of recognition and my thanks is Dr. David Buehler for believing in me from the beginning and never giving up on my abilities when the circumstances got grizzly. The lessons I've learned from him about wildlife and human lives will never be forgotten. Thank you Dr. Buehler!

Finally, I have to thank my family who have helped me become the person I am today.

ABSTRACT

Cooper's hawks (*Accipiter cooperii*) were listed by Ganier (1933) as fairly common permanent residents of western Tennessee during the early 1900's, but populations declined during the 20th Century presumably because of habitat changes, shooting, and effects of pesticides on reproduction (Newton 1979). Breeding bird survey data for Tennessee suggest that Cooper's hawk populations are increasing (+4.6% increase/year, 1966-2000), although sample sizes are too small for significant trends (P = 0.39, Sauer et al. 2001). Nicholson (1997), in the Tennessee Breeding Bird Atlas completed during the early 1990's, still described Cooper's hawks as uncommon permanent residents.

At the same time Cooper's hawk populations appeared to be increasing, northern bobwhite (*Colinus virginianus*) populations were declining precipitously (-3.7 % decrease/year in Tennessee, 1966-2000; Sauer et al. 2001). Many quail biologists have suggested that the decline in quail populations may in part be linked to increasing avian mortality from increasing raptor populations (Hurst et al. 1996, De Maso et al. 1997, Rollins and Carroll 2001). The objectives of the hawk project on Ames Plantation were to describe Cooper's hawk winter ecology, to describe seasonal patterns of raptor abundance and to gain breeding season data for Cooper's hawks.

The study area was Ames Plantation, Tennessee located in southwestern Tennessee. Ames Plantation is comprised of a variety of covertypes including hardwood forests, mixed forests, pine forests, crop fields, old fields, native warm season grasslands, hardwood conversion areas (areas consisting of savannahs where hardwood forests had

been recently harvested, cleared of treetops and trunks, with only a few live trees remaining/ha), and fencerows.

We trapped Cooper's hawks with bal chatri traps baited with house sparrows (*Passer domesticus*) and fitted hawks with radio transmitters. Using radio telemetry, Global Positioning Systems (GPS), and Geographical Information System (GIS) procedures, diurnal and roost locations were obtained for 5 Cooper's hawks. To account for telemetry locational errors, diurnal habitat use was determined by delineating covertypes within 50-m-radius circles around each daytime location. The composition of available habitat was also described within 50-m circles delineated around a systematic grid of random points. Habitat use was examined with compositional analysis (Aebischer et al. 1993) and chi-squared analysis (Neu et al. 1974). Logistic regression models were developed to identify the key habitat features that discriminated between roost locations and random sites.

A 40-km raptor survey was conducted weekly during winters 1999/2000 and 2000/2001 to determine relative raptor abundance and species composition on Ames Plantation. All species seen or heard at each point and between points were recorded. Nonparametric statistics (Kruskal-Wallace *H* Tests) were used to compare the winters of 1999/2000 and 2000/2001, leaf-on and leaf-off surveys, and surveys on and off the field trial area.

Nest observations and measurements were taken at 4 Cooper's hawk nests, 4 red-tailed hawk (*Buteo jamaicensis*) nests, and 1 red-shouldered hawk (*Buteo lineatus*) nest

over two breeding seasons (2000 and 2001). A nest camera was set up at 1 red-tailed hawk nest for 2 days and 1 Cooper's hawk nest for 2 days.

We trapped for 533 trap hours on 34 days in winter 1999/2000 and 1,729 trap hours on 53 trap days in winter 2000/2001. We captured 35 raptors, including Cooper's hawks, American kestrels (*Falco sparverius*), barred owls (*Strix varia*), northern harriers (*Circus cyaneus*), red-tailed hawks, red-shouldered hawks, and sharp-shinned hawks (*Accipiter striatus*). Nine Cooper's hawks were trapped in winter 1999/2000 (59 h/capture) and 2 Cooper's hawks in winter 2000/2001 (865 h/capture). Based on capture success, Cooper's hawk abundance appeared to be much lower in winter 2000/2001 than in winter 1999/2000.

The home range of the 1 male Cooper's hawk tracked in the winter was 331 ha (95% minimum convex polygon) and the mean size of female home ranges was 836 ha and ranged from 8 ha to 2,529 ha. Diurnal winter habitats used by Cooper's hawks were ranked in order of most preferred to least preferred as follows: Forests $\geq$ Edge $\geq$ Field $\geq$ Other, based on the compositional analysis (λ=0.0722, F=12.84, P=0.0322; MANOVA). Cooper's hawks used forests more than expected and fields less than expected compared to their availability (N=458, χ^2=68.76, df=8, P<0.0001; Neu et al. 1974).

Twenty-two roost sites were located in 1999/2000 and 34 roost sites were located in 2000/2001. Some of the roost sites were used repeatedly. Vertical cover (P=0.0332), canopy cover (P=0.0030), and canopy cover variance (P=0.0353) were greater in roost sites than random sites, whereas the height of the overstory (P=0.0674) was (marginally) lower in roosts than in random sites. Edges, fencerows, and pines were used more than

expected for roosting, while hardwood stands and hardwood conversion areas were used less than expected (χ^2=30.27, *P*=0.0001). Radio-tagged Cooper's hawks emerged from the roost site on average 38 min before sunrise and changed roost sites during the night 12.5% of the time. Cooper's hawks roosted in dense honeysuckle (*Lonicera japonica*), briar (*Rubus alleghaniensis*), and cedar thickets (*Juniperus virginiana*) near the ground under canopies that were highly variable.

A total of 1,671 individual raptors were recorded during 47 surveys (31 winter surveys). Red-tailed hawks (on average 4 - 14.5 birds were detected per survey by month) were the most abundant species while American kestrels (0 - 2.3), northern harriers (0 - 1.5), and red-shouldered hawks (0 - 4.3) were detected less. Cooper's hawk (0 - 1) and sharp-shinned hawks (0 - 0.5) were detected the least. Total raptor abundance (all species) and red-tailed hawk abundance were greater in the second year (winter 2000/2001) than the first year (winter 1999/2000). Greater red-tail abundance the second winter likely occurred in response to the colder winter temperatures. Total raptor abundance, northern harriers, and red-tailed hawks were detected more on the field trial course, while American kestrels and red-shouldered hawks were detected more off the field trial course. The detection rate of Cooper's hawks and sharp-shinned hawks averaged about 0.5 hawks per survey- too low to detect differences between years or on/off the field trial area. Visible areas along the 40-km survey route totaled 258 ha.

Out of 4 Cooper's hawk nests, 2 were confirmed to have failed while the other 2 have an unknown fate, but activity at late dates in the breeding season suggest a successful nesting effort. Out of 4 red-tailed hawk nests, 1 was confirmed successful, 1

was confirmed to have failed, 1 was probably successful, and 1 had an unknown fate. The success of the red-shouldered hawk nest is also unknown. The averages for the 4 Cooper's hawk nests are as follows; nest height, 16.55 m; nest tree diameter, 53.08 cm; vertical cover, 6.06%; canopy cover, 48.8%; and basal area 30.58 m^2/ha. The averages for the 4 red-tailed hawk nests are as follows; nest height, 18.7 m; nest tree diameter, 49.83 cm; vertical cover, 11.94 %; canopy cover, 62.73 %; and basal area 19.06 m^2/ha. The measurements for the red-shouldered nest are as follows; nest height, 15 m; nest tree diameter, 53.75 cm; vertical cover, 12.5 %; canopy cover, 49.22 %; and basal area 34.39 m^2/ha.

Cooper's hawks were found to primarily use forests in the winter at Ames Plantation. However, Cooper's hawks and northern bobwhites occupied similar habitats (old fields and forest edges with a dense understory of honeysuckle and briars) a significant portion of each day. Prey remains (n = 19) from Cooper's hawks were primarily passerines (n = 10), morning doves (*Zenaida macroura*) (n = 4), and northern bobwhite (n = 4). In both winters, radio-tagged Cooper's hawks moved from Ames to a nearby plantation to prey on pen-reared quail that were released for weekend hunts.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Cooper's hawks were listed by Ganier (1933) as fairly common permanent residents of western Tennessee during the early 1900's, but populations declined during the 20th Century presumably because of habitat changes, shooting, and effects of pesticides on reproduction (Newton 1979). Breeding bird survey data for Tennessee suggest that Cooper's hawk populations are increasing (+4.6% increase/year, 1966-2000), although sample sizes are too small for significant trends (P = 0.39, Sauer et al. 2001). Nicholson (1997), in the Tennessee Breeding Bird Atlas completed during the early 1990s, still described Cooper's hawks as uncommon permanent residents.

Cooper's hawks are medium size raptors with short rounded wings characteristic of the forest dwelling raptors in the genus *Accipiter* (Rosenfield and Bielelfeldt 1993). Like other accipiters, Cooper's hawks are excellent avian predators. During the breeding season, Cooper's hawks have been found to prey upon a variety of small-medium sized birds, including the northern bobwhite, and mammals (Meng 1959, Toland 1985, Kennedy and Johnson 1986, Peterson and Murphy 1992, Rosenfield and Bielefeldt 1993). The composition of Cooper's hawk stomachs examined between 1924 and 1947 contained fragments of birds (64%), mammals (33%), reptiles and amphibians (10%), and insects (10%) (Duncan 1966).

Cooper's hawks prey upon quail (Toland 1985, Rosenfield and Bielefeldt 1993) making their ecology important to quail managers. Biologists, past and present, have observed raptors preying on quail as the quail were flushed (Stoddard 1932), as they were feeding at supplemental food stations (Townsend et al. 1999), and as they were being

monitored by radio telemetry (Burger et al. 1995). Raptor predation on quail may not be detrimental at the population level if the predation is compensatory (Dimmick 1990). Predation on quail may reflect the vulnerability of the population in that sick and unfit individuals are susceptible to predation (Errington 1967, Roseberry and Klimstra 1984). Northern bobwhite populations have been decreasing in Tennessee at a rate of 3.74% decrease/year from 1966-2000 (Sauer et al. 2001). Although much of this decline may be attributed to significant habitat changes and the increased intensity of farming (Exum et al. 1982), the decline in quail populations may in part be linked to increasing mortality from increasing predator populations (Hurst et al. 1996, De Maso et al. 1997, Rollins and Carroll 2001). The effects of predation on quail may not be adequately understood if studied only from the standpoint of mortality on the prey species (Leopold and Hurst 1994, Hurst et al. 1996). More research is needed on quail and their predators to better understand how predation affects quail populations under current landscape conditions (Hurst et al. 1996).

Learning more about the winter diurnal habitat use and home ranges of Cooper's hawks is essential for effective management of Cooper's hawks and/or their prey, including northern bobwhite. Raptor home ranges and the habitat they use are dependent on food availability, number of feeding places, and distances between the feeding places (Newton 1979). If there is an abundance of prey in an area, raptors can effectively hunt without flying long distances or searching many habitats. Increased understanding of Cooper's hawk habitat utilization will provide land managers with the information needed to make effective decisions, whether to decrease predator/prey interactions or to

manage for Cooper's hawks where their populations are in duress. Quail managers are interested in understanding Cooper's hawk ecology as a means of Cooper's hawks predation on northern bobwhite. Stoddard (1932) recommended eliminating as many Cooper's hawks as possible naming them "the worst natural enemy of the bobwhite" (Stoddard 1932: 221), but killing hawks is now illegal and habitat management is the only alternative.

Northern bobwhite winter habitat requirements include a variety of covertypes including wooded areas with a dense understory, native grasslands, old fields, crop fields, fencerows, and pastures (Roseberry and Klimstra 1984, Dimmick 1992). Stoddard (1932) stressed the importance of edge and the positioning of the habitat types to minimize the travel distance between life requirements such as food, water, roosting cover, and loafing areas. Despite management efforts to reduce the amount of predation on quail, predators such as Cooper's hawks and quail share the same habitat; thus quail mortality from avian predators is inevitable. Burger et al. (1995) reported high avian predation during the fall-spring period on radio-tagged quail. Field trial managers are often faced with more challenges to provide adequate protection from avian predators because they must manage for more open habitats so that the quail and dogs may be more easily observed. Quail habitat management, therefore, should be viewed as an effort to reduce predation to acceptable levels, rather than to eliminate it.

Although Cooper's hawk nesting habitat has been described in many areas (Reynolds et al. 1982, Oregon; Fischer 1986, Utah; Asay 1987, California; Murphy et al. 1988, Wisconsin; Kritz 1989, Missouri; Boal and Mannan 1998, Arizona; Garner 1999,

Arkansas), little is known about their diurnal habitat use in the winter, especially in the southeastern United States. Effective management of Cooper's hawks and/or their prey, including northern bobwhite requires more information about Cooper's hawk winter habitat use.

Raptor winter density is, in part, determined by the abundance of prey species in an area (Newton 1979). When the abundance of prey is high, the density of raptors potentially will increase. Raptor species counted in the winters of 1985-1986 in Fayette and Hardeman counties of Tennessee included black vultures, turkey vultures, northern harriers, sharp-shinned hawks, Cooper's hawks, red-tailed hawks, and American kestrels (Stedman 1988). The trends for these raptor species in the Breeding Bird Survey (BBS) have been increasing since 1966 (Sauer et al. 2001). Because significant winter mortality of quail can be attributed to avian predation (Burger et al. 1995, Chambers 2001 unpublished data), it is important to know the abundance and species composition of raptors on Ames Plantation to more effectively manage for quail.

The objectives of this study were to document diurnal habitat use by Cooper's hawks (Chapter 1), describe winter roost habitat selection of Cooper's hawks in winter (Chapter 2), to determine seasonal raptor abundance and species composition at Ames Plantation (Chapter 3), and to document habitat characteristics and breeding season data for Cooper's hawks and red-tailed hawks on Ames Plantation, Tennessee (Chapter 4).

Study Area

The data for this project were gathered on Ames Plantation (60 km east of Memphis, TN and 5 km north of the Tennessee-Mississippi state line) in Fayette and

Hardeman counties in western Tennessee (Figure 1). Ames Plantation is a University of Tennessee Agricultural Experiment Station as well as the home of the National Championship Field Trial for pointing bird dogs. Ames is a non-profit foundation presently owned and operated by Richard Harte, Jr., Waldo E. Dodge, Robert H. Frey, Oliver A. Spalding, and Fleet National Bank, Boston, Massachusetts. Hobart and Julia Ames bought the plantation in 1901 and owned it until their deaths. According to Mrs. Ames' will, the plantation was to be used for the National Championship Field Trial for pointing bird dogs as well as for the benefit of The University of Tennessee.

Ames Plantation is comprised of approximately a 75:25 mix of forested and open areas and covers 7,537 ha. The forested areas of the plantation are a mixture of hardwood stands dominated by upland oaks (2,920 ha, See Appendix II for scientific names) and bottomland species (1,040 ha), while the pine stands are dominated primarily by loblolly pines (1,400 ha). The remaining open areas, increasing in number from the west to the east of the plantation, are subdivided into agricultural fields, pastures, grasslands, old fields, and hardwood conversion areas (native warm season grass and forb savannahs created where hardwood forests had been recently harvested, cleared of treetops and trunks, with only a few live trees remaining/ha). Corn (252 ha), soybeans (384 ha), cotton (62 ha), and improved pastures (400 ha) are grown to feed the livestock and raise money for plantation operation. Pastures for cattle are dominated by fescue. The grasslands, old fields, and hardwood conversion areas total 480 ha and are found primarily on the field trial courses which cover 2000 ha on the southeastern portion of the plantation. The grasslands are often dominated by Sericea lespedeza, panicum grasses,

partridge pea, broomsedge, and common ragweed. Sumac, sweetgum, Japanese honeysuckle, and briars characterize old field areas and field borders. Recent additions to the landscape at Ames (1999/2000) are the hardwood conversion areas which are now savannah-like native warm season grass and forb mixtures with few trees remaining per ha. These tracts were previously mature hardwood forests that were clearcut with all remaining stumps sheared and tree tops burned. These conversions were made to provide more nesting and brood habitat for northern bobwhites. Buildings, ponds, rivers, roads, and research plots compose the remaining 480 ha of land on Ames Plantation.

Because the plantation is the site of the National Championship Field Trial for pointing bird dogs, 2,000 ha of land is managed intensively for northern bobwhites. Food plots with milo (28 ha) are planted along the edges of the fields and woods. Milo is used as a supplemental food source and approximately 60 bushels are spread along field trial roads by tractors and a seed spreader once every 2 weeks year-round. Row crops beneficial to bobwhites, primarily corn, milo, and soybeans, are grown on the field trial course with no-till practices. Corners or strips of crops are left unharvested for quail. In the fall or winter, strips of vegetation (15 - 30 m wide) in the grasslands and old fields are roller-chopped and/or mowed along the field trial course to enhance visibility of the competing dogs during field trials. After the National Championship is completed in late February, the plantation undergoes a regime of prescribed burning to control succession in old fields and grasslands. Woodlands are burned to control woody brush and encourage herbaceous growth, which increases visibility during the field trials. Annual burns include one third of the old field and brushy habitat as well as some forested areas.

Forest burns maintain a more open understory. Deciduous, coniferous, and mixed forests are managed for timber production.

Fayette and Hardeman counties are located in the Southern Mississippi Valley Silty Uplands resource area (TVA 1982) and the Loess Plain physiographic region (Nicholson 1997). This land resource area has elevations ranging from 30 to 180 m above sea level. The upland soils are derived from loess and are very fertile (TVA 1982). Mean annual rainfall ranges from about 113 to 150 cm with the frost-free season usually lasting 200 to 250 days a year (TVA 1982). The many streams dissecting Ames Plantation are part of the watershed of the North Fork of the Wolf River and drain westward to the Mississippi River. Most streams are full of sand as a result of erosion problems in the watershed. In addition, erosion ditches 3-5 m deep occur on some hillsides as a result of farming practices in the early 1900's. The climate is typical of the mid-South with average daily temperatures in the winter ranging from 0-13 degrees C and 18-31 degrees C in the summer.

CHAPTER 1.
WINTER DIURNAL HABITAT USE AND HOME RANGE OF COOPER'S HAWKS AT AMES PLANTATION, TENNESSEE

Introduction

Habitat selection of raptors during the non-breeding season (winter) must provide for the basic daily energetic requirements through foraging opportunities and also provide sufficient cover to facilitate survival during inclement weather and avoidance of other predators. Cooper's hawks are a medium-sized accipiter capable of preying on a variety of avian and mammalian prey species from a variety of habitats. They are susceptible to predation by larger raptors, including great-horned owls and red-tailed hawks. Cooper's hawk nesting ecology has been studied in many areas (Reynolds et al. 1982, Oregon; Fischer 1986, Utah; Asay 1987, California; Murphy et al. 1988, Wisconsin; Kritz 1989, Missouri; Boal and Mannan 1998, Arizona; Garner 1999, Arkansas). However, little is known about their diurnal habitat use in the winter, especially in the southeastern United States.

Breeding Cooper's hawks used montane forested areas which consisted of 50-80 year-old-conifer stands in northwestern Oregon (Reynolds et al. 1982), whereas Cooper's hawks in Utah preferred oak-maple woodlands and oak shrubland/grasslands and avoided aspen-maple woodlands and open montane slopes (Fischer 1986). Out of 77 Cooper's hawk nests located in California, 75 were in live oak trees (Asay 1987). Murphy et al. (1988) found that Cooper's hawks nesting in a suburban area avoided wooded residential, residential/business, and open areas and preferred oak-pine woods and shrub savannah habitats. In Missouri, Cooper's hawks were found to nest in pine trees in shortleaf pine

stands (40 %), mixed pine stands (35 %), oak-hickory stands (23 %), and one scotch pine stand (2%; Kritz 1989). Introduced eucalyptus (70.8%), Aleppo pine (25%), and native cottonwood trees (4.2%) were used for Cooper's hawk nest sites more than expected based on their availability in an urban area of Tucson, Arizona (Boal and Mannan 1998). Cooper's hawk nest sites in Arkansas (n=12) were all located in dense medium age loblolly pine stands with moderately-dense understories (Garner 1999).

Although little is known about non-breeding habitat use of Cooper's hawks, northern goshawk (Squires and Ruggiero 1995) and sharp-shinned hawk (Bohall and Collopy 1984) winter diurnal habitat use has been studied. Wintering goshawks use riparian areas (Squires and Ruggiero 1995), aspen, spruce/fir, lodgepole pine, ponderosa pine, and open habitats (Squires and Reynolds 1997) in the Rocky Mountains. Sharp-shinned hawks used a variety of habitats in north-central Florida including open areas, open areas with scattered trees, longleaf pine and turkey oak forests, pine flat woods, and wetland areas (Bohall and Collopy 1984).

The habitat use of breeding Cooper's hawks and the winter habitat use of other accipiter species vary greatly throughout the country. Differences in habitat use are related to differences in habitat availability, as well as prey distribution and abundance. As woodland hawks, accipiters use forests the majority of the time, although, the composition of the forests may differ. Because home range size is related to the distances required to forage successfully, Cooper's hawk home ranges may differ depending upon habitat composition and prey abundance within habitats (Newton 1979, Mannan and Boal 2000).

Estimates of home range size for breeding male Cooper's hawks, based on radio telemetry vary widely: 65.5 ha (adaptive kernel) in an urban setting in Arizona (Mannan and Boal 2000), 784 ha (100% minimum convex polygon) in a suburban setting in Wisconsin (Murphy et al. 1988), and 1,206 ha (95% harmonic mean) in the Jemez Mountains, New Mexico (P. Kennedy, unpubl. data). Although these home ranges were determined from males, they were probably centered on a nest because males participate in various aspects of the nesting effort (Kennedy and Johnson 1986). Radio-tagged breeding female Cooper's hawks in the Jemez Mountains, New Mexico had an estimated home range of 2,803 ha (95% harmonic mean; P. Kennedy, unpubl. data).

Winter home ranges may differ from breeding ranges because there is no need to return to a central place (nest), energy requirements differ, and prey distribution and abundance may differ considerably (Newton 1979). Non-breeding Cooper's hawks in southern Georgia and northern Florida were tracked using radio-telemetry from August 16 – March 15 during the winters of 1996-2000 (B. Millsap, unpubl. data). The average home ranges of males from Tall Timbers (n=4) and Dowling Park (n=11) were 391 ha and 895 ha (minimum convex polygons) while the average female home ranges from Tall Timbers (n=6) and Dowling Park (n=9) were 1,282 ha and 2,185 ha, respectively (minimum convex polygons).

Learning more about the winter diurnal habitat use and home ranges of Cooper's hawks is essential for effective management of Cooper's hawks and/or their prey, including northern bobwhite. Raptor home ranges and the habitat they use are dependent on food availability, number of feeding places, and distances between the feeding places

(Newton 1979). If there is an abundance of prey in an area, raptors can effectively hunt without flying long distances or searching many habitats. Increased understanding of Cooper's hawk habitat utilization will provide land managers with the information needed to make effective decisions, whether to decrease predator/prey interactions or to manage for Cooper's hawks where their populations are in duress. Quail managers are interested in understanding Cooper's hawk ecology as a means of minimizing habitat overlap between Cooper's hawks and northern bobwhite. Managing habitat to provide quail with more protection from Cooper's hawks or providing better habitats for viable Cooper's hawk populations both require a better understanding of Cooper's hawk diurnal winter habitat use. The objectives of this chapter were to document winter habitat use and home ranges of Cooper's hawks.

Methods

Radio-telemetry

Cooper's hawks were trapped on Ames Plantation during the winters (November 1 to March 31) of 1999/2000 and 2000/2001. The birds were trapped with bal chatri traps approximately 20 cm by 30 cm wide and 10 cm deep (Berger and Mueller 1959) baited with 1 or 2 house sparrows. Between 5 and 10 traps were set at one time in an area where a Cooper's hawk had been recently sighted or where one was likely to forage. Once set, traps were checked every 20 min. Successful Cooper's hawk trapping lines were along logging roads and ditches in mixed pine/hardwood forests with a thick understory. The time of day that traps were set varied initially from before sunrise to mid afternoon, but no raptors were caught before 1100 hr and all Cooper's hawks were caught after 1400 hr. After the first month, traps were set between 1200 and 1300 hr and were

checked until sunset (at which time they were removed). Five-hundred and thirty-three hours were spent trapping on 34 days in winter 1999/2000 and 1,729 hours were spent trapping on 53 trap days in winter 2000/2001. Upon capture, Cooper's hawks were fitted with 10 g (female) and 7 g (male) radio transmitters with an expected life of 18 and 12 months, respectively (American Wildlife Enterprises, Monticello, FL). The radios were mounted dorsally on the hawks via an X attachment backpack (Buehler et al. 1995) with a 1-cm-wide Teflon ribbon harness (Bally Ribbon Mills, Bally, PA). Knots and all harness ends were treated with superglue to prevent unraveling. Superglue enhancers were used to speed up the drying process (Loctite Corp, Hartford, CT). Each bird was banded with a U.S. Fish and Wildlife Service band (size 4-6) and released at the trap site. Handling time was less than 25 min.

Radio-tagged hawks were relocated with the homing technique and partial triangulation (White and Garrott 1990) with ATS (Advanced Telemetry Systems, Isanti, MN) receivers and 3-element yagi antennas. Tracking began the day following a hawk's release, but the locations from the first 2 weeks were not included in the analysis to allow adaptation to the radios (White and Garrott 1990). Birds were tracked 1-3 times a day, but only locations obtained 4 hours apart were used in the analysis to maintain some independence between same-day locations. The x and y coordinate of each location was obtained in the field with a Global Positioning System (GPS) unit (Trimble Geoexplorer II) or by determining the location on 1:24,000 U.S.G.S. Digital Orthographic Quadrangles (DOQ's) of Ames Plantation.

All locations were entered into a Geographical Information System using Arcview software (E.S.R.I., Redlands, CA). To determine telemetry error, an assistant placed 10 radios in locations frequented by Cooper's hawks and recorded the GPS locations. These radios were located in a manner similar to the method used in locating hawks. The x and y coordinates of the estimated location were determined with the GPS unit. The actual coordinates were then compared to the estimated coordinates to calculate the telemetry error. Based on this approach, the average error was 30 m. Because the radios remained motionless during the homing process, this test did not completely account for the telemetry error caused when the birds flew to a different location before their original locations could be determined. As a result, to be conservative, a 50-m radius circle was created in Arcview around each hawk location to incorporate telemetry error.

Covertype Delineation

Covertypes were delineated within each of the 50-m radius circles to determine the percentages of covertypes used by the Cooper's hawks. In Arcview, covertypes included hardwood forest, pine forest, crop field, grass field, old field, fencerow, hardwood conversion area (native warm season grass and forb mixtures savannahs created where hardwood forests had been recently harvested, cleared of treetops and trunks, with only a few live trees remaining/ha), road, aquatic, and human-developed areas. Covertypes were combined (forest, field, edge, and other) for the compositional analysis in an effort to fulfill the assumptions that there are less covertypes than birds (Aebischer et al. 1993). The forest covertype included hardwood forests, mixed forests, and pine forests which were predominantly comprised of upland oaks and/or loblolly

pine. The field covertype included crop fields, grasslands, and hardwood conversion areas. Crop fields included corn, soybeans, or cotton fields planted the previous spring. Grasslands were covered in mixtures of Sericea, panicum grasses, partridge pea, bicolor lespedeza, broomsedge, common ragweed, and fescue. Hardwood conversion areas consisted of native warm season grass and forb savannahs where hardwood forests had been recently harvested, cleared of treetops and trunks, with only a few live trees remaining/ha. Edge was comprised of old fields, fencerows, and roads. Old fields were successional grasslands comprised of sumac, sweetgum, Japanese honeysuckle, briars and various grasses and forbs. Fencerows were defined as a thin strip of trees or shrubs along a fenceline, road, or field border that typically was no wider than 15 m. Roads included paved roads and field roads where no vegetation was growing. The "other" covertype included aquatic sites, and human developed areas. Aquatic sites included ponds and lakes that were present all year. Human-developed areas included buildings, parking lots, and yards.

To determine the amount of available habitat within each covertype, a 200 x 200 m grid with 200 points was overlaid on the study area. An effective study area was delineated by combining all Cooper's hawk home ranges and tracing the outer perimeter of that area in Arcview. A 50-m radius circle was drawn in Arcview around each location from the availability grid and covertype polygons were delineated as mentioned above. The relative proportion of available habitat for each covertype was calculated by summing across the acreages within individual 50-m circles. The home range extension

of Arcview (Carr and Rogers 1998) was used to determine 95% minimum convex polygons (MCP) and 95% and 50% adaptive kernel polygons for each bird.

Statistical Analysis

Habitat preferences were examined with compositional analysis (Aebischer et al. 1993) and chi-squared analysis (Neu et al. 1974). Compositional analysis assumes that each animal is a sampling unit, the number of locations for each animal is > 30, the locations are independent, there is differential habitat use by groups of individuals, all habitats in the study area are available to the animal, there are more animals than covertypes, and all covertypes are used (there are no zeros in a covertype for an animal). Not all of these assumptions were met in this analysis because the number of locations was less than 30 for 3 birds and not all covertypes were used by each bird. Because the locations were all 4 hours apart, they were considered independent. The other assumptions met in the compositional analysis were that each animal was a sampling unit and there were more animals than covertypes.

Multivariate analysis of variance (MANOVA) procedures were used to determine if the differences of the log-transformed use-to-availability proportions were different from zero (Aebischer et al. 1993, Pendleton et al. 1998). Habitats (classified as forests, fields, edge, or other) were then ranked in order of preference. As an alternative method for comparison, chi-squared analysis was used to determine if habitats were used more or less than expected in relation to their availability. Bonferroni 95% confidence intervals were calculated for each use value (Neu et al. 1974, Byers et al. 1984). Confidence intervals were determined for both the percentage of each covertype used and percentage

of each covertype available to account for the variance associated with sampling the available habitat. Covertypes that were used significantly greater than availability were deemed "preferred", whereas covertypes used less than availability were deemed "avoided".

Results

The size of one male home range and the mean size of female home ranges (N = 5), were 331 ha and 836 ha (female range = 8 – 2,529 ha; Table 1) based on the 95% minimum convex polygon (MCP). However, 50% of the locations (Adaptive Kernel) occurred within 172 ha for the male and within 478 ha on average for the females (range = 6 – 1529 ha; Table 1). The home range of female 393 (8 ha, MCP) may have been larger, but due to interference, radio telemetry locations were limited. In the first winter, 2 out of three home ranges overlapped with at least 1 other home range (Figure 2) and in the second winter, all home ranges overlapped (Figure 3). Female 316 was tracked for 2 winters and had virtually identical home ranges, both in size and position, from the first year to the second year. Cooper's hawk daily movements were typically < 1 km, but sometimes were large enough to cross their entire home range in one 24-h period (in one case about 2 km).

Based on compositional analysis, habitat use by Cooper's hawks was not random (λ=0.0722, F=12.84, P=0.0322; MANOVA). Habitats were ranked in the following order: Forests $\geq$ Edge $\geq$ Field $\geq$ Other (Table 2 and Table 3). The use of forests and field, forests and other, forest and edge (marginally), field and other, and edge and other

differed compared to their availability ($P<0.0187$, $P<0.0014$, $P<0.0948$, $P<0.0156$, $P<0.0028$).

Cooper's hawks did not use hardwood and mixed forests, pine forests, old fields, fencerows, crop fields, grasslands, hardwood conversion areas, roads and human-developed areas in proportion to their availability ($N=458$, $\chi^2=68.96$, $df=8$, $P<0.0001$). Comparing the confidence intervals estimated with Bonferroni's statistics, Cooper's hawks used hardwood and mixed forests more than expected and used crop fields less than expected compared to the availability in the study area (Table 4). Use of pine forests, old fields, fencerows, grasslands, hardwood conversion areas, roads and human-developed areas did not differ from the availability of these habitats.

Discussion

Cooper's hawks on Ames Plantation, Tennessee preferred forested habitats in the winter and used fields less than expected compared to availability. Cooper's hawks are woodland hawks, so it is not surprising that their habitat preference is forests and that they use fields less than their availability. Based on daily tracking of these birds for 2 years, Cooper's hawks were seldom observed in open habitats and even then they were generally darting from one patch of cover to another. Cooper's hawks probably restrict their activities to forested habitats to avoid predators. Predation by other raptors, possibly by great horned owls, has been observed in the past (Rudolph 1978, Warkenton and James 1990). Two radio-tagged Cooper's hawks were killed overnight during this study with remains indicating avian predation. Cooper's hawks must offset predation risk with foraging opportunities. On Ames, some of the old field and forested habitats

include cedars, honeysuckle, and briars which provide refuge for small mammals and other birds (brown thrashers, dark-eyed juncos, gray catbirds, northern cardinals, Carolina wrens, and northern bobwhites), making this good Cooper's hawk foraging habitat. In these habitats, Cooper's hawks may combine foraging and predator avoidance, while foraging for prey in more open habitats would increase risk of Cooper's hawk depredation.

Cooper's hawks do not "sit and wait" for their prey (Pianka 1974:203), but rather they perch for a while and then actively forage (Fischer 1986). Male and female Cooper's hawks perched for an average of 6.2 min and 13.9 min respectively between short periods of flight lasting on average 73.2 sec for males and 110.7 sec for females (Fischer 1986). While perched, Cooper's hawks were observed scanning the surrounding area and repeated this behavior at each new perch (Fischer 1986). Cooper's hawks on Ames Plantation may actively forage in more densely vegetated habitats such as forest edges, old fields, and fencerows because of higher prey abundance. In mature hardwood, mixed, and pine forest stands where there were likely less potential prey species, Cooper's hawks may have foraged less, but used these forested areas for perching because of increased protection provided from predators and the cover offered for prey.

Raptor home range size depends on food availability and the distance it takes a raptor to forage successfully (Newton 1979, Mannan and Boal 2000). Because Ames Plantation has an abundance of prey species, Cooper's hawk home ranges may be smaller than Cooper's hawk home ranges in areas with less prey species. The male Cooper's hawk winter home range (331 ha) and the mean female Cooper's hawk winter home

range (836 ha) for Ames Plantation is smaller than the mean winter ranges of male (391 ha, 895 ha) and female (1,282 ha, 2,185 ha) Cooper's hawks tracked on Tall Timbers Plantation and Dowling Park in northern Florida (Millsap unpubl data). The smaller home ranges may indicate a greater abundance of prey species on Ames Plantation.

A number of factors in this study may have affected the home range estimates including the number of telemetry locations, sex, and age. The birds with the smallest home ranges (8.1 ha, 74.3 ha, 331 ha) also had the fewest locations (17, 11, 9). Additional data points may have increased home range size. The average home ranges determined by the first 10, 20, 30, 40, 50, and 60 locations for Cooper's hawks with > 60 locations (3161, 3162, 458) were 216.46 ha, 450.37 ha, 564.02 ha, 936.67 ha, 1155.67 ha, and 1225.76 ha (Table 5) indicating that home range size did increase with the number of locations. The adjusted estimates of home range size based on a sample size of 60 are 21.77 ha, 1,874.37 ha, 710.90 ha, 419 ha, 539.87 ha, and 2,426.50 ha. The male home range adjusted for 60 locations would be 1,874.37 ha while the average female home range (n = 5) adjusted for 60 locations would be 823.61 ha. These adjusted home ranges differ from Cooper's hawk winter home ranges at Tall Timbers, Florida where the average male home range (n = 4) was 391 ha and the average female home range (n = 6) was 1,282 ha (B. Millsap, unpubl. data). Another consideration in home range size is the age of the birds. Two of the 3 birds with the smallest home ranges mentioned above were still in juvenile plumage when trapped, while the two birds with the largest home ranges were adults. These results conflict with the results of Mannan and Boal (2000) where older, more experienced birds had smaller home ranges. Mannan and Boal (2000)

speculated that adults have smaller home ranges presumably because they already know the area and the habitats with large prey abundances and can meet their daily requirements more efficiently.

The home ranges of the Cooper's hawks in this study overlapped spatially and, in 3 instances, temporally. This may reflect limited territorial behavior during winter. These birds could be using the same areas but not at the same time. However, two females (3162 and 458) were located within 150 m of each other at the same time on 3 occasions. There was no indication that these birds were aware of each other. Only on one occasion (February 8, 2001 - a radio-tagged Cooper's hawk flushed from her roost when another Cooper's hawk called) was an interaction between Cooper's hawks observed during the winter and in this case, the birds could have been vocalizing to begin pair-bonding for the upcoming breeding season. Because wintering birds are not tied to a nest, they were not trying to defend an area to keep other Cooper's hawks away from their prey, nest, or mate. The winter home ranges of Cooper's hawks are possibly dependent more on patterns of habitat distribution and prey distribution and abundance than the other Cooper's hawks in the area. Relatively abundant prey and foraging opportunities suggest that Cooper's hawks would have to compete little for foraging sites and resources and there would not be a need to be territorial in the winter. Territorial behavior may begin with the onset of the breeding season (late February – early March) at which time overlap in areas used should be minimal or nonexistent. This appeared to be the case for this study although the sample size was too small for statistical analysis. By late February, no radio-tagged birds were located in the same area. By the beginning

of March, 1 radio-tagged Cooper's hawk as well as another pair not radio-tagged were using areas where they had previously nested. These nests were > 1.5 km apart (5.9 km between nests 1and 2, 6.9 km between nests 1 and 3, and 1.7 km between nests 2 and 3), but it was impossible to tell if the home ranges overlapped because only 1 female was radio-tagged out of the nesting pairs.

Cooper's hawks are most active when their prey species are most active (Fischer 1986) and probably forage in areas with the highest prey abundance. Woodlawn, a plantation neighboring Ames Plantation, conducted weekly northern bobwhite hunts, which included releasing approximately 500 pen-raised quail each week for nearly 2 months (mid December to mid February) in winter. Generally, only about 100 of these quail were harvested by hunters per week. For 2 years, 2 radio-tagged Cooper's hawks moved from Ames Plantation to Woodlawn during these months. The second year, 2 radio-tagged birds were using the same areas within 100 m of each other at the same time. Other, untagged, Cooper's hawks were spotted on Woodlawn during these weeks as well. As soon as these hunts on Woodlawn were over, the Cooper's hawks made movements up to 2 km from Woodlawn to the Ames field trial areas. It is possible that predators were being drawn to Woodlawn with each mass release of quail and raptor densities were greater on Woodlawn than they would have been otherwise. These observations further support the hypothesis that Cooper's hawks do not aggressively maintain intraspecific winter territories.

The winter home ranges of one female (316) for two winters were different than the nesting home ranges of two summers. The locations from November 1 to early

March were all on Ames Plantation and neighboring Woodlawn. By mid-March, though, her locations shifted to the south-east about 3 km and she rarely was located more than 100 m from the nests. During the winter her home ranges were similar in size and location as were her summer home ranges, but the winter home range did not overlap with the summer home range. It is unclear why the winter home range and summer home range for this bird were different.

Raptor habitat selection is strongly influenced by the habitat selection of their prey (Janes 1985). For Cooper's hawks in this study, habitat use, home ranges, and movements reflect abundance of prey in an area, the quality of the habitat, and the availability of preferred habitats. Cooper's hawks were found to prey on a variety of avian species (18/19 prey items) on Ames Plantation during the winter with passerines (10/19) comprising ½ of the prey items (Table 6). Four prey items out of 20 were quail and ½ of these quail prey were from Woodlawn. The abundance of prey on Ames and adjoining property as well as the amount of preferred quality habitats on Ames Plantation may support a larger population of Cooper's hawks than other habitats with less prey or less preferred quality habitats.

CHAPTER 2.
WINTER ROOST SITE HABITAT SELECTION FOR COOPER'S HAWKS AT AMES PLANTATION, TENNESSEE

Introduction

Winter roost site selection is important to birds for protection from the environment and predators when the night is the coldest and longest part of each 24-h diel. Winter roost sites must provide protection from the environment and predators at night, while enabling Cooper's hawks to forage successfully without traveling great distances during the day. Thermal factors important in nocturnal roost selection are shelter from wind and precipitation, local increases in air temperature, and improvement in radiation balance (Walsberg 1986, Webb and Rogers 1988). Severe weather can be deadly to birds even when protective roost sites are used (Odum and Pitelka 1939). Winter roost site selection was found to provide important thermal protection in several raptor species (Hayes and Gessaman 1980, Warkentin and James 1990, Buehler et al. 1991a, Bortolotti and Wiebe 1993, Duguay et al. 1997). Protection from predators is also important because Cooper's hawks may easily be depredated by larger raptors such as great horned owls (Rudolph 1978).

There have been a number of winter roost studies on raptor species that roost communally, such as bald eagles, (Buehler et al. 1991b), northern harriers (Walk 1998), short-eared owls (Walk 1998), snail kites (Sykes 1985), rough-legged hawks (Schnell 1969), and vultures (Thompson et al. 1990). However, few studies have been done on non-communal roosting species.

American kestrels (Bortolotti and Wiebe 1993, Doody 1994, Ardia 2001) and merlins (Warkentin and James 1990) are solitary roosting species with specific habitat preferences in roost sites. American kestrels prefer man-made roost sites such as buildings to natural roost sites (cavities in trees) or nest boxes (Doody 1994, Ardia 2001) and sometimes fly into urban areas specifically to roost in buildings and conifers (Bortolotti and Wiebe 1993). Merlins were found roosting in conifers that were significantly taller and had a greater crown volume than random trees (Warkentin and James 1990).

Little is known, however, about the winter roost sites of North American accipiters. Northern goshawk (Squires and Ruggiero 1995) and sharp-shinned hawk (Bohall and Collopy 1984) winter diurnal habitat use have been studied, but not roost habitat use. Wintering goshawks use cottonwood riparian areas (Squires and Ruggiero 1995), aspen, spruce/fir, lodgepole pine, ponderosa pine, and open habitats (Squires and Reynolds 1997) in the Rocky Mountains. Sharp-shinned hawks use open areas, open areas with scattered trees, longleaf pine and turkey oak forests, pine flat woods, and wetland areas in accordance with their availability in north-central Florida (Bohall and Collopy 1984). A breeding male Cooper's hawk selected pine plantation and oak-pine woods for roosts in Wisconsin (Murphy et al. 1988). Cooper's hawk winter habitat use, including roosting habitat, is not well documented.

Roost sites represent the beginning and ending point of each day and may be central places from which foraging occurs (Orian and Pearson 1977). To fully understand raptor habitat use requires a thorough understanding of where individuals

roost and how roost site selection influences subsequent foraging opportunities. The objectives of this chapter were to document habitat characteristics of roost sites and roosting behavior.

Methods

Cooper's hawks were trapped on Ames Plantation during the winters (November 1 to March 31) of 1999/2000 and 2000/2001. The birds were trapped with bal chatri traps approximately 20 cm by 30 cm wide and 10 cm deep (Berger and Mueller 1959) baited with 1 or 2 house sparrows. Between 5 and 10 traps were set at one time in an area where a Cooper's hawk had been recently sighted or where one was likely to forage. Once set, traps were checked every 20 min. Successful Cooper's hawk trapping lines were along logging roads and ditches in pine/hardwood forests with a thick understory. The time of day that traps were set varied initially from before sunrise to middle afternoon, but no raptors were caught before 1100 hr and all Cooper's hawks were caught after 1400 hr. After the first month, traps were set between 1200 hr and 1300 hr and were checked until sunset (at which time they were removed). Five-hundred and thirty-three hours were spent trapping on 34 days in winter 1999-2000 and 1729 trap hours on 53 trap days were spent trapping in winter 2000/2001. Upon capture, female and male Cooper's hawks were fitted with 10 g and 7 g radio transmitters, respectively, with an expected life of 18 and 12 months (American Wildlife Enterprises, Monticello, FL). The radios were mounted dorsally on the hawks via an X attachment backpack (Buehler et al. 1995) with a 1-cm-wide Teflon ribbon harness (Bally Ribbon Mills, Bally, PA). Knots and all harness ends were treated with superglue to prevent unraveling. Superglue enhancers

were used to speed up the drying process (Loctite Corp, Hartford, CT). Each bird was banded with a U.S. Fish and Wildlife Service band (size 4-6) and released at the trap site. Handling time was less than 25 min.

Roost locations were obtained after sunset and before sunrise to reduce disturbance to the birds. Birds were rarely flushed from their roosts during tracking. Evening locations were taken with minimal disturbance to determine the general area of the roost site. A more specific location was determined before the subsequent sunrise. Telemetry gear was used to home in on roosting birds (within ~20 m) in the dark. The location was then watched until the bird departed from the site. The time of emergence was recorded, the site was checked for cast pellets and prey remains, and the UTM coordinates of the site were determined using a Global Positioning System (GPS) unit (Trimble Geoexplorer II). Emergence times were noted and compared to sunrise times, obtained from a U.S. Naval Observatory website (U.S. Naval Observatory, Astronomical Applications Dept updated March 6, 2001). In some cases, the specific roost tree was located as the bird flew off the roost in the morning or fresh whitewash was located under potential roost trees. When whitewash was present or the bird was observed leaving the roost, that tree became center of the 0.01-ha plot used for habitat analysis. When the specific roost site location could not be determined (i.e., the bird flushed without being observed), the location of the roost site was determined based on the radio signal strength and direction prior to flushing. The 0.01-ha habitat plot was then centered on this area.

To determine habitat characteristics of roost sites, each winter roost site was paired with a random site. A random site was located 1000 m from its paired roost site in

a random direction. Because Cooper's hawks would not be likely to roost in the middle of an open field, all random sites were moved to the nearest suitable area (i.e., where trees were present) if the random point fell into unsuitable habitat. The wooded areas included fencerows with trees, woody corridors, and other forested patches.

Data were collected on roost sites within a month after they were located (Table 7). Since the habitat study was conducted during winter, vegetation structure remained fairly constant. Vertical cover (VCOV), canopy cover (CCOV), the overstory hardwood component of the hardwood basal area (BAHW), and the total basal area of the understory (BAUS) were determined by averaging the measurements taken in the cardinal directions 5.6 m from the plot center. VCOV was measured as the percent of a vertical coverboard (29.5 cm wide x 153 cm tall) obscured by vegetation. CCOV was measured with a spherical densiometer such that the number of squares not covered by the canopy were counted, multiplied by 1.04 and then subtracted from 100. BAHW was determined by counting "in" trees (>10 cm diameter) that were hardwoods in the overstory using a 2.5 m^2 /ha basal area prism. The variance of the vertical cover (VCVR) and the CCVR were calculated in SAS (1999) for each site as the variance of the measurements from the four cardinal directions. Mean height of the overstory (HTOS) was visually estimated to the nearest 5 m from average trees in the overstory. Patch size (PATC) and the distance to the nearest edge (EDGE) were measured in Arcview (E.S.R.I. 1997) using 1:24,000 U.S.G.S. Digital Orthographic Quadrangles (DOQ's) of Ames Plantation.

When a roost site, not necessarily the same exact tree, was used more than once by a Cooper's hawk, the plot was measured again and a new random location was selected for measurement.

Covertypes were classified into hardwood forest, hardwood conversion, pine forest, mixed pine-hardwood forest, edge, or fencerow. Hardwood forest sites were located in forests predominantly comprised of upland oaks and other deciduous trees. The hardwood conversion areas consisted of native warm season grasses and forbs savannahs where hardwood forests had been recently harvested, cleared of treetops and trunks with only a few live trees remaining/ha. Pine stands occurring on Ames Plantation primarily consisted of loblolly pine plantations. Any site within 20 m of the forest border was defined as edge regardless of the forest composition, unless it was located in a thin strip of trees along a fenceline, road, or field border (no wider than 15 m) in which case, it was classified as a fencerow.

Statistical Analysis

PROC CORR (SAS 1999) was used to check for correlations among explanatory variables. Only uncorrelated variables ($r < 0.50$) with potential biological significance in the analysis were used. Ten explanatory variables were included in a backwards logistic regression analysis (PROC LOGISTIC, SAS 1999) to determine which variables best discriminated between roost sites and random sites for each year. In this analysis a *P*–value of 0.05 was required for entry into the model and a *P*–value < 0.10 for staying in the model. The fit of the logistic regression model was assessed with a goodness-of-fit test (Hosmer and Lemeshow 1989). Chi-squared analysis (PROC FREQ, SAS 1999) was

used to test for differences in the proportion of covertypes represented by roost and random sites.

Results

Roost Observations

Three birds were tracked each winter, with 1 individual bird being tracked both years (Figure 4). I located 22 roost sites for the winter of 1999/2000 and 34 roost sites for the winter of 2000/2001 (Table 8). Radio-tagged Cooper's hawks emerged from the roost site on average 38 min before sunrise (n=38) and were found to move from one site to another during the night 12.5% of the time (n=7). Three of these times the bird was flushed prior to first light when a train passed. The causes of the other relocations are unknown. Sixty-three percent of the roost sites (n=35), not necessarily the same exact tree, were used more than one night (Table 9). During the course of the study, no radio-tagged Cooper's hawk was found to roost communally, even during the breeding season. Birds used dense pines in mixed pine-hardwood stands or cedars and never roosted >5 m above ground. All hardwood trees used for roosting were surrounded by dense honeysuckle and/or briars. Often, birds roosted near the ground in dense vegetation with honeysuckle and briars. Cooper's hawks could not be tracked at the roost during the evening until well after sunset because they were still moving, possibly foraging. Whitewash and prey remains were found at 7 roost sites. One cast pellet was found.

Habitat Analysis

VCOV (P=0.0332), CCOV (P=0.0030), and the CCVR (P=0.0353) were greater in the roost sites than the random sites, and HTOS (P=0.0674) was marginally lower for

the roost sites than the random sites (Table 10). The other habitat parameters (VCVR, BAHW, BAUS, PATC, and EDGE) did not differ between roost and random sites ($P>0.05$). Covertypes were not used in proportion to their availability ($\chi^2=30.27$, $P=0.0001$). Edges, fencerows, and pines were used more than expected for roosting, while hardwood stands and hardwood conversion areas were used less than expected for roosting (Table 11).

Discussion

Wintering Cooper's hawks roosted in dense vegetation in greater proportion than its availablity. Roost sites were comprised of a dense understory of briars and honeysuckle growing under a patchy canopy that consisted of cedars, pines, and hardwoods. The variability of the canopy allowed these sites to have a thick mid-story with honeysuckle growing on saplings and cedars. Honeysuckle kept its leaves and remained green throughout the winter decreasing visibility where it grew. The available forested habitat on Ames (the majority being mature pine and hardwood stands) was more open in the understory and mid-story because less sunlight filtered to the forest floor during the growing season. The canopy of the mature hardwood stands, typically described as good nesting habitat for Cooper's hawks (Titus and Mosher 1981, Moore and Henny 1983, Kritz 1989, Bosakowski, et al. 1992, Garner 1999, Trexel et al. 1999), was bare during the winter and not used for roosting. VCOV (44.63%), CCOV (66%), and total basal area (57.18 m^2/ha) were greater in Cooper's hawk winter roost sites than nest sites (VCOV = 6.06 %, CCOV = 48.8 %, total basal area = 30.58 m^2/ha) on Ames Plantation (See chapter 4). The nest site habitat variables were measured during the leaf-

on season and would have had even less VCOV and CCOV if measured during the winter. Cooper's hawks may use dense vegetation for roosting because of thermal benefits and predation avoidance.

Winter creates many environmental stresses on birds including colder temperatures, wind, and precipitation. These conditions are also combined with longer nights and less foraging time during the day (Walsberg 1985). The dense vegetation selected for Cooper's hawk roost sites probably provides protection from the elements. Roost sites for a variety of species have been found to have less rain penetration and lower wind velocity than in unsheltered areas (Francis 1976, Walsberg 1986), while increased canopy cover may protect birds from radiation lost to the open night sky (Walsberg 1985). The roosting behavior of Cooper's hawks such that they roost on/close to the ground may further increase their thermal benefits because there is less wind velocity closer to the ground (Kelty and Lustick 1977). This behavior may be dependent on temperature increasing with declining temperature (Grubb 1975). Accipiters have greater resting metabolic rates throughout the day than other falconiforms of similar size (Kennedy and Gessaman 1991). The demanding energy requirements of Cooper's hawks may intensify the need for thermal protection at night.

Predator avoidance is another vital reason for selecting dense, protective habitats in winter roost sites. The depredation by other raptors, likely great horned owls, has been observed at winter raptor roost sites in the past (Rudolph 1978, Warkenton and James 1990). Furthermore, 2 radio-tagged Cooper's hawks were killed overnight during this study with remains indicating avian predation. Predator avoidance may be a factor in the

use of different roost sites (Warkenton and James 1990). Although Cooper's hawks were found to roost at the same site multiple times, they did not roost at 1 site more than 8 times and rarely used one site more than 2 consecutive nights.

Whether Cooper's hawk movements at dusk were random or directed towards a certain roost remains unknown, but their behavior indicates that at least in some instances, they were selecting certain roost sites. Birds were difficult to track at dusk because they moved rapidly and seemed to be moving with a purpose to a certain roost. However, on more than one occasion, these birds roosted in areas used for diurnal activity.

Cooper's hawk roost site selection may influence other aspects of their ecology such as diurnal habitat use and foraging. In some cases, Cooper's hawks use the same roost site repeatedly where sites may serve as a "central place" from which foraging at least begins at a landscape scale at the beginning of the day (Orian and Pearson 1977). Because of the dense cover, roost sites may also provide camouflage for Cooper's hawks from unsuspecting prey in the morning (Janes 1985). Cooper's hawk diurnal habitat use is sometimes in dense vegetation, similar to the habitat of roost sites (see Chapter 1). Because diurnal environmental conditions are usually less stressful than nocturnal conditions, the use of this habitat during the day may indicate Cooper's hawks are using dense habitat for foraging and/or predator avoidance (Atkinson 1993). Habitat used by Cooper's hawks for roost sites and occasional foraging may be limited in the winter because of leaf loss on deciduous trees (Belthoff and Ritchison 1990). The lack of suitable habitat may contribute to repeated use of certain roost sites. The availability of

suitable roost habitat may be related to the controlled burning program. Controlled burning is used to control woody growth and promote herbaceous grown. Controlled burning, however, also tends to eliminate honeysuckle, briars, and cedars (W. Minser, pers comm.). Cedar, honeysuckle, and briars provide good refuge/roosting cover for small mammals and other birds (brown thrashers, dark-eyed juncos, gray catbirds, northern cardinals, Carolina wrens, and northern bobwhites), making this habitat also good for Cooper's hawk roosting and foraging.

CHAPTER 3.
SEASONAL ABUNDANCE AND SPECIES COMPOSITION OF DIURNAL RAPTORS ON AMES PLANTATION

Introduction

Raptor densities, home ranges and the habitat they use are dependent on food availability, number of feeding places, and distances between the feeding places (Newton 1979). Areas with high prey densities can support higher wintering raptor populations (Newton 1979). During winter, raptors are faced with finding cover from the elements and ample food. Colder weather forces many prey species to either migrate or hibernate, while at the same time, some preferred raptor habitats are changing because of leaf fall. Thermal factors important in nocturnal roost selection such as shelter from wind and precipitation, local increases in air temperature, and improvement in radiation balance (Walsberg 1986, Webb and Rogers 1988) may also be important factors in winter habitat selection. Nearly every raptor species performs some kind of migratory movement, which can involve a massive shift twice a year between the breeding and wintering ranges (Newton 1979). These migrations are spurred primarily by the fluctuations in the prey abundance both seasonally and annually (Newton 1979). In some temperate regions, the numbers of wintering raptors fluctuate with the numbers of prey species in the area such that greater wintering raptor diversity reflects greater prey abundances (Newton 1979). Raptor migration can also be influenced by weather; red-tailed hawks and northern harriers moved further south in the central U.S. during La Niña winters (Kim 2001).

The effect of avian predation on gamebird populations (and other prey species) has been studied for years (Stoddard 1932, Errington 1934). Raptors have been implicated in the decline of southeastern quail populations (Rollins and Carroll 2001). Northern bobwhite populations studied by Burger et al. (1995) experienced high avian predation during the fall-spring period. It is unclear, however, whether raptors have a significant enough effect on quail to depress the population (Dimmick 1990). It has been suggested (Leopold and Hurst 1994, Hurst et al. 1996) that the effects of predation on quail will not be adequately understood if studied only from the standpoint of mortality on the prey species. To manage quail more effectively, data on the abundance and composition of raptor species are needed.

Raptor surveys are used to identify the relative abundance and species composition of raptors to make better management decisions (Craighead and Craighead 1956). Because raptors are highly mobile, low in density, and often wary of human presence, they are difficult to study (Fuller and Mosher 1981). Roadside surveys have been used often in many areas to document relative abundance and species composition (Nice 1934, Allan and Sime 1943, Craighead and Craighead 1956, and Enderson 1965). Roadside surveys, however, have also been criticized because some species are more detectable because of their size, plumage, or behavior (Diesel 1984); and vegetation, observers (Millsap and LeFranc 1988), and time of day (Bunn et al. 1995) could create biases.

Raptor populations in Tennessee have been increasing since 1966 (Sauer et al. 2001) after they plummeted in the 20th Century presumably because of habitat changes,

shooting, and effects of pesticides on reproduction. Cooper's hawk populations in the Southeast have stabilized and may even be increasing (Adkisson 1990). Turkey vultures, red-tailed hawks, and American kestrels are listed in the Tennessee Breeding Bird Atlas as common permanent residents in Tennessee (Nicholson 1997). Red-shouldered hawks and black vultures were listed as uncommon to fairly common permanent residents of Tennessee, while sharp-shinned hawks and Cooper's hawks were listed as uncommon permanent residents of Tennessee (Nicholson 1997). The Cooper's hawk, sharp-shinned hawk, and northern harrier are listed as "in need of management" in Tennessee (Nicholson 1997). Raptor population trends (calculated from the nearest BBS route to Ames Plantation) from 1966-2000 during the breeding season in percent increase/year are as follows: black vulture, 7.2; turkey vulture, 3.8; sharp-shinned hawk, 10.1; Cooper's hawk, 4.6; red-tailed hawk, 2.6; American kestrel, 3.9; and red-shouldered hawk, 5.6 (Sauer et al. 2001). Black vultures, northern harriers, sharp-shinned hawks, Cooper's hawks and red-shouldered hawks were detected on average less than 1/100 party hours during the Christmas Bird Count (CBC) in Tennessee from 1959-1988 (0.98, 0.80, 0.03, 0.01, and 0.54, respectively; Sauer et al. 1996). Turkey vultures (5.69 / 100 party hours), red-tailed hawks (3.42 / 100 party hours), and American kestrels (3.12 / 100 party hours) were counted more often (Sauer et al. 1996). Tennessee winter raptor population trends from 1959-1988 in percent increase/year are as follows: black vulture, 7.3; turkey vulture, 3.0; sharp-shinned hawk, 2.0; Cooper's hawk, 1.7; red-tailed hawk, 3.5; American kestrel, 2.1; and red-shouldered hawk, 1.4 (Sauer et al. 1996). Raptor species counted in 1986 during winter roadside counts in Fayette and Hardeman counties of

Tennessee include black vultures, turkey vultures, northern harriers, sharp-shinned hawks, Cooper's hawks, red-tailed hawks, and American kestrels (Stedman 1988).

The objectives of this chapter were to describe the current relative abundance and species composition of raptors on Ames Plantation to better understand how raptors and avian predation are tied into northern bobwhite population dynamics.

Methods

A survey approach similar to the U.S. Fish and Wildlife Services Breeding Bird Survey was used to census raptors along a 40-km route on Ames Plantation (Robbins and Van Vezen 1966). Surveys were conducted weekly beginning in October 1999 through March 2001. The survey route consisted of 50 points located at 0.8 km intervals along the route. Half of the survey on the field trial area was conducted on unimproved roads on a Kawasaki ORV. A truck was used for the second half of the survey off of the field trial, which was conducted along a county road, partially off the plantation. The starting point was alternated so that every other week the survey was run in reverse order. Each point was visited for a 3 min duration in which all raptors seen or heard were recorded. All raptors observed en route from point to point were also recorded. During the breeding season (February 15 – May 31), taped vocalizations of target raptor species (Cooper's hawks and red-tailed hawks) were broadcast for 30 seconds after the initial 3-minute observation period to enhance detection. After the broadcasts, 3 additional minutes were spent counting any raptors that may have approached (Rosenfield et al. 1988). The survey was not conducted in fog, steady drizzle, prolonged rain, or winds greater than 13 km/h (Mosher et al. 1990). Every time a raptor was counted, the

precipitation, percent cloud coverage, estimated temperature, location, species, age, and activity of the bird (flying, perching, soaring, calling) were recorded. The activities recorded were later summed by species. The surveys started ½ hour after sunrise and took 5 to 6 hours to complete. Turkey vultures and black vultures were counted and are reported in the summary statistics, but were not included in the analyses.

Methods of Analysis

The raptor abundance was determined to be non-normal; therefore, non-parametric statistics were used. The Kruskal-Wallace *H* test was used to test for differences in raptor abundance/survey between three variables; leaf-on and leaf-off months, year 1 (winter 1999/2000) and year 2 (winter 2000/2001), and points on the field trial course and off the field trial course. Each of these three tests was run independently. The leaf-on season was April 1 to October 31, while the leaf-off season was November 1 – March 31. Points on the field trial included #'s 1-20 and 26-29 along the route while the points off the field trial were #'s 21-25 and 30-50. For the northern harrier, the field trial test was run using only winter surveys, but for all other species all surveys were analyzed.

The density of each species per 100 ha was calculated by dividing the mean abundance/survey of the winter months by the survey area, multiplied by 100. The survey area was delineated in Arcview by drawing polygons around all areas visible along the survey route.

Craighead and Craighead (1969) determined that only 1/3 of the known Cooper's hawks in an area were being counted in a series of winter censuses. They calculated a

correction factor and multiplied the number of Cooper's hawks by three (Craighead and Craighead 1969). In an effort to correct for detectability bias of Cooper's hawks and red-tailed hawks, detection trials were conducted on 2 radio-tagged red-tailed hawks and 2 radio-tagged Cooper's hawks 10 times during winter 2000/2001. To conduct a trial, each target bird was located with telemetry gear. When a bird was found along the survey route and within the visible area, a technician would simulate the raptor survey through the area. The detection rate was calculated as the number of birds detected compared to the number of times they were close enough to be detected. The actual number of birds detected in the real raptor survey was divided by this correction factor to get a projected density of red-tailed hawks and Cooper's hawks per 100 ha.

Results

A total of 1,671 raptors were recorded during 47 surveys (31 winter) on Ames Plantation from October 1999 to March 2001 (Figure 5). The average monthly abundance for the total number of raptors ranged from 5.3 birds detected per survey to 20.7 birds detected per survey (Table 12, Figure 6). The range for the average monthly abundance per survey for all other species were as follows: American kestrel, 0 - 2.3; Cooper's hawk, 0 - 1; northern harrier, 0 - 1.5; red-shouldered hawk, 0 - 4.3; red-tailed hawk, 4 - 14.5; and sharp-shinned hawk, 0 - 0.5; turkey vulture, 0 – 25.5; and black vulture, 0 – 3.3 (Table 12, Figures 7 - 14). We also observed bald eagles, barred owls, broad-winged hawks, and 1 osprey.

The total raptor abundance and red-tailed hawk abundance were greater ($P < 0.05$, Kruskal-Wallis *H* Test) the second year than the first year (Table 13). No other species exhibited significant differences in abundance between years ($P>0.10$).

The total number of raptors, northern harriers, and red-tailed hawks were detected more often ($P < 0.05$, Kruskal-Wallis *H* Test) on the field trial points, while American kestrels and red-shouldered hawks were detected more often ($P < 0.05$, Kruskal-Wallis *H* Test) off the field trial area (Table 14). Cooper's hawk and sharp-shinned hawk abundance did not differ among field trial and non-field trial points ($P > 0.10$).

Total raptors, northern harriers, and red-tailed hawks were detected less often ($P < 0.05$, Kruskal-Wallis *H* Test) during the leaf-on season than the leaf-off season (Table 15). American kestrels were detected marginally less ($P < 0.1$, Kruskal-Wallis *H* Test) in the leaf-on season than the leaf-off. Cooper's hawk, red-shouldered hawk, and sharp-shinned hawk abundance did not differ between the leaf-on and leaf-off seasons ($P>0.10$).

An area of 258 ha was delineated around the 40-km survey route (Figure 5). Mean raptor densities per 100 ha by species in winter were as follows; total, 6.95; American kestrel, 0.41; Cooper's hawk, 0.16; northern harrier, 0.39; red-shouldered hawk, 0.73; red-tailed hawk, 4.63; and sharp-shinned hawk, 0.08 (Table 16). Cooper's hawks and red-tailed hawks were detected 7.7% and 68.4 % of the time when tracked by radio-telemetry after accounting for detection bias. The projected densities for Cooper's hawks and red-tailed hawks were 2.08 and 6.77 birds/100 ha, respectively.

Cooper's hawks, northern harriers, and sharp-shinned hawks were observed most when they were flying (67%, 68%, and 56% of observations, respectively; χ^2=225.20, *P*=0.0001; Table 17). American kestrels were detected perching 55% of the time (χ^2=225.20, *P*=0.0001). Red-tailed hawks were most often detected soaring (43% of observations; χ^2=225.20, *P*=0.0001), while the majority of red-shouldered hawk detections were vocal (63% of observations; χ^2=225.20, *P*=0.0001).

Discussion

Ames Plantation supports a diverse raptor community that is seasonally and annually dynamic. The abundance and composition of raptors on Ames Plantation, specifically on the field trial areas, are important because northern bobwhites, which are the focus of the management, are likely prey species. This survey indicates that raptor populations may change annually and that detection rates can vary by habitat.

The raptor survey on Ames Plantation was useful in determining the relative abundance of raptors by season on and off the field trial areas. Because red-tailed hawks were detected often, the total raptor abundance results were similar to red-tail results. Accipiters were detected so infrequently that the analyses were unable to determine any differences between years, seasons, or on/off the field trial area. In reality, however, there probably were differences. Cooper's hawks and sharp-shinned hawks are more secretive and soar less often than buteos and use forested habitats; therefore detection probabilities are low. Accipiters are not likely to perch in open habitats and therefore have less chance of detection than most other raptors. Red-shouldered hawks were

probably detected more than accipiters, but less than red-tails, because although they frequent forested habitats, they also call regularly, thus aiding in detection.

Despite the efforts made to standardize this survey, the results reflect inherent biases. Variation in raptor behavior (Diesel 1984), the detectability of each species (Craighead and Craighead 1969), temperatures, years, seasons, vegetation, observers (Millsap and LeFranc 1988), and time of day (Bunn et al. 1995) may have effected the number of raptors counted during the surveys. Some variation in the survey has been addressed in this study and will be discussed, but other variation was beyond the scope of this study and could not be avoided. Despite these biases, the survey indicated that red-tailed hawks were undoubtedly the most abundant raptor in open habitats, red-shouldered hawks were restricted to more forested sites, and American kestrels used open pastures dominated by fescue, primarily off the field trial area. Cooper's hawks and sharp-shinned hawks were usually observed as they darted from one wooded area to another. They also are woodland raptors, but were not detected calling as the red-shouldered hawks were; therefore, Cooper's hawks were not counted as often.

Stedman (1988) determined the relative winter abundance of raptors (number of birds/40 km) in western Tennessee as follows; black vultures, 7.48; turkey vultures, 7.52; northern harriers, 0.17; sharp-shinned hawks, 0.33; Cooper's hawks, 0.17; red-tailed hawks, 4.64; and American kestrels, 3.66. Although these densities were determined after only 2 surveys compared to >22 surveys for middle and eastern Tennessee, black vultures, turkey vultures, northern harriers, sharp-shinned hawks, Cooper's hawks, and red-tailed hawks were found at greater densities in western

Tennessee than the rest of the state (Stedman 1988). Although the results of Stedman's survey and the results of the survey on Ames would be difficult to compare (the Ames survey consisted of 50 - 3 min points while Stedman's survey was driven continuously), it seems that there are more raptors were detected on the Ames survey.

Winter weather patterns influenced raptor abundance between years (Craighead and Craighead 1969, Kim 2001). The mean temperature (3.7 C, Figure 15) for year 1 was warmer than the mean temperature (2.3 C) for year 2. Not only was the second winter colder, but record-breaking cold weather hit Ames Plantation in early December (Year 1 December mean = -1.0 C, Year 2 December mean = -4.2 C) while raptors were still migrating. When this cold front first moved into the area, one of my radio-tagged Cooper's hawks left the plantation (See chapter 1). This cold winter appeared to change the raptor populations on Ames Plantation from the year before. There were significantly more red-tailed hawks the second winter. The major migratory movement of red-tailed hawks in Wisconsin occurs from October 10 to November 13 (Brinker and Erdman 1983), which could possibly put migrating red-tailed hawks in/near western Tennessee in late November or early December. According to Kim (2001), red-tailed hawks moved further south in the central U.S. during cold La Niña winters; an observation supported during the second winter at Ames Plantation.

The surveys on Ames Plantation did not show any difference in the abundance of accipiters between years, but evaluation of trapping data hint that there may have been fewer Cooper's hawks and more sharp-shinned hawks the second winter. An increase in trapping effort resulted in fewer Cooper's hawks trapped (See chapter 1). In the first

winter of trapping, 9 Cooper's hawks and 1 sharp-shinned hawk were caught, but the second winter, 2 Cooper's hawks and 5 sharp-shinned hawks were trapped in spite of an almost 10-fold increase in trap effort (Tables 18 - 19). Another difference in the trapping was that 9 red-shouldered hawks were caught in year 2, but none were caught in the first year. If the colder weather pushed the red-tails (and maybe the red-shouldered hawks as well) further south onto Ames Plantation, it may have also pushed the Cooper's hawks to migrate beyond this area to a warmer, more southern region. However, more sharp-shinned hawks were trapped during the colder, second winter. Studies on sharp-shinned hawk migration in the East (Clark 1983, Laurie and Jenkins 1983) found that sharp-shinned hawks from eastern New York, Quebec, and New England winter in the southeastern states of North Carolina, South Carolina, and Florida, but have been found as far west as Mississippi, Texas, and Louisiana. Possibly sharp-shinned hawks that normally winter in more northerly latitudes than Ames Plantation were pushed further south by the colder winter.

Another factor that may have played a role in the changing raptor populations on Ames Plantation from year 1 to year 2 was the extensive clearing of forests (25% of the field trial area) of the field trial grounds before, during, and after the first winter. These areas were harvested and all stumps and treetops were removed. The landscape of these harvest areas changed from a predominantly forested area to open savannahs with a few scattered trees. Raptors may have responded to this change in habitat; the more open habitat attracted more red-tailed hawks and discouraged use by red-shouldered hawks and Cooper's hawks.

The field trial areas on Ames are not only unique due to the forest management, but also because of the intense habitat management for northern bobwhites. As described in the study area, the field trial landscape is a patchwork of grasses, old fields, crop fields, food plots, and forests of various successional stages. The habitat diversity and abundance of food provides optimal foraging for many prey species including a diversity of birds and mammals. This survey indicated that northern harriers and red-tailed hawks were detected more on the field trials than off, while American kestrels and red-shouldered hawks were detected less on the field trials than off. Although accipiters lack statistical power to show a difference either way, personal observations suggest that there were more Cooper's hawks on the field trials than off during the first winter. The second winter, Cooper's hawks were not observed on the field trials any more than they were observed off of the field trials. The total raptor abundance shows that there were more raptors on the field trials of Ames Plantation than off.

The habitats off the field trial areas consisted of old fields, grass fields, forests, human developed sites, and pastures. A major difference between on and off the field trial areas was the dominance of fescue and minimal native grasses in the open areas off the field trial. Open field species such as the northern harriers and red-tailed hawks preferred the habitat on the field trial areas while American kestrels preferred the short grass in the pastures. Red-shouldered hawks were detected more off the field trials than on, but the other forest hawks, the accipiters, did not show a difference. Although, not a part of this study, owls were observed (during and outside the survey) on and off the field trial areas. A few great horned owls were seen on the plantation throughout the study and

when 2 radio-tagged Cooper's hawks were killed by an avian predator during the night (See Chapter 2), great-horned owls were the suspected predators. Barred owls were trapped and heard calling in the forested areas on and off the plantation and screech owls were occasionally observed near human-developed areas.

The Ames Plantation field trial areas attracted more raptors, especially red-tailed hawks, than the surrounding areas. There is an abundance of small birds and mammals on the field trial areas. Raptors have been shown to occupy smaller home ranges at higher densities when there is an abundant food supply (Newton 1979). The corn and soybean field borders left standing as well as the food plots of milo provide an excellent food source for granivorous birds and small mammals during the winter. These prey species may be attracted to the field trial areas because of the food and cover provided and possibly because of the supplemental corn and milo spread weekly throughout the year. In the same way, raptors are attracted to the field trial areas because of the abundance of prey and preferable habitats. Raptors were possibly concentrated in the general area near Ames because of the weekly winter releases of quail on the neighboring plantation, Woodlawn.

The results of this study indicate that some species were detected more during the leaf-off season than the leaf-on season. The species that did not show a difference between seasons were forest hawks (Cooper's hawks, sharp-shinned hawks, and red-shouldered hawks) where there was a lack of statistical power. Because red-shouldered hawks were detected primarily by their calls, visibility bias probably was not as important. Differences, therefore, were not detected between leaf-on and leaf-off

seasons. Leaves would have decreased the visibility of raptors, especially in the forests because all vegetation hinders the rate of detectability (Diesel 1984, Millsap and LeFranc 1988). Visibility during the leaf-on and leaf-off seasons confounds the actual seasonal population numbers. Raptor abundance should be greatest in winter because there are breeding residents as well as migrant winter residents in the area (Newton 1979). However, the visibility bias due to the lack of leaves may confound the magnitude of this effect.

Although this study focused on wintering raptors, surveys conducted during the spring while playing Cooper's hawk and red-tailed hawk calls did not attract any more birds than those without the calls. Despite the success of many others to attract raptors when playing calls (Rosenfield et al. 1985, Mosher et al. 1990, Morrell et al. 1991, Stewart et al. 1996, Bosakowski and Smith 1998), few raptors on Ames responded. The reasons for this are not fully understood.

Cooper's hawks were not detected in this survey with sufficient frequency to provide information on population trends. Because of the greater number of Cooper's hawks trapped during the first winter compared to the second winter, Cooper's hawk populations appear to be both seasonally and annually dynamic. The number of Cooper's hawk sightings outside the survey was much lower in the second year than the first. Because Cooper's hawks are forest raptors, their numbers on Ames Plantation may have decreased because of extensive removal of the hardwood forests. However, Cooper's hawks are also affected by climatic factors (cold temperatures) and may have migrated further south. Red-tailed hawks could have been influenced to move further south by the

temperature as well, but their increase during the second winter may have also been a positive response to the hardwood conversion area and the potential increase in prey it provided. Additional research is necessary to determine if the colder temperatures or the harvested forests had more of an impact on the accipiter and buteo populations.

CHAPTER 4.
OBSERVATIONS ON BREEDING COOPER'S HAWKS, RED-TAILED HAWKS AND RED-SHOULDERED HAWKS IN FAYETTE AND HARDEMAN COUNTIES, TENNESSEE.

The presence of breeding Cooper's hawks, red-tailed hawks, and red-shouldered hawks in Fayette and Hardeman counties of southwestern Tennessee was confirmed during the summers of 2000 and 2001. All Cooper's hawk nests, one red-tailed hawk nest, and the red-shouldered hawk nest were located in Fayette county, Tennessee but one red-tailed hawk nest was located in Hardeman county, Tennessee. Cooper's hawks were reported as common to Tennessee in the early 1900's (Ganier 1933), but after the decline in all raptor populations due to shooting, habitat loss, and pesticide poisoning, the number of Cooper's hawks in Tennessee declined. After this decrease in populations, the only confirmed nesting Cooper's hawk locations were in middle and eastern Tennessee, until McWhirter (2000) documented a pair nesting in Shelby County. Red-tailed hawks, although considered common in Tennessee today (Nicholson 1997), were reported as rare breeders in western Tennessee in the early 1900's (Ganier 1917, Ganier 1933). Red-shouldered hawks were listed as fairly common for western Tennessee in the early 1900's (Ganier 1917, Ganier 1933), but are now less common because of the loss of bottomland forests (Nicholson 1997).

Two pairs of Cooper's hawks, 2 pairs of red-tailed hawks, and 1 pair of red-shouldered hawk were observed nesting on Ames Plantation, Tennessee during the breeding seasons of 2000 and 2001 (Table 20). It is uncertain if both individuals of a pair were the same both years, although for 1 Cooper's hawk and 1 red-tailed hawk nest, 1 individual was radio-tagged and was present in both 2000 and 2001. For clarification, the

pairs will be called coha1 (the female was radio-tagged), coha2, rtha1 (one of the pair was radio-tagged), rtha2, and rsha.

Coha1

The nests of coha1 were located outside (0.3 km away from human development) Grand Junction, in Fayette County, Tennessee both years. The male and the female were aged as adults by their plumage. Prior to the breeding season in 2000, the female was trapped in a bal chatri and fitted with a radio transmitter to learn more about Cooper's hawk winter ecology. She was located daily during daylight hours and once or twice a week on the roost. Mid-March, she left her wintering area on Ames Plantation and moved about 2 km to Grand Junction and on March 29, a nest was located in the area with whitewash and prey remains present. This nest was located in a hardwood forest on the outskirts of Grand Junction. Before sunrise on April 12, the male's presence was detected when he emitted a "kik" call at the nest (Rosenfield and Bielefeldt 1993), and the female flew to him. The female was located, but not seen, near the nest 3 more times in April (13, 15, and 17). On April 29, the female was located and seen on the nest, possibly incubating. During the first 2 1/2 weeks of May, the female was observed on the nest incubating (May 2, 4, 8, 16, and 18). On the 8th, 16th, and 18th, the male was heard kikking about 50 m southeast of the nest. Within seconds of the call, the female flew in his direction. During the time the female was away from the nest, the male appeared on the nest for approximately 30 – 60 sec. On May 19, the female behaved strangely and would not sit inside the bowl of the nest. She would cock her head from side to side for a minute or two and then fly away. This behavior lasted for about 20 min. Then she flew

to the nest, ate something, and carried ¾ of an eggshell from the nest. May 19 was the hatch date for the first egg. The nest apparently failed shortly after May 19 and the pair abandoned the nest thereafter. The female was tracked monthly for the rest of the summer and she was usually located about 300 m northwest of this nest.

The nest tree for coha1 during the summer of 2000 was climbed after it failed and measurements were taken. The nest was 11.4 m high in the bowl of a white oak, with nest dimensions of 46.5 cm by 60 cm wide and 7 cm deep on the inside. Other nest site characteristics were measured as well and are described below.

After the female from the coha1 pair was tracked another winter, a nest was located on March 19, 2001 about 300 m northwest of the nest from 2000. On March 20, 2001, the male was heard kikking and the female flushed from the nest. The female was tracked on the nest on March 28 and 29, but she flushed as I approached. On April 19 she did not flush from the nest as I walked beneath it and I suspected that she was incubating. The female was seen and heard on May 11. The nest was checked again on May 14 and while neither of the Cooper's hawks were detected, a great horned owl was seen in the tree adjacent to the nest tree. Because the Cooper's hawks were not observed near the nest or even within 1 km of the nesting area again, I suspect that the nest was depredated by the great horned owl. The female was tracked around 1 km west of the nesting area the rest of the summer.

Coha2

The second pair of nesting Cooper's hawks, coha2, was much more secretive as well as more successful. The nest of coha2 in 2000 was not located until the winter of

2001 (after the foliage was gone), but the Cooper's hawks were heard in the area in summer 2000 and observed as they exchanged prey. The nest was located high at the top of the canopy in a loblolly pine about 1 km from the nearest human development in Fayette county. On May 23, 2000, a Cooper's hawk was heard "kikking" in the area. Both the female and the male were seen as prey was exchanged on May 30. They then flew to the area where the nest was later discovered. Both birds were either seen or heard on June 2, 5, and 8. Although no young were observed and the nest area was not checked later than June 8, I suspect that this nest was successful because the parents were bringing prey into the nesting area through at least the middle of June.

The nest for coha2 in 2001 was located March 22 by systematically searching the area. It was found approximately 50 m north of the previous nest in a yellow poplar. On both March 22 and 28, 2001, a Cooper's hawk was heard calling near the nest. By April 19, it was obvious that the nest was active by the behavior of the female. She followed me around, calling as I located at the nest from the ground. She "kik'd" the most when I was nearest to the nest. She returned to the nest as I left, indicating that she may have been incubating. The male was heard "kikking" to the female on May 9, but was not seen. On May 11, the female was observed flying to the nest. No birds were seen or heard on the morning of May 22 and a nest camera was erected 10 m from the ground in a tree approximately 30 m east of the nest that afternoon. Due to bad weather and technical difficulties, limited video was recorded. For two mornings, May 23 and May 27, the nest was video taped, but the quality of the video was poor due to high winds. On May 23, the female was recorded as she left and returned to the nest. When she was on

the nest, only her tail could be seen, indicating that she was probably incubating or brooding. On May 27, though, she sat vertically and was much higher in the nest with the majority of her body being above the bowl, appearing to be brooding. The camera was removed for repairs June 2. On June 22, the female was seen leaving the nesting area and returned 20 minutes later calling. Once again, no young were seen or heard in the nesting area. The nest was not checked after June 22. The fate of this nest is unknown, although activity at the nest at that late date suggests a successful nesting effort.

Coha3

A third Cooper's hawk nest was discovered March 26, 2001 in Fayette county, Tennessee, but after 3 months of observation, it was determined not to be active. On March 26, 27, and 29, as well as April 19, a Cooper's hawk, probably a male, was heard or seen soaring above or flying near the nest. The nest was built in a large white oak tree and it looked fresh with new twigs. On May 3, the Cooper's hawk was seen bringing sticks to the nest 4 times. Because two birds were never observed together at the nest site and no other activity was recorded during further nest checks, I suspect we had observed an immature male exhibiting nest-building behaviors. Based on the limited observations, the bird's age was not determined.

Rtha1

Prior to the 2000 nesting season, a red-tailed hawk was trapped in a bal chatri and fitted with a radio transmitter (rtha1). On March 13, 2000, this bird was located in a nest constructed in a loblolly pine in Fayette county, Tennessee and it appeared to be

incubating. During the month of March (March 14, 15, 16, 20 and 23), a red-tailed hawk was observed incubating this nest. I was not certain if the radio-tagged hawk was the individual incubating or if it was perched so close to the nest (but not visible to me) that the signal appeared to be coming from the nest. I did not determine the sex of the radio-tagged bird. On March 29, though, the radio-tagged hawk was located on a perch about 350 m from the nest while its mate was incubating, causing me to suspect it was a male. On April 4 and 5, the nest was observed, but there was no sign of any red-tailed hawk activity indicating it had failed. The radio-tagged bird was located about 500 m from the nest and neither bird was ever seen near the nest again.

This pair of red-tailed hawks (rtha1) was watched throughout the following year and on March 12, 2001, a nest was discovered approximately 200 m from the nest of the year before. On March 13, 15, and 22, the mate of the radio-tagged hawk was observed incubating suggesting that the radio-tagged bird was indeed a male. The female was sitting higher in the nest on March 28 and began calling as we approached indicating that the eggs may have hatched. The red-tailed was brooding when checked again on March 30. By April 19, two nestlings could be seen in the nest, which was showing signs of wear. Again on April 24, the chicks could be heard begging, but no parents were at the nest. The young were observed many times (May 4, 9, 15, and 22) and a camera was set up for two days (May 4 and 22) to record nest activity. On May 4, the nestlings (approximately 5 weeks old) were still covered in white down with just the sheaths of tail feathers beginning to protrude. They were recorded sleeping, defecating, watching a bug swarm around, stretching, and flapping. The mate of the radio-tagged red-tailed hawk

flew to the nest 3 times during the video (recorded from 1600 hr to dark; 8 hrs) and the first time she brought food. The prey item was a small to medium-sized mammal, possibly a gray squirrel. The parent pulled pieces from the prey and fed each of the young repeatedly while eating some herself. By May 15, the nestlings (approximately 7 weeks old) were beginning to grow flight feathers and were speckled with white and brown coloring. They had at least doubled in size and were now tearing apart the prey (unidentified) from the parent by themselves. The other nesting behavior was similar to that recorded on May 4. On June 9, the fledglings (approximately 10 weeks old) were observed flying around the nest (within 40 m), indicating a successful nesting effort.

Rtha2

The second red-tailed hawk nest (rtha2) was discovered on March 15, 2000 in Hardeman county, Tennessee and was confirmed to be active on March 22 when the female flushed from the nest. The female was incubating when the nest was checked on April 4. On April 14, the female was also on the nest, but it was difficult to determine if she was incubating or brooding. On May 5, the bird was sitting high in the nest and the base of the tree was surrounded by whitewash, indicating the eggs had hatched. One nestling was observed on May 9. By June 2, no birds were present, but the amount of whitewash around the base of the tree had multiplied. It is possible that the nestling(s) had fledged by this date and this nest was probably successful.

During the breeding season of 2001, the exact nest used by the red-tailed hawks (rtha2) in 2000 was used again by red-tailed hawks, but not until later in the breeding season. The nest was checked on March 21, 2001 to detect activity. There were many

pellets and bones scattered at the base of the nest tree and on March 28 a barred owl was seen and heard approaching the nest. The use of this nest by the barred owl, or any other raptor, was not detected when it was checked again on April 19. On May 22, the nest was occupied by a red-tailed hawk which appeared to be incubating. The fate of this nest was unknown because it was not checked after this date.

Rsha

A red-shouldered hawk nest was located during a raptor survey on March 2, 2000. This nest was in a large yellow poplar along Ames Road in Fayette county, Tennessee. On both March 2 and April 6, the red-shouldered hawk flushed from the nest and called wildly as I conducted the survey. On April 12, the hawk was incubating and by May 5 she appeared to be brooding. When checked again on May 31, there was no activity at the nest and the bird was not seen or heard. It is unknown if this nest fledged or failed due to the time period between nest checks.

Nest Habitat Measurements

Measurements including nest height (clinometer), nest tree diameter (diameter tape), vertical cover (cover board), canopy cover (densiometer), and basal area (2.5 m^2/ha prism) were taken on the nests after the breeding season was complete (Table 21). The averages for the four Cooper's hawk nests were as follows; nest height, 16.55 m; nest tree diameter, 53.08 cm; vertical cover, 6.06%; canopy cover, 48.8%; and basal area 30.58 m^2/ha. Tree species at nest sites included mockernut hickory, northern red oak, willow oak, white oak, slippery elm, flowering dogwood, sweetgum, loblolly pine, yellow poplar, and red maple. The mean height of the overstory was 17.48 m with a

mean diameter of 29.95 cm for the overstory trees. The mean height of the understory was 8.75 m with a mean diameter of 20.83 cm for the understory trees.

The averages for the four red-tailed hawk nests were as follows; nest height, 18.7 m; nest tree diameter, 49.83 cm; vertical cover, 11.94 %; canopy cover, 62.73 %; and basal area 19.06 m^2/ha. Tree species at nest sites included mockernut hickory, white oak, slippery elm, and loblolly pine. The mean height of the overstory was 19.79 m with a mean diameter of 39.3 cm for overstory trees. The mean height of the understory was 4.75 m with a mean diameter of <10 cm for understory trees.

The measurements for the red-shouldered nest were as follows; nest height, 15 m; nest tree diameter, 53.75 cm; vertical cover, 12.5 %; canopy cover, 49.22 %; and basal area 34.39 m^2/ha. Tree species at the nest site included white oak, tulip poplar, and sweetgum. The mean height of the overstory was 22.6 m with a mean diameter of 40.38 cm for overstory trees. The mean height of the understory was 5 m with a mean diameter of <10 cm for understory trees.

Although these were the only nests I found, I suspect that there were more Cooper's hawks and red-tailed hawks breeding in the area. The survey results (See chapter 3, Table 3.1) indicated that there was an average of 11.58 red-tailed hawks observed per survey during the months of March and April, but there was an average of 4.3 red-tailed hawks observed per survey during May, June, and July. The observations of Cooper's hawks per survey were minimal and a difference could not be detected. On the survey during the breeding season, Cooper's hawks and red-tailed hawks that were not described in this paper, but could have potentially been breeding birds, were counted.

More research is needed to determine the food habits of nesting Cooper's hawks and to better determine the nesting densities of the raptors on Ames Plantation.

LITERATURE CITED

LITERATURE CITED

Adkisson, C. S. 1990. Accipiters. Pages 63 – 69 *in* Pendleton, B.G. ed. Proceedings of the Southeast Raptor Management Symposium and Workshop. National Wildlife Federation, Washington, D.C., USA.

Aebischer, N. J., P. A. Robertson, and R. E. Kenward. 1993. Compositional analysis of habitat use from animal radio-tracking data. Ecology 74:1313-1325.

Allan, P. F. and P. R. Sime. 1943. Hawk census on a Texas panhandle highway. Wilson Bulletin 55:29-39.

Ardia, D. R. 2001. Winter roosting behavior of American kestrels. Journal Raptor Research 35:58-61.

Asay, C. E. 1987. Habitat and productivity of Cooper's hawks nesting in California. California Fish and Game 73:80-87.

Atkinson, E. C. 1993. Winter territories and night roosts of northern shrikes in Idaho. Condor 95:515-527.

Belthoff, J. R. and G. Ritchison. 1990. Roosting behavior of postfledging eastern screech-owls. Auk 107:567-579.

Berger D. D. and H. C. Mueller. 1959. The bal-chatri: A trap for the birds of prey. Bird Banding 30:18-26.

Boal, C. W. and R. W. Mannan. 1998. Nest-site selection of Cooper's hawks in an urban environment. Journal Wildlife Management 62:864-871.

Bohall, P. G. and M. W. Collopy. 1984. Seasonal abundance, habitat use, and perch sites of four raptor species in north-central Florida. Journal Field Ornithology 55:181-189.

Bortolotti, G. R. and K. L. Wiebe. 1993. Roosting American kestrels (*Falco sparverius*) during migration in Saskatchewan. Journal Raptor Research 27:47-49.

Bosakowski, T., 1984. Roost selection and behavior of the long-eared owl (*Asio otus*) wintering in New Jersey. Journal Raptor Research 18:137-142.

_____, and G.D. Smith. 1998. Response of a forest raptor community to broadcasts of heterospecific and conspecific calls during the breeding season. Canadian Field-Naturalist 112:198-203.

_____., _____, and R. Speiser. 1992. Nest sites and habitat selected by Cooper's hawks, *Accipiter cooperii*, in northern New Jersey and southeastern New York. Canadian Field-Naturalist 106:474-479.

Brinker, D. F. and T. C. Erdman. 1983. Characteristics of autumn red-tailed hawk migration through Wisconsin. Pages 107-136 *in* M. Harwood, editor. Proceedings of Hawk Migration Conference IV. Rochester, New York, March 1983. Hawk Migration Association of North America and Hawk Mountain Sanctuary Association.

Buehler, D. A., T. J., Mersmann, J. D., Fraser, and J. K. D. Seegar. 1991a. Winter microclimate of bald eagle roosts on the northern Chesapeake Bay. Auk 108:612-618.

_____, _____, _____, and _____. 1991b. Nonbreeding bald eagle communal and solitary roosting behavior and roost habitat on the northern Chesapeake Bay. Journal Wildlife Management. 55:273-281.

_____, J. D., Fraser, M. R., Fuller, L. S., McAllister, and J. K. D. Seegar. 1995. Captive and field-tested radio transmitter attachments for bald eagles. Journal Field Ornithology 66:173-180.

Bunn, A. G., W. Klein, and K. L. Bildstein. 1995. Time-of-day effects on the numbers and behavior of non-breeding raptors seen on roadside surveys in eastern Pennsylvania. Journal Field Ornithology 66:544-552.

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

Byers, C. R. R. K. Steinhorst, and P. R. Krausman. 1984. Clarification of a technique for analysis of utilization-availability data. Journal Wildlife Management 48:1050-1053.

Carr, A. P. and A. R. Rogers. 1998. The home range extension for Arcview, tutorial guide and user's manual. Centre for Northern Forest Ecosystem Research, Ontario Ministry of Natural Resources.

Clark, W. S. 1983. The migrating sharp-shinned hawk at Cape May Point: banding and recovery results. Pages 137-148 *in* M. Harwood, editor. Proceedings of Hawk Migration Conference IV. Rochester, New York, March 1983. Hawk Migration Association of North America and Hawk Mountain Sanctuary Association.

Craighead, J. J., and F. C.Craighead. 1969. Hawks, owls, and wildlife. Dover Publications, NewYork, USA.

DeMaso, S. J., S. A. Cox, and E. S. Parry. 1997. Quail mortality study: Upland game investigations. Oklahoma Department Wildlife Conservation W-82-R.

Diesel, D. A. 1984. Evaluation of the road survey technique in determining flight activity of red-tailed hawks. Wilson Bulletin 96:315-318.

Dimmick, R. W. 1990. Bobwhites, raptors, and thresholds of security. Pages 158-161. *in* Pendleton, B.G. ed. Proceedings Southeast Raptor Management Symposium and Workshop. National Wildlife Federation, Washington, D.C., USA.

Dimmick, R. W. 1992. Northern bobwhite (*Colinus virginianus*). US Army Corps of Engineers Wildlife Resources Management Manual. Technical Report EL-92-18.

Doody, J. S. 1994. Winter roost-site use by female American kestrels (*Falco sparverius*) in Louisiana. Journal Raptor Research 28:9-12.

Duguay, T. A., G. Ritchison, and J. P. Duguay. 1997. The winter roosting behavior of eastern screech-owls in central Kentucky. Journal Raptor Research 31:260-266.

Duncan, S. 1966. An analysis of the stomach contents of some Cooper's hawks (*Accipiter cooperii*). Auk 83:308.

Enderson, J. H. 1965. Roadside raptor count in Colorado. Wilson Bulletin 77:82-83.

Errington, P. L. 1934. Vulnerability of bobwhite populations to predation. Ecology 15:110-127.

Errington, P. L. 1967. On predation and life. Iowa State University, Ames, Iowa, USA.

Exum, J. H., R. W. Dimmick, and B. L. Dearden. 1982. Land use and bobwhite populations in an agricultural system in west Tennessee. Pages 6-12 *in* F. Schitoskey, Jr., E. C. Schitoskey, and L. G. Tallent, editors. Proceedings Second National Bobwhite Quail Symposium. Oklahoma State University, Stillwater, Oklahoma, USA.

Fischer, D. L. 1986. Daily acitivity patterns and habitat use of coexisting Accipiter hawks in Utah. Ph.D. thesis. Brigham Young University Provo, Utah, USA.

Francis, W. J. 1976. Micrometeorology of a blackbird roost. Journal Wildlife Management 40:132-136.

Fuller, M. R. and J. A. Mosher. 1981. Methods of detecting and counting raptors; A review. Studies Avian Biology 6:235-246.

Ganier, A. F. 1917. Preliminary list of the birds of Tennessee, Tennessee Department Game and Fish, Nashville, Tennessee, USA.

Ganier, A. F. 1933. A distributional list of the birds of Tennessee, Tennessee. Avifauna No. 1, Ornithological Society, Nashville, Tennessee, USA.

Garner, H. D. 1999. Distribution and habitat use of sharp-shinned and Cooper's hawks in Arkansas. Journal Raptor Research 33:329-332.

Grubb, T. 1975. Weather-dependent foraging behavior of some birds wintering in a deciduous woodland. Condor 77:175-182.

Hayes, S. R. and J. A. Gessaman. 1980. The combined effects of air temperature, wind, and radiation on the resting metablolism of avian raptors. Journal Thermal Biology 5:119-125.

Hosmer D. W. and S. Lemeshow 1989. Applied logistic regression. John Wiley and Sons, New York, USA.

Hurst, G. A., L. W. Burger, B. D. Leopold. 1996. Predation and galliforme recruitment: An old issue revisited. Transactions 61st North American Wildlife and Natural Resources Conference 61:62-76.

Janes, S. W. 1985. Habitat selection in raptorial birds. Pages 159-188 *in* Cody, M. L., editor. Habitat selection in birds. Academic Press Orlando, Florida, USA.

Kelty, M. P. and S. I. Lustick. 1977. Energetics of the starling (*Sturnus vulgaris*) in a pine woods. Ecology 58:1181-1185.

Kennedy, P. L. and D. R. Johnson. 1986. Prey-size selection in nesting male and female Cooper's hawks. Wilson Bulletin 98:110-115.

Kennedy, P. L. and J. A. Gesseman. 1991. Diurnal resting metabolic rates of Accipiters. Wilson Bulletin 103:101-105.

Kim, D. H. 2001. Biotic and abiotic factors influencing nonbreeding raptor assemblages in southern Texas. PhD dissertation. Texas A&M University, College Station, Texas and Texas A&M University-Kingsville, Kingsville Texas, USA.

Kritz, K. J. 1989. Nesting ecology and nest site habitat of sharp-shinned and Cooper's hawks in Missouri. M.S. thesis. University of Missouri, Columbia, Missouri, USA.

Laurie, P. and J. C. Jenkins. 1983. Autumn hawk migrations at Fort Johnson, Charleston, South Carolina. Pages 355-360 *in* Harwood, M. editor. Proceedings of

Hawk Migration Conference IV. Rochester, New York, March 1983. Hawk Migration Association of North America and Hawk Mountain Sanctuary Association.

Leopold, B. D. and G. A. Hurst. 1994. Experimental designs for assessing impacts of predators on gamebird populations. Transactions 59th North American Wildlife and Natural Resources Conference 59:477-487.

Mannan, R. W. and C. W. Boal. 2000. Home range characteristics of male Cooper's hawks in an urban environment. Wilson Bulletin 112:21-27.

McWhirter, S. N. 2000. Confirmed breeding of Cooper's hawk in urban Shelby county. Migrant 71:4-6.

Meng, H. 1959. Food habits of nesting Cooper's hawks and goshawks in New York and Pennsylvania. Wilson Bulletin 71:169-174.

Millsap, B. A. and M. N. LeFranc, Jr. 1988. Road transect counts for raptors: How reliable are they? Journal Raptor Research 22:8-16.

Morrell, T. E., R. H. Yahner, and W. L. Harkness. 1991. Factors affecting detection of great horned owls by using broadcast vocalizations. Wildlife Society Bulletin 19:481-488.

Moore, K. R. and C. J. Henny. 1983. Nest site characteristics of three coexisting accipiter hawks in northeastern Oregon. Journal Raptor Research 17:65-76.

Mosher, J. A., M. R. Fuller, and M. Kopeny. 1990. Surveying woodland raptors by broadcast of conspecific vocalizations. Journal Field Ornithology 61:453-461.

_____, _____. 1996. Surveying woodland hawks with broadcasts of great horned owl vocalizations. Wildlife Society Bulletin 24:531-536.

Murphy, R. K., Gratson, M. W., and R. N. Rosenfield. 1988. Activity and habitat use by a breeding male Cooper's hawk in a suburban area. Journal Raptor Research 22:97-100.

Neu, D. W., R. Byers, and J. M. Peek. 1974. A technique for analysis of utilization – availability data. Journal Wildlife Management 38:541-545.

Newton, I. 1979. Population ecology of raptors. Buteo Books, Vermillion, South Dakota, USA.

Nice, M. M. 1934. A hawk census from Arizona to Massachusetts. Wilson Bulletin 46:93-95.

Nicholson, C. P. 1997. Atlas of the breeding birds of Tennessee. The University of Tennessee Press Knoxville.

Odum, E. P. and F. A. Pitelka. 1939. Storm mortality in a winter starling roost. Auk 45:451.

Orian, G. H. and N. E. Pearson. 1977. On the theory of central place foraging. Pages 155-177 *in* Horn, D. J., G. R., Stairs, and R. D. Mitchell, editors. Analysis of ecological systems. The Ohio State University, Columbus, Ohio, USA.

Pendleton, G. W., K. Titus, E. DeGayner, C. J. Flatten, and R.E. Lowell. 1998. Compositional analysis and GIS for study of habitat selection by goshawks in southeast Alaska. Journal Agriculture Biological Environmental Statistics 3:280-295.

Peterson, D. J. and R. K. Murphy. 1992. Prey delivered to two Cooper's hawk, *Accipiter cooperii*, nests in northern mixed grass prairie. Canadian Field-Naturalist 106:385-386.

Pianka, E. 1974. Evolutionary ecology. Harper and Row, New York, USA.

Reynolds, R. T., E. C. Meslow, and H. M. Wight. 1982. Nesting habitat of coexisting accipiters in Oregon. Journal Wildlife Management 46:124-138.

Robbins, C. S. and W. T. Van Velzen. The breeding bird survey, 1966. US Fish and Wildlife Service, Special Scientific Report – Wildl. No. 102.

Rollins, D., and J. P. Carroll. 2001. Impacts of predation on northern bobwhite and scaled quail. Wildlife Society Bulletin 29:39-51.

Roseberry, J. L. and W. D. Klimstra. 1984. Population ecology of the bobwhite. Southern Illinois University, Carbondale, Illinois, USA.

Rosenfield, R. N., J. Bielefeldt, R. K. Anderson, and W. A. Smith. 1985. Taped calls as an aid in locating Cooper's hawk nests. Wildlife Society Bulletin 13:62-63.

Rosenfield, R. N., J. Bielefeldt, and R. K. Anderson. 1988. Effectiveness of broadcast calls for detecting breeding Cooper's hawks. Wildlife Society Bulletin 16:210-212.

Rosenfield, R. N. and J. Bielefeldt. 1993. Cooper's hawk (*Accipiter cooperii*). *in* Poole, A. and F.Gill, editors. The Birds of North America, No.75. The Academy of Natural Sciences, Philadelphia, Pennsylvania, and The American Ornithologists' Union, Washington, D.C., USA.

Rudolph, S. G. 1978. Predation ecology of coexisting great horned and barn owls. Wilson Bulletin 90:134-137.

SAS/STAT User's Guide, Version 6, Fourth Edition., 1990. Cary, North Carolina, USA.

Sauer, J. R., J. E. Hines, and J. Fallon. 2001. The North American Breeding Bird Survey, results and analysis 1966 - 2000. Version 2001.2, USGS Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Sauer, J. R., S. Schwartz, and B. Hoover. 1996. The Christmas bird count home page. Version 95.1 Patuxent wildlife research center, Laurel, Maryland. USA.

Schnell, G. D. 1969. Communal roosts of wintering rough-legged hawks (*Buteo lagopus*). Auk 86:682-690.

Squires, J. R. and L. F. Ruggiero. 1995. Winter movements of adult northern goshawks that nested in southcentral Wyoming. Journal Raptor Research 29:5-9.

Squires, J. R. and R. T. Reynolds. 1997. Northern goshawk (*Accipiter gentilis*). *in* Poole, A. and F.Gill, editors. The Birds of North America, No..298. The Academy of Natural Sciences, Philadelphia, Pennsylvania, and The American Ornithologists' Union, Washington, D.C., USA.

Stedman, S. J. 1988. The winter roadside raptor survey in Tennessee: 1986-1987 results. The Migrant. 59:14-20.

Stewart, A. C., R. W. Campbell, and S. Dickin. 1996. Use of dawn vocalizations for detecting breeding Cooper's hawks in an urban environment. Wildlife Society Bulletin 24:291-293.

Stoddard, H. L. 1932. The bobwhite quail: its habits, preservation and increase. Charles Schribner's Sons, New York, USA.

Sykes, P. W. Jr. 1985. Evening roosts of the snail kite in Florida. Wilson Bulletin 97:57-70.

Titus, K. and J. A. Mosher. 1981. Nest-site habitat selected by woodland hawks in the central Appalachians. Auk 98:271-281.

Thompson, W. L., R. H. Yahner, and G. L. Storm. 1990. Winter use and habitat characteristics of vulture communal roosts. Journal Wildlife Management 54:77-83.

Toland, B. 1985. Food habits and hunting success of Cooper's hawks in Missouri. Journal Field Ornithology 56:419-422.

Townsend II, D. E., R. L. Lochmiller, S. J. DeMaso, D. M. Leslie, Jr., A. D. Peoples, S. A. Cox, and E. S. Perry. 1999. Using supplemental food and its influence on survival of northern bobwhite (*Colinus virginianus*). Wildlife Society Bulletin 27:1074-1081.

Trexel, D. R., R. N. Rosenfield, J. Bielefeldt, and E. A. Jacobs. 1999. Comparative nest site habitats in sharp-shinned and Cooper's hawks in Wisconsin. Wilson Bulletin 111:7-14.

Tennessee Valley Authority. 1982. Inventory of agricultural land in the Tennessee valley region and its availability for fuel crops.

Walk, J. W. 1998. Winter roost sites of northern harriers and short-eared owls on Illinois grasslands. Journal Raptor Research 32:116-119.

Walsberg, G. E. 1985. Habitat selection in raptorial birds. Pages 389-414 *in* Cody, M. L., editor. Habitat selection in birds. Academic Press, Orlando, Florida, USA.

Walsberg, G. E. 1986. Thermal consequences of roost-site selection: The relative importance of three modes of heat conservation. Auk 103:1-7.

Warkentin, I. G. and P. W. James. 1990. Winter roost-site selection by urban merlins (*Falco columbarius*). Journal Raptor Research 24:5-11.

Webb, D. R. and C. M. Rogers. 1988. Nocturnal energy expenditure of dark-eyed juncos roosting in Indiana during winter. Condor 90:107-112.

White, G. C. and R. A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press, San Diego, California, USA.

APPENDICES

APPENDIX I

FIGURES AND TABLES

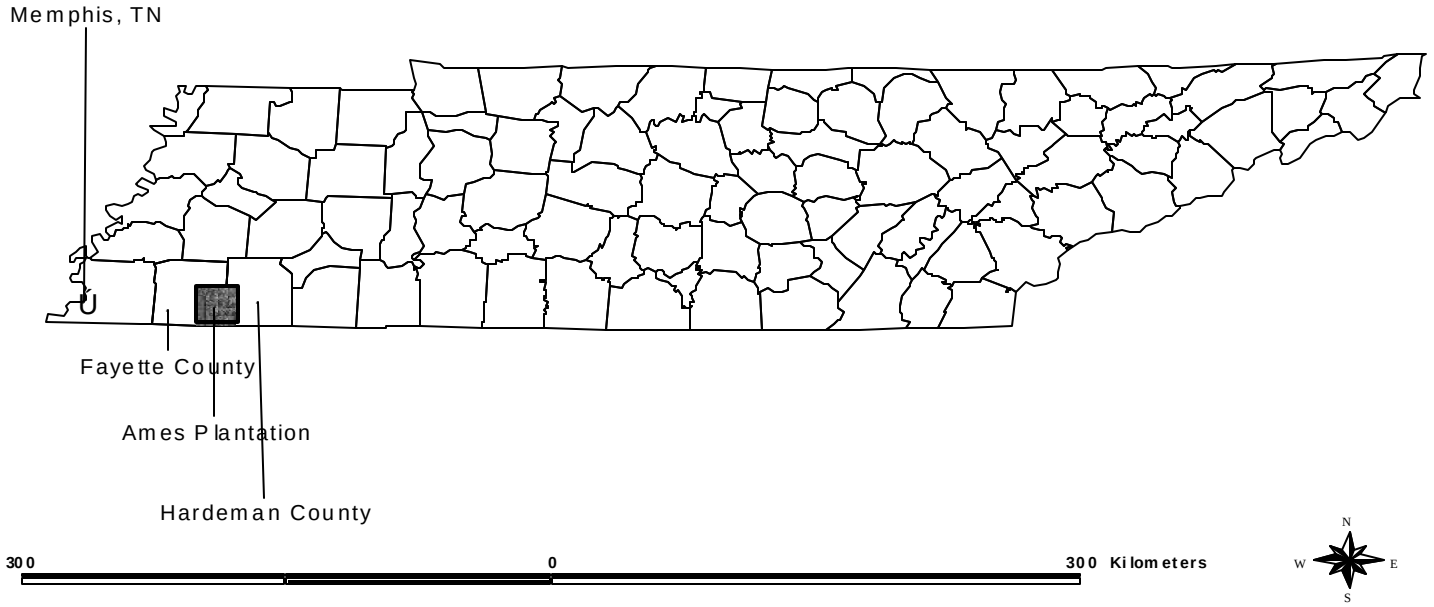

Figure 1. Ames Plantation in Fayette and Hardeman counties in Tennessee.

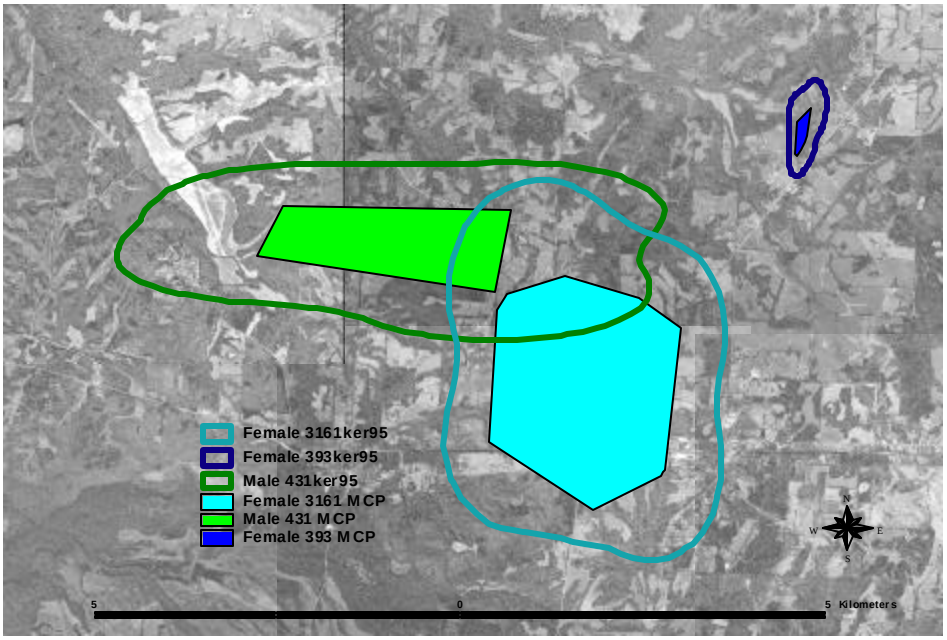

Figure 2. Cooper's hawk winter home ranges for 1999/2000 (95% minimum convex polygon and 95% adaptive kernel) on Ames Plantation, Tennessee.

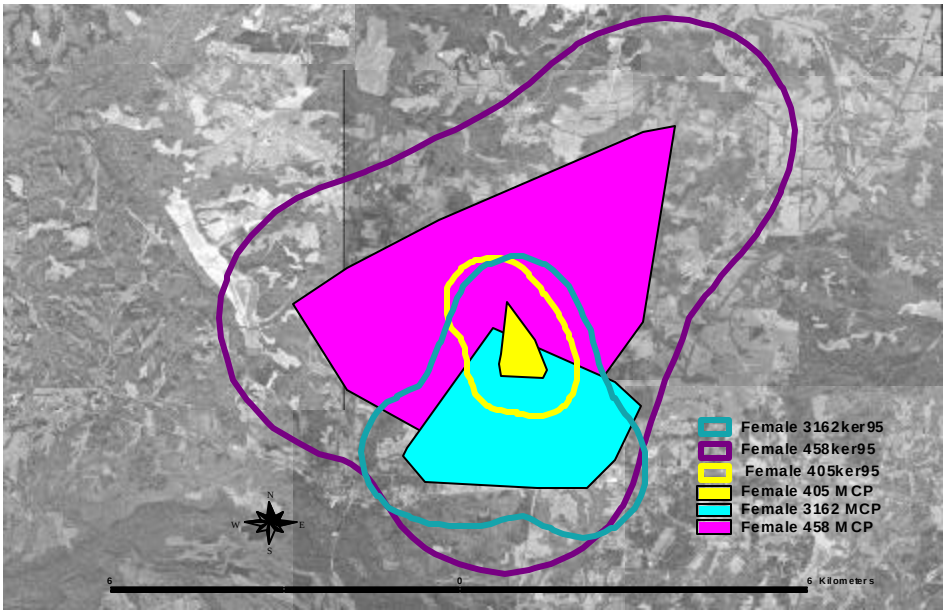

Figure 3. Cooper's hawk winter home ranges for 2000/2001 (95% minimum convex polygon and 95% adaptive kernel) on Ames Plantation, Tennessee.

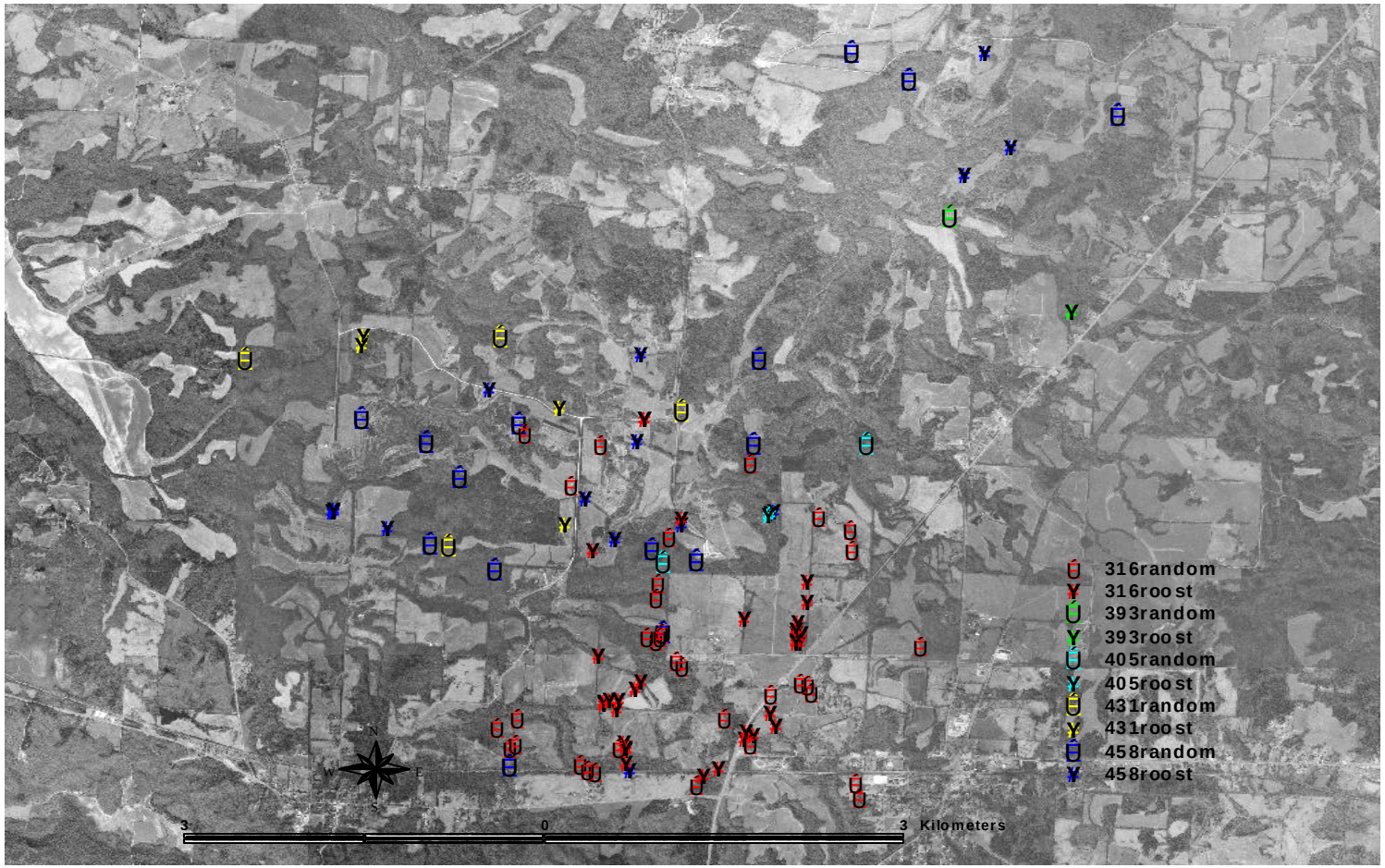

Figure 4. Cooper's hawk roost and random sites at Ames Plantation, Grand Junction, Tennessee, Nov 1999 – Mar 2001.

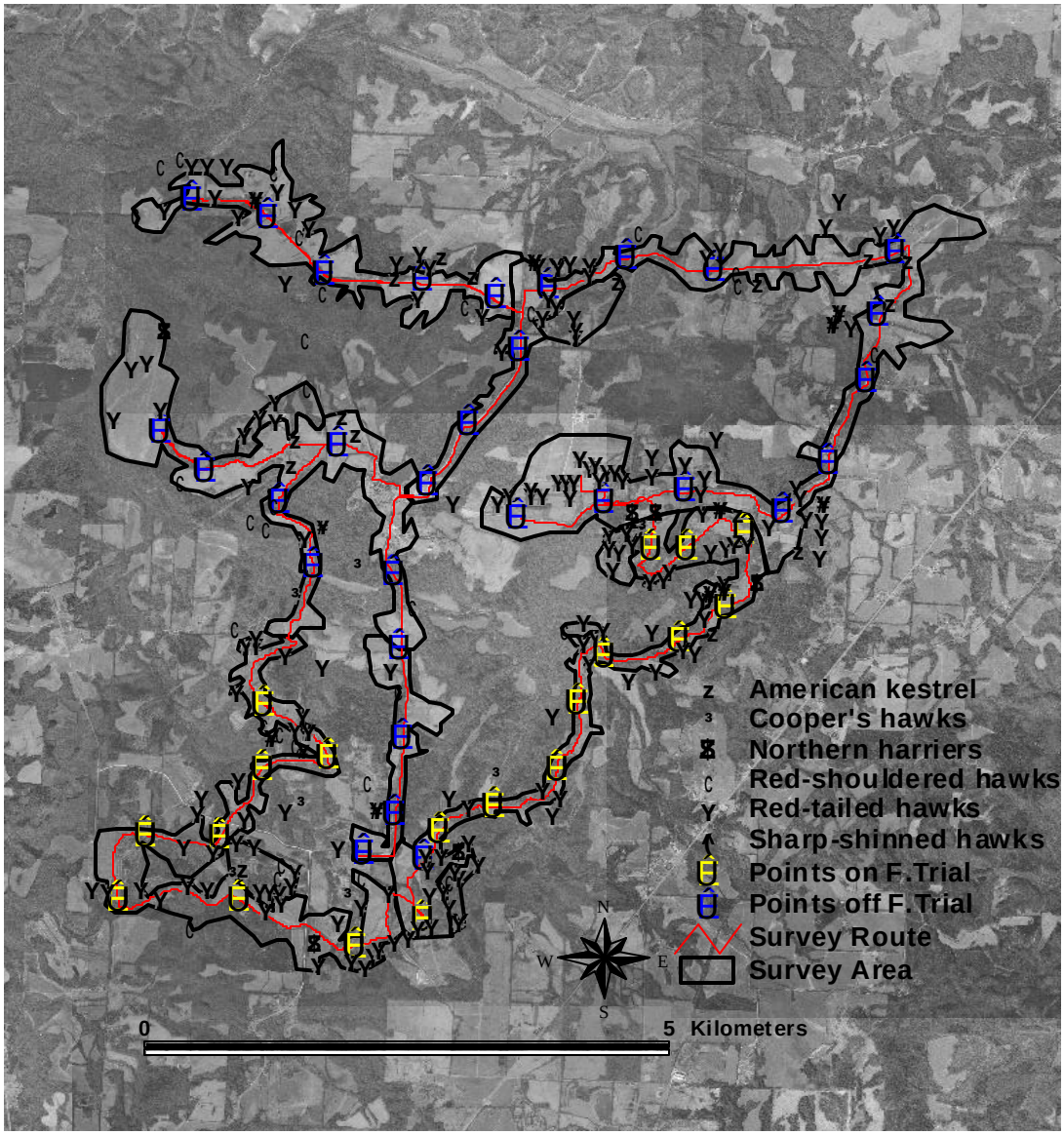

Figure 5. Survey route and raptor locations on Ames Plantation, Tennessee, Nov 1999 – Mar 2001.

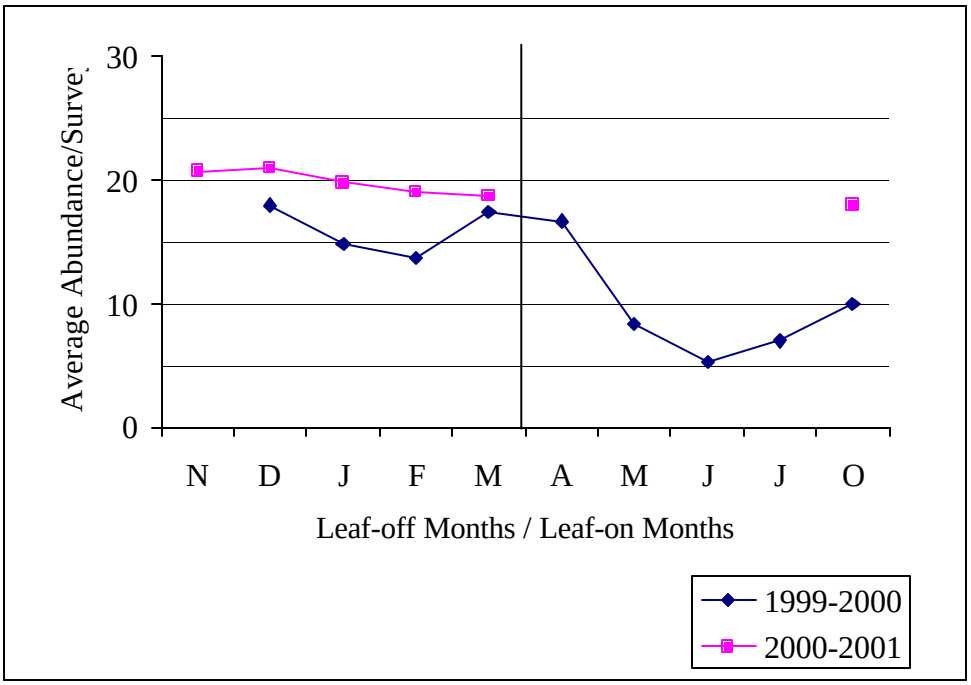

Figure 6. Mean total raptor abundance by month at Ames Plantation, Tennessee in 1999/2000 and 2000/2001.

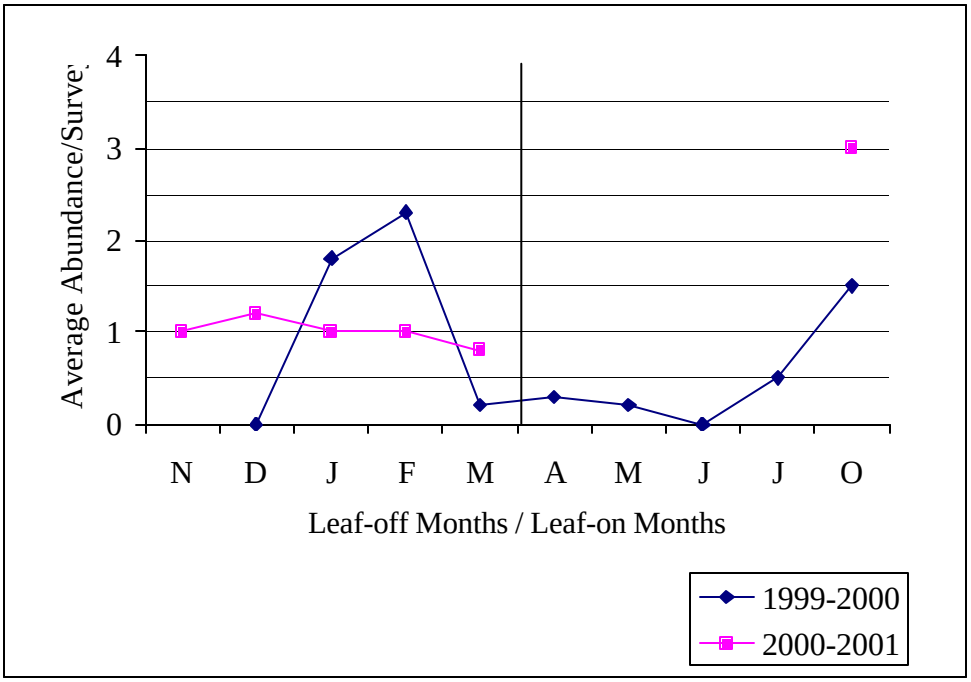

Figure 7. Mean American kestrel abundance by month at Ames Plantation, Tennessee in 1999/2000 and 2000/2001.

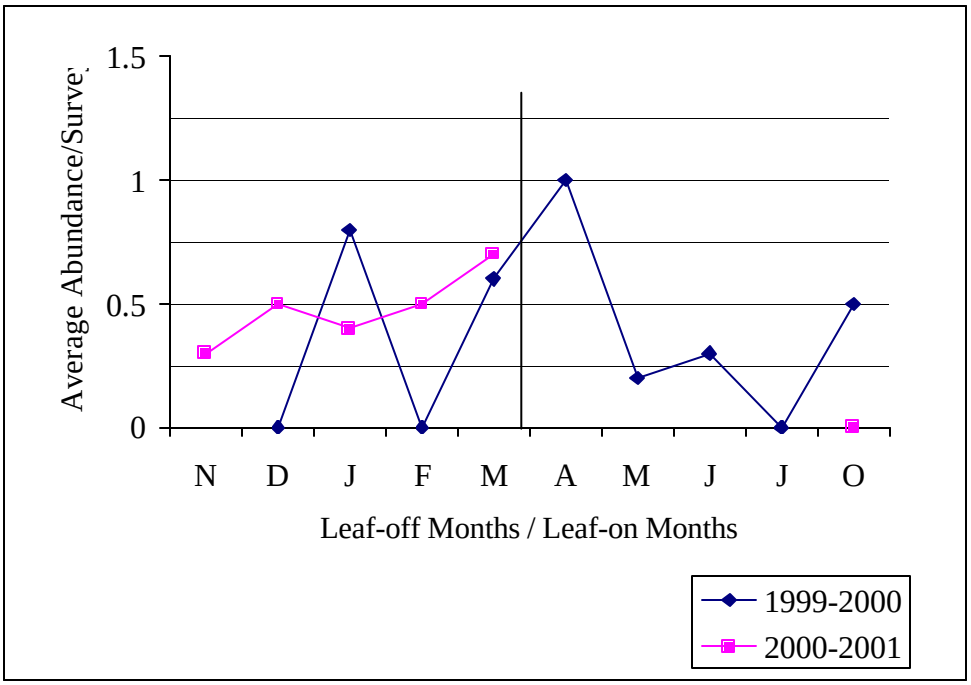

Figure 8. Mean Cooper's hawk abundance by month at Ames Plantation, Tennessee in 1999/2000 and 2000/2001.

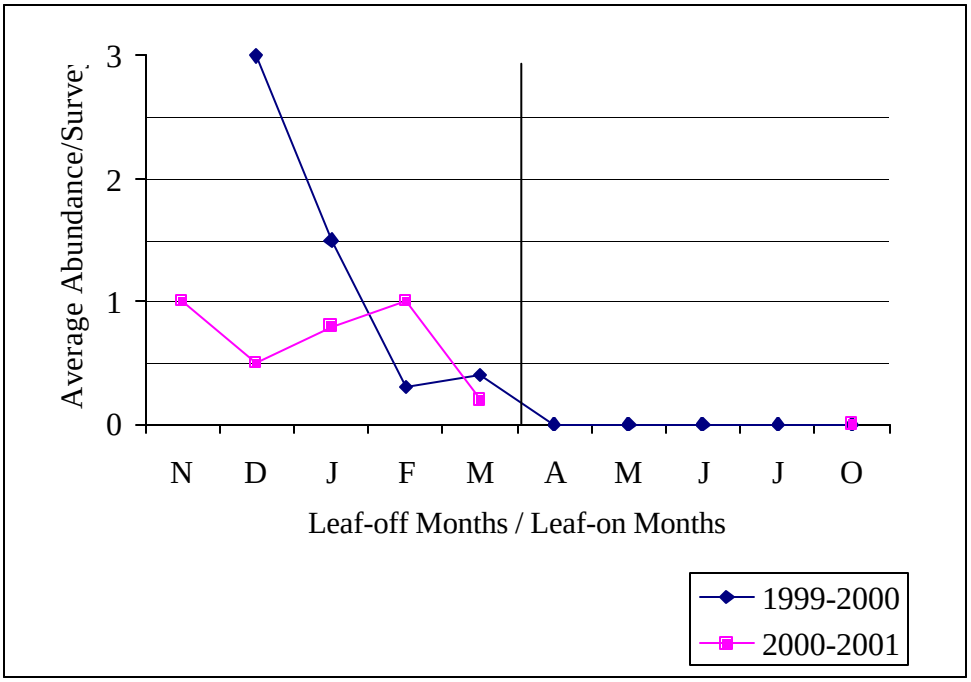

Figure 9. Mean northern harrier abundance by month at Ames Plantation, Tennessee in 1999/2000 and 2000/2001.

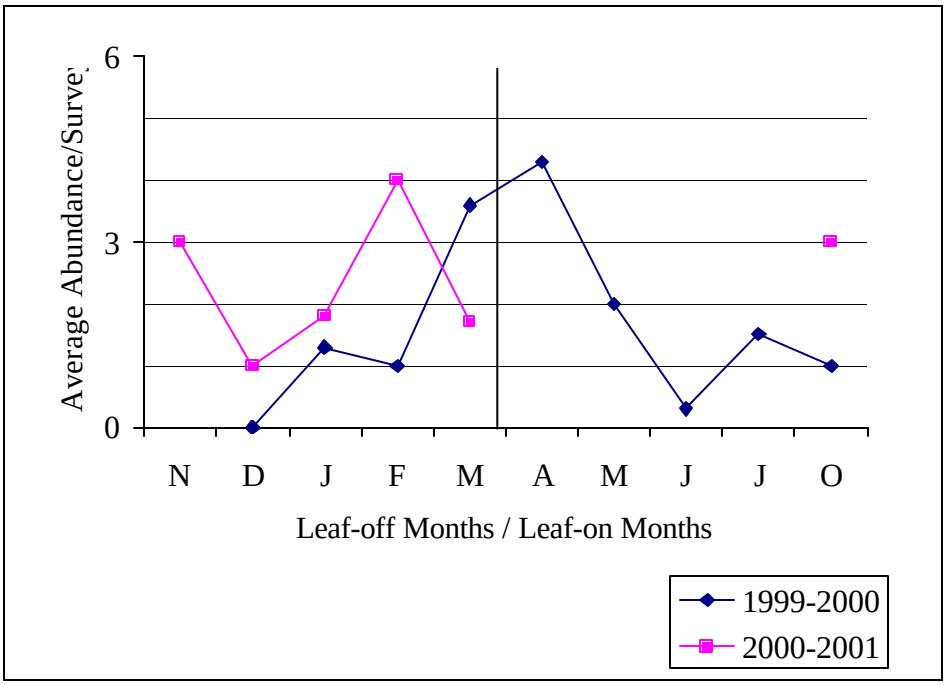

Figure 10. Mean red-shouldered hawk abundance by month at Ames Plantation, Tennessee in 1999/2000 and 2000/2001.

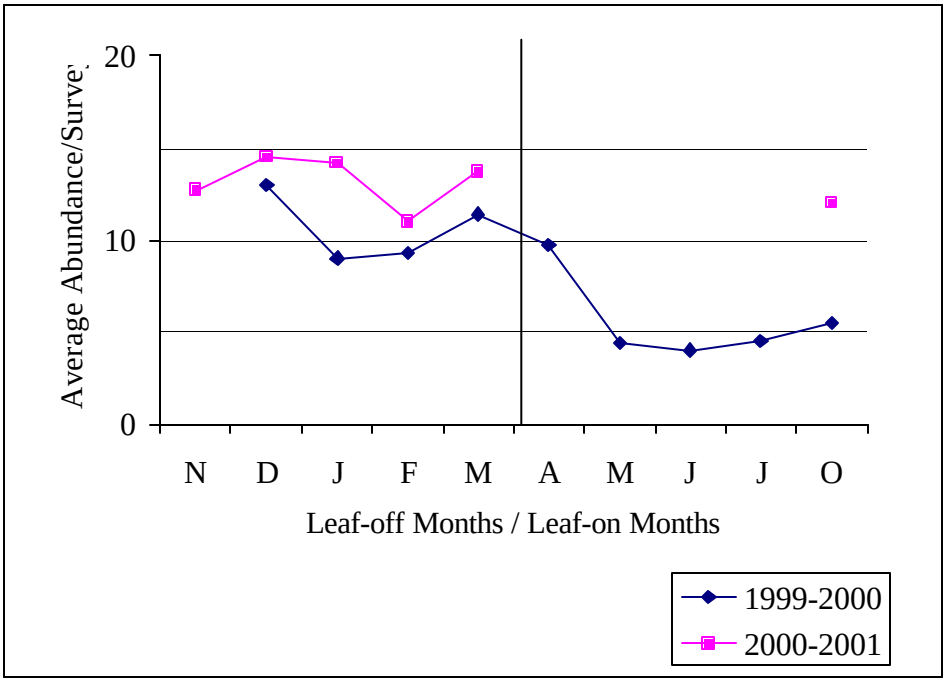

Figure 11. Mean red-tailed hawk abundance by month at Ames Plantation, Tennessee in 1999/2000 and 2000/2001.

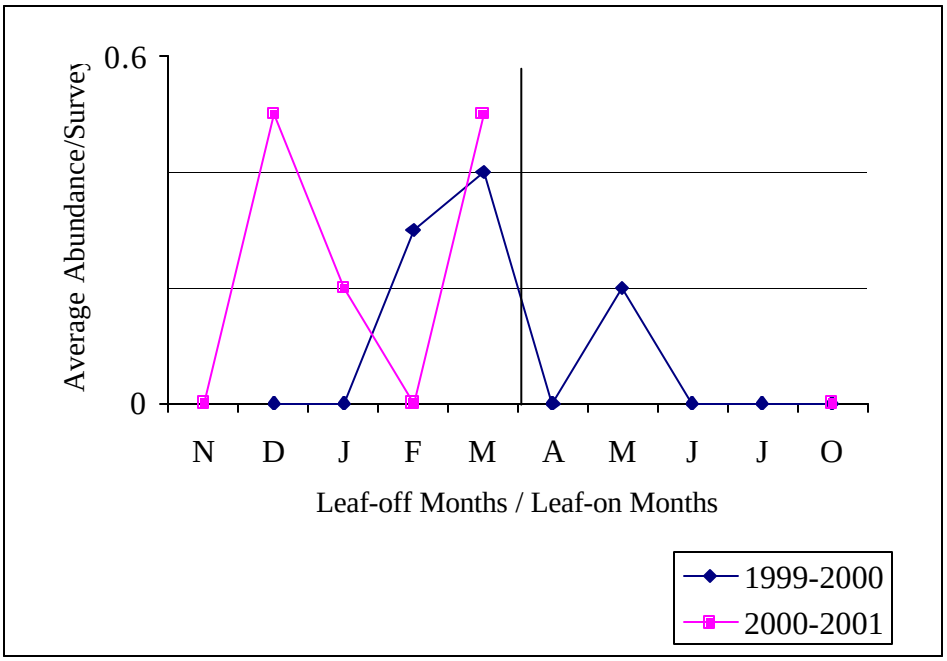

Figure 12. Mean sharp-shinned hawk abundance by month at Ames Plantation, Tennessee in 1999/2000 and 2000/2001.

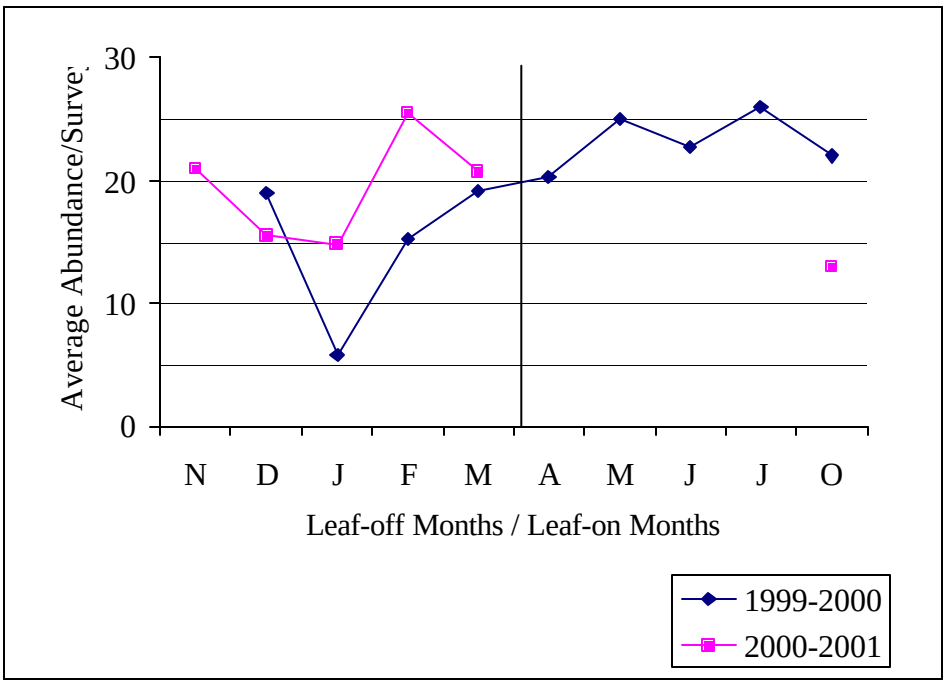

Figure 13. Mean turkey vulture abundance by month at Ames Plantation, Tennessee in 1999/2000 and 2000/2001.

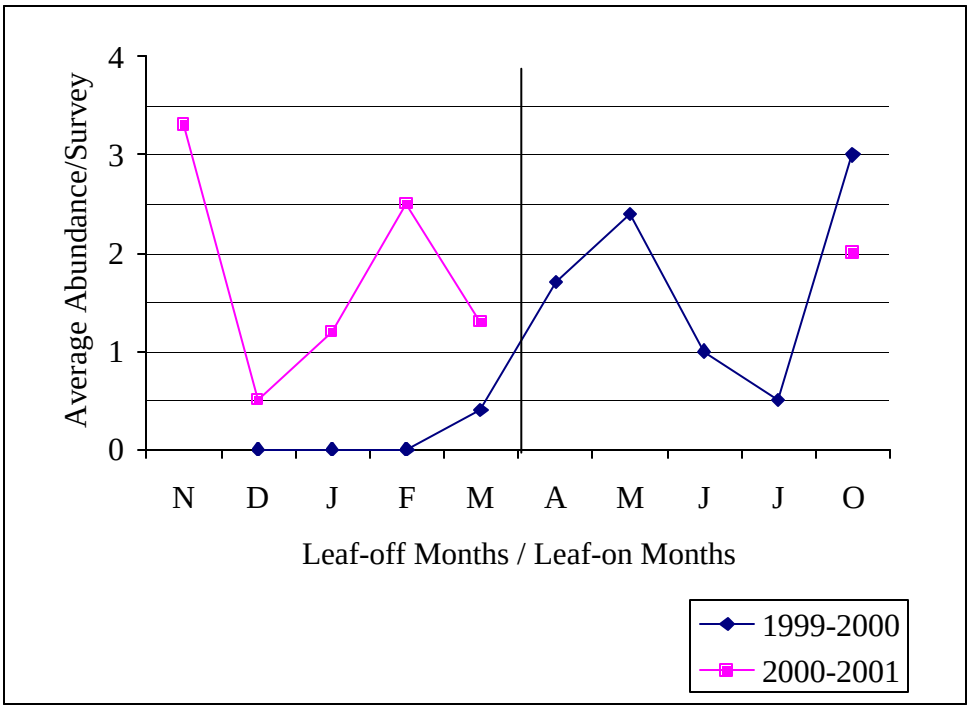

Figure 14. Mean black vulture abundance by month at Ames Plantation, Tennessee in 1999/2000 and 2000/2001.

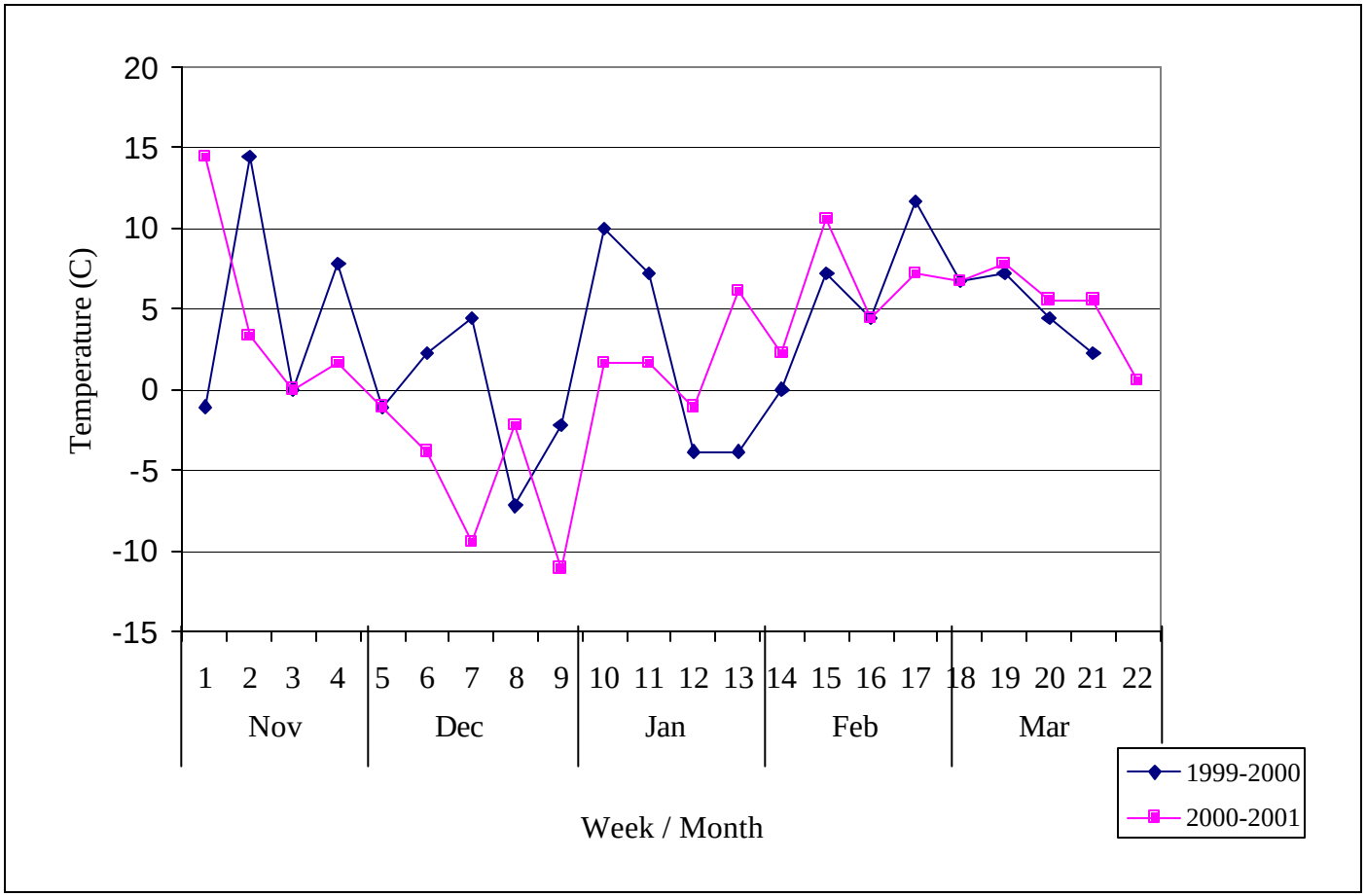

Figure 15. Survey morning temperatures (800 hr, November 1 – March 31) on Ames Plantation, Tennessee during the winters 1999/2000 and 2000/2001.

Table 1. Home ranges of radio-tagged Cooper's hawks at Ames Plantation, Tennessee, November 1999 – March 2001.

ID	Sex	Number of Locations	Tracking Period	MCP 95% (ha)	Adaptive Kernel 95% (ha)	Adaptive Kernel 50% (ha)
1999/2000						
393	F	17	12/16/99 – 1/25/00	8	54	6
431	M	9	1/5/00 – 1/23/00	331	1593	172
316	F	62	1/19/00 – 3/31/00	715	1801	383
2000/2001						
405	F	11	11/1//00 – 12/11/00	74	513	87
316	F	93	11/1/00 – 3/31/01	854	1805	385
458	F	67	12/7/00 – 3/8/01	2529	6632	1529

Table 2. Compositional analysis percent winter diurnal use and availability of forests, edges, fields, and other habitats by Cooper's hawks on Ames Plantation, Tennessee during the winters of 1999/2000 and 2000/2001.

Bird	Forests	Field	Other	Edge
405	60	39	0.01	1
431	65	11	1	23
393	97	2	0.01	1
458	62	22	0.01	15.9
3161 (1999/2000)	77	12	0.01	11
3162 (2000/2001)	83	9	0.16	8
Mean	73	16	10	1
Available	42	38	3	12

Table 3. Matrix and rank of habitat types in compositional analysis.

	Forest	Field	Other	Edge	Count	Rank
Forest		1.7	4.79	<u>1.26</u>	3	3
Field	-1.7		3.27	-<u>0.45</u>	-1	1
Other	-4.97	-3.27		-3.72	-3	0
Edge	-1.26	-0.45	3.72		1	2

Forest > <u>Edge > Field</u> > Other

Underlined ranks indicate no significant differences ($P > 0.05$).

Table 4. Chi-squared winter diurnal habitat use and availability of Cooper's hawks on Ames Plantation, Tennessee during November 1999 – March 2001.

Covertype	Total Area of Availability (Ha)	Expected Proportion of Area Used	Bonferroni Confidence Interval on Expected Proportion	Observed Proportion of Area Used	Bonferroni Confidence Interval on Proportion of Occurrence	Differences Between Use and Available
Hardwood/ Mixed	2006	0.406	$0.310 \leq P_1 \leq 0.502$	0.731	$0.655 \leq P_1 \leq 0.808$	***
Pine	267	0.059	$0.013 \leq P_2 \leq 0.104$	0.022	$0.000 \leq P_2 \leq 0.047$	
Old Field	435	0.088	$0.033 \leq P_3 \leq 0.144$	0.063	$0.021 \leq P_3 \leq 0.105$	
Fencerow	124	0.025	$0.000 \leq P_4 \leq 0.056$	0.031	$0.001 \leq P_4 \leq 0.062$	
Crop field	1038	0.210	$0.130 \leq P_5 \leq 0.289$	0.034	$0.003 \leq P_5 \leq 0.065$	***
Grassland	637	0.129	$0.064 \leq P_6 \leq 0.195$	0.063	$0.021 \leq P_6 \leq 0.106$	
Conversion	227	0.041	$0.002 \leq P_7 \leq 0.080$	0.042	$0.007 \leq P_7 \leq 0.076$	
Roads	54	0.011	$0.000 \leq P_8 \leq 0.032$	0.013	$0.000 \leq P_8 \leq 0.032$	
Human	148	0.030	$0.000 \leq P_9 \leq 0.063$	0.001	$0.000 \leq P_9 \leq 0.006$	

Table 5. Home ranges of the first 10, 20, 30, 40, 50, and 60 locations of Cooper's hawks 3161, 3162, and 458 on Ames Plantation, Tennessee, Nov 1999 – Mar 2001.

Bird	Number of Locations	Minimum Convex Polygons (ha)
3161	10	99.87
	20	414.94
	30	443.00
	40	495.35
	50	604.75
	60	710.90
3162	10	167.26
	20	292.20
	30	382.51
	40	383.12
	50	459.33
	60	539.87
458	10	382.26
	20	643.96
	30	866.56
	40	1931.54
	50	2403.64
	60	2426.50
Average	10	216.46
	20	450.37
	30	564.02
	40	936.67
	50	1155.91
	60	1225.76

Table 6. Cooper's hawk prey remains during the winters 1999/2000 and 2000/2001 at Ames Plantation, Tennessee.

Hawk ID	Date	Prey	Location
393	1-27-00	Chicken	Dairy Farm
393	1-27-00	Mourning Dove	Dairy Farm
316	1-27-00	Northern Bobwhite	Woodlawn
316	2-7-00	Mourning Dove	Across from Larry's House
316	2-7-00	Northern Bobwhite	Across from Larry's House
316	2-7-00	Northern Bobwhite	Across from Larry's House
316	2-23-00	Northern Cardinal	Morgan Swamp
316	3-29-00	Blue Jay	Grand Junction
316	3-29-00	Eastern Towhee	Grand Junction
316	1-22-01	Northern Cardinal	North of Larry's House
458	1-23-01	Blue Jay	Fargason's Land
458	1-23-01	American Goldfinch	Fargason's Land
458	1-23-01	American Robin	Fargason's Land
316	1-23-01	Mourning Dove	Morning Breakaway
316	1-25-01	Northern Cardinal	Morgan Swamp
316	2-2-01	Northern Bobwhite	Woodlawn
458	2-20-01	Red-winged Blackbird	Stables
316	2-22-01	Eastern Cottontail	North of Larry's House
316	3-23-01	Northern Cardinal	Woodlawn

Table 7. Habitat variables measured at Cooper's hawk roost and random sites at Ames Plantation, Tennessee, November 1999 – March 2001.

Variable	Code	How measured
Vertical Cover (%)	VCOV	The percent of a vertical coverboard (29.5cm wide x 153cm tall) not visible due to vegetation was estimated in the cardinal directions (N, S, E, W) 5.6 m from plot center and averaged.
Variance of VCOV	VCVR	Variance of the mean vertical cover for each site was calculated in PROC MEANS (SAS 1999).
Canopy Cover (%)	CCOV	Percent canopy cover was measured 5.6 m from plot center in the cardinal directions (N, S, E, W) with a spherical densiometer. The number of squares on the densiometer not covered by the canopy were counted, multiplied by 1.04 and then subtracted from 100. Canopy cover readings at the four points were averaged.
Variance of CCOV	CCVR	Variance of the mean canopy cover for each site was calculated in PROC MEANS (SAS 1999).
Basal Area Of Overstory (Hardwood Component)	BAHW	The hardwood component of the percent basal area of the overstory was determined by counting "in" trees (>10 cm) that were hardwoods in the overstory using a 2.5 m^2/ha prism.
Basal Area Of Understory	BAUS	Percent basal area of the understory was determined by counting all "in" trees (>10 cm) in the understory using a 2.5 m^2/ha prism.
Mean Height of Overstory (m)	HTOS	Mean overstory height was visually estimated to the nearest 5 m from average trees in the overstory.
Patch Size (ha)	PATC	Habitat patches were delineated and the size measured using Arcview (ESRI 1997).
Edge Sites	EDGE	The distance to the nearest forest edge was measured in Arcview for each site. All sites within 20 m from a border were considered on an edge.

Table 8. Trapping date and number of roosts for each individual Cooper's hawk on Ames Plantation, Tennessee.

Bird ID	Trap Date	Date of Last Location	No. of Roosts Year 1	No. of Roosts Year 2
148.393	12/16/99	1/25/00	1	0
148.431	1/5/00	1/19/00	4	0
148.316	1/19/00	5/23/01	17	17
148.405	10/12/00	12/11/00	0	2
148.458	12/7/00	3/8/01	0	15
		Total	22	34

Table 9. Roost sites used more than once by a Cooper's hawks at Ames Plantation, Tennessee, November 1999 – March 2001.

Location Used	Number of Times
1. North of Larry's house	8
2. North of Woodlawn's pond	5
3. North of Woodlawn manor house	4
4. Pine stand west of LaGrange-Somerville Road	3
5. Between State Routes 18 and 57	3
6. The Gauntlet	2
7. Hardwood Conversion along National Championship	2
8. Behind the garage along State Route 18	2
9. North edge of Woodlawn	2
10. Most southeastern corner of Woodlawn	2
11. North of Morgan Swamp	2

Table 10. Habitat variable means and standard errors (SE) of Cooper's hawk roost (n=56) and random sites (n=56) and summary of logistic regression results at Ames Plantation, Grand Junction, Tennessee, 1999-2001.

	Roost		Random		Parameter		
Habitat variable	Mean	SE	Mean	SE	estimate	χ^2	*P*
Patch Size	74.61	30.05	121.05	33.43		0.0300	0.8625
Basal Area of Understory	21.12	2.75	32.54	2.56		0.0383	0.8448
Basal Area of Overstory (Hardwood Component)	27.05	3.07	64.46	4.98		0.5223	0.4699
Edge Sites	0.4821	0.0673	0.2679	0.0597		0.6268	0.4285
Variance of Vertical Cover	751.22	107.87	265.10	53.13		0.8716	0.3505
Vertical Cover (%)	44.63	3.80	15.50	1.85	0.0590	11.0445	0.0009
Canopy Cover (%)	65.99	2.04	55.03	1.40	0.0891	11.3480	0.0008
Variance of Canopy Cover	216.33	39.14	62.28	10.64	0.0060	4.9779	0.0257
Mean Height of Overstory	14.02	0.84	23.57	0.82	-0.1061	5.2537	0.0219

Max-rescaled R-Square = 0.6826 Percent Concordant = 93.2 Hosmer and Lemeshow = 0.8130 corr.class = 85.7% df 1

Table 11. Chi-squared analysis of Ames Plantation covertypes by Cooper's hawk roost and random sites at Ames Plantation, Tennessee, 1999/2001.

	Covertype					
	Hardwood Forest	Hardwood Conversion	Mixed	Edge	Fencerow	Pine
Roost						
Observed	11 (10%)	1 (1%)	0 (0%)	27 (24%)	8 (7%)	9 (8%)
Expected	22	2	2	21	4.5	5
Chi-square	5.5	0.5	0	1.7	2.7	3.2
Random						
Observed	33 (29%)	3 (3%)	3 (3%)	15 (13%)	1 (1%)	1 (1%)
Expected	22	2	2	21	4.5	5
Chi-square	5.5	0.5	5.36	1.7	2.7	3.2

$x^2 = 225.20$, df = 15, $P < 0.0001$

Table 12. Average monthly abundance of raptors detected per survey on Ames Plantation, Tennessee during the winters of 1999-2000 and 2000-2001.

Species	1999-2000 2000-2001	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Total Abundance (without vultures)		10	----	18	14.8	13.7	17.4	16.7	8.4	5.3	7
		18	20.7	21	19.8	19	18.7	----	----	----	----
American kestrel		1.5	----	0	1.8	2.3	0.2	0.3	0.2	0	0.5
		3	1	1.5	1	1	0.8	----	----	----	----
Black vultures		3	----	0	0	0	0.4	1.7	2.4	1	0.5
		2	3.3	0.5	1.2	2.5	1.3	----	----	----	----
Cooper's hawk		0.5	----	0	0.8	0	0.6	1	0.2	0.3	0
		0	0.3	0.5	0.4	0.5	0.7	----	----	----	----
Northern harrier		----	3	1.5	0.3	0.4	0	0	0	0	0
		0	1	0.5	0.8	1	0.2	----	----	----	----
Red-shouldered hawk		1	----	0	1.3	1	3.6	4.3	2	0.3	1.5
		3	3	1	1.8	4	1.7	----	----	----	----
Red-tailed hawk		5.5	----	13	9	9.3	11.4	9.7	4.4	4	4.5
		12	12.7	14.5	14.2	11	13.7	----	----	----	----
Sharp-shinned hawk		0	----	0	0	0.3	0.4	0	0.2	0	0
		0	0	0.5	0.2	0	0.5	----	----	----	----
Turkey vulture		22	----	19	5.8	15.3	19.2	20.3	25	22.7	26
		13	21	15.5	14.8	25.5	20.7	----	----	----	----

Occasionals: Bald eagle, Barred owl, Broad-winged hawk, Osprey

---- No surveys conducted during these months

Table 13. Means and 95% confidence intervals of raptors detected per survey during the winter on Ames Plantation, Tennessee during 1999-2000 and 2000-2001.

	1999-2000			2000-2001					Difference
Species	L.C.I.	Mean	U.C.I.	L.C.I.	Mean	U.C.I.	χ^2	*P*-value	in years
Total Abundance	13.92	15.77	17.62	17.36	19.61	21.86	5.3448	0.0208	***
American kestrel	0.420	1.154	1.888	0.582	1.000	1.418	0.0161	0.8992	
Cooper's hawk	0.000	0.462	0.931	0.193	0.500	0.807	0.2151	0.6428	
Northern harrier	0.396	1.000	1.604	0.264	0.611	0.958	1.1187	0.2902	
Red-shouldered hawk	1.045	2.000	2.955	1.020	2.111	3.202	0.0270	0.8696	
Red-tailed hawk	8.904	10.31	11.71	11.72	13.44	15.17	6.1962	0.0128	***
Sharp-shinned hawk	0.000	0.231	0.496	0.000	0.278	0.563	0.0008	0.9780	

N = 11 surveys 1999-2000; N = 18 surveys 2000-2001

Table 14. Means and confidence intervals of raptors detected per survey on and off the field trial area of Ames Plantation, Tennessee during 1999-2000 and 2000-2001 (Years pooled).

	On Field Trial			Off Field Trial					Difference
Species	L.C.I.	Mean	U.C.I.	L.C.I.	Mean	U.C.I.	χ^2	*P*-value	on and off
Total Abundance	8.117	9.574	11.03	4.852	5.681	6.509	16.2294	0.0001	***
American kestrel	0.059	0.170	0.282	0.452	0.723	0.995	12.357	0.0004	***
Cooper's hawk	0.130	0.277	0.423	0.059	0.170	0.282	1.0898	0.2965	
Northern harrier (Leaf-off months only)	0.334	0.613	0.892	0.000	0.161	0.328	8.7301	0.0031	***
Red-shouldered hawk	0.312	0.660	1.007	1.008	1.383	1.758	11.418	0.0007	***
Red-tailed hawk	6.116	7.234	8.352	2.210	2.787	3.365	32.199	0.0001	***
Sharp-shinned hawk	0.043	0.149	0.255	0	0.043	0.102	3.0392	0.0813	*

N = 25 points/survey on field trials; N = 25 points/survey off field trials.

Table 15. Means and 95% confidence intervals of raptors detected per survey on Ames Plantation, Tennessee during the leaf-on and leaf-off seasons of 1999-2000 and 2000-2001.

	Leaf-on			Leaf-off					Difference
Species	L.C.I.	Mean	U.C.I.	L.C.I.	Mean	U.C.I.	χ^2	*P*-value	in Leaf-on/off
Total Abundance	3.924	5.000	6.076	7.837	8.984	10.13	16.767	0.0001	***
American kestrel	0.053	0.281	0.510	0.328	0.532	0.736	2.9156	0.0877	*
Cooper's hawk	0.045	0.188	0.330	0.123	0.242	0.361	0.2124	0.6449	
Northern harrier	0.000	0.000	0.000	0.219	0.387	0.555	12.0563	0.0005	***
Red-shouldered hawk	0.524	1.000	1.476	0.710	1.032	1.354	0.0720	0.7884	
Red-tailed hawk	2.046	2.969	3.891	5.087	6.065	7.042	15.216	0.0001	***
Sharp-shinned hawk	0.000	0.031	0.095	0.043	0.129	0.215	2.3061	0.1289	

N = 16 surveys leaf-on; N = 29 surveys leaf-off.

Table 16. Minimum, mean, and maximum density of raptors detected per 100 ha on Ames Plantation, Tennessee during the winters of 1999-2000 and 2000-2001.

Species	Minimum	Mean	Maximum	Projected density
Total abundance (witout vultures)	5.3	7.0	8.1	
American Kestrel	0.0	0.4	1.2	
Cooper's Hawk	0.0	0.2	0.2	2.1
Northern Harrier	0.0	0.4	1.2	
Red-shouldered Hawk	0.0	0.73	1.6	
Red-tailed Hawk	2.1	4.6	5.6	6.8
Sharp-shinned Hawk	0.0	0.1	0.2	

Cooper's hawk and red-tailed hawk densities were projected based on detection rates; Cooper's hawks were detected 7.7% of the time; red-tailed hawks were detected 68.4% of the time.

Table 17. Raptor activities on the survey at Ames Plantation, Tennessee November 1999 to March 2001.

Species	Flying	Perching	Soaring	Calling
Cooper's Hawk	14	1	5	1
American Kestrel	15	22	2	1
Northern Harrier	15	1	6	0
Red-shouldered Hawk	0	17	14	52
Red-tailed hawk	122	78	169	27
Sharp-shinned	5	1	2	1

Table 18. Raptor trap success at Ames Plantation, Tennessee from November 1999 to March 2001.

Species	Number trapped	Trap Days	Trap Hours	Trap success (hrs/capture)
Nov 1999 – April 2000				
American Kestrel	2	34	533	267
Barred Owl	0	34	533	na
Cooper's Hawk	9	34	533	59
Northern Harrier	1	34	533	533
Red-tailed Hawk	3	34	533	178
Red-shouldered Hawk	0	34	533	na
Sharp-shinned Hawk	1	34	533	533
Oct 2000 – Mar 2001				
American Kestrel	1	53	1729	1729
Barred Owl	2	53	1729	865
Cooper's Hawk	2	53	1729	865
Northern Harrier	0	53	1729	na
Red-tailed Hawk	0	53	1729	na
Red-shouldered Hawk	9	53	1729	192
Sharp-shinned hawk	5	53	1729	346
Totals	35	87	2262	

Table 19. Raptor species trapped at Ames Plantation, Tennessee from November 1999 to March 2001.

Species	Date	Time	Location
Cooper's Hawk	11/30/99	1315	Turner Ditch
Red-tailed Hawk	12/7/99	1610	PM Breakaway
Cooper's Hawk	12/8/99	1445	Cedar Hill
American Kestrel	12/14/99	1520	Cedar Hill
Red-tailed Hawk	12/16/99	1130	Hogtown
Northern Harrier	12/16/99	1215	PM Breakaway
Red-tailed Hawk	12/16/99	1405	Dairy Ridge
Cooper's Hawk	12/16/00	1512	Dairy Farm
Cooper's Hawk	12/17/99	1530	Cox's Ridge
Cooper's Hawk	1/5/00	1555	Turner Ditch
Cooper's Hawk	1/5/00	1555	Turner Ditch
Cooper's Hawk	1/6/00	1545	Turner Road
Cooper's Hawk	1/19/00	1430	National Championship
Sharp-shinned Hawk	1/24/00	1420	Turner Ditch
American Kestrel	1/28/00	1600	AM Breakaway
Cooper's Hawk	4/11/00	1830	Edward Clark Pasture
Cooper's Hawk	10/12/00	1730	Gauntlet
Sharp-shinned Hawk	11/6/00	1600	Gauntlet
Red-shouldered Hawk	12/4/00	1600	Hancock Place
Red-shouldered Hawk	12/4/00	1600	Hancock Place
Sharp-shinned Hawk	12/5/00	1350	West Pasture
Barred Owl	12/5/0	1535	West Pasture
Cooper's Hawk	12/12/00	1335	Turner Ditch
Red-shouldered Hawk	21/21/00	1615	E/W Bird Pens
Sharp-shinned Hawk	12/21/00	1640	E/W Bird Pens
American Kestrel	1/4/01	1615	Buckle Way
Red-shouldered Hawk	1/5/01	1625	Sand Ditch
Red-shouldered Hawk	1/9/01	1200	Hogtown
Red-shouldered Hawk	1/9/01	1430	Hogtown
Red-shouldered Hawk	1/15/01	1640	Sand Ditch
Red-shouldered Hawk	1/30/01	1130	Dusco Place
Sharp-shinned Hawk	2/14/01	1445	Hancock Place
Barred Owl	2/22/01	1450	Gauntlet
Sharp-shinned Hawk	2/27/01	1459	Sand Ditch
Red-shouldered Hawk	2/28/01	1635	Sand Ditch
Sharp-shinned Hawk	3/6/01	1410	John Fason Ridge

Table 20. Chronology of nesting activity for Cooper's hawks, red-tailed hawks, and red-shouldered hawks in Fayette and Hardeman counties, Tennessee, for the breeding seasons in 2000 and 2001.

		March				April				May					June		
Pair	Week	2	3	4	5	1	2	3	4	1	2	3	4	5	1	2	3
Coha1	2000				29-near nest			18-inc				19-hatch	22-failed				
	2001			19-near nest				19-inc			11-inc	14-failed					
Coha2	2000												23-inc?	30-brd		8-brd	
	2001			22-near nest				19-laying?/inc?					22-inc?/brd?				22-brd
Rtha1	2000		13-inc			4-failed											
	2001		12-inc		28-brd			19-nestlings visible					22-young still on nest			9-fledged	
Rtha2	2000			22-inc	29-brd						9-nestling visible				2-nest empty, likely		
	2001		21-barred owl nest					19-no sign of any raptor use at nest					22-rtha2 inc			fledged	
Rsha	2000	2-on nest, laying?					12-inc			5-on nest, brd?				31-no signs of activity, fate unknown			

inc = incubating
brd = brooding

Table 21. Nest measurements for Cooper's hawks, red-tailed hawks, and red-shouldered hawks in Fayette and Hardeman counties of Tennessee during the breeding seasons of 2000 and 2001.

Mean Measurements	Cooper's hawk (N=4)	Red-tailed hawk (N=4)	Red-shouldered hawk (N=1)
Nest Height In tree (m)	16.55	18.7	15
Nest Tree dbh (cm)	53.08	48.83	53.75
Vertical Cover (%)	6.06	11.94	12.5
Canopy Cover (%)	48.83	62.73	49.22
Basal Area (m^2/ha)	30.58	19.06	34.39
Overstory Height (m)	17.48	19.79	22.6
Overstory dbh (cm)	29.95	39.3	45.38
Understory Height (m)	8.75	4.75	5
Understory dbh (cm)	20.83	< 5 cm	< 5 cm

APPENDIX II

LIST OF SCIENTIFIC NAMES

Wildlife

American kestrel	*Falco sparverius*
American robin	*Turdus migratorius*
American goldfinch	*Corduelis tristis*
Bald Eagle	*Haliaeetus leucocephalus*
Barred Owl	*Strix varia*
Black vulture	*Coragyps atratus*
Blue jay	*Cyanocitta cristata*
Broad-winged hawk	*Buteo platypterus*
Brown thrasher	*Toxostoma rufum*
Brown-headed cowbird	*Molothrus ater*
Carolina chickadee	*Parus carolinensis*
Carolina wren	*Thryothorus ludovicianus*
Cooper's hawk	*Accipiter cooperii*
Dark-eyed junco	*Junco hyemalis*
Eastern cottontail	*Sylvilagus floridanus*
Eastern towhee	*Pipilo erythrophthalmus*
Fox sparrow	*Passerella iliaca*
House sparrow	*Passer domesticus*
Gray catbird	*Dumetella carolinensis*
Great horned owl	*Bubo virginianus*
Merlin	*Falco columbarius*
Mourning dove	*Zenaida macroura*
Northern bobwhite	*Colinus virginius*
Northern cardinal	*Cardinalis cardinalis*
Northern goshawk	*Accipiter genilis*
Northern harrier	*Circus cyaneus*
Osprey	*Pandion haliaeetus*
Red-shouldered hawk	*Buteo lineatus*
Red-tailed hawk	*Buteo jamaicensis*
Red-winged blackbird	*Agelaius phoeniceus*
Rough-legged hawk	*Buteo lagopus*
Sharp-shinned hawk	*Accipiter striatus*
Short-eared owl	*Asio flammeus*
Snail kite	*Rostrahamus sociabilis*
Turkey vulture	*Cathartes aura*
White-crowned sparrow	*Zonotrichia leucophrys*
White-throated sparrow	*Zonotrichia albicollis*

Plants and Trees

Allepo pine	*Pinus halepensis*
Aspen spp.	*Populus* spp.
Briars	*Rubus alleghaniensis*
Broomsedge	*Andropogon virginicus*
Common ragweed	*Ambrosia artemisiifolia*
Cottonwood	*Populus fremontii*
Eastern red cedar	*Juniperus virginiana*
Eucalyptus	*Eucalyptus* spp
Fescue	*Festuca arundinacea*
Fir	*Abies* spp
Flowering dogwood	*Cornus florida*
Hickories	*Carya* spp
Japanese honeysuckle	*Lonicera japonica*
Live oak	*Quercus agrifolia* and *Q. wislizenii*
Loblolly pine	*Pinus taeda*
Lodgepole pine	*Pinus contorta*
Longleaf pine	*Pinus palustris*
Maple spp.	*Acer* spp.
Milo	*Sorghum vulgare*
Mockernut hickory	*Carya tomentosa*
Northern red oak	*Quercus rubra*
Oaks	*Quercus* spp
Panicum grasses	*Panicum* spp.
Partridge pea	*Cassia fasciculate*
Pine spp.	*Pinus* spp.
Ponderosa pine	*Pinus ponderosa*
Red maple	*Acer rubrum*
Sericea lespedeza	*Lespedeza cuneata*
Scotch pine	*Pinus sylvestris*
Short-leaf pine	*Pinus echinata*
Slippery elm	*Ulmus rubra*
Spruce	*Picea* spp.
Sweetgum	*Liquidambar styra ciflua*
Sumac	*Rhus glabra*
Turkey oak	*Quercus laevis*
White oak	*Quercus alba*
Willow oak	*Quercus phellos*
Yellow poplar	*Liriodendron tulipifera*

VITA

Laura A. Lake was born in Cincinnati, Ohio and grew up in Brookville, Indiana. She moved to Indianapolis to attend Marian College after graduating from Franklin County High School in 1995. In May, 1999 she graduated from Marian College with a B.S. in Biology. During the summers of 1997 and 1998 Laura worked as a park ranger for the U.S. Army Corps of Engineers at Brookville Lake, Indiana. During the summer of 1999 she worked as a technician at Big Oaks National Wildlife Refuge in Madison, Indiana. Upon the completion of this position, Laura moved to Knoxville, Tennessee to begin her graduate assistantship in the wildlife program at the University of Tennessee. May, 2002 Laura graduated from the University of Tennessee with her M.S. in wildlife management.