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Raptor Assemblage, Abundance, Nesting Ecology, and Habitat Characteristics Under Intensive Forest Management in the Central Appalachian Mountains

Rebecca D. M. Smith

**Thesis submitted to the
College of Agriculture, Forestry, and Consumer Sciences
at West Virginia University
in partial fulfillment of the requirements
for the degree of**

**Master of Science
in
Wildlife and Fisheries Resources**

**Petra Bohall Wood, Ph. D., Chair
W. Mark Ford, Ph. D.
John W. Edwards, Ph. D.**

Division of Forestry

**Morgantown, West Virginia
2003**

Keywords: **Forest management; raptor populations; *Buteo*; timber harvests; broadcast surveys; nesting ecology**

ABSTRACT

Raptor Assemblage, Abundance, Nesting Ecology, and Habitat Characteristics Under Intensive Forest Management in the Central Appalachian Mountains

Rebecca D.M. Smith

Raptor abundance and diversity were examined in three treatments (20-, 40-, and 80-yr harvest rotations) on an industrial forest in the central Appalachian Mountains. I conducted diurnal broadcast surveys, compared nocturnal survey protocols, examined habitat characteristics at two spatial scales (564 m and 1000 m buffers), and described nesting ecology (including prey composition) of 3 *Buteo* species. I detected 17 species and found no significant differences in abundance among treatments for all raptors. Forest species were detected more often than edge species and Red-shouldered Hawk (*Buteo lineatus*) was the most abundant. Using a Barred Owl (*Strix occidentalis*) vocalization survey protocol, Barred Owls were detected most often and most owls were detected. I monitored fourteen nesting attempts of five species. For three *Buteo* species, mammals were the most common prey delivered to the nest. My study suggests that at current levels of disturbance, forest raptors are able to survive and successfully breed on an active, industrial forest.

DEDICATION

This thesis is dedicated to my grandparents, Doyle G. and Allene McKinney, who have shown me that through faith, love, and hope the world can belong to you!

And to my best friend and husband, Brian.

Thank you for all of your devotion, support, and your love!

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I leave you with one of my favorite quotes from Ralph Waldo Emerson: "I know that if I can dream it, I can do it because it is not my aptitude, but my attitude, that determines my altitude."

TABLE OF CONTENTS

ABSTRACT……………………………………………………………………………ii

DEDICATION……………...………………………………………………………iii

ACKNOWLEDGMENTS…...………………………………………………………iv

TABLE OF CONTENTS ………………………………………………………...vi

LIST OF TABLES...…………………………………………………………...viii

LIST OF FIGURES …………………………………………………………………x

LIST OF APPENDICES …..………………………………………………………xii

CHAPTER 1: GENERAL INTRODUCTION……………………………………………1

Thesis Project Introduction ……………………………………………………..9
Literature Cited……………………..…………………………………………11

CHAPTER 2: ASSEMBLAGE, ABUNDANCE, AND HABITAT CHARACTERISTICS OF THE RAPTOR COMMUNITY OF AN INDUSTRIAL FOREST IN CENTRAL WEST VIRGINIA……15

Abstract…………………………………………………………………………16
Introduction…...………………………………………………………………17
Study Site …………..…………………………………………………………19
Methods……………………..…………………………………………………21
Broadcast Surveys ………..……………………………………………21
Landscape Habitat Analyses ……………………………………..…23
Microhabitat Analyses …………………………………………………25
Statistical Analyses ……………………………………………………..25
Results…………………………………………………………………………27
Broadcast Surveys ………..……………………………………………27
Landscape Habitat Analyses ……………………………………..…29
Microhabitat Analyses …………………………………………………31
Discussion……………………………………………………………………..32
Conclusions and Management Recommendations ………………………………36
Literature Cited ………………………………………………………………..37

CHAPTER 3: COMPARISON OF SURVEY METHODS FOR NOCTURNAL RAPTORS ON AN INDUSTRIAL FOREST IN CENTRAL WEST VIRGINIA ……………………………………………………..56

Abstract……………………………………………………………………..57
Introduction…………………………………………………………………57
Study Site ……………………………………………………………………58
Methods ………………………………………………………………………59
Statistical Analyses……………………………………………………… 61
Results…………………………………………………………………………61
Discussion ……………………………………………………………………62
Literature Cited ……………………………………………………………64

CHAPTER 4: ECOLOGY AND HABITAT CHARACTERISTICS OF NESTING DIURNAL RAPTORS ON AN INDUSTRIAL FOREST IN CENTRAL WEST VIRGINIA ……………………..…70

Abstract……………………………………………………………………..71
Introduction…………………………………………………………………71
Study Site ..……………………………………………………………………73
Methods……………………..…………………………………………………75
Nest Searching and Monitoring ……………………………………………75
Prey Delivery Rates and Species Composition ………………………..…76
Microhabitat Analyses………………………………………………………77
Landscape Analyses …………………………………………………………78
Statistical Analyses ..…………………………………………………...79
Results…………………………………………………………………………79
Nest Searching and Monitoring ……………………………………………79
Prey Delivery Rates and Species Composition ………………………..…80
Microhabitat Analyses………………………………………………………82
Landscape Analyses …………………………………………………………82
Discussion……………………………………………………………………..84
Unusual Observations………………………………………………………..86
Conclusions and Management Recommendations ………………………………87
Literature Cited……………………………………………………………..89

VITA…………………………………………………………………………………106

LIST OF TABLES

CHAPTER 2: ASSEMBLAGE, ABUNDANCE, AND HABITAT CHARACTERISTICS OF THE DIURNAL RAPTOR COMMUNITY OF AN INDUSTIAL FOREST IN CENTRAL WEST VIRGINIA

Page

2.1. Description of landscape variables examined (564 and 1000 m) in landscape analysis of habitat use for raptors on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during summers 2000 and 2001 …………42

2.2. Raptor species detected during broadcast surveys and as incidental observations in 2000 and 2001 on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia ……………………………………………………………..43

2.3. Mean abundance and standard error (SE) for all raptor species detected during diurnal broadcast surveys in three harvest rotations on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001 ……….44

2.4. Significant habitat variables selected by stepwise logistic regression for predicting presence of Red-shouldered Hawks (RSHA), Red-tailed Hawks (RTHA), and Broad-winged Hawks (BWHA) by season at two landscape levels (564 m and 1000 m) on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001 ………………………………………………………………..45

2.5. Significant habitat variables selected by stepwise multiple linear regression for predicting abundance of Red-shouldered Hawks (RSHA), Red-tailed Hawks (RTHA), and Broad-winged Hawks (BWHA) by season at 2 landscape levels (564 m and 1000 m) on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001……………………………………………………..46

2.6. Mean and standard error of the 17 habitat variables at two landscape levels (564 m and 1000 m) for the presence/absence of Red-shouldered Hawks (RSHA), Broad-winged Hawks (BWHA), Red-tailed Hawks (RTHA), and Northern Goshawk (NOGO) at 48 broadcast survey points on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001 ……………………………...47

2.7. Mean and standard error of the habitat variables at two landscape levels (1000 m and 564 m) for presence/absence of Barred Owls on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001 ……….49

CHAPTER 3:COMPARISON OF SURVEY METHODS FOR NOCTURNAL RAPTORS ON AN INDUSTRIAL FOREST IN CENTRAL WEST VIRGINIA

Page

3.1. Owl species detected for each nocturnal survey protocol (n = 3) in summers 2000 and 2001 on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia ……………………………………………………………………...67

3.2. Total detections (n), mean abundance (mean), and standard error (SE) for all owl species detected using various broadcast survey methods on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during summers 2000 and 2001 ……………….…………………….……………………………..68

CHAPTER 4: ECOLOGY AND HABITAT CHARACTERISTICS OF NESTING DIURNAL RAPTORS ON AN INDUSTRIAL FOREST IN CENTRAL WEST VIRGINIA

4.1. Prey deliveries for a breeding pair of Red-shouldered Hawk (RSHA), Broad-winged Hawk (BWHA), and Red-tailed Hawk (RHTA) the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001…………………………………………………………………………………………92

4.2. Description of microhabitat variables examined in landscape analysis of nest habitat use for raptors on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001 ………………………..…………93

4.3. Description of habitat variables examined in landscape analysis of nest habitat use for raptors on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001 ………….……………………………………..94

4.4. Mean and standard error of the 20 microhabitat variables describing nests of Red-shouldered Hawks (RSHA, n = 4), Broad-winged Hawks (BWHA, n = 4), Red-tailed Hawks (RTHA, n = 5), and Northern Goshawk (NOGO, n = 1) on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001……………………………………………………………………………………95

4.5. Mean and standard error of the 17 habitat variables at nests of Red-shouldered Hawks (RSHA, n = 4), Broad-winged Hawks (BWHA, n = 4), Red-tailed Hawks (RTHA, n = 5), and Northern Goshawk (NOGO, n = 1) on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001…………………………………………………………………………………………96

4.6 Nest records for all raptor species on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001………..97

LIST OF FIGURES

CHAPTER 2: ASSEMBLAGE, ABUNDANCE, AND HABITAT CHARACTERISTICS OF THE RAPTOR COMMUNITY OF AN INDUSTIAL FOREST IN CENTRAL WEST VIRGINIA

Page

2.1. Location of the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia ……………………………………………………………..50

2.2. Disturbance patterns on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during (A) 2000 and (B) 2001……………………...51

2.3. Location of A) diurnal broadcast survey points for three harvest rotations and B) nocturnal raptor broadcast survey points on the MeadWestvaco Wildlife and Ecosystem Research Forest (MWERF) in Randolph County, West Virginia ………………………………52

2.4. Example of a digitized broadcast survey point on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001 ……….53

2.5. Mean total abundance of raptors by treatment for forest-dwelling (F = 2.45, P = 0.23) and edge-dwelling (F = 1.37, P = 0.38) species, regardless of season, on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001 ……………………………………………………………..54

2.6. Mean total abundance of the most abundant species, Red-shouldered Hawk (RSHA; F = 5.36, P = 0.10), Broad-winged Hawk (BWHA; F = 0.15, P = 0.87), and Red-tailed (RTHA; F = 1.16, P = 0.42), by treatment, regardless of season, on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001……..…55

CHAPTER 3: COMPARISON OF SURVEY METHODS FOR NOCTURNAL RAPTORS ON AN INDUSTRIAL FOREST IN CENTRAL WEST VIRGINIA

3.1. Location of nocturnal broadcast survey points on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001 ……….69

CHAPTER 4: ECOLOGY AND HABITAT CHARACTERISTICS OF NESTING DIURNAL RAPTORS ON AN INDUSTRIAL FOREST IN CENTRAL WEST VIRGINIA

4.1. Nest locations for diurnal raptor species within three harvest rotations on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001 ………………………………….……………………….98

Page

4.2. Percent of prey delivered per hour at the nests of Red-shouldered Hawk (RSHA), Broad-winged Hawk (BWHA), and Red-tailed Hawk (RTHA) on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001……………………………………………………………………………………99

4.3. Example of digitized occupied Red-tailed Hawk nest (KS-02) on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during summer 2001………………………………………………………………..100

LIST OF APPENDICES

Page

1. Helpful Hints for Using ArcView 3.2 and Patch Analyst 2.2 extension ……………………101

2. Land cover for each summary statistics in each buffer zone derived from ArcView 3.2 with Patch Analyst 2.2 extension……………………………………………………………….105

CHAPTER 1:

GENERAL INTRODUCTION

GENERAL INTRODUCTION

Bird populations, including raptors, can be limited by natural factors and human impacts (Newton 1979, Newton 1998). Natural factors include parasites, diseases, predators, habitat suitability (including prey availability), and abiotic factors (e.g., weather and fire; Elphick et al. 2001). Human factors, such as timber harvesting, development, mining, and pollution have had negative effects on some raptor species by removing or altering nesting habitat (Falk and Stauffer 1988, Cannings 1993, Elphick et al. 2001). Additionally, forest structure alterations may affect foraging habitat and prey species availability to avian predators from shifts or changes in small mammal (Buckner and Shure 1985, Yahner 1988), songbird (Weakland et al. 2002), and herpetofaunal communities (deMaynadier and Hunter 1995). Why examine raptor populations in West Virginia? Raptors are considered by some as important biomonitors (Sheffield 1997) and hence, may provide an understanding of effects to other wildlife species. Conversely, if avian predator populations fluctuate widely, then they may have an impact on prey species populations. For example, if populations of prey species increase in abundance, then seed predation and herbivory pressures on plants will increase and can have cumulative effects within the food chain.

Timber Harvesting in West Virginia

Natural and man-made disturbances promote a mixture of habitats by creating openings within eastern forests (Buckner and Shure 1985). Species assemblage, richness, and relative abundance of wildlife can be affected by disturbance size (Miller 1982). Forest management is one of the most common forms of disturbance in West Virginia and the central Appalachian Mountains today. Although peak timber harvesting in West Virginia occurred in 1909-1910 with

1.5 billion board feet harvested, current levels throughout the 1990's (and probably through today) are at approximately 76 billion board feet (in 1997), with the first net loss in volume occurring in 1995 and the overall net volume of standing marketable timber increasing (Stephenson 1993, Whipkey 1997). Second generation forests currently are being harvested to satisfy society's increasing demand for wood products. Harvesting in West Virginia may be higher than neighboring states because of the high-value species mix and amount of corporate lands (P. D. Keyser, MeadWestvaco Corporation, pers. comm.). Other sources contributing to current declines in standing timber volume include recent gypsy moth defoliation, ice and windstorms, droughts, wildfire, and deer damage to regeneration (Whipkey 1997).

Wide-scale railroad logging occurred in this region of West Virginia from the 1900-1920's that resulted in the current second growth stands established by that regeneration (Clarkston 1993). Changes in today's forests include a reduction in tree species diversity, composition, and a shift to shade tolerant species such as sugar maple (*Acer saccharum*) and American beech (*Fagus grandifolia*) domination documented within the region (Schuler and Gillespie 2000). A decrease is noted in heavy mast species such as American chestnut (*Castanea dentata*) which disappeared from eastern North American forests due to chestnut blight (*Cryphonectria parasitica*), a fungal pathogen (Stephenson 1993). Additionally, the volume of oak (*Quercus* spp.) has declined over the last several decades (Schuler and Gillespie 2000, Whipkey 1997). The reduction in hard-mast producing species may have lead to a shift in wildlife communities, possibly resulting in a change in the diet of predatory species such as raptors.

Limited information exists about modern forest management effects on cavity-nesting raptors. Many forest management practices include the harvest of potential cavity trees and an overall lack of snag retention. Moreover, Occupational Health and Safety Association (OSHA) regulations require large snag trees be removed during logging operations or the area surrounding the snag tree must be avoided to ensure safety of logging crews, thereby possibly decreasing nesting habitat through harvest operations. In intensive forest management, snags and other cavity trees may not exist at the end of a short rotation (e.g., 20-40 years; Smith 1962). Alternatively, snags and cavity trees may result from damaged trees left during harvests, especially partial or selective harvests.

Raptors and Silviculture

Forest management activities can have positive and negative habitat impacts on forest-dependent and non-forest dependent wildlife. Increased edge and fragmentation in eastern forests is advantageous for some species and disadvantageous for others (Falk and Stauffer 1988). Harvest size, harvest method, harvest configuration, and forest structure and composition will influence which animal species flourish and which species decline (Hunter 1990). Raptor communities (i.e., species assemblage and relative abundance) can be affected by habitat alterations. For example, in the mid-Atlantic and Northeastern states, modern forest management practices combined with excessive deer herbivory have led to creation of steady-state openings in the understory layer of forested areas (Waller and Alverson 1997), potentially creating opportunities for avian predators to increase foraging efficiency.

Ecological effects of timber harvesting on raptors have been studied on commercial tree farms (Bosakowski et al. 1999), old-growth forests (Horton 1996), and managed forests (Mannon and Meslow 1984, Horton 1996) in other regions of the United States and the world. Nonetheless, there have been few studies of forest-dwelling raptors in the eastern United States that have focused on how timber harvesting impacts. Mannon and Meslow (1984) compared bird populations in managed forests to old-growth mixed-coniferous forests in Quebec and found that Sharp-shinned Hawks (*Accipiter striatus*), Great Horned Owls (*Bubo virginianus*), Northern Saw-whet Owls (*Aegolius acadicus*), and Red-tailed Hawks (*Buteo jamaicensis*) occurred in both forest types with no difference in abundance between the two forest treatments. Northern Goshawks (*Accipiter gentilis*) and Flammulated Owls (*Otus flammeolus*) were found only in old-growth stands, whereas Cooper's Hawks (*Accipiter cooperii*) were found only in managed stands (Mannon and Meslow 1984).

Some raptor species display habitat tolerance to changes in their environment (Nelson and Titus 1988). For instance, Broad-winged Hawks (*Buteo platypterus*) often nest in managed forests or in younger forest stands (Titus and Mosher 1981). Short harvest rotation schedules have been used to maintain this species (Goodrich et al. 1996). Clearcutting, although often silviculturally preferred, creates unsuitable habitat for some woodland species of raptors (Gosse and Montevecchi 2001), but can benefit species that require open areas within their home range, such as Red-tailed Hawks. Moorman and Chapman (1996) found that Red-shouldered Hawks (*Buteo lineatus*) were associated with large areas of hardwood forest whereas Red-tailed Hawks were associated with more disturbed areas that included agriculture. However, in Moorman and Chapman's (1996) study, silvicultural activities left upland habitats and bottomland corridors undisturbed.

Red-shouldered Hawks in Quebec are dependent on contiguous forests dominated by beech (*Fagus grandifolia*) or sugar maple and nest in stands with well-developed, mature overstory and reduced subcanopy (Morris and Lemon 1983). Selective harvests (and long cutting cycles) may be best for Red-shouldered Hawks because these areas leave potential nest trees and allow remaining trees to further mature (Nelson and Titus 1988). Additionally, Red-shouldered Hawk nests often are associated with riparian areas, and with birds often preying on frogs and other amphibians (Titus and Mosher 1981, Howell and Chapman 1998) and mammals during their breeding season (Crocoll 1994). Some best management practices (BMP) mandated by state forestry divisions require that timber harvests retain a stream-side management zone (SMZ), or simply a border of trees of predetermined width along a stream. Based on known habitat requirements of Red-shouldered Hawks, it is possible that intensively managed forests with adjacent undisturbed older-growth stands and riparian areas may allow nesting near harvested areas. Additionally, Red-shouldered Hawks may be able to hunt successfully in harvested areas as long as the SMZ are left in place, and these management strategies may not affect long-term viability and population status of Red-shouldered Hawks.

Raptor species may differ in their tolerance to disturbance. Northern Goshawks in a commercial tree farm in Washington successfully nested in stands that did not receive commercial or pre-commercial thinning, and therefore, did not seem to tolerate canopy openings in nesting habitat (Bosakowski et al. 1999). No nesting attempts in this study were located in areas of thinning; all were located in stands in the stem exclusion stage of development (Oliver and Larson 1996). However, Penteriani and Faivre (2001) concluded that Northern Goshawks in Europe would continue to nest in stands that had <30% canopy cover reduction in the nesting stand. Their study recommended harvest operations be conducted before the birds' courtship and egg-laying stage but could resume a few weeks after hatching. Grubb et al. (1998) noted that noise from logging operations might be less noticeable to Northern Goshawks than to humans.

Raptors such as Northern Spotted Owls (*Strix occidentalis*) and Northern Goshawks have drawn recent attention to the controversy of disturbance from timber harvests. Removal of snags during timber harvesting operations can affect species such as Northern Spotted Owls, Barred Owls (*Strix varia*), Eastern Screech-owls (*Otus asio*), and Northern Saw-whet Owls (Cannings 1993) that use snags and large cavities for nesting. Great Horned Owls prefer areas that have forest adjacent to open areas (Johnson 1992, Morrell and Yahner 1994). Therefore, timber harvesting and other landuses that create openings in forest stands may increase the number of Great Horned Owls locally (Morrell and Yahner 1994). Northern Hawk Owls (*Surnia ulula*) also may benefit from timber harvesting. Duncan and Harris (1997) suggest that Northern Hawk Owls require a mixture of forest patches of differing ages and structure and variable-sized harvests staggered over time. In the midwestern region of the United States, forest habitat consists mainly of patches of forest within a matrix of human development, agriculture, and fragmentation from various other sources. Conversely, in West Virginia, and throughout most of the central Appalachian Mountains, the landscape is nearly opposite with a large matrix of undisturbed forest habitat and small patches of human disturbance (e.g., small development, mining activities, and timber harvests). Harvest patches can be large (> 40 ha), but are still temporal in nature and most often do not represent habitat "conversion". Therefore, understanding the dynamics of raptor communities with core forest areas under patchy (but locally intense) forest management is critical to understanding management options for raptor populations in the central Appalachian Mountains.

Two main questions arise as a result of the interaction of raptors and silvicultural practices: (1) can forest-dwelling raptors persist and nest successfully in an intensively managed, industrial forest in the central Appalachians; and (2) how will the raptor community respond to habitat alterations (i.e., scale, scope, and timing)? For forest-dwelling raptors, there is insufficient evidence to determine how disturbance influences nesting and foraging success.

Why study the raptor community?

Due to the decline of many large predators, niches in forest ecosystems may have opened and allowed medium-sized mammalian predators and avian predators (raptors) to become more prevalent. However, studies of raptor abundance and habitat use (including predatory response) that examine effects of this trend in intensively managed forests are lacking. Most studies of raptor populations and habitat use focus on one species rather than an entire raptor community (Nelson and Titus 1988). Direct responses of these predators to intense habitat modification rarely have been investigated. A general lack of knowledge about the daily needs of raptors in rapidly changing environments makes it difficult to predict impacts of forest management activities on the raptor community (Nelson and Titus 1988).

Large-scale, long-term surveys such as the Breeding Bird Survey (BBS) rarely account for avian predator species (Takats et al. 2001). The type of information desired by researchers and/or agencies must be considered when designing a protocol for monitoring (Clark 1988). Programs such as the U.S. Geological Survey's BBS, the Audubon Society's Christmas Bird Count, and U.S. Fish and Wildlife Service's Waterfowl Census are designed to monitor songbird and waterfowl populations, and census raptor species only if encountered (Sauer et al. 2000, Elphick et al. 2001). For the most part, population trends are often monitored using migration counts (Elphick et al. 2001) at places such as Hawk Mountain Sanctuary in Pennsylvania, Cape May Bird Observatory in New Jersey, and Goschute Mountains in Nevada. Although migration counts provide vital information on population trends, those data are not necessarily complete or fully informative about current productivity.

Most raptor species are difficult to census, monitor, and locate because of their activity patterns (Smith 1990). Forest-dwelling raptors are secretive and factors affecting their detectability are numerous. For raptors, detectability and identification can be influenced by differences among observers (Pendleton 1988, Titus 1988, Pendleton 1995), habitat, and topography (Mosher et al. 1990). For example, in an intensively managed forest, detection rates are different in recently harvested stands than in stands undergoing thinning or no treatment (i.e., mature stands; Pendleton 1995).

THESIS PROJECT INTRODUCTION

My thesis consists of three chapters describing investigations of species assemblage, relative abundance, and responses to habitat fragmentation of the raptor community on an active, industrial forest in the central Appalachian Mountains of West Virginia. The objectives of this field research were (1) to determine species assemblage, relative abundance, and basic ecology of the breeding and migratory raptor community on an industrial forest, (2) to provide an understanding of how raptors initially respond to fragmentation of various harvest intensities, and (3) to examine habitat use patterns and landscape characteristics of breeding raptors. Information contained in this thesis includes raptor distribution, breeding success, predator-prey interactions, and landscape habitat characteristics in an intensively managed forest landscape and may be of interest to land managers when making decisions about land use and wildlife management. Chapters are written in The *Journal of Raptor Research* style.

In Chapter Two, I present results from 15 mo of broadcast surveys on an industrial forest. Species assemblage, richness, and relative abundance were calculated for breeding and non-breeding seasons within three harvest rotation treatments in place on the study site. I performed five mo of nocturnal surveys during summer over two years to determine the presence of nocturnal species. Species documented were typical of a raptor community in eastern deciduous forest. I also examined habitat characteristics at two spatial scales (home range and landscape levels) to predict presence and abundance of the most commonly detected raptor species on surveys. These data will be used as baseline for inclusion in MeadWestvaco's Appalachian Landscape Ecology Project that is currently encompassing my study site. As part of the long-term study, the property was initially divided into two ecologically similar blocks, and then further subdivided into six compartments that are based on further community similarities, current disturbance, and compactness (e.g., approximately 526 ha each; P. D. Keyser, MeadWestvaco Corporation, pers. comm.). Each compartment within a block was randomly assigned one of three levels of harvest intensity treatments: a 20-, 40-, or 80-year rotation.

Chapter Three compares three protocols to determine the most efficient method of surveying for multiple species of nocturnal raptors. As a result of the numerous surveys, species assemblage, richness, and abundance were calculated during the summer months. Development of efficient sampling methods will allow long-term monitoring of nocturnal avian predator populations. This chapter will be modified for publication as a short communication for the Journal of Raptor Research.

In Chapter Four, I describe nesting ecology of diurnal raptors on site. Nests were located and monitored to report chronology, nesting success, and mean number of fledglings from four species of diurnal raptors. Prey species composition and delivery rates were determined from use of cameras mounted on a supporting branch of nest trees. In addition to home range and landscape level characteristics, microhabitat characteristics were sampled within a 0.04 ha circular plot around each nest tree. Comparisons also were made between occupied nests and random potential nest trees at the microhabitat scale. Additionally, comparisons were made at the landscape level (1000 m) between the amount of resources used in the territory and the amount available based on the entire MeadWestvaco Wildlife and Environmental Research Forest (MWERF).

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CHAPTER 2:

ASSEMBLAGE, ABUNDANCE, AND HABITAT CHARACTERISTICS OF THE RAPTOR COMMUNITY OF AN INDUSTIAL FOREST IN CENTRAL WEST VIRGINIA

ABSTRACT

I conducted 718 diurnal broadcast surveys to determine species assemblage and abundance of the diurnal raptor community on an industrial forest in central West Virginia during 2000-2001. I quantified species assemblage and abundance of nocturnal raptors on 130 nocturnal broadcast surveys. During all broadcast surveys and incidental sightings, I detected 17 species of raptors that reflected a typical eastern deciduous forest community. The most common diurnal species were Red-shouldered Hawks (*Buteo lineatus*), Red-tailed Hawks (*B. jamaicensis*), and Broad-winged Hawks (*B. platypterus*). Barred Owl (*Strix varia*) was the most common species of owl. I found no difference in mean abundance among treatments (20, 40, and 80 yr harvest rotations) for all raptors combined and by individual species. Forest-dwelling species and Broad-winged Hawk detections were greater during the breeding seasons, whereas edge-dwelling species were more common during the non-breeding season ($P < 0.05$). Landscape analyses found no variables at either the home range (564 m) or landscape (1000 m) level to be significant habitat characteristics in predicting Barred Owl presence. Shannon's Evenness Index (i.e., a measure of relative landscape patch distribution and abundance) was a significant habitat characteristic for predicting the presence of Red-shouldered Hawks during the breeding season at the landscape level. For Broad-winged Hawks, the best-fit model used number of forest patches and distance to nearest water source to predict presence during the breeding season at the landscape level. For Red-tailed Hawks, the best-fit model for predicting presence was during the breeding season and included the amount of early successional forest, Shannon's Evenness Index, and distance to nearest water source. As disturbance levels increase, habitat variables for predicting presence and abundance may change and species composition may shift from forest-dwelling species to edge-dwelling species.

INTRODUCTION

Natural and man-made disturbances promote a mixture of habitats within a forest (Buckner and Shure 1985, Hunter 1990). Species assemblage, richness, and relative abundance of wildlife can be affected by the size of these disturbances (Miller 1982). Forest management is one of the most common forms of disturbance in West Virginia and the central Appalachian Mountains today. Second generation forests currently are being harvested to satisfy society's increasing demand for wood products. Harvesting in West Virginia may be higher than neighboring states because of the high value species mix and amount of corporate lands (P. D. Keyser, MeadWestvaco Corporation, pers. comm.). Increased edge and fragmentation in eastern forests is advantageous for some species, but not for others (Falk and Stauffer 1988). Factors such as harvest size, harvest method, and harvest configuration will influence which species flourish and which species decline (Hunter 1990). Raptor communities (i.e., species assemblage and relative abundance) are affected by habitat alterations. For example, in the mid-Atlantic and northeastern states, modern forest management practices combined with excessive deer herbivory have led to the creation of steady-state openings in the understory of forested areas by altering the vertical and horizontal structural diversity (Waller and Alverson 1997). Forest structure alterations may affect foraging habitat, efficiency, and prey species availability of avian predators by exposing potential prey. Clearcutting, although often silviculturally preferred, creates unsuitable habitat for some woodland species of raptors (Gosse and Montevecchi 2001).

Nonetheless, there have been few studies on forest fragmentation resulting from timber harvest impacts that have focused on raptors in the eastern United States, and most studies of raptor populations and habitat use focus on one species rather than on entire raptor communities

(Nelson and Titus 1988). Gosse and Montevecchi (2001) suggested that old-growth stands contain more individuals and raptor species than younger stands. Mannon and Meslow (1984) compared bird populations in managed forests to old-growth mixed-coniferous forests in Quebec and found that Sharp-shinned Hawks (*Accipiter striatus*), Great Horned Owls (*Bubo virginianus*), Northern Saw-whet Owls (*Aegolius acadicus*), and Red-tailed Hawks (*Buteo jamaicensis*) occurred in both forest types. Red-tailed Hawks preferred habitats that contained open areas and perches to hunt from (Preston and Beane 1993) and were found in logged stands but not in unlogged stands (Franzreb and Ohmart 1978). Morrell and Yahner (1994) stated that Great Horned Owls tend to be associated with fragmented landscapes in Pennsylvania because they are habitat generalists. Northern Goshawks (*A. gentilis*) and Flammulated Owls (*Otus flammeolus*) were found only in old-growth stands whereas Cooper's Hawks (*Accipiter cooperii*) were found only in managed stands (Mannon and Meslow 1984). American Kestrels (*Falco sparverius*) were found nesting and foraging in recent clearcuts in western Newfoundland (Gosse and Montevecchi 2001). However, Northern Goshawks on a commercial tree farm in Washington successfully nested in stands that did not receive commercial or pre-commercial thinning, and therefore, do not seem to tolerate canopy openings in nesting habitat (Bosakowski et al. 1999). Penteriani and Faivre (2001), on the other hand, concluded that Northern Goshawks would continue to nest in stands that had <30% canopy cover reduction in the nesting stand.

Red-shouldered Hawks (*Buteo lineatus*) in Quebec are dependent on contiguous forests dominated by beech (*Fagus grandifolia*) or sugar maple (*Acer saccharum*) and nest in stands with well-developed, mature overstory and reduced subcanopy (Morris and Lemon 1983). Selective harvests (and long cutting cycles), may benefit Red-shouldered Hawks most because these areas leave potential nest trees and allow remaining trees to further mature (Nelson and

Titus 1988). Red-shouldered Hawk nests are often associated with riparian areas, and many birds prey mostly upon frogs and other amphibians (Titus and Mosher 1981, Howell and Chapman 1997) and mammals during the breeding season (Crocoll 1994). Some best management practices (BMP) mandated by state forestry divisions require timber harvests to retain a stream-side management zone (SMZ), or simply a border of trees of predetermined width along a stream.

Three main questions arise as a result of the interaction of raptors and silvicultural practices: (1) can forest-dwelling raptors persist and nest successfully in an intensively managed, industrial forest in the central Appalachians; (2) how will the raptor community respond to habitat alterations (i.e., scale, scope, and timing); and (3) at what level of disturbance do changes in species composition and nesting success occur? For forest-dwelling raptors, there is insufficient evidence to determine how disturbance influences nesting and foraging success. The specific objectives of my study were to: (1) determine species assemblage and abundance of diurnal and nocturnal raptor communities, (2) determine landscape-level habitat characteristics that indicate presence based on detections of each species, and (3) compare diurnal raptor abundance among three harvest treatments.

STUDY SITE

I conducted my research on the MeadWestvaco Wildlife and Ecosystem Research Forest (MWERF) near Adolph (38° 42’ latitude and 80° 3’ longitude) in Randolph County, West Virginia (Figure 2.1). The MWERF is a 3,413-ha second growth forest and was established in 1994 as an area to investigate the impacts of modern and intense forest management on ecological processes in an Appalachian setting. This site provided a unique opportunity to examine responses of a raptor community to habitat changes in an intensively managed forest (Fig. 2.2).

The MeadWestvaco Corporation initiated the Appalachian Landscape Ecology Project on the MWERF in January 2000. As part of this long-term study, the property was initially divided into two ecologically similar blocks (P. D. Keyser, MeadWestvaco Corporation, pers. comm.). The blocks were subdivided into six compartments based on further similarities, current levels of disturbance, and compactness (e.g., approximately 526 ha each; P. D. Keyser, MeadWestvaco Corporation, pers. comm.). Each compartment within a block was randomly assigned one of three levels of harvest intensity treatments: a 20-, 40-, or 80-year rotation. Each rotation is replicated twice on the area. The 40-year rotation reflects the average rotation length on industrial forests anticipation for fiber production in the Appalachian region, the 20-year rotation is more intense, and the 80-year rotation represents a less intense level of disturbance. At the end of each rotation, 75% of the cut acreage will be clear-cut and 25% will be deferment cuts (P. D. Keyser, MeadWestvaco Corporation, pers. comm.). Deferment cuts are clearcuts with ≤10 % residual basal area. The current age and species structural composition of second growth forest of the MWERF is a result of past high-grading. In 2000, non-forested habitat in the three treatments averaged 4.7% in the 20-yr compartments, 4.7% in the 40-yr, and 6.7% in the 80-yr.

Elevations on the MWERF ranged from 740-1200 m (Fenneman 1938). Climate is moist and cool with average rainfall and snowfall of 114 cm and 150 cm, respectively (Strausbaugh and Core 1977). Soils are acidic and typically well-drained (Stephenson 1993). Forest cover is Allegheny hardwood-northern hardwood at higher elevations, and cove-hardwood and mixed mesophytic at lower elevations (Eyre 1980). The Allegheny hardwood-northern hardwood forest type is dominated primarily by yellow birch (*Betula alleghaniensis*), American beech (*Fagus* *grandifolia*), sugar maple (*Acer sacharrum*), red maple (*A. rubrum*), black cherry (*Prunus serotina*), red spruce (*Picea rubens*), white ash (*Fraxina americana*), and Fraser's magnolia (*Magnolia fraseri*). Lower elevation species include tuliptree (*Liriodendron tulipifera*), sweet birch (*Betula lenta*), northern red oak (*Quercus rubra*), and American basswood (*Tilia americana*; Ford and Rodrigue 2001). Riparian areas of the forest are a mixture of red spruce, eastern hemlock (*Tsuga canadensis*), and rosebay rhododendron (*Rhododendron maximum*). The shrub layer throughout the forest consists of rhododendron and striped maple (*Acer pennsylvanicum*; Ford and Rodrigue 2001). The southern portion of the forest was not included in any of the compartments but was used to conduct species-specific nest searches for Northern Goshawks and Northern Saw-whet Owls. This area along the highest elevations on the MWERF contains a boreal community of red spruce and eastern hemlock.

METHODS

Broadcast Surveys. I quantified raptor abundance, species richness, and habitat use at 48 points divided equally among the three harvest rotation treatments on the MWERF (Fig. 2.3). I conducted monthly diurnal broadcast surveys from May to November 2000 and March to October 2001. Sixteen points per treatment (*N* = 48) were selected from a vegetation inventory grid on the MWERF created in 1994 (Weakland 2000). I randomly started on the northwest side of the MWERF and selected every third point throughout the forest. Any points at the intersection of two or more compartments were not included. Points were divided into four survey routes and each survey day, the route and survey direction were randomly chosen. I conducted surveys from 30 min after sunrise (0630 hrs) to approximately 1300 hrs during spring and summer (McLeod and Anderson 1998). In late fall and winter, I shifted the survey period to approximately 0800 to 1600 hrs to account for changing activity levels of the birds (Bunn et al. 1995) and different day lengths. During non-hunting seasons, both observers wore camouflage or dark clothing. During hunting seasons, both observers wore bright orange vests while hiking to survey points. Surveyer disturbance, such as conversations and movement, were kept to a minimum before, during, and after each survey.

I used broadcast surveys to sample raptor populations because broadcasting conspecific vocalizations have been shown to be an effective method to survey for targeted species (Rosenfield 1988, Belthoff and Ritchison 1989, Mosher et al. 1990, Kimmel and Yahner 1996). Survey methods were modified from Fuller and Mosher (1987). Each playback survey was 10 min and was conducted with two observers. My equipment included a personal CD player attached to a TOA Transitor® (Frederick Goertz LTD., Victoria, British Columbia, Canada) megaphone speaker. The callback CD was made using a Great Horned Owl vocalization from Peterson's Field Guide to Bird Songs of Eastern and Central North America CD® (Peterson Field Guide Series 1990). Mosher and Fuller (1996) reported Great Horned Owl vocalizations elicit responses from multiple species of raptors in a single survey period, whereas conspecific vocalizations yield responses from that species. Six, 20-sec vocalizations were evenly spaced and alternated with 40 sec of listening periods over the first 5-min and 20-sec period on the CD. The vocalization period was followed by a 4-min and 40-sec listening period (i.e., total of 10 min at each point). The speaker was held 1.5 m above the ground and was rotated at 120° intervals throughout the survey period (McLeod and Andersen 1998). The vocalizations were broadcast between 100-110 db (measured 1 m from speaker).

Two observers trained in raptor identification were present during each survey. I was the primary observer, responsible for recording all observations, and was present at each survey.

The second observer alternated among seven other individuals over the two-year study; the second person held the broadcast equipment and stood back-to-back with me. During each survey period, we simultaneously scanned for visual or audio responses from any raptor species. The data I recorded included start and end time for each survey, latency (time into survey) and type of response (e.g., vocal only, fly and call, perch and call, silent flight, and silent perch), category of wind speed (0-3), temperature, amount of cloud cover, and any disturbance at the point. Because weather can affect detectability of raptors (Fuller and Mosher 1987, Smith 1990), I followed Breeding Bird Survey protocols for acceptable weather conditions during typical bird surveys (Sauer 2000). Surveys were not conducted during constant precipitation, when wind speeds were >3 on the Beaufort scale (i.e., 13-19 km/h when leaves and twigs are in constant motion), or in the presence of heavy fog.

I also conducted 5 mo of nocturnal broadcast surveys during Jun-Jul 2000 and Jun-Aug 2001 at 14 survey points established along roads (Fig. 2.3). Each nocturnal broadcast survey used the same general protocol and equipment as diurnal surveys, but used different vocalizations or a suite of vocalizations to detect nocturnal raptors. Vocalizations used included Northern Saw-whet Owl, Eastern Screech-owl, and Barred Owl. Surveys were conducted monthly, centered around the 2 wk period prior to and following the new moon (Takats et al. 2001). Each survey was conducted from approximately 2000 to 0000 hr EST when activity is closest to the core of a pair's home range (Clark 1988, Takats and Holroyd 1997). The primary observer wore a headlamp with a red parafilm filter. In addition to the other weather variables, moon phase was recorded for each survey.

Landscape Habitat Analysis. Landscape habitat characteristics were measured and related to raptor presence and abundance. For landscape analyses, I plotted the geographically referenced locations of each survey point were on Digital Orthophoto Quadrangles (DOQQ) of the study site taken in 1996. I modified land cover from the photos to reflect conditions during the two years of my study. ArcView 3.2® with Patch Analyst 2.2® extension was used to create two buffer zones around each survey point and to analyze all habitat variables within each buffer zone (see Appendix 1). The 564 m (1 km^2, 100 ha) buffer zone was based on average home range size of Red-shouldered Hawks in the eastern United States (Moorman and Chapman 1996, Howell and Chapman 1997). The 1000 m (2 km^2, 312 ha) buffer zone was based on the maximum home range for this species (Bednarz and Dinsmore 1981), which is more representative of the landscape perspective and a size typically used in landscape analyses (McGarigal and McComb 1995).

Land covers within and surrounding the MWERF were digitized into eight categories: water and wetland, roads and bare ground, grassland and powerlines, early succession (deciduous), middle succession (deciduous), late succession hardwood, late successional conifer mix, and human development (Table 2.1). Classification of early, mid-, and late-successional stands were based on characteristics of stand age defined by Oliver and Larson (1996). I specifically identified early successional stands as 0-9 yr, mid-successional as 10-50 yr, and late successional as >50 yr.

Buffer zones at 564 m and 1000 m were clipped out of the overall coverage and summarized using Patch Analyst 2.2 extension (Fig. 2.3). Because the landscape changed during the course of this study, landscape composition for each year was calculated and examined separately (Fig. 2.2). With Patch Analyst 2.2, I used the land covers to calculate other landscape variables including total amount of mature forest (regardless of species composition), mean patch size of mature forest, total number of forest patches, total core area of mature forest, mean patch size of each core area, edge density, Shannon's Diversity Index (measure of relative landscape patch diversity), Shannon's Evenness Index (measure of patch distribution and abundance), and distance to nearest water source or wetland area (in m; Table 2.1).

Microhabitat Analyses. In addition to landscape analyses, I derived slope, aspect, and elevation from the digital elevation model for all diurnal and nocturnal survey points using ArcView 3.2.

Statistical Analyses. For diurnal raptor survey data, I used ANOVA (PROC GLM in SAS V.8, SAS® Institute 1991) to compare mean abundance and species richness of all raptors combined and mean abundance of forest-dwelling raptors, edge-dwelling raptors, and the three most common species among the three harvest rotation treatments, between years, and seasons (breeding and non-breeding). ANOVA is robust to heterogeneous variances and non-normal data (Zar 1999). Abundance and richness were dependent variables in the ANOVA model, whereas harvest rotation treatment, compartment, year, season, the interaction between treatment and year, the interaction between compartment and year, and the interaction between treatment and season were independent variables. Peak breeding season was determined for each of the most common diurnal species based on nests monitored on the MWERF and in current literature. Red-shouldered Hawk breeding season was April to July (Crocoll 1994), Red-tailed Hawk breeding season was March to July (Preston and Beane 1993), and Broad-winged Hawk breeding season was May to August (Goodrich et al. 1996). Mean abundance was calculated as mean number of responses for all raptor species and each species by treatment. Species richness was defined as number of species detected in each treatment. All differences were considered significant when $P \leq 0.05$.

For nocturnal survey data, I used ANOVA (PROC GLM in SAS V.8, SAS® Institute 1991) to compare mean abundance of all owls detected between years. Abundance was the dependent variable in the model and year was the independent variable. I also compared yearly abundance of Barred Owls because they were the most commonly detected nocturnal species. Other species detected were not analyzed separately due to small sample detections. I used a *t*-test (PROC TTEST in SAS V.8) to compare habitat variables at both landscape scales with the presence of Barred Owls. Pearson product-moment correlation analysis (PROC CORR in SAS V. 8, SAS® Institute 1991) was used to examine correlations between the number of owl responses and cloud cover, temperature, and wind speed.

I used stepwise logistic regression (PROC LOGISTIC in SAS® V.8, SAS® Institute 1991) to identify important landscape habitat characteristics that predicted the presence/absence of each of the most abundant species. The Hosmer and Lemeshow goodness-of-fit statistic (H/L) tests the null hypothesis that the data fit the model. A H/L with $P \leq 0.05$ indicates the data does not fit the model. Habitat characteristics to predict abundance for each of the most common species were analyzed using multiple linear regression (PROC REG in SAS® V.8). Abundance data were log-transformed for multiple linear regression analysis. Model R^2 explains the amount of variation in the dependent variables accounted for by all significant independent variables, whereas the partial R^2 indicates the amount of variation in the individual independent variables (SAS 1991). For both multiple linear and logistic regression, I used a level of $\alpha = 0.3$ to enter the model and $\alpha = 0.10$ to remain.

Logistic and multiple regression models were run on each buffer zone for all points in all three harvest rotation treatments between the two seasons for diurnal raptors, and for all survey points in both years for nocturnal surveys. Abundance and presence were dependent variables in the multiple linear and logistic regression models respectively, whereas landscape variables (Table 2.1) were independent variables. I focused analyses on species detected most often during both years of surveys: Red-shouldered Hawk, Broad-winged Hawk, Red-tailed Hawk, and Barred Owl. For Broad-winged Hawks during the breeding season, the landscape level model for predicting presence would not converge with all variables I chose to evaluate. Therefore, I used Pearson product-moment correlation to examine correlations among all variables. Since FOREST was strongly correlated with many other variables, it was removed from the logistic regression analysis; the model converged without that variable. The resulting model included the same variables as the model developed prior to removing FOREST.

To examine microhabitat characteristics of each of the most common species during the breeding season and the non-breeding season, I used analysis of variance (ANOVA) to compare the mean slope, aspect, and elevation at the survey points with and without each species presence. Aspect data was linearly transformed (Odom et al. 2001). Results were considered significant at $P \leq 0.05$ and are reported as means $\pm$ standard deviation.

RESULTS

Broadcast Surveys. During the two-year study, 17 species of raptors were detected during diurnal surveys, nocturnal surveys, and incidental sightings (Table 2.2). During diurnal broadcast surveys, a total of 273 responses were detected from nine raptor species. In addition to species detected during the broadcast surveys, six species were detected as incidental observations. An additional two species were detected only during nocturnal broadcast surveys (Table 2.2). Responses were recorded at 41 of 48 (85%) survey points in 2000 and 47 of 48

(98%) in 2001. The most abundant species detected were Red-shouldered Hawk (*n* = 104 responses), Broad-winged Hawk (*n* = 79), and Red-tailed Hawk (*n* = 41; Table 2.3).

For all diurnal raptor responses, I found no significant difference in overall abundance among the three treatments (Table 2.3; F = 2.50, *P* = 0.23), between years (F = 1.84, *P* = 0.27), interaction between years within the treatments (F = 2.10, *P* = 0.27), or between breeding and non-breeding season (F = 2.54, *P* = 0.11). Species richness also was not significantly different among the three treatments (F = 1.33, *P* = 0.37), with no difference among years (F = 2.33, *P* = 0.27), and no interaction between treatment and year (F = 1.33, *P* = 0.37).

The majority of raptors I detected are considered forest-dwelling species (e.g., Red-shouldered Hawks, Broad-winged Hawks, Sharp-shinned Hawks, Cooper's Hawks, and Barred Owls; n = 210 detections). I found no difference in mean number of responses among treatments for the forest-dwelling species (Fig. 2.3; F = 2.45, *P* = 0.23); however, this group of species was detected more often during the breeding season (F = 8.16, *P* = 0.003; Table 2.3). Edge-dwelling species such as Red-tailed Hawks, Great Horned Owls, and Golden Eagles (*Aquila chrysaetos*) were detected in lower abundance (n = 48). I found no difference in mean number of responses among treatments for the edge species (Fig. 2.3; F = 1.37, *P* = 0.38). Edge-dwelling species were detected more often during the non-breeding season (Table 2.3; F = 3.83, *P* = 0.04).

Red-shouldered Hawks were detected most often (n = 104; Table 2.3) and were observed at 26 (54 %) of the survey points in 2000 and 25 (52 %) in 2001. I found no significant differences among treatments (F = 5.36, *P* = 0.10), seasons (F = 2.23, *P* = 0.14), or interaction between treatment and season (F = 0.11, *P* = 0.97). Broad-winged Hawks were detected at 17 (35.4 %) of the survey points in 2000 and 25 (52%) during 2001. I found no difference in mean abundance among treatments (F = 0.15, *P* = 0.86) or interaction among treatment and season (F

= 0.91, P = 0.48). Mean detections were greater during the breeding season (F = 7.11, P = 0.005) only because this species is highly migratory. Red-tailed Hawks were detected at 11 (23 %) of the survey points during 2000 and 16 (33 %) in 2001. I found no significant differences in mean number of detections among treatments (F = 1.16, P = 0.42), between seasons (F = 0.03, P = 0.97) or interaction between treatment and season (F = 0.03, P = 0.99).

During 130 nocturnal surveys, I detected four species of owls, two of which were not detected during diurnal surveys (Table 2.2). Owls responded during 52 (40%) of the 130 surveys conducted. The most common species detected was the Barred Owl (n = 58 responses). I found no significant differences in abundance of Barred Owl responses (F = 0.31, P = 0.57) or in total number of owls detected (F = 0.13, P = 0.71) between years. Since nocturnal surveys were based on the road system and not harvest treatments, analyses among treatments were not performed. Other species detected were Eastern Screech-owl (n = 6), Northern Saw-whet Owl (n = 1), and Great Horned Owl (n = 1). I examined the correlation between weather variables such as cloud cover (r = 0.17, p = 0.06), temperature (r = 0.09, p = 0.32), and wind speed (r = 0.02, p = 0.79), and found no significant correlation between these variables and owl detections.

For all raptor responses in both years of diurnal surveys, 58% were detected during the Great Horned Owl vocalization time segment of the surveys. Responses consisted of vocalizations (72%), including fly and call, perch and call, vocalization only, and of silent responses (28%), including silent fly and silent perch. For all nocturnal surveys in both years, >52% of the responses detected were during the listening time segment of the surveys. Response types consisted of fly and call (19.4%), perch and call (79.2%), and silent perch (1.4%).

Landscape Analysis. Overall, for all species and seasons evaluated, the best-fit models were for predicting the presence or absence of each species. H/L goodness of fit values were high for all but one model (Table 2.4). In contrast, R^2 values for all multiple regression models were low (Table 2.5). Means and standard errors for all habitat variables for each of the most abundant species were similar (Table 2.6).

For Red-shouldered Hawks, the most commonly detected raptor species, both logistic (Table 2.4) and multiple linear regression (Table 2.5) models at the landscape level (1000 m) included a positive influence of Shannon's Evenness Index (SEI) during the breeding season (April to July) as predictors of presence and abundance. This variable indicated that Red-shouldered Hawks are present and more abundant in landscapes that are less diverse. The model for predicting presence was a better fit (H/L fit = 0.41) than the model for predicting abundance (R^2 = 0.06). At the home range level (564 m buffer), the amount of mid-successional deciduous forest (MSdecid) and edge density (ED) were significant predictors of presence (H/L fit = 0.14) and abundance (R^2 = 0.12), although fit was low. During the non-breeding season (August to March) at the landscape level, the model for predicting abundance included a positive influence of Shannon's Diversity Index (SDI) and amount of water (WATER; R^2 = 0.22; Table 2.5). The model for predicting presence included SDI and a negative relationship to the amount of early successional forest (EARLY; H/L fit = 0.99) and was a much better fit at this spatial scale (Table 2.4). In the non-breeding season at the home range level, the best fit model predicted presence of Red-shouldered Hawks at points with more late successional forest (FOREST), decreasing EARLY, increasing mean patch size of mature forest, and greater SDI (H/L fit = 0.90). The model for predicting abundance included the amount of development (DEVELOPED) and late successional forest (LSDECID; R^2 = 0.17).

During the non-breeding season (August to April), Broad-winged Hawks migrated out of the study area resulting in few detections; therefore, no models were constructed for this species during this time period. During the breeding season (May to July), Broad-winged Hawks were the second most commonly detected raptor species. Their presence and abundance were negatively related to distance to water (DISWATER) at the landscape and territory scales (H/L = 0.60; Table 2.4 and 2.5). At the landscape scale, they were present where number of forest patches was greater (H/L fit = 0.96) and more abundant where the amount of development was greater. At the home range scale, abundance was greater where forest cover was lower (R^2 = 0.10). The model for abundance which included DISWATER and DEVELOP (R^2 = 0.11) was not as good of a predictor (Table 2.5).

Red-tailed Hawks (third most commonly detected raptor) were more abundant at points with more FOREST cover at the landscape level (Tables 2.5 and 2.6) during the breeding (March to July; R^2 = 0.10) and non-breeding (August to February; R^2 = 0.08) seasons. For both seasons at the landscape level, no variables were kept in the model to predict presence (Table 2.4). At the home range level, Red-tailed Hawks were more commonly detected at points with increasing amounts of EARLY (R^2 = 0.05). The model for predicting presence including EARLY, DISWATER, and SEI was a much better fit (H/L = 0.63). At the home range level, Red-tailed Hawks were present at points with more EARLY, increasing amount of mid-successional forest, and larger MPSFOREST (H/L fit = 0.50), and was the best fit model. The model for predicting abundance included only EARLY (R^2 = 0.06).

Landscape characteristics also were used to predict the presence of Barred Owls, the most abundant nocturnal species. No variables were retained in the models for predicting abundance and presence of Barred Owls at either spatial scale.

Microhabitat Characteristics. Red-shouldered Hawks were detected at survey points with a mean aspect of 222° $\pm$ 18.0° (F = 0.02, P = 0.89). This species was detected at a mean slope of 13.88% ± 1.09 ($F = 0.53$, $P = 0.047$) and the highest mean elevation of 930 ± 13.2 m ($F = 0.02$, $P = 0.88$) of all three species. Broad-winged Hawks were detected at survey points with a mean slope of 15.79% ± 1.26 ($F = 8.83$, $P = 0.003$). This species was detected at a mean aspect of 158° ± 24.8 ($F = 22.39$, $P < 0.001$), and mean elevation of 884 ± 11.6 m ($F = 19.67$, $P < 0.0001$). Red-tailed Hawks were observed at survey points with a mean elevation of 893 ± 19.7 m ($F = 8.50$, $P = 0.004$). This species was detected at a mean aspect of 208° ± 30.9 ($F = 6.24$, $P = 0.01$) and a mean slope of 14.85% ± 1.19 ($F = 0.93$, $P = 0.33$).

Slope ($F = 0.93$, $P = 0.33$), aspect ($F = 0.46$, $P = 0.50$), and elevation ($F = 0.93$, $P = 0.33$) at the survey point were not significant variables for detecting Barred Owls or all owl species. No variables were significantly different between points where Barred Owls were present and absent at either spatial scale (Table 2.7).

DISCUSSION

Forest management activities modify habitat and can affect species assemblage, abundances, and richness, depending on the size of the disturbance for many species of wildlife (Miller 1982, Buckner and Shure 1985, Nelson and Titus 1988, Riffell et al. 1996, Weakland et al. 2002). A mixture of early and late successional habitats can maintain a diversity of raptor species, but a lack of mature forest can limit available habitat for some species (Cline 1990). My results suggest that at the current level of disturbance on the MWERF, forest-dwelling raptors are still present in high abundance and are more common than early successional species. Currently, abundance of forest species did not differ among the harvest intensities; however, as timber harvests continue and levels of disturbance within the three treatments begin to differ, changes in species composition may become apparent. Shifts in species composition may include Red-shouldered Hawks and Barred Owls becoming less abundant, whereas Red-tailed Hawk and Great Horned Owls will likely become more abundant (Bednarz and Dinsmore 1982, Bryant 1986, Johnson 1992). Nesting and roosting habitat must also be sustained for diversity and abundance (Cline 1990). From detection of successful nests on the area, nesting habitat is still available and the raptor community continues to reproduce and fledge young (Chapter 4).

Species such as American Kestrels and Great Horned Owls may increase in abundance with increasing amounts of clearcut areas (Johnson 1992, Gosse and Montevecchi 2001). A male American Kestrel was observed in the southern portion of the MWERF during the summer of 2001 in two clearcuts harvested in fall 2000. Although not documented on a survey, the bird was observed foraging numerous times by myself and several knowledgeable observers. In 2000, the only American Kestrels documented on the study area were incidental sightings during fall migration. The male Kestrel spotted in summer 2001 may be evidence that the shift in species composition may be beginning, or it could be a natural population increase that was not evident in 2000. I documented 17 species of raptors on the MWERF in 2000 and 2001 of 21 species that could potentially occur in the area (Hall 1983, Buckelew and Hall 1994). Forest dependent species accounted for the majority of detections.

Within the Appalachian Landscape Ecology Project, one important ecological question to be addressed is at what level of fragmentation from timber harvest do changes in the raptor community occur. Monitoring landscape and home range-level habitat variables may help answer this question. Habitat variables used to predict species presence and abundance before fragmentation should assist in determining when and where changes occur as a result of disturbance from timber harvesting. Most models in this study for predicting presence and abundance of Red-tailed Hawks indicated the importance of early successional habitat (Table 2.4

and 2.5). Red-tailed Hawks tend to be found in habitats with more open areas than Red-shouldered Hawks (Preston and Beane 1993, Bednarz and Dinsmore 1982), but habitats of the two species have also been found to overlap (Bosakowski et al. 1992). Studies suggest that for some silvicultural practices that include selective logging, Red-shouldered Hawks can lose territory to Red-tailed Hawk encroachment (Bednarz and Dinsmore 1982, Bryant 1986).

Bednarz and Dinsmore (1981) suggested that human disturbance and habitat alterations should be minimized within a 1-km radius of an occupied Red-shouldered Hawk nest. Red-shouldered Hawks nest in mature forest stands and often are associated with water or wetland areas (Bednarz and Dinsmore 1981, Titus and Mosher 1981). Best-fit models for predicting presence and abundance had a positive relationship with Shannon's Evenness index, indicating Red-shouldered Hawks were more abundant and present in areas where the landscape was not as diverse as other areas of the MWERF. However, Morris and Lemon (1983) did not mention the wetland aspect of this species' habitat and my models did not identify water or wetland habitat as important variables because even the riparian areas on the MWERF are not too different in species composition. The MWERF receives high amounts of rainfall and snow each year (Strausbaugh and Core 1977), but little wetland area occurs on the site. Instead, three major streams run through the property providing considerable riparian habitat, which in turn, does not seem to provide critical habitat for *Sorex* spp. as previously thought in the central Appalachian Mountains (Ford and Rodrigue 2001) but could serve as important landscape characteristics that influence Red-shouldered Hawk populations (Falk and Stauffer 1988). Based on known habitat requirements of Red-shouldered Hawks, it is possible that intensively managed forests with adjacent undisturbed older growth stands and riparian areas may allow nesting and hunting to occur successfully in harvested areas as long as SMZ are left in place. Low levels of harvesting may not have an immediate effect on this species viability and population status because riparian areas functionally are no different than most of the unharvested uplands on the MWERF.

Broad-winged Hawks appear to be more tolerant than other species to disturbance (Nelson and Titus 1988, Goodrich et al. 1996) and have also been associated with wetland areas (Titus and Mosher 1981). Because Broad-winged Hawks and Red-shouldered Hawks have similar nesting habitat characteristics in the central Appalachians, they are often syntopic in their breeding territory requirements (Titus and Mosher 1981). For all models in this study, distance to water was an important predictor of presence and abundance of Broad-winged Hawks. Younger forest stands are needed to maintain this species (Titus and Mosher 1981, Goodrich et al. 1996), so silvicultural systems that involve short rotations (~40 yrs) may be beneficial.

The structural composition of forest cover on the MWERF is second-growth northern and Allegheny hardwoods, but the structural composition of the area is changing as the harvest rotations are implemented. Literature suggests that as harvest intensity, area, and frequency increase, the raptor species composition in the treatments may shift (Johnson 1992, Preston and Beane 1993, Crocoll 1994, Goodrich et al. 1996). Cavity trees removed in harvesting operations on the MWERF may limit the amount of available nesting habitat for owls and other cavity-nesting species of wildlife. It also may be possible that past high-grading of timber stands can increase the possibility of the presence of snags because of damage and weakness after harvesting operations. Edge-dwelling or open area species (e.g., Great Horned Owls and American Kestrels) may become more prevalent (Houston et al. 1998). Morrell and Yahner (1994) state that Great Horned Owls tend to be associated with fragmented landscapes in Pennsylvania because they are generalists. Johnson (1992) found that Great Horned Owls are more abundant in forest landscapes that have a high edge-to-old forest ratio, suggesting that owl populations may shift away from Barred Owl dominance to Great Horned Owl dominance as the timber harvest intensifies. Consequently, shifts in raptor species composition may result in added pressure on populations of prey species such as Allegheny woodrat (*Neotoma magistar*) and northern flying squirrels (*Glaucomys sabrinus*), as Great Horned Owls are more likely to prey upon these species than Barred Owls.

Northern Saw-whet Owls tend to be found in higher elevation, mostly woodland areas, and are associated with dense stands of boreal conifers (Cannings 1993). These three conditions are found only in the southern portion of the MWERF. Several birds were detected on the area, confirming their presence during the summer months. Northern Saw-whet Owls perch near the ground and in dense cover to hunt for rodents (Cannings 1993). Slash, wind-thrown trees, young regeneration, and remnant skid trails found on the MWERF probably provide important roosting and hunting areas for these owls.

CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

Raptor species documented on the MWERF are typical of a forest-dwelling raptor community in the eastern United States and these data represent a baseline of survey information about raptor populations on the MWERF. Habitat modifications have been documented to affect guilds of species by changing their composition (Buckner and Shure 1985, Nelson and Titus 1988, Waller and Alverson 1997, Riffell et al. 1996, Weakland et al. 2002). The question for biologists is at what level of disturbance do these changes occur? To thoroughly document potential effects of timber harvesting, long-term monitoring is needed. Therefore, I recommend that raptor surveys continue during the breeding season to monitor population fluctuations and nesting success as timber harvest intensity continues to increase.

Options to reduce negative effects of timber harvesting on breeding raptors may include retaining buffer zones around active nests and timing of harvests. Buffer zones of no disturbance are recommended for Bald Eagle (*Haliaeetus leucocephalus*) nests, however, no such formal restrictions exist for forest-dwelling hawks. Bednarz and Dinsmore (1981) suggest minimizing human activity within a 1-km radius of active Red-shouldered Hawk nests. A European study of Northern Goshawks suggested that buffer zones should be at least 5 ha, so the nest tree would not be isolated. This size buffer zone may be more economically feasible for most landowners and yet still provide some protection for the nesting raptors. Zones of little or no disturbance may not have to be so large, if harvests were restricted to the non-breeding season (Grubb 1998). Although not a guarantee to maintain raptor populations, these simple considerations may allow these birds to reproduce successfully, and thus, let populations continue to exist (Chapter 4).

These nocturnal survey data represent a baseline of survey information about the summer nocturnal raptor population on the MWERF. Surveys for nocturnal raptors should be continued and possibly expanded earlier in the breeding season. Additional surveys may assist in determining characteristics for predicting presence and abundance of Barred Owls and other owl species, and monitor population shifts, including the potential increase of Great Horned Owl presence as disturbance levels change on the MWERF.

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Table 2.1. Description of landscape variables examined (564 and 1000 m) in landscape analysis of habitat use for raptors on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during summers 2000 and 2001.

Abbreviation	Description
ROAD	Amount of roads and bare ground (in ha).
WATER	Amount of open water and wetland areas (in ha), which includes ponds, lakes, streams, rivers and wetland that could be seen on an aerial photo.
DEVELOPED	Amount of human development (in ha), which includes resident and commercial buildings and gas wells.
GRASS	Amount of grassland areas (in ha).
EARLY	Amount of early successional deciduous forest (in ha), which are harvested areas that were < 10 years old.
MSDECID	Amount of mid-successional deciduous forest (in ha), which are stands that were 10-50 years old.
LSDECID	Amount of late successional deciduous forest (in ha), which are stands that were > 50 years old.
LSCONIFER	Amount of late successional conifer forest (in ha), which consists of stands that were > 50 years old.
FOREST	Amount of total mature forest area (in ha), which consists of LSCONIFER and LSDECID.
MPSFOREST	Mean patch size of FOREST.
TFP	Total number of FOREST patches.
TCA	Total core area of FOREST.
MPSTCA	Mean patch size of the total core area.
ED	Edge density.
SDI	Shannon's Diversity Index, which is a measure of relative patch density, based on digitized land use.
SEI	Shannon's Evenness Index, which is a measure of patch distribution and abundance, based on digitized land use.
DISWATER	Distance to the nearest body of water, stream, or wetland area (in m).

Table 2.2. Raptor species detected during broadcast surveys and as incidental observations in 2000 and 2001 on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia.

Species	Time of year present
Diurnal	
Northern Harrier (*Circus cyaneus*) [c]	migration
Sharp-shinned Hawk (*Accipiter striatus*) [a]	winter, breeding
Cooper's Hawk (*A. cooperii*) [a]	winter, breeding
Northern Goshawk (*A. gentilis*) [c,d]	breeding
Red-tailed Hawk (*Buteo jamaicensis*) [a,d]	winter, breeding
Red-shouldered Hawk (*B. lineatus*) [a,d]	winter, breeding
Broad-winged Hawk (*B. platypterus*) [a,d]	breeding
American Kestrel (*F. sparverius*) [c]	winter, breeding
Bald Eagle (*Haliaeetus luecocephalus*) [c]	migration
Golden Eagle (*Aquila chrysaetos*) [a]	migration
Osprey (*Pandion haliaetus*) [c]	migration
Turkey Vulture (*Cathartes aura*) [a,d]	breeding
Black Vulture (*Coragyps atratus*) [c]	migration
Nocturnal	
Great Horned Owl (*Bubo virginianus*) [a,b]	winter, breeding
Barred Owl (*Strix varia*) [a,b]	winter, breeding
Eastern Screech-owl (*Otus asio*) [b]	breeding
Northern Saw-whet Owl (*Aegolius acadicus*) [b]	breeding

[a]Species was detected on diurnal surveys.
[b]Species was detected on nocturnal surveys.
[c]Species was detected outside of normal surveys (i.e., incidental sightings).
[d]Confirmed breeding on the MWERF (see chapter 4).

Table 2.3. Mean abundance and standard error (SE) for all raptor species detected during diurnal broadcast surveys in three harvest rotations on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001.

		20-year		40-year		80-year		ANOVA by treatment	
Species/group	season[a]	Mean	SE	Mean	SE	Mean	SE	F	*P*
Red-shouldered Hawk	BR	0.28	0.05	0.13	0.04	0.13	0.04	5.36	0.102
	NB	0.16	0.05	0.08	0.03	0.11	0.03		
Red-tailed Hawk	BR	0.08	0.03	0.05	0.02	0.04	0.02	1.16	0.424
	NB	0.09	0.03	0.05	0.02	0.05	0.02		
Broad-winged Hawk	BR	0.19	0.05	0.15	0.04	0.24	0.06	0.15	0.865
	NB	0.10	0.03	0.04	0.02	0.03	0.01		
Cooper's Hawk[b]	BR	0.01	0.01	0.05	0.02	0.01	0.01		
	NB	0.02	0.01	0.02	0.01	0.00	0.00		
Sharp-shinned Hawk[b]	BR	0.00	0.00	0.01	0.01	0.01	0.01		
	NB	0.04	0.02	0.01	0.01	0.01	0.01		
Golden Eagle[b]	BR	0.00	0.00	0.00	0.00	0.01	0.01		
	NB	0.01	0.01	0.01	0.01	0.01	0.01		
Barred Owl[b]	BR	0.00	0.00	0.02	0.01	0.01	0.01		
	NB	0.01	0.01	0.01	0.01	0.02	0.01		
Turkey Vulture[b,c]	BR	0.25	0.07	0.08	0.03	0.09	0.04		
	NB	0.17	0.05	0.12	0.05	0.13	0.04		
Forest-dwelling species	BR	0.46	0.07	0.37	0.06	0.38	0.06	2.45	0.23
	NB	0.32	0.06	0.13	0.03	0.15	0.04		
Edge-dwelling species	BR	0.05	0.02	0.04	0.02	0.04	0.02	1.37	0.38
	NB	0.13	0.04	0.07	0.03	0.06	0.02		
Overall Abundance		0.51		0.35		0.32		2.50	0.229
Species Richness		6.50	0.50	6.00	1.00	6.00	1.00	1.33	0.368

[a]BR indicates breeding season and NB indicates non-breeding season
[b]Species-specific analyses not conducted, too few detections.
[c]Observations not used in overall abundance and richness analyses.

Table 2.4. Significant habitat variables selected by stepwise logistic regression for predicting presence of Red-shouldered Hawks (RSHA), Red-tailed Hawks (RTHA), and Broad-winged Hawks (BWHA) by season at two landscape levels (564 m and 1000 m) on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001.

Buffer	Variable	Mean (SE)		Parameter estimate	H/L Goodness-of-fit	χ^2	*P*-value
		presence	absence				
Breeding							
RSHA							
1000 m	SEI	0.48 (0.01)	0.48 (0.01)	9.99	0.41	7.13	0.003
564 m	MSdecid	1.73 (0.77)	0.30 (0.15)	0.23			0.033
	ED	157.17 (8.25)	140.90 (7.05)	0.01	0.14	11.05	0.031
BWHA[a]							
1000 m	NFP	13.18 (1.79)	9.76 (0.72)	0.06			0.065
	DISwater	203.84 (25.43)	265.61 (18.03)	-0.003	0.96	2.08	0.060
564 m	DISwater	193.75 (24.34)	265.61 (18.03)	-0.002	0.60	5.48	0.023
RTHA							
1000 m	-[b]	-	-	-	-	-	-
564 m	EARLY	10.31 (1.67)	6.64 (0.66)	0.19			0.005
	DISwater	296.48 (44.71)	229.73 (15.37)	-5.04			0.075
	SEI	0.48 (0.03)	0.48 (0.02)	0.01	0.63	5.27	0.020
Non-Breeding							
RSHA							
1000 m	SDI	0.97 (0.02)	0.90 (0.02)	11.14			0.067
	EARLY	22.87 (1.76)	20.35 (1.22)	-0.06	0.99	1.00	<.000
564 m	EARLY	7.03 (0.99)	7.31 (0.81)	-0.15			0.011
	FOREST	81.00 (3.20)	86.76 (1.28)	-0.06			0.018
	MPSforest	26.18 (2.36)	25.56 (2.10)	0.04			0.057
	SDI	0.94 (0.04)	0.78 (0.03)	5.71	0.90	2.84	0.000
RTHA							
1000 m	-	-	-	-	-	-	-
564 m	EARLY	9.70 (1.36)	6.72 (0.69)	0.14			0.016
	MSdecid	1.81 (1.29)	0.67 (0.29)	0.14			0.055
	MPSforest	27.94 (5.56)	25.34 (1.57)	0.03	0.50	6.31	0.080

[a]Only 3 detections of BWHA in non-breeding season (August to April), so not included in analyses.
[b]Dash indicates no significant variables in model.

Table 2.5. Significant habitat variables selected by stepwise multiple linear regression for predicting abundance of Red-shouldered Hawks (RSHA), Red-tailed Hawks (RTHA), and Broad-winged Hawks (BWHA) by season at two landscape levels (564 m and 1000 m) on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001.

		Mean (SE)		Parameter	Partial		Full Model	
Buffer	**Variable**	**presence**	**absence**	**estimate**	R^2	P	R^2	P
Breeding								
RSHA								
1000 m	SEI	0.53 (0.01)	0.48 (0.01)	1.51	0.06	0.016	0.06	0.016
564 m	MSdecid	1.73 (0.77)	0.30 (0.15)	0.05	0.07	0.002		
	ED	157.17 (8.25)	140.90 (7.05)	0.002	0.05	0.023	0.12	0.003
BWHA[a]								
1000 m	DEVELOP	0.03 (0.01)	0.01 (0.00)	2.57	0.07	0.012		
	DISwater	203.84 (25.43)	265.61 (18.03)	-0.00	0.04	0.045	0.11	0.006
564 m	DISwater	193.75 (24.34)	265.61 (18.03)	-0.01	0.04	0.030		
	FOREST	81.43 (2.92)	86.61 (1.43)	-0.000	0.06	0.053	0.10	0.008
RTHA								
1000 m	FOREST	254.74 (14.90)	273.79 (1.75)	-0.003	0.10	0.002	0.10	0.002
564 m	EARLY	10.31 (1.67)	6.64 (0.66)	0.01	0.05	0.025	0.05	0.025
Non-breeding								
RSHA								
1000 m	SDI	1.01 (0.02)	0.88 (0.02)	1.24	0.03	<.000		
	WATER	1.75 (0.15)	1.47 (0.08)	0.10	0.19	0.056	0.22	<.000
564 m	DEVELOP	0.01 (0.00)	0.00 (0.00)	10.56	0.11	0.001		
	LSdecid	54.70 (3.61)	68.01 (2.39)	-0.01	0.06	0.010	0.17	0.000
RTHA								
1000 m	FOREST	254.80 (16.02)	273.54 (1.72)	-0.003	0.08	0.006	0.08	0.006
564 m	EARLY	9.70 (1.36)	6.72 (0.69)	0.01	0.06	0.016	0.06	0.016

[a]Only 3 detections of BWHA in non-breeding season (August to April), so not included in analyses.

Table 2.6. Mean and standard error of the 17 habitat variables at two landscape levels (564 m and 1000 m) for the presence/absence of Red-shouldered Hawks (RSHA), Broad-winged Hawks (BWHA), and Red-tailed Hawks (RTHA) during breeding and non-breeding seasons at 48 broadcast survey points on MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001.

Buffer	Variable	RSHA		BWHA		RTHA	
		Presence Mean(SE)	**Absence** Mean(SE)	**Presence** Mean(SE)	**Absence** Mean(SE)	**Presence** Mean(SE)	**Absence** Mean(SE)
Breeding							
1000 m	DEVELOP	0.01 (0.00)	0.02 (0.01)	0.03 (0.01)	0.01 (0.00)	0.02 (0.01)	0.01 (0.01)
	ROAD	10.32 (0.75)	10.17 (0.29)	10.34 (0.43)	10.13 (0.34)	10.60 (0.38)	9.94 (0.37)
	WATER	1.55 (0.12)	1.57 (0.08)	1.66 (0.14)	1.51 (0.08)	1.55 (0.10)	1.58 (0.10)
	GRASS	5.64 (0.96)	4.84 (0.82)	6.20 (1.43)	4.24 (0.78)	5.42 (1.31)	4.63 (0.83)
	EARLY	26.22 (2.68)	20.37 (1.07)	21.92 (1.88)	21.03 (1.20)	22.87 (1.76)	20.35 (1.22)
	MSdecid	1.11 (0.71)	3.35 (0.91)	3.00 (1.27)	2.97 (0.98)	3.81 (1.46)	2.43 (0.86)
	LSdecid	208.26 (13.47)	200.91 (5.34)	207.43 (7.97)	199.23 (6.33)	193.43 (7.81)	275.33 (1.97)
	Lsconifer	59.66 (13.45)	71.33 (5.94)	61.99 (8.42)	73.44 (7.02)	74.86 (8.80)	65.80 (6.91)
	FOREST	254.74 (14.90)	273.79 (1.75)	271.05 (2.50)	270.37 (4.31)	263.42 (6.61)	275.33 (1.97)
	NFP	9.63 (1.40)	11.24 (0.91)	13.18 (1.79)	9.76 (0.72)	12.02 (1.15)	10.28 (1.09)
	MPSFOREST	34.94 (5.18)	38.91 (3.07)	34.52 (4.29)	40.29 (3.45)	32.78 (3.87)	41.83 (3.62)
	TCA	150.62 (8.07)	158.06 (4.24)	151.24 (6.71)	159.87 (4.53)	149.86 (5.36)	161.38 (5.11)
	MPSTCA	41.39 (6.95)	47.75 (2.94)	43.49 (4.58)	48.44 (3.36)	44.06 (3.94)	48.41 (3.67)
	ED	145.03 (11.17)	148.68 (4.57)	149.20 (7.27)	147.45 (5.22)	155.18 (6.12)	143.41 (5.68)
	SDI	0.92 (0.04)	0.92 (0.02)	0.92 (0.02)	0.92 (0.02)	0.97 (0.02)	0.90 (0.02)
	SEI	0.49 (0.02)	0.50 (0.01)	0.51 (0.01)	0.50 (0.01)	0.53 (0.01)	0.48 (0.01)
	DISwater	285.37 (43.27)	235.41 (15.69)	203.84 (25.43)	265.61 (18.03)	248.49 (21.50)	240.61 (20.49)
564 m	DEVELOP	0.01 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	ROAD	3.31 (0.22)	3.16 (0.18)	3.36 (0.20)	3.15 (0.19)	3.04 (0.37)	3.25 (0.15)
	WATER	0.53 (0.04)	0.52 (0.06)	0.57 (0.10)	0.50 (0.03)	0.40 (0.06)	0.55 (0.05)
	GRASS	0.80 (0.25)	1.09 (0.29)	1.21 (0.40)	0.85 (0.21)	1.46 (0.53)	0.88 (0.21)
	EARLY	6.86 (1.09)	7.44 (0.76)	7.47 (0.99)	7.08 (0.81)	10.31 (1.67)	6.64 (0.66)
	MSdecid	1.73 (0.77)	0.30 (0.15)	1.00 (0.56)	0.79 (0.38)	0.00 (0.00)	1.02 (0.38)
	LSdecid	58.53 (3.36)	66.65 (2.62)	65.76 (3.22)	62.16 (2.72)	64.19 (5.76)	63.30 (2.26)
	Lsconifer	27.66 (3.59)	20.31 (2.67)	20.14 (3.07)	24.90 (2.91)	20.03 (5.75)	23.81 (2.35)
	FOREST	83.95 (2.37)	85.32 (1..74)	81.43 (2.92)	86.61 (1.43)	84.06 (2.00)	84.81 (1.62)
	NFP	4.73 (0.53)	4.50 (0.34)	4.64 (0.39)	4.56 (0.40)	4.46 (0.58)	4.62 (0.33)
	MPSFOREST	25.84 (2.22)	25.73 (2.21)	22.09 (1.56)	27.79 (2.28)	27.87 (6.03)	25.39 (1.54)
	TCA	48.81 (2.47)	50.95 (2.08)	48.00 (2.46)	51.26 (2.05)	48.50 (4.27)	50.40 (1.71)
	MPSTCA	26.81 (3.02)	29.16 (2.77)	22.57 (2.22)	31.33 (2.86)	29.03 (5.87)	28.08 (5.89)
	ED	157.17 (8.25)	140.90 (7.05)	140.67 (8.07)	150.99 (7.09)	142.89 (4.27)	148.16 (5.89)
	SDI	0.89 (0.04)	0.80 (0.03)	0.84 (0.05)	0.83 (0.03)	0.85 (0.06)	0.83 (0.03)
	SEI	0.51 (0.02)	0.46 (0.02)	0.48 (0.03)	0.48 (0.02)	0.48 (0.03)	0.48 (0.02)
	DISwater	248.49 (21.50)	234.70 (20.23)	193.75 (24.34)	265.61 (18.03)	296.48 (44.71)	292.73 (15.37)

Table 2.6 cont.

Buffer	Variable	RSHA		BWHA		RTHA	
		Presence Mean(SE)	**Absence** Mean(SE)	**Presence** Mean(SE)	**Absence** Mean(SE)	**Presence** Mean(SE)	**Absence** Mean(SE)
Non-breeding							
1000 m	DEVELOP	0.03 (0.01)	0.01 (0.00)	0.03 (0.01)	0.01 (0.00)	0.02 (0.02)	0.02 (0.00)
	ROAD	10.75 (0.38)	9.91 (0.35)	10.26 (0.57)	10.18 (0.31)	10.22 (0.52)	10.20 (0.30)
	WATER	1.74 (0.15)	1.47 (0.08)	1.69 (0.17)	1.53 (0.08)	1.67 (0.14)	1.55 (0.08)
	GRASS	5.90 (1.42)	4.43 (0.80)	8.39 (1.67)	3.91 (0.76)	5.33 (1.69)	4.87 (0.80)
	EARLY	21.79 (1.56)	21.12 (1.32)	23.72 (2.08)	20.64 (1.16)	23.13 (1.75)	21.02 (1.16)
	MSdecid	3.38 (1.39)	2.77 (0.93)	3.97 (1.76)	2.68 (0.86)	3.38 (2.50)	2.90 (0.80)
	LSdecid	184.52 (7.78)	211.36 (6.09)	212.48 (9.53)	199.05 (5.76)	209.22 (9.90)	200.82 (5.60)
	Lsconifer	84.44 (8.88)	61.50 (6.67)	52.02 (9.49)	74.55 (6.37)	59.59 (10.69)	71.20 (6.12)
	FOREST	270.68 (2.60)	270.58 (4.24)	266.15 (2.89)	271.94 (3.68)	254.80 (16.02)	273.54 (1.72)
	NFP	13.61 (1.82)	9.58 (0.72)	13.36 (1.95)	10.26 (0.85)	9.80 (1.65)	11.19 (0.90)
	MPSFOREST	34.06 (4.72)	40.44 (3.23)	26.87 (2.92)	41.63 (3.29)	35.64 (5.78)	38.73 (3.02)
	TCA	146.42 (7.07)	162.26 (4.28)	140.29 (6.48)	161.73 (4.36)	157.44 (8.67)	156.70 (4.20)
	MPSTCA	39.91 (3.83)	50.24 (3.54)	34.84 (3.86)	50.21 (3.21)	43.36 (6.19)	47.31 (3.00)
	ED	164.64 (5.97)	139.29 (5.32)	145.40 (8.15)	148.87 (4.93)	141.76 (8.20)	149.23 (4.77)
	SDI	1.01 (0.02)	0.88 (0.02)	0.93 (0.04)	0.92 (0.02)	0.94 (0.03)	0.92 (0.02)
	SEI	0.54 (0.01)	0.48 (0.01)	0.51 (0.02)	0.50 (0.01)	0.51 (0.02)	0.50 (0.01)
	DISwater	242.36 (23.19)	244.45 (19.41)	175.01 (29.26)	264.16 (16.71)	222.98 (40.46)	247.57 (16.14)
564 m	DEVELOP	0.01 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
	ROAD	3.24 (0.25)	3.20 (0.17)	3.44 (0.28)	3.15 (0.16)	2.99 (0.32)	3.27 (0.15)
	WATER	0.55 (0.05)	0.51 (0.06)	0.54 (0.05)	0.52 (0.05)	0.56 (0.06)	0.52 (0.05)
	GRASS	1.40 (0.44)	0.76 (0.20)	1.28 (0.47)	0.89 (0.22)	0.94 (0.44)	0.98 (0.22)
	EARLY	7.03 (0.99)	7.31 (0.81)	9.21 (1.21)	6.62 (0.72)	9.70 (1.36)	6.72 (0.69)
	MSdecid	1.60 (0.72)	0.48 (0.31)	0.82 (0.40)	0.88 (0.40)	1.82 (1.29)	0.67 (0.29)
	LSdecid	54.70 (3.61)	68.01 (2.39)	68.11 (3.58)	62.04 (2.49)	64.00 (4.43)	63.32 (2.36)
	Lsconifer	29.16 (2.62)	19.20 (2.49)	16.01 (3.22)	25.36 (2.61)	19.42 (4.16)	23.98 (2.47)
	FOREST	81.00 (3.20)	86.76 (1.82)	77.00 (4.17)	87.09 (1.23)	83.97 (1.46)	84.94 (1.66)
	NFP	4.57 (0.53)	4.60 (0.35)	4.41 (0.45)	4.65 (0.36)	4.25 (0.54)	4.66 (0.34)
	MPSFOREST	26.18 (2.36)	25.56 (2.10)	22.85 (2.10)	26.65 (1.96)	27.94 (5.56)	25.34 (1.57)
	TCA	46.74 (3.03)	51.87 (1.80)	44.23 (2.84)	51.85 (1.84)	49.01 (3.42)	50.33 (1.78)
	MPSTCA	27.29 (3.81)	28.72 (2.42)	19.93 (2.38)	30.70 (2.50)	29.43 (5.51)	27.99 (2.21)
	ED	167.90 (7.93)	136.56 (6.75)	141.17 (8.68)	149.17 (6.53)	139.27 (12.95)	148.95 (5.96)
	SDI	0.94 (0.04)	0.78 (0.03)	0.85 (0.06)	0.83 (0.03)	0.92 (0.06)	0.82 (0.03)
	SEI	0.53 (0.02)	0.46 (0.02)	0.47 (0.03)	0.49 (0.02)	0.52 (0.03)	0.47 (0.01)
	DISwater	242.36 (23.19)	239.00 (19.20)	159.41 (26.01)	264.16 (16.71)	237.08 (40.39)	240.77 (15.99)

Table 2.7. Mean and standard error (SE) of the 17 habitat variables at two landscape levels (1000 m and 564 m) for presence/absence of Barred Owls on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001.

		Barred Owl					
Buffer	**Variable**	**Presence**		**Absence**		**T Value**	***P***
		Mean	**SE**	**Mean**	**SE**		
1000 m	ROAD	10.32	0.51	10.25	0.68	-0.03	0.97
	WATER	1.61	0.14	1.46	0.20	-0.42	0.67
	DEVELOPE	0.03	0.02	0.06	0.05	0.75	0.45
	GRASS	3.46	1.57	6.36	3.11	0.94	0.35
	EARLY	19.35	2.05	14.64	3.46	-1.29	0.20
	MSDECID	1.97	1.25	3.84	2.56	0.72	0.47
	LSDECID	205.40	8.02	181.68	16.69	-0.67	0.50
	LSCONIFER	70.44	9.68	94.28	21.05	1.22	0.23
	FOREST	277.95	2.80	277.41	6.18	0.03	0.98
	MPSFOREST	63.08	12.21	50.68	14.27	-0.44	0.66
	TFP	9.00	1.78	10.68	3.23	0.39	0.70
	TCA	161.19	7.73	150.56	13.20	-0.33	0.78
	MPSTCA	50.85	5.83	45.82	8.53	-0.29	0.77
	ED	155.61	8.61	181.25	16.38	1.68	0.11
	SDI	0.95	0.03	0.94	0.04	-0.38	0.71
	SEI	0.51	0.01	0.51	0.02	-0.24	0.81
	DISWATER	182.69	24.53	219.48	46.31	1.11	0.27
564 m	ROAD	4.34	0.00	4.34	0.40	-0.03	0.97
	WATER	0.46	0.07	0.43	0.12	-0.42	0.67
	DEVELOPE	0.00	0.00	0.01	0.01	0.75	0.45
	GRASS	0.57	0.27	0.80	0.55	0.94	0.35
	EARLY	9.85	1.84	7.46	2.40	-1.29	0.20
	MSDECID	0.00	0.00	0.00	0.00	0.72	0.47
	LSDECID	60.72	3.35	54.83	6.72	-0.67	0.50
	LSCONIFER	23.48	3.92	31.55	7.57	1.22	0.23
	FOREST	84.66	1.78	86.80	2.14	0.03	0.98
	MPSFOREST	24.39	3.09	26.76	4.40	-0.44	0.66
	TFP	4.63	0.63	4.44	1.14	0.39	0.70
	TCA	40.80	2.49	39.02	3.75	-0.33	0.78
	MPSTCA	16.19	1.50	17.08	2.76	-0.29	0.77
	ED	161.40	10.82	189.54	24.89	1.68	0.11
	SDI	0.93	0.04	0.90	0.06	-0.38	0.71
	SEI	0.54	0.02	0.52	0.03	-0.24	0.81
	DISWATER	182.69	24.53	219.48	46.31	1.11	0.27

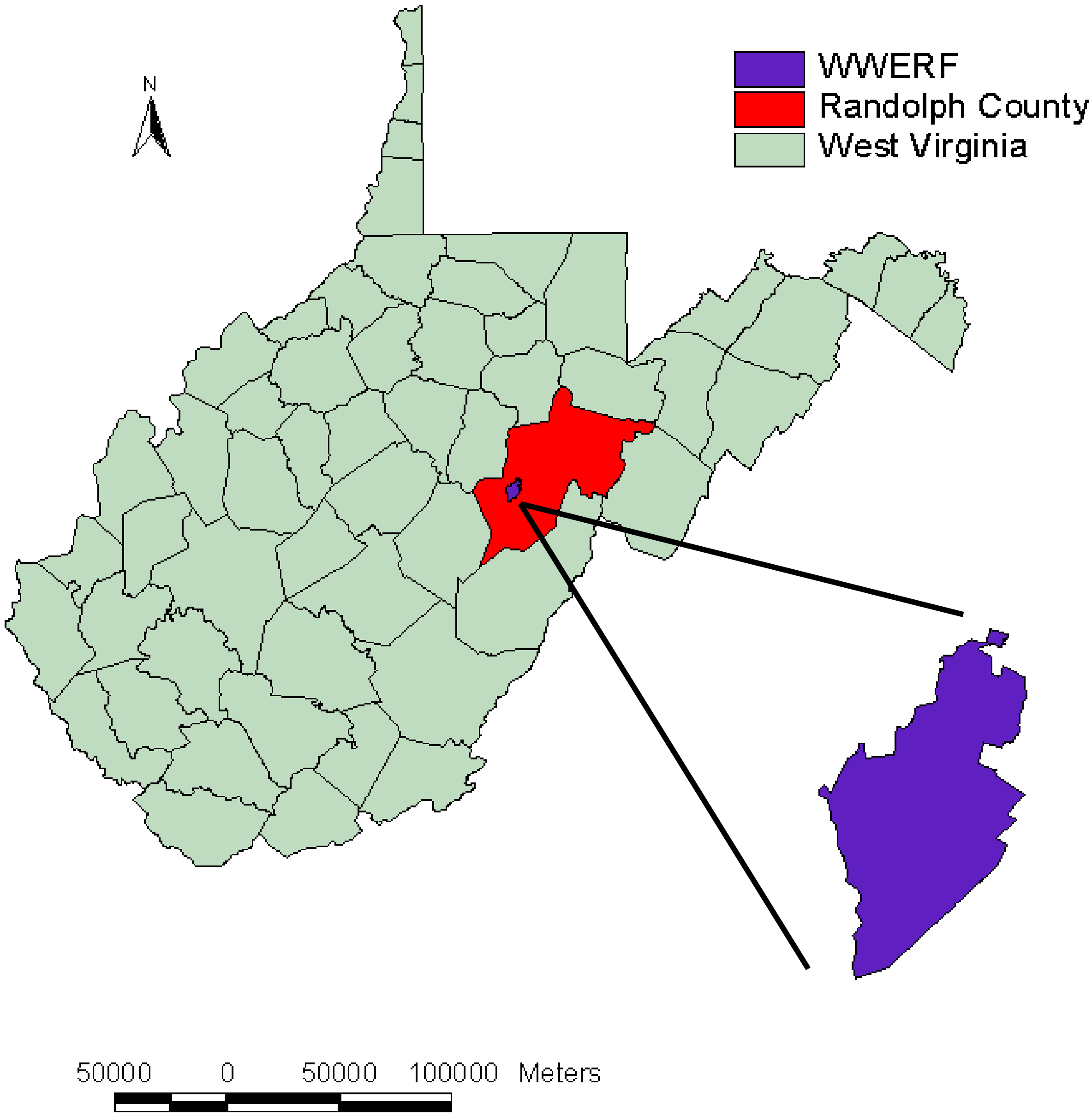

Figure 2.1. Location of the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia.

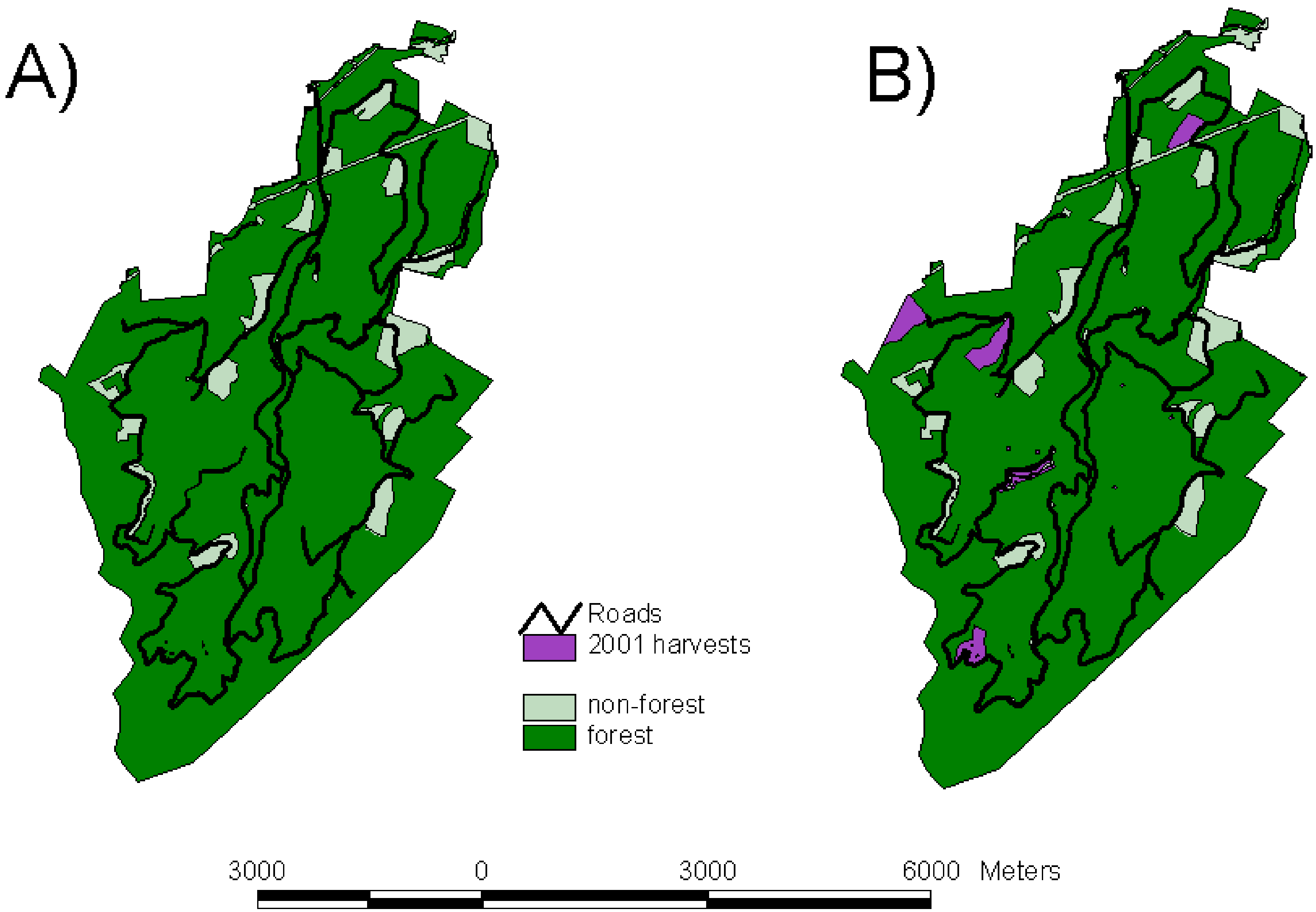

Figure 2.2. Disturbance patterns on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during (A) 2000 and (B) 2001.

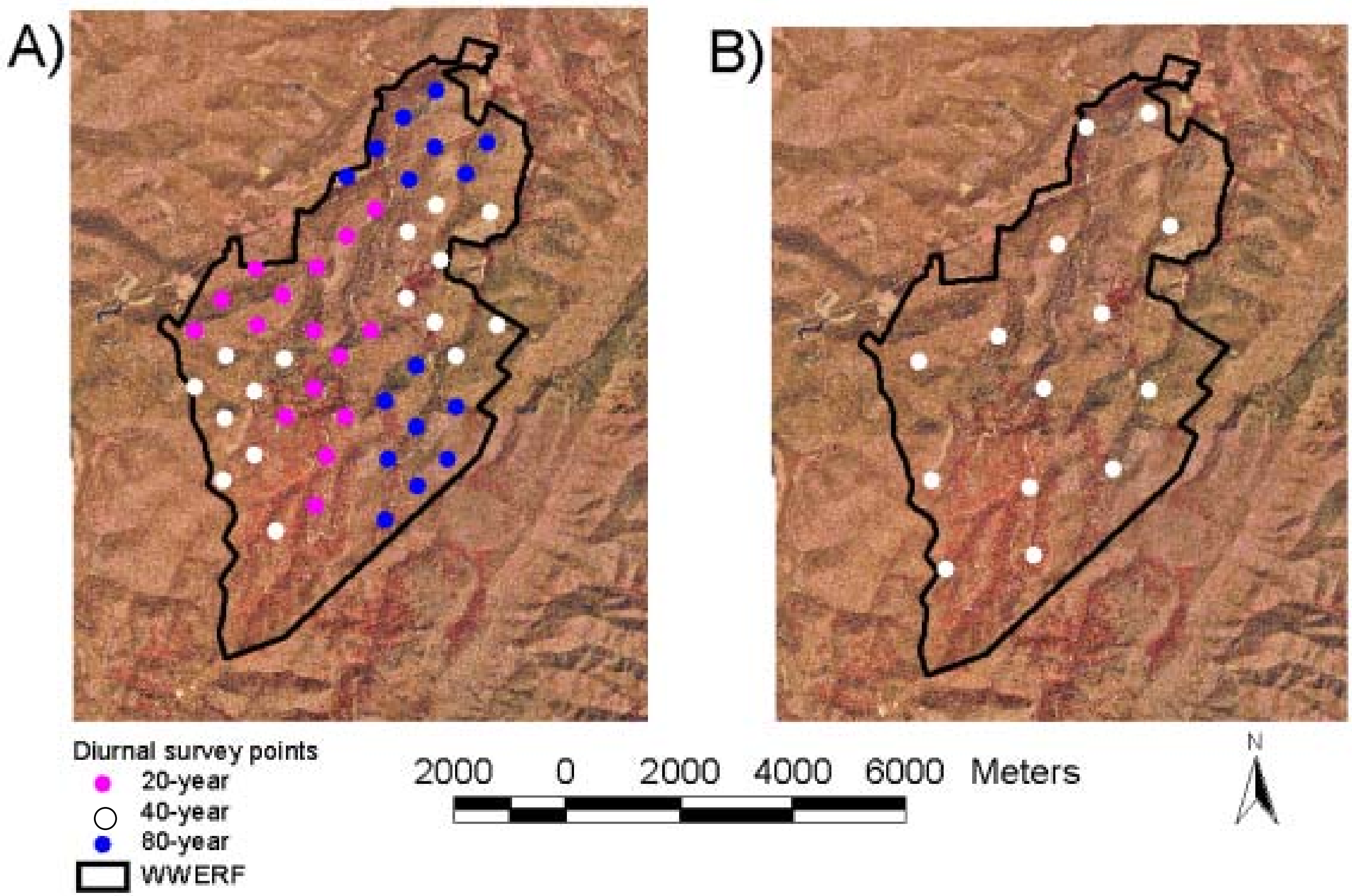

Figure 2.3. Location of A) diurnal broadcast survey points for 3 harvesting treatments and B) nocturnal broadcast survey points on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001.

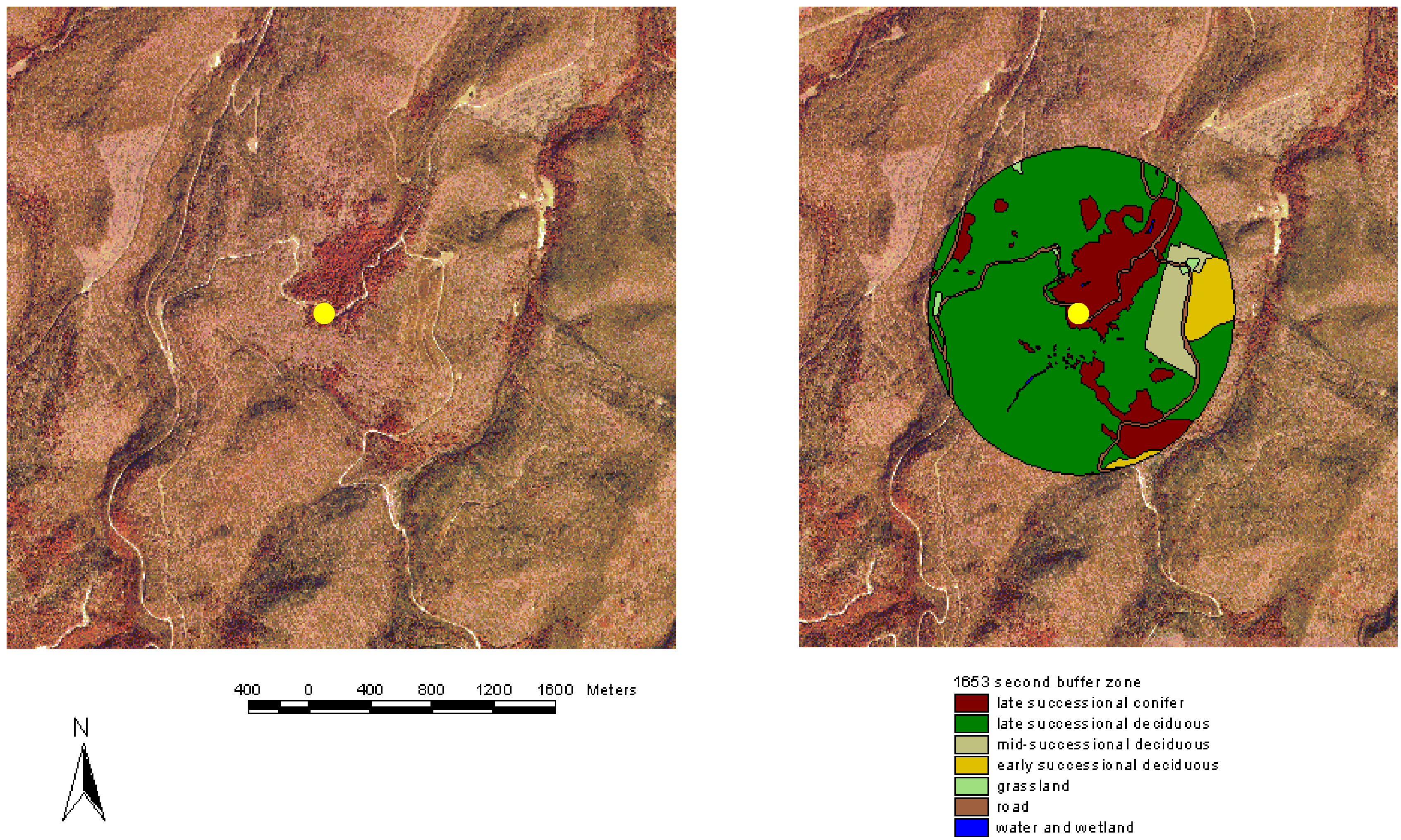

Figure 2.4. Example of a digitized broadcast survey point on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001.

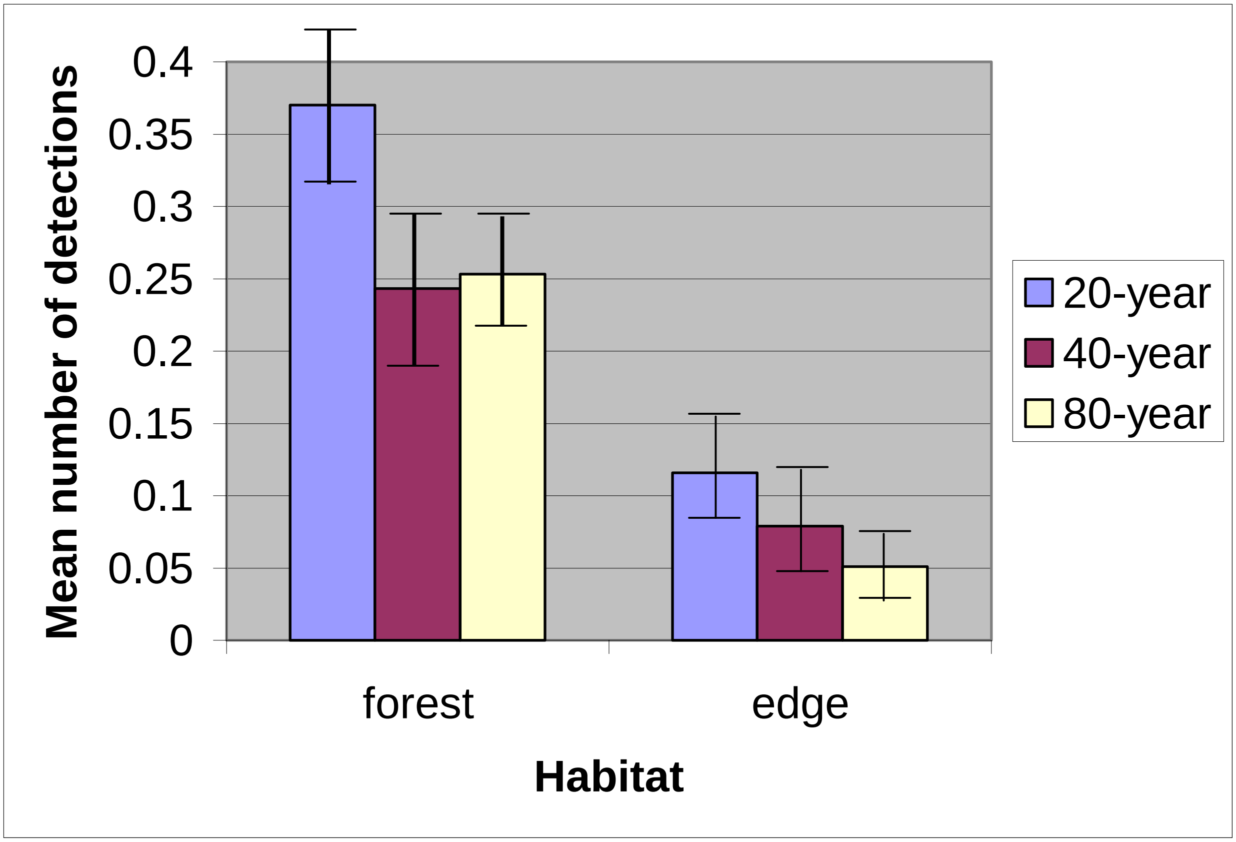

Figure 2.5. Mean total abundance of raptors by treatment for forest-dwelling (F = 2.45, *P* = 0.23) and edge-dwelling (F = 1.37, *P* = 0.38) species, regardless of season, on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001.

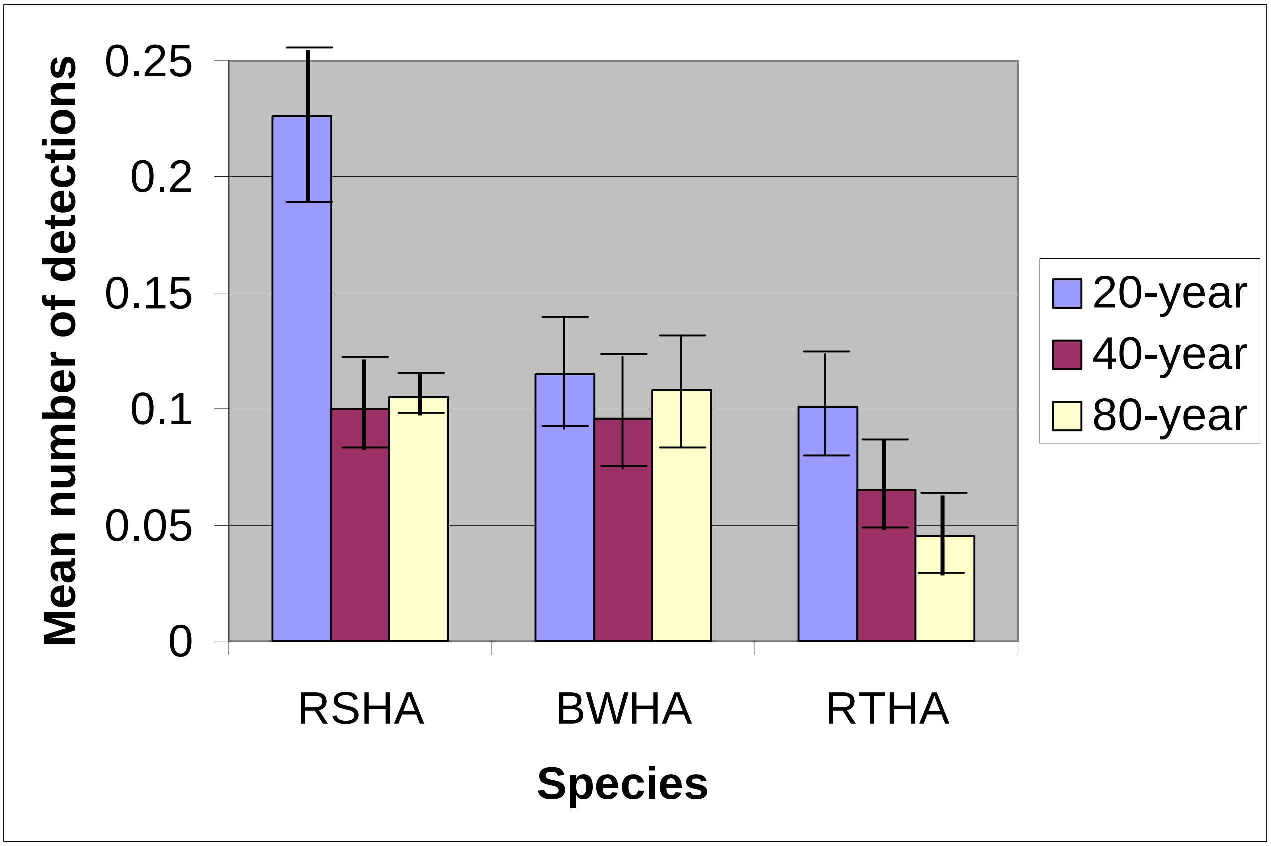

Figure 2.6. Mean total abundance of the most abundant species, Red-shouldered Hawk (RSHA; F = 5.36, *P* = 0.10), Broad-winged Hawk (BWHA; F = 0.15, *P* = 0.87), and Red-tailed (RTHA; F = 1.16, *P* = 0.42), by treatment, regardless of season, on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001.

CHAPTER 3:

COMPARISON OF SURVEY METHODS FOR NOCTURNAL RAPTORS ON AN INDUSTRIAL FOREST IN CENTRAL WEST VIRGINIA

ABSTRACT

During the summers of 2000-2001, I examined the efficiency of three different broadcast survey protocols for multiple owl species: species-specific (A), Barred Owl (*Strix varia*; B), and multiple species (C). I surveyed for owls monthly from May – August at 14 points located along gravel roads throughout an intensively managed, industrial forest in the central Appalachian Mountains of West Virginia. Overall, I detected four species of owls over the 2-yr period. Barred Owls were the most commonly detected species (*n* = 58 responses) for all protocols combined and were detected at the most points (*n* = 13) with Protocol B. Of the three protocols examined, the protocol using a Barred Owl vocalization appeared to be most effective in eliciting responses from multiple species and was the most time efficient.

INTRODUCTION

Many forest-dwelling raptor species are secretive and the characteristics affecting their detectability by humans are numerous (Takats and Holroyd 1987). Broadcast surveys are an effective method for surveying targeted individual owl species (Clark 1988, Belthoff and Ritchison 1989, Erdman and Brinker 1997, Evans 1997). However, many owl species respond infrequently when vocalizations of other species are used (Evans 1997). Accordingly, conspecific vocalizations have been found to be useful to survey for Barred Owls (*Strix varia*; Clark 1988), Eastern Screech-owls (*Otus asio*; Belthoff and Ritchison 1989), and Northern Saw-whet Owls (*Aegolius acadicus*; Erdman and Brinker 1997, Evans 1997).

Owls, as well as other raptors, are important biomonitors, because they may provide an indication of toxic contaminants and changes in habitat that impact lower tropic (prey) species (Sheffield 1997). Monitoring owl populations can provide an understanding of the effects of disturbance and alterations of habitat to other wildlife species. However, inadequate information is available for surveying multiple species of owls at the same time (Takats et al. 2001). Due to inadequate monitoring methods, abundance and populations trends of most owl species are poorly understood (Takats et al. 2001). Therefore, the objective of this study was to compare survey protocols for nocturnal species of owls to improve methods for monitoring owl populations.

STUDY SITE

I conducted this research on the MeadWestvaco Wildlife and Ecosystem Research Forest (MWERF) near Adolph (38° 42' latitude and 80° 3' longitude) in Randolph County, West Virginia (Figure 2.1). The MWERF is a 3,413-ha second growth forest and was established in 1994 by MeadWestvaco as an area to investigate the impacts of modern and intensive forest management on various ecological processes in an Appalachian setting. This site provided a unique opportunity to examine responses of a raptor community to habitat changes in an intensively managed forest.

Elevations on the MWERF ranged from 740-1200 m (Fenneman 1938). Climate was described as moist and cool with average rainfall and snowfall of 114 cm and 150 cm, respectively (Strausbaugh and Core 1977). Soils were acidic and typically well-drained (Stephenson 1993). Forest cover was described as Allegheny hardwood-northern hardwood at higher elevations, and cove-hardwood and mixed mesophytic at lower elevations (Eyre 1980). The Allegheny hardwood-northern hardwood forest type was dominated primarily by yellow birch (*Betula alleghaniensis*), American beech (*Fagus grandifolia*), sugar maple (*Acer sacharrum*), red maple (*A. rubrum*), black cherry (*Prunus serotina*), red spruce (*Picea rubens*), white ash (*Fraxina americana*), and Fraser's magnolia (*Magnolia fraseri*). At lower elevations, species include tuliptree (*Liriodendron tulipifera*), sweet birch (*Betula lenta*), northern red oak (*Quercus rubra*), and American basswood (*Tilia americana*). Riparian areas of the forest were a mixture of red spruce, eastern hemlock (*Tsuga canadensis*), and rosebay rhododendron (*Rhododendron maximum*). The shrub layer throughout the forest consisted of rosebay rhododendron and striped maple (*Acer pennsylvanicum*). The southern portion of the forest contained a mixture of red spruce and eastern hemlock, and reaches the highest elevations on the MWERF (Ford and Rodrigue 2001).

METHODS

Broadcast surveys for owls were conducted from Jun-Jul 2000 and Jun-Aug 2001 at 14 survey points established along the extensive road system (Figure 3.1). The points were divided into two routes and each survey night the route and direction were randomly selected. Surveys were conducted once a month centered within the 2 wk period prior to and following the new moon (Takats et al. 2001). Each 10 min survey was conducted with two observers from approximately 2000 to 0000 EST when activity is typically closest to the core of an owl pair's home range (Clark 1988, Takats and Holroyd 1997). The primary observer wore a headlamp with a red parafilm filter. Equipment included a Radioshack® Optimus tape player (CTR-116) attached to a TOA Transitor® megaphone speaker. I was responsible for the primary observations and recording data, while a second observer held the speaker approximately 1.5 m above the ground. Vocalizations were broadcast between 90-100 db (measured 1 m from speaker).

I used broadcast protocols modified from Fuller and Mosher (1987). The general protocol called for six 20 sec vocalizations each followed by a 40 sec listening period for the first 5 min 20 sec of the survey. The last 4 min 40 sec of the survey was a silent listening period. Three variations of this protocol were used and involved changing the vocalizations to a different species or suite of species. I made tapes using vocalizations from Peterson Field Guide to Bird Songs of Eastern and Central North American® (Peterson Field Guide Series 1990).

Protocol A was the general protocol used with conspecific vocalizations of Eastern Screech-owls and Barred Owls. The first two nights of surveys, Eastern Screech-owl vocalizations were used to survey all points. The next two nights, Barred Owl vocalizations were used at each point. Protocol B used only Barred Owl vocalizations to survey for multiple species of owls. Therefore, Protocol A required twice as much time to complete as Protocol B. In 2000, I compared Protocols A and B.

Protocol C included multiple species of owl vocalizations during one 10-min survey period: two Northern Saw-whet Owl, the next two Eastern Screech-owl, and the last two Barred Owl. Between each species' vocalizations was a 1 min listening period, which extended the vocalization period to 6 min and the final listening period decreased to 4 min. At each survey point, Protocol B or C was chosen randomly by flipping a coin. Once all points were surveyed, the entire route was completed again using the alternate protocol. In 2001, I compared Protocols B and C.

Because weather also can affect detectability of owls (Fuller and Mosher 1987, Smith 1990), I followed the Breeding Bird Survey (BBS) protocol for acceptable weather conditions during typical bird surveys (Sauer 2000). I did not conduct surveys during constant precipitation, when wind speeds were >3 on the Beaufort scale (i.e., 13-19 km/h when leaves and twigs are in constant motion), or in the presence of heavy fog. In addition to the species, time, and type of detection, I recorded wind speed, temperature, cloud cover, and moon phase.

Statistical Analyses. I used analysis of variance (ANOVA), using Statistical Analysis Software V. 8.0 (SAS 2001)®, to compare the mean abundance and owl species richness detected with the Barred Owl vocalization (Protocol B) between years, in 2000 to compare Protocols A and B, and to compare Protocols B and C for 2001. Abundance and richness were dependent variables in the ANOVA model, while protocol and year (when applicable) were the independent variables. Mean abundance was calculated as the mean response number of each species for each survey for each protocol. Species richness was defined as the species number detected in each protocol. I used Pearson product-moment correlation analysis (PROC CORR in SAS® V8) to determine if there was a relationship between owl presence and cloud cover, temperature, and wind. Aspect data was linearly transformed (Odem et al. 2001). Differences were considered significant when $P < 0.05$ for all analyses.

RESULTS

During 2000 – 2001 surveys, four species of owls were detected on the MWERF (Table 3.1). Owls responded during 52 (40%) of the 130 surveys conducted. The most common species detected was the Barred Owl with 58 responses (Table 3.2). Other species detected were Eastern Screech-owl (n = 6), Northern Saw-whet Owl (n = 1), and Great Horned Owl (n = 1). For all protocols in both years, >52% of the responses were detected during the listening segment of the surveys. Response types consisted of perch and call (79.2%), fly and call (19.4%), and silent perch (1.4%). I found no significant correlation between all owl responses combined and cloud cover ($r = 0.17$, $P = 0.06$), temperature ($r = 0.02$, $P = 0.32$), and wind speed ($r = 0.09$, $P = 0.79$).

When I compared Protocols A and B in 2000 (Table 3.2), there were no significant differences in the abundance of all owls detected (F = 1.42, $P = 0.65$) or in the abundance of Barred Owl responses (F = 2.12, $P = 0.59$). I detected three species with Protocol A and two species with Protocol B. Protocol A (species-specific) elicited responses at 78.6 % of the points. Protocol B (Barred Owl only) elicited responses at 71.4 % of the points.

In 2001, I compared Protocols B and C (Table 3.2) and found no significant difference in the abundance of all owls detected (F = 0.08, $P = 0.52$) or in the abundance of Barred Owl responses (F = 0.02, $P = 0.42$). Two species were detected with each protocol. Protocol C (multiple species) elicited responses at 85.7 % of the points, while Protocol B had responses at 57.1 % of the points.

When comparing Protocol B between years (2000 and 2001), I found no significant differences in the abundance of Barred Owl responses (F = 0.31, $P = 0.57$) or in the total number of owls detected (F = 0.13, $P = 0.71$). Two species were detected each year; three different species over the two years.

DISCUSSION

Based on my study, nocturnal avian predators are numerous, and therefore, may have as much of an ecological effect on populations of potential prey communities as their diurnal counterparts in the central Appalachian Mountains. Methods for long-term or large-scale monitoring of any wildlife should be developed such that it can be easily applied and understood (Takats et al. 2001). Surveys were conducted to gain an understanding of nocturnal raptor species assemblage within the scope of an active industrial forest, and to determine an efficient survey method for owls in the central Appalachian Mountains. Barred Owl vocalizations were effective for surveying multiple species of owls: three species responded. Eastern Screech-owls were not detected with this vocalization, however this is not surprising because Barred Owls are a known predator of this species (Gehlbach 1995). Interestingly, a Northern Saw-whet Owl responded even though they are also a potential prey item for Barred Owls.

Few Great Horned Owls were detected during my surveys, regardless of the protocol used. Morrell and Yahner (1994) found that Great Horned Owls tend to be associated with fragmented landscapes in Pennsylvania because they are forest habitat generalists. During my surveys, the MWERF was relatively unfragmented and Great Horned Owls appeared to be rare. Additional factors that could explain the lack of Great Horned Owl responses are that the surveys were not targeted for the species, surveys were conducted late in their breeding cycle, and/or that Great-horned Owl responses were silent and therefore, not detected. To survey for Great Horned Owls, routes should be established and surveyed from late winter (January) to late spring (May; Morrell and Yahner 1994); my surveys were conducted primarily during summer months.

Time can be a limiting factor when monitoring any wildlife species. Protocol A was more time consuming than other protocols used in this study, requiring at least one night for each vocalization used. Protocol B and C required the same amount of time to conduct surveys, but Protocol B elicited responses from a more diverse group of owl species, indicating it is the preferred protocol for the MWERF. Cost is often another limiting factor when monitoring wildlife species. Protocol A required more time to complete, and is therefore a more expensive survey alternative (i.e., personnel time). A protocol such as B or C can reduce costs, as well as time involved by only conducting the route once. Regardless of time and costs, monitoring of wildlife populations may become a requirement by regulatory agencies and efficient survey methods should be developed.

Survey methods must be easily deployable and effective at sampling. In the Appalachian Mountains, surveyors should take advantage of roads, access such as abandoned skidder trails, and other forms of disturbance. My study demonstrates that multiple nocturnal raptors can be detected with a variety of survey methods. I detected responses from Barred Owls most often using each of the three protocols, which suggests that Barred Owls are an abundant nocturnal predator in the region. However, to determine the most effective survey method, longer-term monitoring is needed to examine time allocated, costs incurred, and responses detected over a broad array of circumstances.

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Table 3.1. Owl species detected for each nocturnal survey protocol (n = 3) in summers 2000 and 2001 on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia (n = 14 survey points).

Protocol	Species detected	% of points with responses
2000		
A: Conspecific Vocalizations		
Eastern Screech-owl	Eastern Screech-owl	14.3
	Barred Owl	14.3
	Unknown	7.1
Barred Owl	Northern Saw-whet Owl	7.1
	Barred Owl	71.4
Combined[a]	Eastern Screech-owl	14.3
	Barred Owl	78.6
	Northern Saw-whet Owl	7.1
	Unknown	7.1
B: Barred Owl	Northern Saw-whet Owl	7.1
	Barred Owl	71.4
2001		
B: Barred Owl	Barred Owl	57.1
	Great Horned Owl	7.1
	Unknown	21.4
C: Multiple Species[b]	Eastern Screech-owl	28.6
	Barred Owl	78.6

[a]Used for comparison with Protocol B in 2000.
[b]Northern Saw-whet Owl, Eastern Screech-owl, and Barred Owl vocalizations.

Table 3.2. Total detections (n), mean abundance (mean), and standard error (SE) for all owl species detected using three broadcast survey methods on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during summers 2000 and 2001.

	Protocol A			Protocol B						Protocol C		
				2000			2001					
Species	n	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE
Northern Saw-whet Owl	1	0.02	0.02	1	0.01	0.01	0	0.00	0.00	0	0.00	0.00
Eastern Screech-owl	2	0.04	0.03	0	0.00	0.00	0	0.00	0.00	4	0.10	0.05
Barred Owl	23	0.48	0.10	21	0.56	0.09	18	0.42	0.11	17	0.40	0.11
Great Horned Owl	0	0.00	0.00	0	0.00	0.00	1	0.02	0.02	0	0.00	0.00
Unknown	1	0.02	0.02	0	0.00	0.00	4	0.10	0.06	0	0.00	0.00
Overall Abundance	**27**	**0.57**	**0.10**	**22**	**0.79**	**0.15**	**23**	**0.55**	**0.12**	**21**	**0.50**	**0.12**
Richness[a]	**3**			**2**			**2**			**2**		

[a]Protocols were not used in both years, so ANOVA was not performed on these data. Unknowns were not included in estimate.

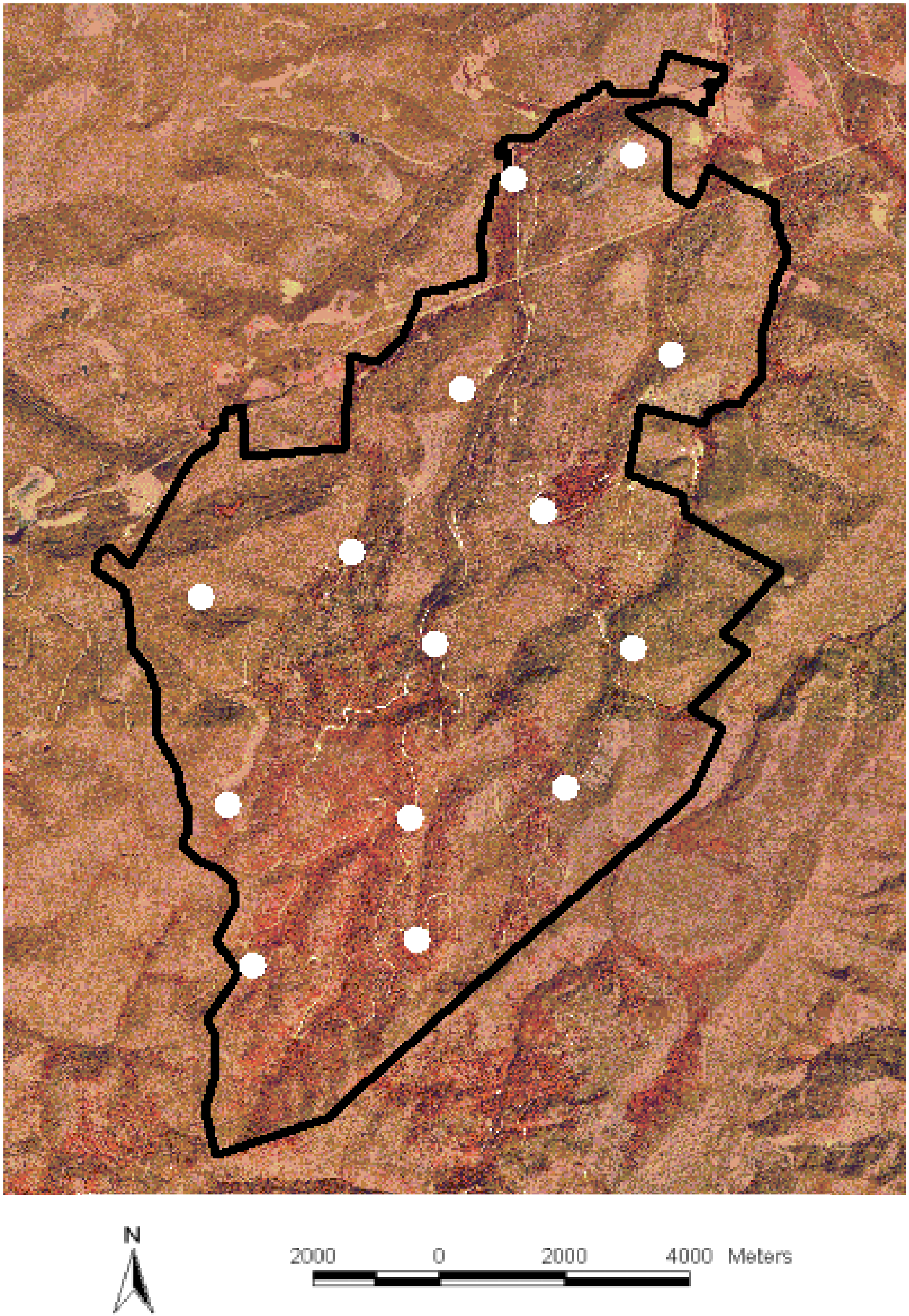

Figure 3.1. Location of nocturnal broadcast survey points on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001.

CHAPTER 4:

ECOLOGY AND HABITAT CHARACTERISTICS OF NESTING DIURNAL RAPTORS ON AN INDUSTRIAL FOREST IN CENTRAL WEST VIRGINIA

ABSTRACT

I examined prey delivery rates and prey species composition at three diurnal raptor nests: a Red-tailed Hawk nest (*Buteo jamacensis*), a Red-shouldered Hawk nest (*B. lineatus*), and a Broad-winged Hawk nest (*B. platypterus*) on the MeadWestvaco Wildlife and Ecosystem Research Forest (MWERF) in the central Appalachian Mountains of West Virginia. I also examined habitat characteristics at three spatial scales (microhabitat, home range, and landscape levels) for 14 nests (Red-tailed Hawks, $n = 5$; Red-shouldered Hawks, $n = 4$; Broad-winged Hawks, $n = 4$; Northern Goshawk [*Accipiter gentilis*], $n = 1$). Red-shouldered Hawk diets consisted of mammals (85.1%) delivered at a rate of 0.74 items/hr. Red-shouldered Hawks used grassland (grassed log landings and herbaceous openings) significantly less than available, suggesting a choice of nest sites with less disturbance. For Broad-winged Hawks, I found 68.1% of the diet to be mammalian and 22.4% to be herpetofaunal delivered at a rate of 0.81 items/hr. Broad-winged Hawks used sites with less mid-successional deciduous forest than available. For Red-tailed Hawks, 82.7% of the diet was mammals delivered at a rate of 0.30 items/hr. Red-tailed Hawks used late-successional deciduous forests significantly more and mid-successional deciduous forests significantly less than available, coinciding with the lower elevation nest sites on the MWERF. Results from my study were similar to other Appalachian studies on forest-dwelling raptors. My results suggest that at current levels of disturbance, forest-dwelling raptors nest and successfully breed on an active, industrial forest.

INTRODUCTION

Raptor abundance and distribution can be affected by the availability of suitable nesting habitat (Newton 1979). A mixture of early and late successional habitats can help maintain diversity of species, but lack of mature forest can limit nesting habitat for species such as Red-shouldered Hawks (*Buteo lineatus*, Cline 1990). Generally, studies of raptor abundance and habitat use that examine effects of increasing disturbance levels in intensively managed forests are lacking. This makes it difficult to predict impacts of forest management activities on the raptor community as a whole (Nelson and Titus 1988).

In the eastern United States, Red-shouldered Hawks tend to nest in mature deciduous or mixed coniferous forests associated with wetland or riparian areas (Bednarz and Dinsmore 1981, Titus and Mosher 1981), and prey mostly upon amphibians and mammals during the breeding season (Titus and Mosher 1981, Crocoll 1994, Howell and Chapman 1997). Red-shouldered Hawks also tend to use sites with little human development in many areas (Bosakowski et al. 1992). This species can lose territory to encroachment from Red-tailed Hawks (*B. jamaicensis*) in areas being logged (Bednarz and Dinsmore 1982, Bryant 1986). Nelson and Titus (1988) qualified this by suggesting that selective harvests and long cutting cycles may be beneficial for Red-shouldered Hawks because these areas leave potential nest trees and allow remaining trees to further mature.

Some raptor species are more tolerant to changes in their environment (Nelson and Titus 1988). Broad-winged Hawks (*B. platyterus*) often nest in managed forests (Goodrich et al. 1996) or in younger forests (Titus and Mosher 1981). Short harvest rotation schedules (>40 yrs) have been used to maintain this species (Goodrich et al. 1996). Clearcutting, although silviculturally preferred in some circumstances, creates unsuitable habitat for some woodland species of raptors (Gosse and Montevecchi 2001), but can benefit species that require open areas within their home range. Red-tailed Hawks prefer habitats that contain open areas and perches (Preston and Beane 1993), and have been found in logged stands but not in unlogged stands (Franzreb and Ohmart

1978). Moreover, several studies have documented Red-tailed Hawks nesting closer to developed areas than Red-shouldered Hawks (Bosakowski et al. 1992, Bednarz and Dinsmore 1982).

Northern Goshawks (*Accpitier gentilis*) on a commercial tree farm in Washington successfully nested in stands that did not receive commercial or pre-commercial thinning, and therefore, did not seem to tolerate canopy openings in nesting habitat (Bosakowski et al. 1999). Mannon and Meslow (1984) found similar results in that Northern Goshawks in Oregon were found only in old-growth stands. No nesting attempts in this study were located in areas of thinning, all were located in stands of the stem exclusion stage of development (Oliver and Larson 1996). However, Penteriani and Faivre (2001) concluded that Northern Goshawks would continue to nest in stands that had <30% canopy cover reduction in the nesting stand. This study recommended harvesting operations be conducted before the birds' courtship and egg-laying stage but could resume a few weeks after hatching. Grubb et al. (1998) noted that noise from logging operations may be less noticeable to Northern Goshawks than to humans, and consequently, harvesting effects may be temporary.

For forest-dwelling raptors, there is insufficient evidence to determine what level of timber harvest influences nesting and foraging success. My specific objectives were to (1) quantify prey delivery rates and prey species composition on an active, industrial forest, and (2) quantitatively describe habitat characteristics at multiple spatial scales for nesting raptors.

STUDY SITE

I conducted research on the MeadWestvaco Wildlife and Ecosystem Research Forest (MWERF) near Adolph (38° 42' latitude and 80° 3' longitude) in Randolph County, West

Virginia. The MWERF is a 3,413-ha second growth forest and was established in 1994 as an area to investigate the impacts of modern and intensive forest management on ecological processes in an Appalachian setting. This site provided a unique opportunity to examine responses of a raptor community to habitat changes in an intensively managed forest.

The MeadWestvaco Corporation initiated the Appalachian Landscape Ecology Project on the MWERF in January 2000. As part of this long-term study, the property was initially divided into two ecologically similar blocks (P. D. Keyser, MeadWestvaco Corporation, pers. comm.). The blocks were subdivided into six compartments that are based on further similarities, current levels of disturbance, and compactness (e.g., approximately 526 ha each; P. D. Keyser, MeadWestvaco Corporation, pers. comm.). Each compartment within a block was randomly assigned one of three levels of harvest intensity treatments: a 20-, 40-, or 80-year rotation. Each rotation is replicated twice on the area. The 40-year rotation reflects the average rotation length on industrial forests anticipation for fiber production in the Appalachian region, the 20-year rotation is more intense, and the 80-year rotation represents a less intense level of disturbance. At the end of each rotation, 75% of the cut acreage will be clear-cut and 25% will be deferment cuts (P. D. Keyser, MeadWestvaco Corporation, pers. comm.). Deferment cuts are clearcuts with $\leq$10 % residual basal area. The current age and species structural composition of second growth forest of the MWERF is a result of past high-grading. In 2000, non-forested habitat in the three treatments averaged 4.7% in the 20-yr compartments, 4.7% in the 40-yr, and 6.7% in the 80-yr.

Elevations on the MWERF ranged from 740-1200 m (Fenneman 1938). Climate is moist and cool with average rainfall and snowfall of 114 cm and 150 cm, respectively (Strausbaugh and Core 1977). Soils are acidic and typically well-drained (Stephenson 1993). Forest cover is an Allegheny hardwood-northern hardwood at higher elevations, and cove-hardwood and mixed mesophytic at lower elevations (Eyre 1980). The Allegheny hardwood-northern hardwood forest type is dominated primarily by yellow birch (*Betula alleghaniensis*), American beech (*Fagus grandifolia*), sugar maple (*Acer saccharinum*), red maple (*A. rubrum*), black cherry (*Prunus serotina*), red spruce (*Picea rubens*), white ash (*Fraxina americana*), and Fraser's magnolia (*Magnolia fraseri*). Lower elevation species included tuliptree (*Liriodendron tulipifera*), sweet birch (*Betula lenta*), northern red oak (*Quercus rubra*), and American basswood (*Tilia americana*; Ford and Rodrigue 2001). Riparian areas of the MWERF were a mixture of red spruce, eastern hemlock (*Tsuga canadensis*), and rosebay rhododendron (*Rhododendron maximum*). The shrub layer throughout the forest consisted of rosebay rhododendron and striped maple (*Acer pennsyvanicum*). The southern portion of the forest was not included in any of the compartments but was used to conduct species-specific nest searches for Northern Goshawks and Northern Saw-whet Owls. This area along the highest elevations on the MWERF contains a montane boreal community of red spruce and eastern hemlock.

METHODS

Nest Searching and Monitoring. I located nests by systematic searches of the study area prior to leaf out in the winter of 2000 and 2001, from incidental observations by other researchers, and by searching areas near broadcast survey points where raptors responded. Additionally, three nests were located during a 4 d span in 2001 by a fellow researcher investigating survival of juvenile Ruffed Grouse (*Bonasa umbellus*; B. Smith, West Virginia University unpublished data). I visually checked each nest for signs of activity every week using binoculars and/or a spotting scope. I monitored nests until young fledged or the nest failed. I considered a nest successful if at least one young fledged. The total number of fledglings was recorded for each nest. For nests found when young were already branching out, the number of fledglings was estimated from the number seen or heard and is likely an underestimate.

Prey Delivery Rates and Species Composition. I installed Microcam2 miniature video cameras near nests connected with a 61m (200 ft) figure-8 cable to LCTLV time-lapse video recorders from post-hatch to fledging to observe nestling behavior and prey deliveries. The cameras record black-and-white images every 3 sec for 24 hr on standard VHS tapes. The cameras emit infrared light at a wavelength not visible to vertebrate species (R. Fuhrman, Fuhrman Diversified, Inc., pers. comm.). In darkness, the infrared emitters were capable of illuminating objects up to 1 m from the camera. The camera and infrared emitters were enclosed within a 32 mm x 32 mm x 60 mm aluminum housing and attached to an articulating arm which was clamped to a supporting branch, not touching the nest structure. The camera and arm were camouflaged to reduce visibility to adults. A deep cycle 12-volt marine battery powered both the camera and recorder.

Cameras were placed on a supporting branch near the nest (<1 m) after eggs hatched. I determined approximate age of nestlings using characteristics at the time of camera installation. I approached each nest tree between 1300 and 1600 for installation, tape, and battery changes. Ambient temperature was at least 18.3°C (65°F), with no constant precipitation during the installation process. I equipped a climber, trained in raptor nest climbing, with a Buckingham® safety belt, 2 safety ropes, and Klein Tools® tree climber spikes to install each camera. I changed the battery and videotape each day. Nestlings for all species were considered fledged when they flew out of camera view or were seen away from the nest tree.

Videotape transcription was started after one of the adults began to brood the chicks, indicating acceptance of the camera. For each prey delivery, I recorded the time of day and species of prey. I identified each item to species whenever possible (Table 4.1). I calculated the amount of time transcribed as the number of hours on each tape between 0600 and 2100. Nest material deliveries also were recorded. I calculated delivery rates by dividing the total number of items delivered by hours transcribed. I assumed that all prey deliveries occurred between 0600 and 2100, which corresponded with daylight hours. I also recorded unusual behaviors and visitors to the nest (other than the adults) and recorded nesting material deliveries (Lyon *et al.* 1986).

Microhabitat Analyses. I collected vegetation data at each occupied nest and used these in microhabitat analyses (Table 4.2). I established a 0.4 ha circular plot around each nest tree. Tree species (including snags) and diameter at breast height (DBH) was recorded for all trees $\geq$7.5 cm DBH within the plot. All shrubs, saplings, and poles taller than 0.5 m also were recorded by species within the plot. Percent ground and canopy cover were determined using the ocular site tube method developed by James and Shugart (1970). I used categories for ground cover such as green vegetation, leaf litter, woody debris, rocks and bare ground, moss, and water. Additional variables included nest tree DBH (cm), nest height (m), slope (degrees), aspect (degrees), elevation (m), distance to the nearest edge (m), and mean canopy height (m). I derived slope, aspect, and elevation from the digital elevation model for all diurnal and nocturnal survey points using ArcView 3.2. Aspect data were linearly transformed (Odom et al. 2001). I selected random potential nest trees by using a random numbers table to determine a direction and number of paces from the nest tree. I then chose a tree that could support a nest based on available branches, diameter at breast height, and viability.

Landscape Analyses. For landscape analyses, I plotted the geographically referenced locations of each nest on Digital Orthophoto Quadrangles (DOQQ) of the study site taken in 1996. I modified land cover from the photos to reflect conditions during the two years of my study. Arcview 3.2® with Patch Analyst 2.2® extension (Appendix 1and 2) was used to create two buffer zones around each occupied nest and to analyze all habitat variables within each buffer zone (Appendix 1). The 564 m (1 km^2, 100ha) buffer zone was based on the average home range size of Red-shouldered Hawks in the eastern United States (Moorman and Chapman 1996, Howell and Chapman 1997). The 1000 m (2 km^2, 312 ha) buffer zone was based on the maximum home range for this species (Bednarz and Dinsmore 1981), which is more representative of the landscape perspective and a size typically used in landscape analyses (McGarigal and McComb 1995).

Land covers within and surrounding the MWERF were digitized into eight categories: water and wetland, roads and bare ground, grassland and powerlines, early succession (deciduous), middle succession (deciduous), late succession hardwood, late successional conifer mix, and human development (Table 2.1). Classification of early, mid-, and late-successional stands were based on characteristics of stand age defined by Oliver and Larson (1996). I specifically identified early successional stands as 0-8 yr, mid-successional as 10-50 yr, and late successional as >50 yr.

Buffer zones at 564 m and 1000 m were clipped out of the overall coverage and summarized using Patch Analyst 2.2 extension (Fig. 2.3). Because the landscape changed during the course of this study, landscape composition for each year was calculated and examined separately (Fig. 2.2). Land covers were used to calculate other landscape variables including total amount of mature forest (regardless of species composition), mean patch size of mature forest, total number of forest patches, total core area of mature forest, mean patch size of each core area, edge density, Shannon's Diversity Index (measure of relative landscape patch diversity), Shannon's Evenness Index (measure of patch distribution and abundance), and distance to nearest water source or wetland area (in m; Table 2.1).

Statistical Analyses. I calculated mean and standard error of habitat variables for nests of individual species and for random trees (Table 4.4) using Statistical Analysis System (SAS V.8, SAS® Institute 1991). Microhabitat variables were compared between occupied nests and random trees using a t-test (PROC TTEST in SAS V. 8). Analysis of variance (PROC GLM in SAS V. 8) was used to determine significant differences in the mean of each microhabitat and landscape habitat variable among the three species (Red-tailed Hawk, Red-shouldered Hawk, and Broad-winged Hawk). I used chi-square goodness-of-fit analyses to compare habitat use with habitat availability at the landscape level for each species. I based availability on the digitized land covers on the MWERF. When the overall chi-square indicated a significant difference, I then used a one-tailed t-test to compare use with availability of each land cover to identify which differed. Results of statistical analyses were considered significant at $P \leq 0.05$ with the exception of microhabitat analyses which were considered significant at $P \leq 0.10$.

RESULTS

Nest Searching and Monitoring. I found 12 occupied nests (14 total nesting attempts) of diurnal raptors during 2000-2001 (Fig. 4.1). All but two nesting attempts fledged at least one young (Table 4.6). Mean number of fledglings was 2.5 young/nest (± 0.29) for Broad-winged Hawks (BWHA; $n = 4$), 1.5 young/nest (± 0.95) for Red-shouldered Hawks (RSHA; $n = 4$), 1.6 young/nest (± 0.51) for Red-tailed Hawks (RTHA; $n = 5$), and two young/nest for Northern

Goshawk (n = 1). In addition, I found two Turkey Vulture nests (one failed attempt and one that fledged two chicks), but these nests were not included in the analyses. Fledging dates varied among species. Red-tailed Hawks fledged from 15 May to 27 June. Red-shouldered Hawks fledged from 6 June to 10 July. Broad-winged Hawks fledged from 8-19 July. Northern Goshawk nestlings fledged approximately 20 May.

Occupied nests were found in each of the three harvest treatments over the 2 yr of this study (Fig. 4.1). Four occupied nests were located in the 20-yr harvest rotation (RSHA, BWHA, and RTHA), one nest was located in the 40-yr rotation (RSHA), and five nests were located in the 80-yr rotation (RSHA, BWHA, and RTHA). Two additional nests were located on or very near the MWERF, but not within the compartments. At the time of this study, treatments were being established (i.e., most of the stand rotations/harvests had not began yet), so this information will be treated as a baseline study.

Prey Delivery Rates and Species Composition. Video cameras were installed on three nests: Red-shouldered Hawk (date installed 13 May 2001), Red-tailed Hawk (6 June 2001), and Broad-winged Hawk (18 June 2001). Mean installation time was 70.3 min (range 61-75 min) at the nest tree. Adults returned to the nest in an average of 104.7 min (27-155 min) after the initial camera installation. Adults returned to brooding after an average of 238.3 min (range 217-280 min) after camera installation. The Broad-winged and the Red-tailed Hawk adults fed chicks before brooding. Overall, 913.47 hr of video were transcribed for all three nests from 0600 to 2100 (319.04 hrs for Red-shouldered Hawk over 25 d, 267.80 hrs for Red-tailed Hawk over 21 d, and 326.64 hrs for Broad-winged Hawk over 23 d).

Red-shouldered Hawks delivered at least 10 species of prey (85.1% mammals, 7.7% amphibians, 2.1% reptiles, and 5.1% unidentified) at a rate of 0.74 items/hr (Table 4.1). This nest contained three nestlings at camera installation; one of the nestlings died around 20 May 2001, leaving two to fledge. Broad-winged Hawks delivered at least 13 species of prey (68.1% mammals, 2.6% birds, 13.3% amphibians, 9.1% reptiles, and 6.8% unidentified) at a rate of 0.81 items/hr. This nest contained three chicks throughout the nestling stage. Red-tailed Hawks delivered at least eight species of prey (82.7% mammals, 7.4% birds, 1.2% amphibians, 4.9% reptiles, and 3.7% unidentified) at a rate of 0.30 items/hr. This nest contained two chicks throughout the nestling stage. Each species exhibited a similar temporal pattern of prey deliveries throughout the day (Figure 4.2). All three species have a peak delivery time early in the day, with deliveries tapering off starting about 1500. Peak activity for Broad-winged Hawks and Red-tailed Hawks was approximately 0900. Red-tailed Hawks seem to start delivering prey later than the other two species.

Since not all of the prey items were identified, mass estimates of delivered items was incomplete. However, for Red-shouldered Hawks and Broad-winged Hawks, unidentified mammals were generally shrew- or mouse-sized. The Red-tailed Hawks overall brought fewer prey items to the nest, but each item was larger on average (e.g., Red squirrel [*Tamiasciurus hudsonicus*] and adult Eastern chipmunks [*Tamias striatus*]). All three species delivered nesting material throughout the nestling period at a rate of 0.23 items/hr (Red-shouldered and Broad-winged Hawk) and 0.06 items/hr (Red-tailed Hawk).

Each nest monitored by a camera was noted as having at least one visitor to the nest. Visitors included southern flying squirrels (*Glaucomys volans*), *Peromycus* sp., and an unidentified songbird. Visitation seemed to occur when the female was not present at the nest during the day or night hours.

Microhabitat Analyses. The only microhabitat variable that differed between random trees and all occupied nests was the number of snags within the plot (t = 2.06, P = 0.05). Red-shouldered Hawk nests had significantly more saplings (t = -4.71, P = 0.003) and fewer snags (t = 3.27, P = 0.02) at the nest than at random points (Table 4.4). Broad-winged Hawk nests had significantly fewer 7.6-20.3 cm DBH trees than random trees (t = 2.78, P = 0.03). Red-tailed Hawk nests showed no significant differences among the microhabitat variables when compared to random trees.

Among the three species of hawks, I found a difference in slope (F = 3.34, P = 0.07) at the nest (Table 4.4). Red-tailed Hawk nests were found on the greatest average slope, 38.6 ± 7.4°, which was different from the Red-shouldered Hawk nest sites with an average of 20.3 ± 2.8°. Broad-winged Hawk nest sites were not significantly different from either Red-tailed Hawks or Red-shouldered Hawks with a mean slope of 25.8 ± 0.9°. Canopy height of the nest stand (F = 6.31, P = 0.02) differed among the species. Red-tailed Hawk nests were found in the tallest average canopy height 32.5 ± 1.2 m, which was significantly different from the Red-shouldered Hawks (24.5 ± 1.7 m) and Broad-winged Hawk nest sites (25.2 ± 2.9 m). The number of pole-sized trees (5 to 8 cm at diameter breast height) present in the nesting stand differed between Broad-winged Hawk nests (15.5 ± 4.3°) and Red-shouldered Hawks nest sites (4.0 ± 0.4 poles; F = 3.53, P = 0.07). Red-tailed Hawk nests were not significantly different from either Broad-winged Hawks or Red-shouldered Hawks with a mean of 11.2 ± 2.80 poles.

Landscape Analyses. Means and standard errors for each of the 17 landscape level variables are listed in Table 4.5. Although not statically significant, trends emerged and are reported. At the landscape level (1000 m), Red-tailed Hawks had the highest mean amount of early successional forest habitat (Table 4.4). Red-shouldered Hawks had the nearest distance to water, and also had the least amount of early successional forest habitat, the greatest mean amount of core forest area, greatest mean patch size of the core area, and the greatest amount of mature forest (Table 4.4). At the home range level (564 m buffer zone), Red-tailed Hawks were the only species to contain human development (0.01 ± 0.00 ha) and showed the smallest mean patch size of mature forest (22.0 ± 6.8 ha). Broad-winged Hawks were similar to Red-tail Hawks in total amount of forest and mean patch size of mature forest. Amount of water and riparian areas was similar for each of the three species at this level. Red-shouldered Hawks illustrated the highest amount of mature forest (conifer and deciduous combined; 91.2 ± 2.7 ha) and were nearest to water or wetland areas (50.9 ± 10.0 m).

I compared the use and availability of landcovers surrounding nests of each species at the landscape level (1000 m). Landscapes used for nesting by Red-shouldered Hawks showed an overall significantly different use verses availability of landcovers ($\chi^2 = 22.1$, $P < 0.001$), and specifically, chose less grassland than available ($t = -3.99$, $P = 0.02$), coinciding with less disturbed nest sites. Landscapes used for nesting by Broad-winged Hawks showed an overall significantly different use of resources ($\chi^2 = 16.8$, $0.01 < P < 0.025$). This species chose less often than available ($t = -4.00$, $P = 0.02$). Landscapes used for nesting by Red-tailed Hawks showed an overall significantly different use of resources ($\chi^2 = 7.97$, $0.001 < P < 0.005$). This species chose less mid-successional deciduous forest ($t = -5.00$, $P = 0.004$) and more late successional deciduous forest ($t = 3.29$, $P = 0.02$), coinciding with the landscape of lower elevation nest sites on the MWERF.

DISCUSSION

Successful reproduction is one measure of population health and is a way to monitor the population status over time (Newton 1979). Wildlife species may still inhabit areas associated with disturbance, but may not be able to reproduce or they experience annual fluctuations in population, making them appear unstable. At the current level of disturbance on the MWERF, populations appear stable and may be a source for other populations because of the current reproductive rates. Long-term changes must be monitored carefully to understand the point in time of actual change. The Appalachian Landscape Ecology Project was designed to monitor flora and fauna to determine at what level of disturbance changes occurs. Nesting success of the raptor populations on the MWERF suggests that this population is not adversely impacted by disturbance at this point in time. Mean fledglings per nest for Red-tailed Hawks and Red-shouldered Hawks were consistent with another study conducted in the Appalachians in Maryland by Janik and Mosher (1982). Number of Broad-winged Hawk fledglings was slightly greater than averages reported from the mountains in western New York at 1.9 ± 1.0 (Goodrich et al. 1996). Although chronology varies between years, Red-tailed Hawks nest earlier than other species such as Red-shouldered Hawks (Moorman et al. 1999).

Raptor populations are limited by the available amounts and types of food (Newton 1979). Disturbance from timber harvesting has been shown to affect species composition of potential prey such as songbirds (Weakland et al. 2002), small mammals (Buckner and Shure 1985, Yahner 1988), and herpetofauna (deMaynadier and Hunter 1995). On the MWERF, however, Ford and Rodrigue (2001) found few impacts to soricid populations following partial overstory removal harvests. In my study, mammals represented the majority of the diet (>65%) for all three species (Table 3.1). *Buteo* species in the Appalachians generally consume >50 % of mammals in their diet (Preston and Beane 1993, Crocoll 1994, Goodrich et al. 1996). As nesting progressed, Red-shouldered Hawk adults delivered more reptiles and amphibians. The Broad-winged Hawks nested a few weeks later in the year and had a higher overall percentage of herpetofauna in the diet. One explanation is that increasing ambient temperature also may affect prey availability and appearance.

Habitat characteristics that raptors choose are not fully understood, but some variables seem to be important in nest placement and nest success. Although most trees are not suitable for nest placement (Titus and Mosher 1981), it is often difficult to quantify the characteristics that birds seek. Red-tailed Hawks have been characterized to choose nest sites with high accessibility (Bednarz and Dinsmore 1982). Nests of this species on the MWERF were in areas containing early successional habitat at the landscape level and had a slightly smaller mean patch size of mature forest than Broad-winged Hawks. I believe that Red-tailed Hawks on the MWERF are mostly non-migratory because observations were made of pairs of birds in known territories year-round. These hawks have been documented to nest closer to human development than Red-shouldered Hawks (Bednarz and Dinsmore 1982, Bosakowski et al. 1992). Red-tailed Hawks on this industrial forest were the only species to have development within the home range spatial scale.

Most studies documenting nest-site characteristics cite water or riparian areas to be a consistent component of Red-shouldered Hawk territories (Titus and Mosher 1981, Bosakowski et al. 1992, Crocoll 1994, Moorman et al. 1999, Balcerzak 2001). On the MWERF, Red-shouldered Hawks built nests both in areas close to a water source or riparian area, in mid-canopy, and in large, contiguous areas of mature forest. Nest trees had a large mean DBH and were found the greatest distance away from an edge of a former skid trail or natural opening.

This species was found in the higher elevations of the study site, but this could be a result of the mature forest present in these areas or the coniferous forest component of the forest itself. The MWERF is located within 20 km of the wettest location in West Virginia and in the eastern United States, and therefore, receives considerable amounts of precipitation each year (Strausbaugh and Core 1977). The result is an overall moist environment lacking definable wetlands or large riparian areas, which are overall not very different from surrounding forests. The high moisture levels seem to be enough to support Red-shouldered and Broad-winged Hawks, both of which favor nesting territories that include wet areas in the Appalachian Mountains.

Broad-winged Hawks are the earliest fall migrants (Goodrich et al. 1996), and thus were only found on site during the breeding season. This species has been documented on managed forests (Goodrich et al. 1996) and in younger stands associated with wet areas (Titus and Mosher 1981) in other studies. Short harvest rotations have been used to maintain this species (Goodrich et al. 1996). Habitat characteristics at the microhabitat scale were similar to Red-shouldered Hawks (similar results to Titus and Mosher 1981) and at the home range scale to Red-tailed Hawks indicating that these birds are possibly adaptable to varying conditions or do not have as strong a preference to specific characteristics as other hawk species.

Unusual Observations. During transcription of the videotapes, I noticed that each nest had visitors at night while adults were not present. Southern flying squirrels (*Glaucomys volans*) visited each nest at least once before the young fledged, sometimes to forage for scraps and others to investigate the nestlings, causing no harm. A *Peromyscus* spp. also was seen on numerous occasions foraging in the Red-shouldered nest as the nestlings slept. Several unidentified songbirds also visited the nests during the nestling stage.

The male Red-shouldered Hawk was seen brooding nestlings on several occasions and once all night. Both adult Red-shouldered Hawks (i.e., the mated pair) brooded the nestlings for over 2 hrs during a storm one afternoon. The male also was seen brooding the chicks one night. Male *Buteo* species share some of the responsibility of incubation and brooding, but the extent is not well documented (Preston and Beane 1993).

Other interesting events during my study included a Broad-winged Hawk with a 26.2 m high nest. Researchers from Maryland Department of Natural Resources and the University of Maryland came to place a satellite transmitter to monitor migration patterns on the female from this nest in 2000. The male of the pair was quickly captured, but the female was never caught. She was seen in the area, but eluded the mist net and thus, was excluded from the study. Two nestlings fledged from this nest about 19 July 2000. In 2001, one of the Red-tailed Hawk nests failed. The female laid two eggs and incubated for approximately six weeks before abandoning. Upon inspection of the nest bowl, I found the nest was lined almost entirely with large blades of grass. The bowl and eggs were cold and wet, possibly the reason for failure.

CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

My results suggest that at the current levels of forest canopy disturbance, forest-dwelling raptors successfully breed on the MWERF. Monitoring should continue to determine at what level of disturbance or point in time forest raptor populations start to decline or species composition begins to shift from forest-dwelling species to edge-dwelling species.

Buffer zones of no-harvest activity may be an option for managing forest-dwelling raptors. In 2001, two buffer zones were installed around active nests. One was a 0.1 ha buffer of no disturbance placed around an occupied Red-tailed Hawk nest by the MeadWestvaco

Corporation on a similar nearby property. A clearcut was installed during the breeding season when very young nestlings were in the nest. During the harvest, the nest failed with an unknown number of nestlings. The nest also was not occupied in spring 2002. Another buffer zone was placed around a Red-shouldered Hawk nest on the MWERF. The zone was approximately 0.4 ha in size and was adjacent to a Streamside Management Zone. This buffer zone was larger than the one installed at the Red-tailed Hawk nest, mostly because the Red-tailed Hawk nest was not located until most of the trees surrounding it had been harvested. Around the Red-shouldered Hawk nest, a clearcut was installed on the downhill side, and the stand was thinned uphill from the nest. Both of these harvests were conducted just as the young fledged. This Red-shouldered Hawk nest was occupied again in spring of 2002.

Size and timing of harvests appeared to be important to the reoccupation of these nests. Bednarz and Dinsmore (1981) suggested minimizing human activity within a 1 km radius (312 ha) of active nests. A European study of Northern Goshawks suggested that buffer zones should be at least 5 ha, so the nest tree would not be isolated. This smaller-size buffer zone may be more economically feasible for landowners, and yet provide protection for the nesting raptors. Zones of little or no disturbance also can be smaller if harvests were restricted to the non-breeding season (Grubb 1998). There are no legal buffer zones of “no disturbance” for forest-dwelling hawk species and the 1 km radius distance may not be possible in all situations. Use of buffer zones of no harvesting and harvests conducted out of the nesting season should be considered to reduce direct disturbance to nesting raptors.

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Table 4.1. Prey deliveries for a breeding pair of Red-shouldered Hawk (RSHA), Broad-winged Hawk (BWHA), and Red-tailed Hawk (RHTA) on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001.

	RSHA		BWHA		RTHA	
Species	**n**	**%**	**n**	**%**	**n**	**%**
Mammals						
Eastern chipmunk (*Tamias straitus*)	69		52		28	
Red squirrel (*Tamiasciurus hudsonicus*)	2				9	
Southern flying squrriel (*Glaucomys volans*)					2	
Short-tailed shrew (*Blarina brevacada*)	53		8			
Peromyscus spp.	1		34			
Woodland jumping mouse (*Napaeozapus insignis*)			1			
Unidentified shrew (*Sorex* spp.)			2			
Unidentified vole (*Microtus* spp.)			3			
Unidentified mole (Talpidae spp.)	3		3		3	
Unidentified	73		77		24	
Total mammals	200	85.1	180	68.1	67	82.7
Bird						
Ruffed Grouse (*Bonasa umbellus*)			7		5	
Unidentified bird					1	
Total birds			7	2.6	6	7.4
Amphibians						
Unidentified frogs and toads	7		8		1	
Unidentified salamanders	11		27			
Total amphibians	18	7.7	35	13.3	1	1.2
Reptile						
Unidentified snake	5	2.1	24	9.1	4	4.9
Unidentifiable prey	12	5.1	18	6.8	3	3.7
TOTAL	**235**	**100**	**264**	**100**	**81**	**100**
PREY DELIVERY RATES	**0.74/hr**		**0.81/hr**		**0.30/hr**	

Table 4.2. Description of microhabitat variables examined in landscape analysis of nest habitat use for raptors on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001.

Abbreviation	Description
FLEDGE	Mean number of fledglings from each nest (by species).
NESTHGT	Mean height (in m) of nest structure.
NESTDBH	Nest tree diameter breast height (DBH in cm).
ASPECT	Aspect (in degrees) taken at the nest tree.
SLOPE	Slope (in degrees) taken at the nest tree.
ELEVATION	Elevation (in m) derived at the nest tree from ArcView 3.2.
DISEDGE	Distance to the nearest edge (in m), defined by a break in the canopy (including roads).
CANOPYHGT	Average canopy height, taken from 2 dominant trees in stand (in m).
GREEN	Percent of ground area covered by vegetation.
LITTER	Percent of ground area covered by leaf litter.
WOOD	Percent of ground area covered by woody debris.
MOSS	Percent of ground area covered by moss.
WATER	Percent of ground area covered by water.
ROCK	Percent of ground area covered by bare ground or rock.
%CANOPY	Percent of the sky covered by vegetation.
SAPLING	Number of trees $\leq$ 2.5 cm dbh.
POLE	Number of trees $\geq$ 2.5 – 8 cm dbh.
TREEA	Number of trees > 8 – 38 cm dbh.
TREEB	Number of trees > 38 cm dbh.
SNAG	Number of snags in plot.

Table 4.3. Description of habitat variables examined in landscape analysis (564 and 1000 m) of nest habitat use for raptors on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001.

Abbreviation	**Description**
ROAD	Amount of roads and bare ground (in ha).
WATER	Amount of open water and wetland areas (in ha), which includes ponds, lakes, streams, rivers, and wetlands.
DEVELOPED	Amount if human development (in ha), which includes resident and commercial buildings and gas wells.
GRASS	Amount of grassland areas (in ha).
EARLY	Amount of early successional deciduous forest (in ha), which are harvested areas that were < 10 yrs old.
MSDECID	Amount of mid-successional deciduous forest (in ha), which are stands that were 10-50 yrs old.
LSDECID	Amount of late successional deciduous forest (in ha), which are stands that were > 50 yrs old.
LSCONIFER	Amount of late successional conifer forest (in ha), which consists of stands that were > 50 yrs old.
FOREST	Amount of total mature forest area (in ha), which consists of LSCONIFER and LSDECID.
MPSFOREST	Mean patch size of FOREST.
TFP	Total number of FOREST patches.
TCA	Total core area of FOREST.
MPSTCA	Mean patch size of the total core area.
ED	Edge density.
SDI	Shannon's Diversity Index, which is a measure of relative patch density.
SEI	Shannon's Evenness Index, which is a measure of patch distribution and abundance.
DISWATER	Distance to the nearest body of water, stream, or wetland area (in m).

Table 4.4. Mean and standard error of the 20 microhabitat variables describing nests of Red-shouldered Hawks (RSHA, n = 4), Broad-winged Hawks (BWHA, n = 4), Red-tailed Hawks (RTHA, n = 5), and Northern Goshawk (NOGO, n = 1), and random potential nest trees on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001.

Variable	RSHA nest	RSHA random	BWHA nest	BWHA random	RTHA nest	RTHA random	NOGO
	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)	Mean
FLEDGE	1.50 (0.96)	-	2.50(0.29)	-	1.60 (0.51)	-	2.00
NESTGHT	16.31 (2.55)	-	18.71 (2.90)	-	20.20 (3.38)	-	56.00
NESTDBH	58.17 (2.95)	52.71 (5.64)	43.94 (3.68)	37.85 (3.10)	51.31 (8.59)	47.96 (4.14)	55.88
ASPECT	161.50 (61.54)	287.50 (31.71)	167.25 (64.78)	171.00 (61.02)	173.00 (40.41)	143.75 (52.48)	292.00
SLOPE	20.25 (2.84)	21.25 (3.97)	25.75 (0.95)	24.00 (4.42)	38.60 (7.43)	40.25 (7.63)	28.00
ELEVATION	942.25 (32.50)	970.25 (53.72)	883.50 (37.18)	922.00 (45.21)	885.40 (36.54)	892.50 (48.58)	1113.00
DISEDGE	24.75 (4.80)	20.50 (11.97)	20.00 (5.07)	12.88 (0.52)	12.40 (4.08)	18.00 (4.43)	90.00
CANOPYHGT	24.54 (1.70)	26.14 (2.73)	25.15 (2.87)	26.59 (2.68)	32.49 (1.24)	31.55 (1.48)	26.82
GREEN	20.00 (3.53)	20.00 (7.91)	33.75 (7.47)	30.00 (4.57)	27.00 (6.82)	26.25 (8.26)	15.00
LITTER	55.00 (2.88)	55.00 (10.21)	37.50 (4.79)	35.00 (2.89)	42.00 (7.17)	45.00 (3.54)	70.00
WOOD	16.25 (1.25)	12.50 (1.44)	13.75 (3.15)	20.00 (5.00)	18.00 (2.55)	13.75 (3.75)	15.00
MOSS	1.25 (1.25)	1.25 (1.25)	1.25 (1.25)	2.50 (1.44)	4.00 (2.45)	1.25 (1.25)	0.00
WATER	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	1.25 (1.25)	0.00 (0.00)	1.25 (1.25)	0.00
ROCK	7.50 (2.50)	11.25 (3.15)	2.75 (0.75)	11.25 (3.75)	10.00 (0.00)	12.50 (3.23)	5.00
%CANOPY	68.75 (5.91)	73.75 (2.93)	72.50 (7.22)	77.50 (6.61)	64.00 (11.22)	77.50 (4.33)	65.00
SAPLING	13.50 (1.19)	5.00 (1.35)	14.75 (3.35)	14.50 (5.54)	19.40 (5.09)	9.25 (2.78)	0.00
POLE	4.00 (0.41)	2.75 (1.25)	15.50 (4.33)	23.00 (11.16)	11.20 (2.80)	8.00 (2.68)	15.00
TREEA	11.50 (3.30)	11.50 (4.03)	8.50 (1.04)	7.25 (0.95)	6.20 (0.86)	7.25 (0.48)	9.00
TREEB	5.50 (1.19)	3.25 (1.11)	4.25 (1.11)	2.50 (0.87)	3.00 (0.32)	2.75 (0.63)	4.00
SNAG	1.50 (0.29)	4.00 (0.71)	2.50 (0.87)	3.75 (1.18)	2.60 (0.60)	3.75 (0.85)	6.00

Table 4.5. Mean and standard error of the 17 habitat variables at nests of Red-shouldered Hawks (RSHA, n = 4), Broad-winged Hawks (BWHA, n = 4), Red-tailed Hawks (RTHA, n = 5), and Northern Goshawk (NOGO, n = 1) on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001.

Buffer	**Variable**	**RSHA**		**BWHA**		**RTHA**		**NOGO**
		Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**
1000 m	DEVELOP	0.00	0.00	0.04	0.03	0.01	0.01	0.00
	ROAD	10.04	1.09	9.16	1.65	9.17	1.33	5.40
	WATER	1.38	0.13	1.68	0.15	2.10	0.32	0.29
	GRASS	0.61	0.04	10.33	5.98	6.76	2.66	0.07
	EARLY	16.21	4.01	19.68	6.64	24.99	8.71	0.77
	MSDECID	3.55	3.55	0.00	0.00	0.00	0.00	0.00
	LSDECID	165.83	17.57	201.87	34.36	212.66	5.94	146.29
	LSCONIFER	114.94	22.71	69.79	34.41	51.00	13.98	159.75
	FOREST	282.15	7.20	273.34	5.21	271.65	9.86	306.32
	NFP	3.75	1.81	13.75	5.15	11.00	2.49	2.00
	MPSFOREST	99.39	26.50	33.73	12.50	37.85	16.25	153.16
	TCA	174.78	10.11	136.25	43.83	154.44	19.27	251.71
	MPSTCA	63.34	13.29	45.13	11.76	42.86	17.74	125.85
	ED	165.25	16.15	150.57	25.60	150.08	5.80	199.44
	SDI	1.00	0.03	0.90	0.11	0.94	0.04	0.79
	SEI	0.55	0.01	0.49	0.05	0.50	0.01	0.44
	DISWATER	50.90	10.01	132.53	41.89	210.22	54.64	48.83
564 m	DEVELOP	0.00	0.00	0.00	0.00	0.01	0.01	0.00
	ROAD	3.69	0.06	3.58	0.23	2.45	0.22	2.29
	WATER	0.65	0.09	0.64	0.13	0.66	0.22	0.16
	GRASS	0.02	0.02	1.16	0.95	2.44	0.81	0.00
	EARLY	2.94	1.77	7.20	3.25	7.13	1.82	0.00
	MSDECID	1.62	1.62	0.00	0.00	0.00	0.00	0.00
	LSDECID	42.83	9.98	59.99	12.17	68.11	2.53	34.98
	LSCONIFER	47.68	11.04	26.85	10.52	18.63	4.59	62.01
	FOREST	91.15	2.71	87.49	4.11	87.38	2.37	97.14
	NFP	2.75	0.48	4.00	0.71	5.00	0.89	2.00
	MPSFOREST	36.31	6.11	24.03	4.16	22.04	6.78	48.57
	TCA	53.57	3.46	49.04	7.80	56.90	4.28	77.41
	MPSTCA	26.78	1.73	20.68	4.03	43.26	7.73	38.71
	ED	197.08	17.35	151.93	29.42	153.31	13.88	185.88
	SDI	0.92	0.07	0.91	0.20	0.93	0.03	0.76
	SEI	0.58	0.02	0.53	0.11	0.51	0.01	0.55
	DISWATER	50.90	10.01	132.53	41.89	210.22	54.64	48.83

Table 4.6. Nest records for four raptor species on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001.

Year	Nest ID	Species	# Fledged	Fledge/Fail date	Harvest Rotation	Tree Species	Comments/Reason for failure
2000	SD-01	BWHA	2	19 July 2000	20	black cherry	
	UBS-01	RSHA	0	25 May 2000	20	black cherry	weather? (1 egg)
	RR-01	RTHA	1	16 June 2000	80	tuliptree	
2001	RJ-02	BWHA	3	10 July 2001	20	American basswood	
	KC-05	BWHA	2	July 2001	80	black birch	
	ML-03	BWHA	3	July 2001	80	sugar maple	
	UBS-01	RSHA	2	6 June 2001	20	black cherry	weather (lost 1 chick)
	KS-02	RSHA	2	10 July 2001	80	American beech	
	LH-02	RSHA	4	18 June 2001	40	American beech	
	RR-01	RTHA	3	15 May 2001	80	tuliptree	
	KC-04	RTHA	2	27 June 2001	80	black birch	
	BF-02	RTHA	0	26 May 2001	20	tuliptree	weather? (2 eggs)
	RR-03	NOGO	2	20 May 2001	*	red maple	
	KUMB-01	RTHA	2	8 June 2001	80	sugar maple	

*Nest is located in the southern portion of the MWERF, outside of the harvest rotation compartments.

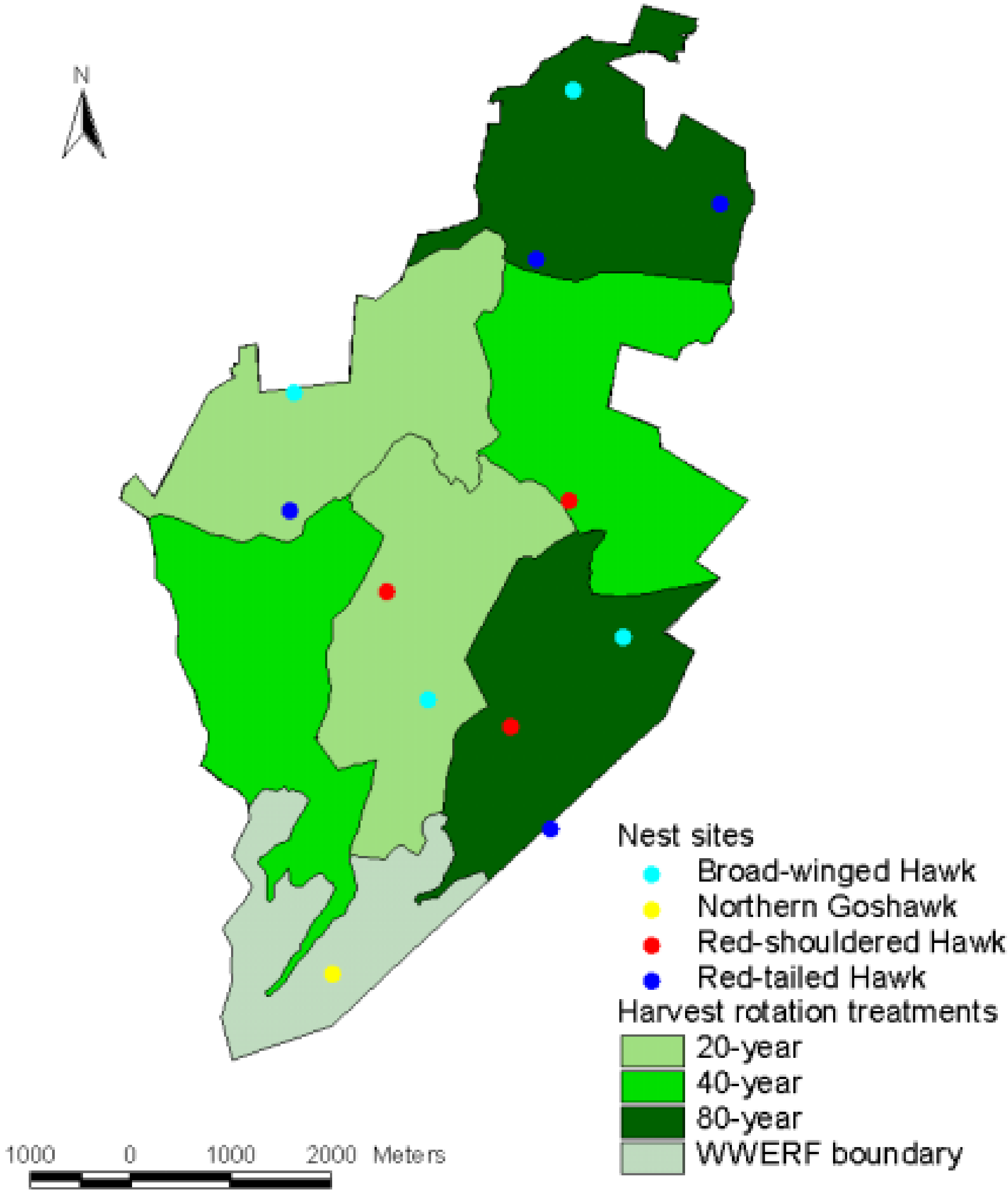

Figure 4.1. Nest locations for four diurnal raptor species for three harvesting rotations on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001.

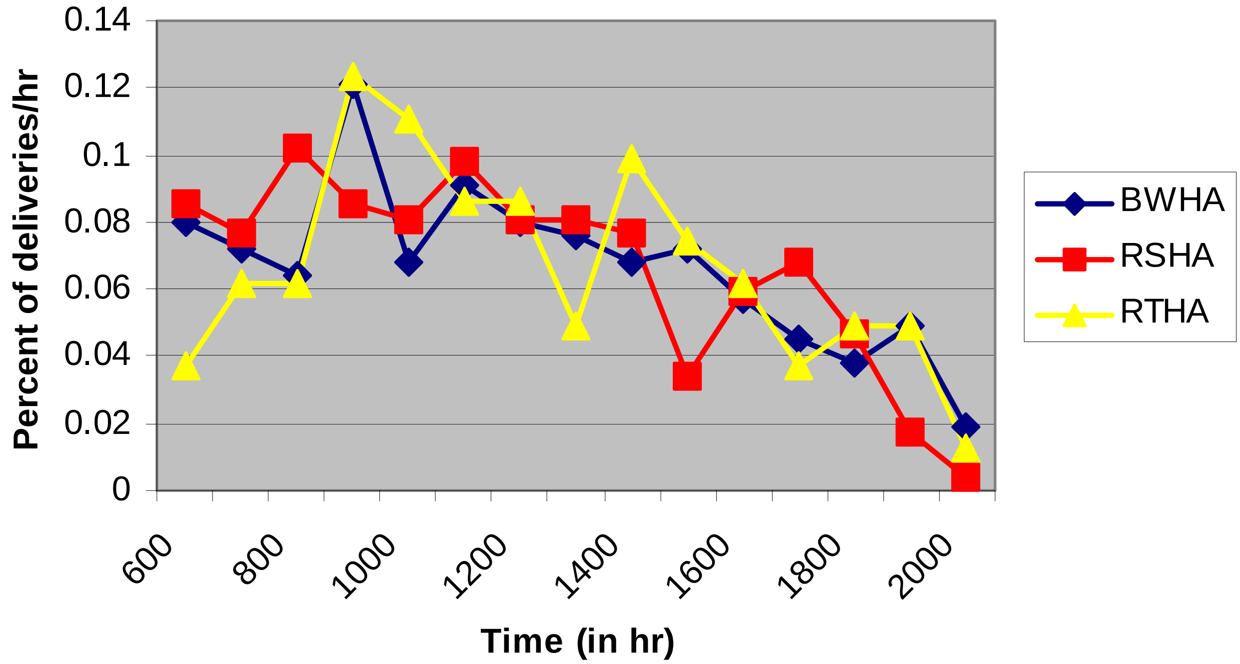

Figure 4.2. Percent of prey delivered per hour at the nests of Red-shouldered Hawk (RSHA), Broad-winged Hawk (BWHA), and Red-tailed Hawk (RTHA) on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during 2000 and 2001.

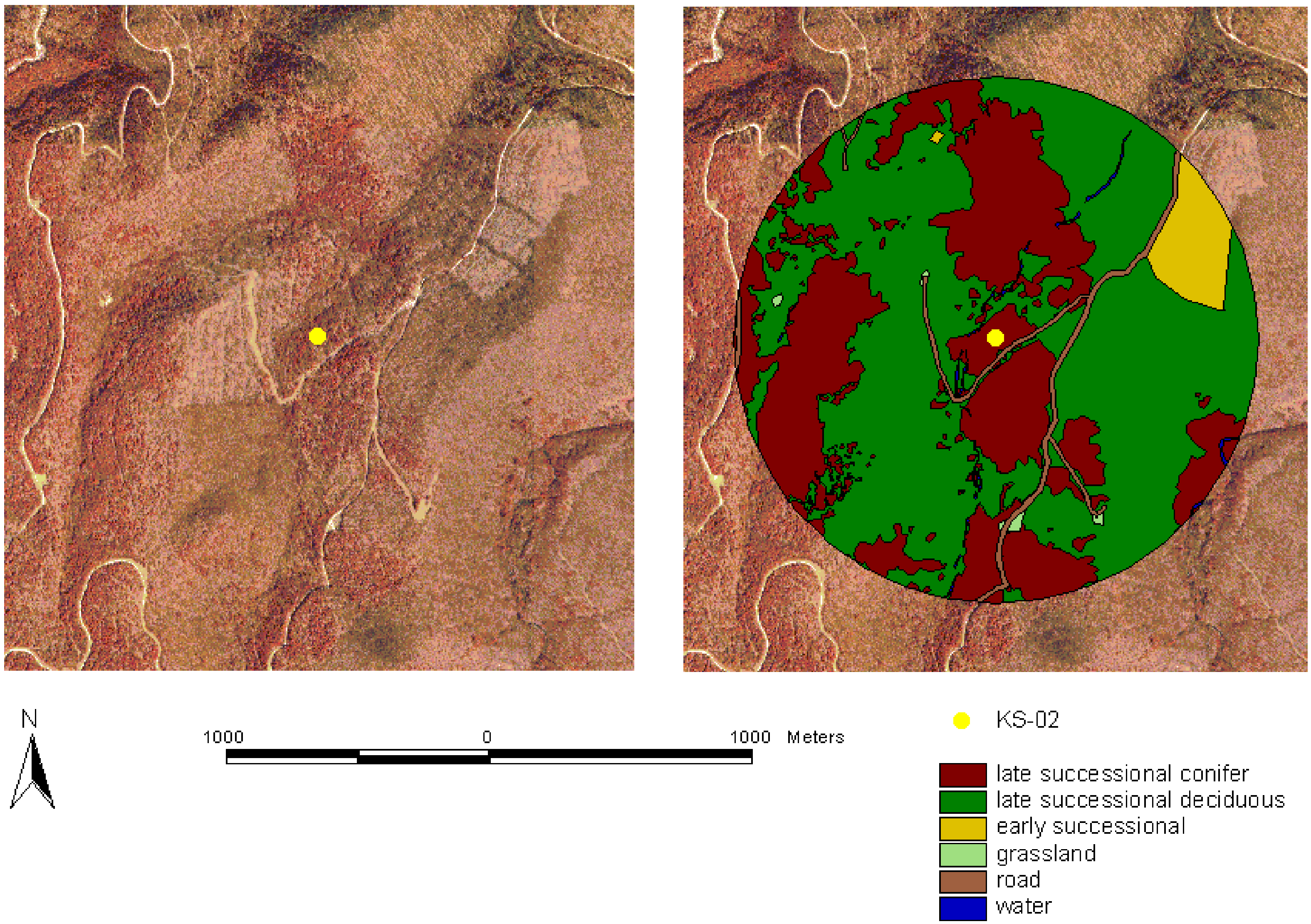

Figure 4.3. Example of digitized occupied Red-tailed Hawk nest (KS-02) on the MeadWestvaco Wildlife and Ecosystem Research Forest in Randolph County, West Virginia during summer 2001.

APPENDIX 1: Helpful Hints for Using ArcView 3.2 and Patch Analyst 2.2 extension

The following steps will increase the efficiency of using GIS to determine habitat variables to identify land cover for a wildlife research project. I have included information about ArcView 3.2 and Patch Analyst 2.2 Extension, which was the most appropriate software available at the time. Basic knowledge of ArcView 3.2 is necessary for use with this guide.

1) Decide on the land covers to be used. I chose water, wetland, bare ground and roads, human development, grassland and powerlines, early successional forest, mid-successional deciduous forest, late successional forests (deciduous and conifer mixture) as classifications of land use in my analyses.

2) Obtain Digital Orthophoto Quadrangles (DOQQ) that will be used in determine land use/land cover (LULC). These images are available at no cost from the U.S. Geological Survey (USGS) website (http://mapping.usgs.gov) or from West Virginia Department of Environmental Protection (WVDEP) website (http://www.dep.state.wv.us). Additional information from topographic maps, gap analyses information, USDA Forest Service and/or landowner maps, and personal ground-truthing information should be used to determine age of stands and disturbance since photos were taken.

3) Create an overall buffer area 100 m greater than the maximum buffer you plan to analyze around all points, nests, etc. to be considered in the analyses which will determine the area to be digitized. I used the CREATE BUFFER tool and used the buffer as a feature of the view. The additional 100 m will be important when determining core areas later in the analyses.

   NOTE: This buffer is not used in the analyses, but only as a guideline for digitizing.

4) Digitize all land use/land cover. The most efficient way to do this is to use the SNAP feature (there are several ways to do this in ArcView 3.2), which will help to eliminate the overlapping of polygons.

5) You will need the following extensions: Patch Analyst 2.2 (which includes PAGeoprocessing) and Buffer Wizard script (georeference buffers to other features such as survey points and nest locations). These codes are available for no cost off ESRI website (http://flash.lakeheadu.ca/~rrempel/patch/).

6) After finishing the LULC for all of the study areas, dissolve all coverages (by attribute cover) in Patch Analyst Geoprocessing (PAGeoprocessing), not Geoprocessing. The PAGeoprocessing uses ArcInfo codes that are necessary in Patch Analyst.

7) You should use the buffer wizard script to create the buffer zones that will be used in your analyses. Use the pull down menu choice CREATE BUFFERS, and make this a separate shapefile. Make sure to choose the attribute that you want to be continued to the new shapefile (e.g., point number or nest name).

8) Using PAGeoprocessing, select a buffer zone and create a new shapefile of the individual buffer zone. You can name these or use the default and temporary directory for your project.

9) Clip the LULC to the new shapefile. Then, get the area of each cover in the new shapefile (you can use [shape].returnarea in a new column or AREA function from the pulldown menu).

10) Select all of the LULC shapefiles that you wish to analyze within the view. (The BATCH feature will allow you to look at many files in a single analysis.) Choose PATCH menu and go to SPATIAL STATISTICS.

11) A) For LULC, you will need to choose CLASS and the attribute from the table that you want statistics run. To run more than 1 buffer at a time, you will have to select each from the list at the top of this box. You can specify the name of the output file for each analysis before you enter each file into the batch.

B) Next, choose LANDSCAPE and the attribute from the table that you want statistics run. You can again specify the name of the output file for this analysis before you enter each file into the batch.

NOTE: APPENDIX 2 contains a list of coverages, options, and statistics derived that I used.

12) I was interested in the total amount of forest and non-forest present within my study area, so I created a new column in the attribute table of the LULC shapefile and determined whether the polygon was forest (1) or non-forest (0). Dissolve by attribute column forest (just created) in PAGeoprocessing.

13) Clip the new forest/non-forest shapefile to each buffer zone as you did with the LULC. Then, get the area of each cover in the new shapefile (you can use [shape].returnarea in a new column or AREA function from the pulldown menu.

14) For FOREST/NON-FOREST overall shapefile, you will need to choose CLASS and the attribute from the table (forest) that you want statistics run. To run more than 1 buffer at a time, you will have to select each from the list at the top of this box. You can specify the name of the output file for each analysis before you enter each file into the batch.

15) I was interested in the amount of core forest within my study area, so I used the FOREST/NON-FOREST overall coverage and chose the PATCH pulldown menu with CREATE CORE AREAS. Just follow directions.

16) Clip the new core area shapefile to each buffer zone as you did with the LULC and forest/non-forest. Then, get the area of each cover in the new shapefile (you can use [shape].return area in a new column or AREA function from the pulldown menu).

17) For CORE AREA, you will need to choose CLASS and the attribute from the table (forest) that you want statistics run. To run more than 1 buffer at a time, you will have to select each

from the list at the top of this box. You can specify the name of the output file for each analysis before you enter each file into the batch.

OR: The total core area (TCA) and mean patch size of the core area (MPSTCA) for each buffer zone can be determined from the attribute table of each shapefile that you have just created. Use SUMMARY STATISTICS to get the total and the mean are equivalent to TCA and MPSTCA, respectively.

OR: You can create grids to determine core area and use weighted edges in your analyses.

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Appendix 2. Land cover for each summary statistics in each buffer zone derived from ArcView 3.2 with Patch Analyst 2.2 extension.

Coverage: option selected	Statistic derived (abbreviation used)
Land use land cover[1]: class	Amount of area in each cover type (CA)
	Total Landscape Area (TLA)[1]
Land use land cover: landscape	Edge density (ED)
	Shannon's Diversity Index (SDI)
	Shannon's Evenness Index (SEI)
Forest / Non-forest: class	Amount of mature forest area (FOREST)
	Mean patch size for forest (MPSforest)
	Number of forest patches (TFP)
Core area (or grid): class[2]	Total core area (TCA)
	Mean patch size for core area (MPSTCA)
Using measure tool: by hand[3]	Distance to water, habitat change, etc. (DISwater)
	Distance between points

[1]Not used in analyses, but make sure to double-check these totals (1000 m = 312 ha; 564m = 99.4 ha). Errors may indicate overlapping or non-digitized areas in the polygons from the buffer.
[2]Can also get this information from attribute table of core area shapefiles for each buffer zone.
[3]These distances can be completed using ArcView 3.2 (nearest neighbor), and I used distance tool to double check estimates.

VITA

Rebecca D. M. Smith

Rebecca Denise McGarvey Smith was born on March 4, 1973 in Jacksonville, North Carolina as the first daughter of Michael T. and Beverly M. McGarvey. Her family moved from North Carolina to central Kentucky when she was very young. She received her high school diploma from Bardstown High School in Bardstown, KY in 1991. She began attending the University of Kentucky in fall 1991, studying Natural Resource Conservation and Management, and completed her Bachelors of Science in December of 1995. After graduating, she took a job as a Conservation Education Program Leader with Kentucky Department of Fish and Wildlife Resources and then as a Wildlife Educator with the Idaho Department of Fish and Game. She married her best friend, Brian W. Smith, on February 20, 1999.

In January 2000, she began as a graduate student in Wildlife and Fisheries Science at West Virginia University under Dr. Petra Bohall Wood. She has had the privilege of working with raptors since 1994, including raptor rehabilitation, a Peregrine Falcon restoration project, mist-netting Northern Saw-whet Owls, Western Screech-owl and Burrowing Owl research with her husband Brian, migration studies in Idaho, Cape May, NJ, and Braddock Bay Observatory, NY, and her own research in West Virginia. After graduation, she will be continuing her career as a biologist with an ecological consulting firm in Kentucky.

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Rebecca D. M. Smith

Division of Forestry
West Virginia University
Morgantown, West Virginia

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