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HABITAT SELECTION OF THE CERULEAN WARBLER IN EASTERN KENTUCKY

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ABSTRACT OF THESIS

HABITAT SELECTION OF THE CERULEAN WARBLER IN EASTERN KENTUCKY

Successful forest management requires an understanding of the habitat requirements of individual species at multiple spatial scales. The cerulean warbler (*Dendroica cerulea*) is a neotropical migratory songbird that has recently gained widespread attention as a species of conservation and management concern. It breeds in mature, deciduous forests of eastern North America and has experienced precipitous range-wide declines over the last 40 years. Although Kentucky likely supports one of the largest breeding populations of the species, no information exists on cerulean warbler habitat selection within the state. The overall purpose of this study was to identify important habitat features associated with cerulean warbler distribution on breeding grounds in eastern Kentucky. In 2004 and 2005, I examined cerulean warbler distribution and associated vegetative characteristics within a hierarchical framework at the stand, territory, and nest-site levels. I used the Information-Theoretic approach to develop 2 sets of *a priori* models. The first set of models attempted to explain cerulean warbler site occupancy through presence and absence data obtained from point counts. The second set of models attempted to explain differences between preferred song perches and available habitat. Due to small sample size, nest-site information was not used in modeling efforts. Results from presence and absence modeling were inconclusive as no habitat-related differences were identified between occupied and unoccupied locations within the study area. However, territory modeling revealed three potentially important predictors of cerulean warbler habitat: large diameter trees, east-facing aspect, and increased shrub cover. This study reinforces general patterns observed throughout the cerulean warbler's breeding range. Although the mechanisms causing cerulean warbler declines are still poorly understood, conservation and management efforts directed toward protecting and establishing large tracts of mature forest with large trees on mesic, sheltered sites should be a reasonable approach to managing cerulean warbler populations on the breeding grounds.

KEYWORDS: Cerulean warbler, *Dendroica cerulea*, habitat selection, Neotropical migrants

Patricia J. Hartman

January 9, 2006

HABITAT SELECTION OF THE CERULEAN WARBLER IN EASTERN KENTUCKY

By

Patricia J. Hartman

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_ January 9, 2006_________

THESIS

Patricia Jennings Hartman

The Graduate School

The University of Kentucky

2006

HABITAT SELECTION OF THE CERULEAN WARBLER IN EASTERN KENTUCKY

THESIS

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in the College of
Agriculture at the University of Kentucky

By

Patricia Jennings Hartman

Lexington, Kentucky

Director: Dr. David S. Maehr, Professor of Conservation Biology

Lexington, Kentucky

2005

MASTER’S THESIS RELEASE

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Signed: _Patricia J. Hartman___

Date: ___January 9, 2006______

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Finally, this thesis is dedicated to my parents, Mike and Sharon Hartman. Thank you for your support and interest in my endeavors; knowing you are behind me gives me the confidence to do things I otherwise wouldn't. You are both constant sources of inspiration in the way you live your lives and are truly the kind of people a daughter aspires to be.

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CHAPTER ONE: INTRODUCTION

Breeding Bird Surveys indicate long-term downward trends in neotropical migratory songbird populations over the last 40 years, especially among forest and grassland species (Peterjohn et al. 1995; Robbins et al. 1992). Habitat loss and fragmentation of breeding and wintering grounds are the most frequently cited causes of the decline (Faaborg et al. 1995; Terborgh 1980, 1992). Songbird population responses vary widely among species, regions, and spatial scales. At the landscape level, increased isolation of forest fragments and reduced patch size eliminate suitable habitat for some species (Freemark & Collins 1992). Additionally, changes in habitat structure such as reduced vertical and horizontal complexity, increased habitat patchiness, and altered plant succession negatively impact songbird species richness and diversity (Thompson et al. 2003). Further, birds occupying smaller fragments frequently exhibit negative demographic responses such as reduced pairing success (Gibbs & Faaborg 1990; Hagan et al. 1996; Porneluzi & Faaborg 1999; VanHorn et al. 1995), higher rates of nest predation (Donovan et al. 1995; Gates & Gysel 1978; Robinson et al. 1995) and increased brood parasitism (Askins et al. 1990; Brittingham & Temple 1983; Chalfoun et al. 2002; Faaborg et al. 1995; Kondo & Nakagoshi 2002; Paton 1994; Robinson 1992; Robinson et al. 1995). Understanding the habitat needs of imperiled songbirds at different spatial scales is important to developing management plans that promote their conservation.

Study Animal

The cerulean warbler (*Dendroica cerulea*) is a canopy-dwelling, neotropical migratory songbird that breeds in mature, deciduous forests in eastern North America. Over the last 40 years, it has exhibited a precipitous range-wide decline of 4.2% annually (Sauer et al. 2001), especially in historically high-density areas such as Kentucky where the annual losses are >6.2% (Hamel 2000b). Concomitant with the decline, the cerulean warbler's range has shifted northeastward (Hamel et al. 2004), likely due to maturing second-growth forest in the northern part of its range (Oliarnyk & Robertson 1996) and loss of bottomland hardwood forest in the southeast (Hamel 2000a). In response to reduced population sizes, the Southeast Environmental Law Center petitioned the U.S. Fish and Wildlife Service to list the cerulean warbler as Threatened under the Endangered Species

Act of 1973 (SELC 2000). It is currently listed as a species of concern in 13 states and in Canada (Rosenberg et al. 2000). With growing awareness of its imperilment, the cerulean warbler has become emblematic of healthy, mature deciduous forests (Jones et al. 2004).

The cerulean warbler's breeding range (Figure 1-1) extends from southeastern Nebraska to western New England and from northern Texas to western North Carolina (Hamel 2000). The Cumberland Plateau region of eastern Kentucky, eastern Tennessee, and southwestern West Virginia is thought to support the largest breeding population of the species (Robbins et al. 1992, Rosenberg et al. 2000). However, the Cerulean Warbler Atlas Project (Rosenberg et al. 2000) identified Eastern Kentucky as one of the largest gaps in recent survey coverage (1997-2000).

The cerulean warbler once was abundant throughout Kentucky (Figgins 1945; Mengel 1965). In the late 19th century, Beckham (1885) claimed the species was so dense, "I several times killed two at one discharge of my gun." Just 40 years ago, Mengel (1965) claimed it "undoubtedly [bred] in every county of the state." In contrast, recent surveys detected singing males in only about 16% of priority blocks statewide (Palmer-Ball 1996). While Mengel (1965) noted the cerulean's abundance in the western and central portions of the state, Breeding Bird Survey estimates from 1937-1971 revealed the highest densities in eastern Kentucky and the Cumberland Plateau (Robbins et al. 1992). Recent Breeding Bird Survey data confirm the presence of established breeding populations in the eastern portion of the state and patchy, local breeding populations west of the Cumberland Plateau (Palmer-Ball 1996; Sauer et al. 2001).

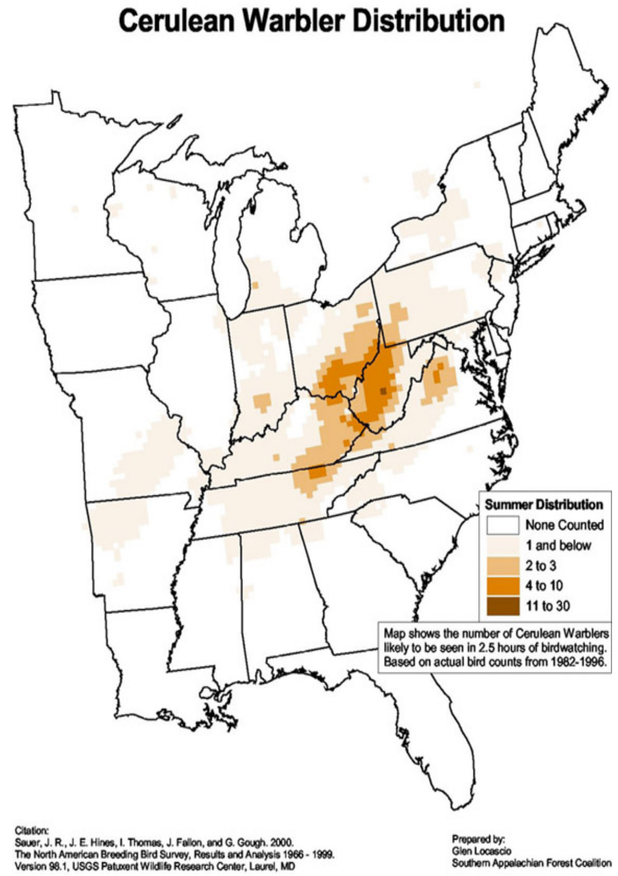
The cerulean warbler is sensitive to forest fragmentation and is frequently classified as area-sensitive (Robbins et al. 1989; Robbins et al. 1992). Large tracts of contiguous forest are the most important landscape features associated with cerulean warbler presence throughout its range (Hamel 2000a; Robbins et al. 1992). Estimated minimum patch sizes for cerulean warbler presence range from 10 to 800 ha (Hamel 2000a; Jones & Robertson 2001; Mueller et al. 1999; Robbins et al. 1989). However, forest tracts believed to support viable breeding populations are larger, ranging from >1600 ha (Robbins et al. 1989) to >8000 ha (Mueller et al. 1999). Within the Southeast Region, which includes Kentucky, over 80% of cerulean warblers recorded during the Cerulean Warbler Atlas Project were found in tracts >2,000 ha (Rosenberg et al. 2000).

Commonly associated with mature forests, the cerulean warbler is found equally in wet bottomlands and mesic uplands and slopes (Hamel 2000a, 2000b; Rosenberg et al. 2000). Owing to range-wide variation in tree species composition, structural characteristics of trees such as large diameter and height are generally thought to be more important than individual tree-species preferences (Hamel 2000b). Indeed, researchers have most frequently found that males selected territorial perch trees with larger than average diameters when compared with available trees (Barg 2002; Jones & Robertson 2001; Nicholson 2003; Oliarnyk & Robertson 1996; Robbins et al. 1992). However, some species-specific preferences have been found. Gabbe et al. (2002) found cerulean warblers selectively foraging in shellbark hickory (*Carya laciniosa*) and Nicholson (2003) found evidence to suggest the species chose black cherry (*Prunus serotina*), sugar maple (*Acer saccharum*), and tulip poplar (*Liriodendron tulipfera*) for nest sites in greater proportion than their abundance in eastern Tennessee. Other vegetative characteristics that may be important in cerulean warbler breeding habitat include the presence of canopy gaps and an open midstory (Hamel 2000a, 2000b; Jones & Robertson 2001; Oliarnyk & Robertson 1996).

Successful management of the cerulean warbler depends on a thorough understanding of its habitat requirements and behavior. Because of range-wide variability in forest composition, topography, soils, and other site characteristics (Hamel 2000b), an understanding of site-specific characteristics promoting habitat use and nesting success is essential. The Cerulean Warbler Technical Group (CWTG), an international research group comprised of academic, government, and industry biologists, developed a list of research priorities to promote better cerulean warbler habitat management. On the breeding grounds, these priorities include**:** 1) population response to silvicultural treatments and timber harvest; 2) effects of forest structure and composition on population demography; 3) basic life history; 4) differences in decreasing and increasing populations with respect to landscape; 5) multi-scale effects of land use on population demography; 6) landscape-scale mechanisms that affect population demography; 7) variation of habitat use/selection across the species range; and 8) migrational habitat needs.

Despite its status as a top conservation priority for the southeast and observed high densities in eastern Kentucky, very little information is available regarding cerulean warbler habitat preferences on these important breeding grounds. In Kentucky, no information exists regarding habitat suitability, nest-site selection, or nesting success of the cerulean warbler. The objectives of my study were to: (1) examine habitat choice of the cerulean warbler in eastern Kentucky at multiple spatial scales (Chapter 3); (2) describe the breeding behavior, nesting chronology, and nesting success in Kentucky (Chapter 4); (3) describe avian community characteristics in areas occupied by the cerulean warbler (Chapter 5); and (4) examine a potential behavioral component to cerulean warbler habitat choice, conspecific attraction (Chapter 6). The findings from this study will fill in gaps in the knowledge and provide land managers with information necessary to design a cerulean warbler conservation plan for eastern Kentucky.

Figure 1-1. Breeding distribution of the cerulean warbler. Adapted from Southeast Environmental Law Center.



Cerulean Warbler Distribution

Map shows the number of Cerulean Warblers likely to be seen in 2.5 hours of birdwatching. Based on actual bird counts from 1982-1996.

Citation:
Sauer, J. R., J. E. Hines, I. Thomas, J. Fallon, and G. Gough. 2000.
The North American Breeding Bird Survey, Results and Analysis 1966 - 1999.
Version 98.1, USGS Patuxent Wildlife Research Center, Laurel, MD

Prepared by:
Glen Locascio
Southern Appalachian Forest Coalition

CHAPTER TWO: STUDY AREA

The study was conducted in the Morehead District of the Daniel Boone National Forest (DBNF) in east-central Kentucky (Figure 2-1). The Morehead Ranger District is the northernmost section of the DBNF and includes portions of Rowan, Bath, and Menifee counties. It is located on the Pottsville escarpment at the northwest boundary of the Cumberland Plateau and the southwest boundary of the Allegheny Plateau (Smalley 1986). The Cumberland Plateau region lies within the core of the breeding range of the cerulean warbler and has been singled out by Partners in Flight (PIF) as an area of “immediate conservation concern” (Rosenberg et al. 2000).

The region is characterized by rough topography with narrow, winding ridgetops, steep slopes, and deep, narrow ravines. On the study sites, ridges typically are oriented in a north-south direction. Soils originate from underlying sandstone, siltstone, and conglomerates of the Pennsylvanian formation (Smalley 1986). Ridgetop soils are typically well-drained and shallow to moderately deep while mid to lower slopes are moderately well-drained and deep (USDA 2004). Elevation ranges from 212 to 394 m above mean sea level.

Within the proclamation boundary of the forest, approximately 95% of the area is forested. It is a transition zone between mixed mesophytic and oak-hickory forest types, and forests in the area are characterized by a diversity of species in the canopy and understory. Typically, oak-hickory forest dominates drier ridgetops while mixed mesophytic forests are found on east and north-facing slopes (Martin 2003; Overstreet 1989). Canopy co-dominants include tulip poplar, sugar maple, northern red oak (*Quercus rubra*), white oak (*Q. alba*), black oak (*Q. velutina*), chestnut oak (*Q. prinus*), white ash (*Fraxinus Americana*), and hickories (*Carya spp.*). In addition to these dominant tree species, cucumbertree (*Magnolia acuminata*), American basswood (*Tilia americana*), black walnut (*Juglans nigra*), and chinquapin oak (*Quercus muehlenbergii*) frequently are observed in the canopy. Flowering dogwood (*Cornus florida*), sourwood (*Oxydendron arboreum*), eastern redbud (*Cercis canadensis*), eastern hophornbeam

(*Ostrya virginiana*), downy serviceberry (*Amelanchier arborea*), American beech (*Fagus grandifolia*) and sassafrass (*Sassafras albidum*) are common in the subcanopy and understory. Frequent and abundant shrubs include spicebush (*Lindera benzoin*), pawpaw (*Asimina triloba*), greenbriar (*Smilax spp.*), and a variety of tree saplings.

The climate of eastern Kentucky is classified as temperate humid continental with warm to hot summers and cool winters (USDA Forest Service 2004). There is no distinct dry season. Annual rainfall averages 113.9 cm (Hill 2005). From March through August, thunderstorms of short duration and high intensity are common (Hill 2005). Average annual temperature is 11.8ºC. When cerulean warblers are present on the breeding grounds (April - August), average daily lows range from 2.5 º to 16.1ºC and average highs from 20.1 º to 30.7 ºC (Hill 2005).

Buffalo Branch – 2004 Season

The Buffalo Branch study area covers approximately 1600 ha in Rowan County, northeast of Morehead between KY Highways 32 and 60. Sites were located within the Morehead and Haldeman U.S. Geological Survey quadrangles. The area is a mosaic of various seral stages of secondary deciduous forest, with the majority of trees ranging in age from 50 to 100 years in age. This area is typical of the oak-hickory and mixed mesophytic transition zone described above, but substitutes red maple for sugar maple as a dominant canopy species. Sugar maple was observed infrequently and its distribution was limited to mesic coves within the area.

Portions of the Morehead Ranger District, including Buffalo Branch, were hit by an ice storm in February 2003. Aerial photography identified >9,000 ha of ice-damaged forest (Lewis 2003). The weight of the ice resulted in crown damage, broken limbs, uprooted trees, and exposure of bare soil. Although basal area remains high, canopy damage has increased the amount of sunlight reaching forest floor, increasing the density of understory vegetation. Approximately 45% of trees in affected areas sustained damage to >⅓ of the crown (Lewis 2003).

In spring 2004, I established five 1-km^2 survey grids in Buffalo Branch (Figure 2-2). Grids were placed randomly, and point count stations within the grids were established systematically at 250 m intervals. Each grid contained 20 point count locations, for a total of 100 points. Grids were spaced at least 250 m apart.

Pioneer Weapons Area and Clear Creek Management Area – 2005 Season

In 2005, I expanded the study to coordinate with a multi-state, multi-year study designed by the Cerulean Warbler Technical Group (CWTG) (Hamel et al. 2004). The purpose of this project is to examine the effects of various silvicultural treatments on forest songbirds. Four 20 ha study plots were established for the CWTG project and the first year of pre-treatment data was collected in 2005. Three plots were established in Pioneer Weapons Area (Figure 2-3) and 1 plot (Heavy Treatment) was established in Clear Creek Management Area (Figure 2-4).

All stands were located within the Salt Lick U.S. Geological Survey quadrangle. The area is bounded by KY highways 211 and 36 to the west and Cave Run Lake to the north and east. The Pioneer Weapons Area (PWA) covers >3,000 ha in southeast Bath County, near the borders of Menifee and Rowan counties. Clear Creek Management Area (CCMA) lies directly southeast of PWA. The forest in this area is somewhat older than Buffalo Branch, with the majority of trees 80 to 115 years old.

Based on criteria set forth by CWTG, plots were located in stands with at least 30 ha of mature forest, were not bisected by roads, and contained cerulean warblers. Flagged grids were established at 25 m intervals using compass and rangefinder. Final plot boundaries were surveyed with a GPS unit. Although treatments have not yet been implemented (planned for Fall 2006), individual plots will be referred to by treatment type: Control, Light Treatment, Intermediate Treatment, and Heavy Treatment (Appendix A contains treatment implementation guidelines).

Figure 2-1. Map of Daniel Boone National Forest, eastern Kentucky. Red arrows indicate study areas.

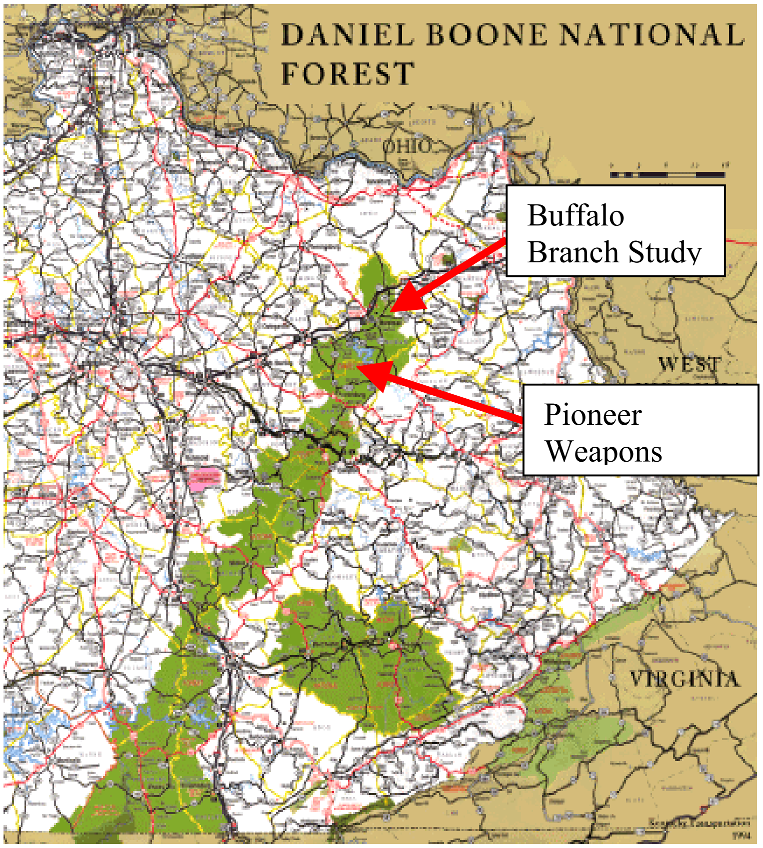


Figure 2-2. Boundaries of five 1 km^2 point count survey grids in Buffalo Branch, Daniel Boone National Forest, eastern Kentucky.

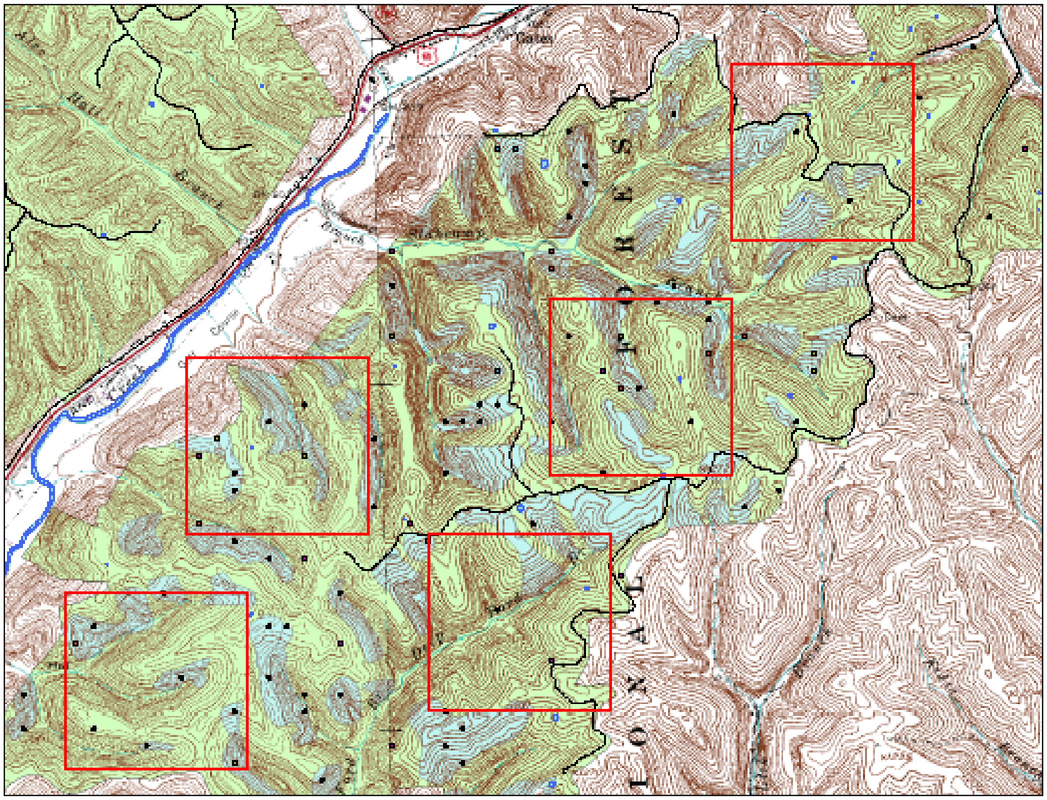


Figure 2-3. Boundaries of three 20 ha plots project in Pioneer Weapons Area. Treatments in this area include Control, Light Treatment, and Intermediate Treatment.

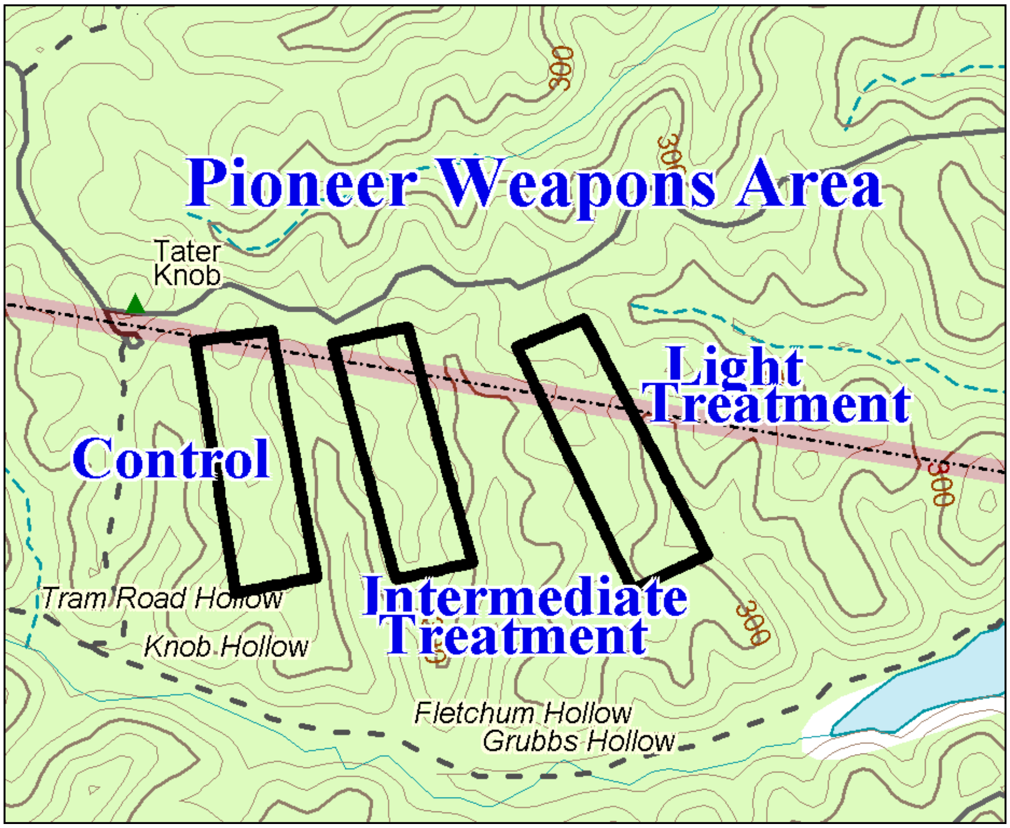
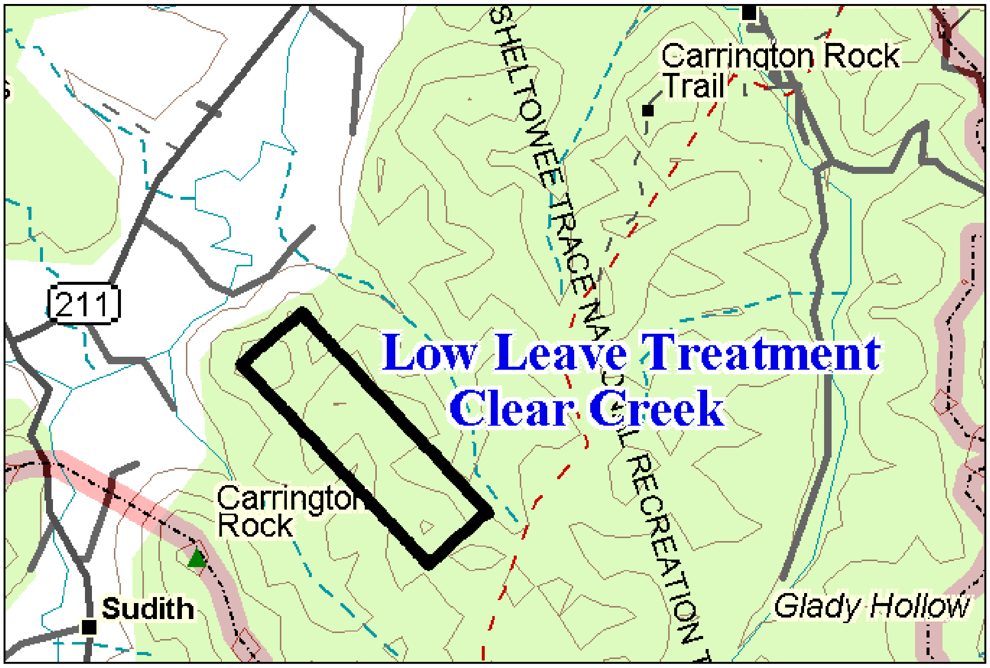


Figure 2-4. Boundary of one 20 ha plot in Clear Creek Management Area. The treatment in this area will be a low leave cut.



CHAPTER THREE: HABITAT SELECTION OF THE CERULEAN WARBLER IN EASTERN KENTUCKY

Introduction

Breeding Bird Surveys indicate long-term downward trends in neotropical migratory songbird populations over the last 40 years, especially among forest and grassland species (Peterjohn et al. 1995; Robbins et al. 1992). Habitat loss and fragmentation of breeding and wintering grounds are the most frequently cited causes of the decline (Faaborg et al. 1995; Terborgh 1980, 1992). Songbird population responses vary widely among species, regions, and spatial scales. At the landscape level, increased isolation of forest fragments and reduced patch size eliminate suitable habitat for some species (Freemark & Collins 1992). Additionally, changes in habitat structure such as reduced vertical and horizontal complexity, increased habitat patchiness, and altered plant succession negatively impact songbird species richness and diversity (Thompson et al. 2003). Understanding the habitat needs of imperiled songbirds at different spatial scales is important to developing management plans that promote their conservation.

The cerulean warbler (*Dendroica cerulea*) breeds in the deciduous forest of eastern North America and has declined dramatically over the last 40 years (Sauer et al. 2001), especially in historically high-density areas such as Kentucky (Hamel 2000b). It is currently a high conservation priority and is listed as a species of concern in 13 states and in Canada (Rosenberg et al. 2000). With growing awareness of its imperilment, the cerulean warbler has gained status as a flagship species for mature deciduous forests (Jones et al. 2004).

Successful management of the cerulean warbler depends on a thorough understanding of its habitat requirements and behavior. Although general landscape features regarding tract size, stand age and degree of fragmentation are thought to be important (summarized in Hamel 2000b; Weakland & Wood 2005), habitat choice for this species remains poorly understood. Vegetative characteristics associated with cerulean warbler breeding habitat have been examined in many parts of its breeding range (Hamel 2000a; Jones et al. 2001;

Jones & Robertson 2001; Oliarnyk & Robertson 1996; Robbins et al. 1992), but sufficient regional ecological variation exists that site-specific research is needed to develop appropriate conservation plans.

The objectives of this study were to describe cerulean warbler breeding habitat in eastern Kentucky and to determine which habitat features were predictive of its distribution within the environment. I examined habitat choice of the cerulean warbler at 2 spatial scales. First, I examined habitat selection within stands. Second, I examined habitat features of territories, specifically singing perches. I also evaluated the relative effectiveness of point counts, territory mapping, and information-theoretic modeling. The findings of this research will provide land managers with information necessary to design a cerulean warbler conservation plan for eastern Kentucky and will aid future researchers in the development of successful study designs.

Methods

In spring 2004, I established 5, 1 km^2 survey grids in Buffalo Branch (Figure 2-2), an ice-damaged stand composed of 50-100 year old mixed hardwoods in Daniel Boone National Forest (DBNF) near Morehead, Kentucky (Figure 2-1). Grids were placed randomly and point count stations within the grids were established systematically at 250 m intervals. Each grid contained 20 point count locations, for a total of 100 points. Grids were spaced at least 250m apart.

In 2005, I established 4, 20 ha study plots in Pioneer Weapons Area (Figure 2-3) and Clear Creek Management Area (Figure 2-4). These plots were created to coordinate with a multi-state, multi-year study designed by the Cerulean Warbler Technical Group (CWTG) (Hamel et al. 2004). The forest within the CWTG plots is somewhat older than Buffalo Branch, and was minimally affected by the 2003 ice storm. Based on criteria set forth by CWTG, plots were located in stands with at least 30 ha of mature forest, were not bisected by roads, and contained cerulean warblers. Three plots were established in Pioneer Weapons Area and 1 plot (Heavy Treatment) was established in Clear Creek

Management Area. Plots were gridded and flagged at 25 m intervals using a compass and rangefinder. Plot boundaries were surveyed with a GPS unit.

Point Counts

In 2004, I conducted point counts to detect cerulean warbler presence within the Buffalo Branch study area. Ten minute, 100-m fixed radius point counts (Hamel et al. 1996; Ralph et al. 1993) were conducted on the 5 grids (n=100 point count stations). Observers recorded all individuals detected within 4 distance classes (0-25 m, 25-50 m, 50-100 m, and >100 m) and 3 time intervals (0-3, 3-5, and 5-10 minutes). Surveys were conducted between sunrise and 1000 EDT on days without rain or high wind (>20 km/hour). Point counts were conducted by 3 observers skilled in bird identification and trained in distance estimation.

Cerulean warblers were classified as "present" if found <50 m from point center or "absent" if found >50 m from point center at each point count location (Nicholson 2003) so that survey points could be effectively compared to local habitat measurements (Petit et al. 1995). While detection of the target species clearly indicated its presence at a survey point, non-detection was not always sufficient to classify it as "absent" (MacKenzie et al. 2002) and may have resulted in underestimation of site occupancy (Gu & Swihart 2004). To reduce the likelihood of non-detection, each point was surveyed twice during the breeding season (May 20-26 and June 7-11).

I sampled topographic and vegetation features at each point count location to determine vegetative characteristics within the study area. Plots were centered on the point count station and included a 50 m radius circle around each point. Measurements were taken in accordance with Kentucky Department of Fish and Wildlife Resources protocols (Appendix B), which included species composition, basal area, average diameter at breast height (dbh), canopy structure, canopy cover, slope, and aspect. Basal area (m^2/ha) was estimated using a 2.5-factor metric prism. Additionally, I identified to species, measured the dbh, and estimated the amount of crown damage for each tree within the prism plots. Percent canopy cover, midstory cover, and understory cover within the 50 m radius were visually estimated. Estimates were made by 3 observers who standardized their observations prior to the start of vegetation work. I also recorded the type of landform (narrow creek bottom, wide bottomland, narrow ridge, broad ridge, gentle slope, or steep slope) and the topographic position (upper, mid, or lower slope).

Cerulean Warbler Territory Selection

In 2005, I used spot-mapping to identify individual territory holders (Bibby 1999) and frequently-used song perches within the 4 CWTG plots. Surveys were conducted from one-half hour after sunrise to 1030 EDT by 4 observers experienced in songbird identification and trained in territory mapping procedures. Each plot was censused every fourth day between 2 May and 30 May for a total of 8 visits per plot. During each census, observers walked at a slow pace and approached within 50 m of each grid point. Starting points and routes taken through the plots varied between surveys. For each individual encountered, we recorded bird age (juvenile or adult), sex, activity (singing, calling, carrying nest material or food, etc.), territorial interactions, and location.

Territories and random points were sampled within each of the 4 study plots to characterize the study area and to compare territories with available habitat. Territory plots were centered on preferred singing perches of males, which were identified during nest-searches and spot-mapping. Available plots were centered on randomly-selected grid points (20 points / grid). Plot measurements included basal area, average dbh, tree height, species composition, slope, aspect, and percent canopy cover in 6 height classes (0.5-3 m, 3-6 m, 6-12 m, 12-18 m, 18-24 m, >24 m) (Appendix C). Height and number of stems of saplings and shrubs were recorded within a 3 m radius of each plot center.

Statistics: Multivariate Analyses

I used the Information-Theoretic approach (Burnham and Anderson 2002) to construct and evaluate 2 sets of models (Presence-Absence and Territory-Available). This method uses Akaike's Information Criterion (AIC) to estimate the Kullback-Liebler (K-L) distance between reality and an individual model. The approach has gained popularity in recent years because it emphasizes biological significance and formulation of *a priori* hypotheses over statistical significance tests and data mining.

AIC_c values were calculated to correct for small sample size. The model with the lowest AIC value was considered the best approximating model given the data and the set of specified models. To determine the weight of the evidence favoring a particular model, AIC differences (Δ_{AIC}) between models, Akaike weights (w_i), and evidence ratios were calculated. Models with $\Delta_i < 2$ were considered to have substantial support while models within 3-7 Δ_i had considerably less support; models with >10 Δ_i had virtually no support (Burnham and Anderson 2002). Akaike weight was interpreted as the probability that a given model was the best model given the data and set of models. SAS® software was used to perform all statistical analyses.

Statistics: Model Development

The relationships between cerulean warbler presence-absence and territory-available habitat were modeled using logistic regression. Within each data set, I developed 3 types of models based on ecological processes that influence reproduction and survival: nesting, predator avoidance, and food availability. A fourth model type, referred to as a "combination" model, included variables thought to be important in 2 or more ecological processes. Variables were selected for inclusion in a model based on previous studies of cerulean warbler habitat selection and field observations (Tables 3-1 and 3-2). Within model types, habitat and topographic variables thought to be important in an ecological process were selected for a general model, then progressively reduced to the 2 to 3 variables deemed most essential to that process. Prior to analysis, variables were tested for correlation and were excluded from the model if highly correlated with other variables in the model. For pairs of habitat variables with Pearson correlation coefficients ≥ 0.3, one variable in each pair was eliminated (cite). The number of variables within each candidate model ranged from 2 to 5.

Nine *a priori* candidate models were developed to predict cerulean warbler presence-absence within the Buffalo Branch grids. The dependent variable was cerulean warbler presence within 50 m of a survey point, and the predictor variables consisted of habitat and avian community characteristics at each point count station. Because species diversity and *Carya* basal area were highly correlated, *Carya* basal area was excluded from presence-absence models. No other correlations were found within the *a priori* models.

Nesting models for presence-absence data included the variables basal area, dbh, percent canopy cover, percent midstory cover, and aspect. With the exception of midstory and aspect, I expected each of these to be higher in CERW-occupied areas than unoccupied areas because they provide nesting substrate and concealment. Midstory cover was expected to be lower because the cerulean is known to have an open space of at least 5 m below the nest (Hamel 2000a). Aspect was thought to be important because it could play a role in temperature regulation at the nest. Predator avoidance models included the variables percent canopy cover, percent understory cover, number of nest predators, and presence or absence of cowbirds. Canopy cover was expected to be higher because of its role in the concealment of nests and incubating females from aerial predators. Understory cover was also expected to be higher because of its potential importance in providing post-fledging habitat for young (Anders et al. 1998; Vega Rivera et al. 1998). Nest predator and cowbird data obtained from point counts were included because nest predation and brood parasitism account for the majority of nest failures in songbird populations (Martin 1992). The food availability model included tree species diversity, percent damaged trees, and aspect. In this case, I thought that increased tree species diversity and the presence of some damaged trees could increase insect abundance and diversity. Similarly, differences in aspect could exert an influence on food availability through insect activity patterns.

Eight *a priori* candidate models were developed to compare habitat associated with frequently-used song perches with available habitat in the CWTG plots. In this case, the dependent variable was the territory, and the predictor variables included habitat conditions at each sample point. Shrub and sapling percent cover and number of stems were all positively correlated with canopy cover between 0 and 3 m (CC1). Because I was interested in structural complexity at that height, but not in differences between saplings and shrubs, I used CC1 and eliminated all shrub and sapling variables from the models. Similarly, I was able to reduce the number of variables related to canopy cover because percent cover at 6-12 m (cc3) and at 12-18 m (CC4) were highly correlated, as were percent cover at 18-24 m (CC5) and >24 m (CC6). Consequently, only CC3 and CC5 were used in modeling.

Results

Presence and Absence

Cerulean warblers were present within 50 m of the observer at 24 out of 100 point count stations. The best-supported logistic regression model of the 9 considered included diameter at breast height (dbh) and aspect (east or west) (Table 3-3). This model had an AIC_c =100.3 and an AIC weight of 0.29, indicating that this model had a 29% chance of being the best K-L model of the 9 models analyzed. However, this model was only 0.05 AIC_c units from the model containing the x-intercept alone, indicating that it was not significantly better than a model with zero variables. Three other models were within 2 AIC_c units of the best model, but we had no evidence to indicate that any model was better supported than the intercept alone.

Because the models were not supported by the data, I performed subsequent exploratory analysis. I used *t*-tests to look for differences in mean values (continuous variables; Table 3-4**)** and chi-square tests to look for differences in expected proportions (categorical variables; Table 3-5) between occupied and unoccupied sites. Only 1 significant difference was found among all variables: aspect. Cerulean warblers were found disproportionately on east-facing aspects within the study area.

Territory Selection

I measured 48 preferred singing perches of territorial males and 80 random points within the CWTG plots. Two of the 8 logistic regression models received considerable support: Nesting #3 (DBH, Aspect) and Combination #2 (DBH, Aspect, CC1) (Table 3-6). These models had AIC_c values of 141.26 and 142.94, respectively. None of the other models were within 2 AIC_c units of the best model, which suggested there was considerably less evidence to support these models. Akaike weights indicated the Nesting #3 model had a 55% chance of being the best K-L model of the 8 models analyzed while Combination #2 had a 24% chance. Further, the evidence ratio of the third best model in the set was almost 5, which suggests that the best model in the set was nearly 5 times more likely to be the best model in the set. Thus, dbh and aspect were identified as important predictors of cerulean warbler territories and a third variable, percent cover at 0-3 m, was also supported.

Discussion

Habitat management requires an understanding of how species respond to natural and anthropogenic change at multiple spatial scales (George & Zack 2001). This is a daunting challenge that is made more complex because the appropriate scale for management varies among species. For example, the black-throated blue warbler is more selective at the stand level than at the territory level (Steele 1992) whereas the opposite characterizes the American redstart (Sodhi et al. 1999). Further, depending on scale, some features may be functionally more important than others (i.e., nesting sites over foraging sites within territories; Matsuoka et al. 1997; Steele 1993). It is well known that the cerulean warbler requires certain features at the landscape scale related to tract size, stand age, and degree of fragmentation (summarized in Hamel 2000b; Weakland & Wood 2005), but variation throughout the range suggests site-specific differences at lower orders of habitat selection. In eastern Kentucky, the best predictors of cerulean warbler habitat selection were found at the territory level.

Presence and Absence

The results from presence and absence modeling were inconclusive. No habitat-related differences were significant in the logistic regression models. Other studies of occupied and unoccupied sites have found higher basal area (Jones & Robertson 2001; Robbins et al. 1992), larger tree diameters (Jones & Robertson 2001; Nicholson 2003; Robbins et al. 1992; Roth 2004), and increased understory cover (Nicholson 2003) in areas where the cerulean warbler was present. Weakland and Wood (2005) also noted increased canopy cover in 2 height classes (6-12 m and >24 m).

Univariate analyses indicated 1 topographic difference between occupied and unoccupied habitat patches within the study area: east-facing aspect. Over 85% of cerulean warblers detected in point counts were located on east-facing slopes. In a similar study using presence and absence data from point counts in Tennessee (Nicholson 2003), the majority of cerulean warblers occurred on NW aspects. In both cases, preferred aspect appears to coincide with more mesic and protected sites in comparison with the surrounding area. Aspect could be related to microclimatic preferences for nesting and is discussed in more detail below.

Territory Selection

My findings suggest that 3 microhabitat characteristics are potential predictors of cerulean warbler territory selection: large diameter trees, understory density, and east-facing aspect. Tree diameter and aspect were particularly important, as both variables were included in the 5 best logistic regression models (Table 7).

The importance of large diameter trees to the cerulean warbler is not new (Barg 2002; Jones & Robertson 2001; Lynch 1981; Nicholson 2003; Robbins et al. 1992). In the CWTG plots, song perches tended to be larger than average-sized trees (54 vs. 40 cm dbh). Early in the breeding season, males were frequently observed singing on open branches high in the forest canopy. Males may select territories with large, prominent trees because they serve as good “advertising locations” to attract mates. By pairing with males in territories with large trees, female ceruleans may improve their fitness through indirect benefits of higher canopy density including increased foraging opportunities (Marshall & Cooper 2004) and reduced predation (Bowman & Harris 1980; Martin & Roper 1988). Both males and females will benefit from increased foliage density of large trees in providing protective cover for nest sites, thus improving chances of offspring survival. The size of a singing perch tree *relative* to other trees in the stand may be more important than an absolute size due to range-wide variation in soils, topography, and tree species composition (Hamel 2000b).

In addition to the presence and absence results from this study, aspect was an important predictor of cerulean warbler territory placement, with >95% of territories found on east-facing slopes. Similarly, >85% of territories were located on NE aspects and ridegtops in West Virginia (Weakland & Wood 2005). Aspect could play a role in temperature regulation of individuals and at the nest. East and northeast slopes are oriented toward sunrise, which would likely allow birds to take advantage of the morning sun while avoiding mid-day heat stress (Calder 1973; Walsburg 1985). In Kentucky, east-facing slopes face away from the prevailing westerly and southwesterly winds, and may be another important factor in regulating nest microclimate (Austin 1976). In the northern hemisphere, east- and north-facing aspects are also generally associated with higher productivity compared to south and west-facing slopes (Tajchman & Lacey 1986), which could support greater food abundance.

Dense understories have been observed in other key breeding areas (Jones & Robertson 2001; Nicholson 2003) and have been broadly attributed to the cerulean's affinity for canopy gaps. These gaps may increase local shrub and sapling cover (Ranney et al. 1981). Although I did not explicitly measure distance to nearest gap in territory selection, the findings from this study are suggestive of increased light penetration associated with gaps because of the high proportion of saplings (>65%) within the shrub layer. Because the understory is not typically used by ceruleans during the breeding season, increased foliage at this lower layer has been viewed as relatively unimportant (Jones & Robertson 2001). I suggest that both gaps and shrub layer may be important features of cerulean warbler habitat.

Although the function of gaps in cerulean warbler territory selection is not clear, occasional breaks in the canopy have been identified as potential limiting characteristics for nesting and foraging sites (Hamel 2000a, b). Nest sites have been frequently observed near or adjacent to canopy gaps (Hamel 2000a, b; Jones & Robertson 2001;

Nicholson 2003; Oliarnyk & Robertson 1996; this study) and have also been associated wtih increased understory density (Jones & Robertson 2001; Nicholson 2003). Nests may be placed near gaps to improve nest-site microclimate, allowing increased sunlight to penetrate the canopy. Alternatively, nests and territories could be placed near gaps due to a positive impact on food availability. However, the effect of canopy gaps on insect abundance is equivocal. They been associated both with greater (Harris & Reed 2002) and lower (Kilgo 2005) invertebrate densities in the understory; the effect on canopy foliage surrounding gaps, which may be more relevant to cerulean warblers, is unknown. Selection for gaps could also relate to mate attraction; transmission of song may be enhanced at canopy gaps compared with the dampening effect of a dense forest (Schiek 1997).

A more developed understory may be important in and of itself. In the vulnerable post-fledging stage, cerulean warbler fledglings frequently make their way to the ground or shrub layer (personal observation). Nicholson (2003) observed family groups in black locust thickets on strip mines, where adults did not normally occur during the breeding season. I spotted my first fledgling by following the path of a male at an unusually low height (~1.5 m). Before it can fly, a fledgling's best defense against predation is probably hiding in thick vegetation. Dense understory may be a vital component of post-fledging habitat selection and may have implications for fitness and survival of offspring. Radiotelemetry studies of the wood thrush have shown that young leave forested areas of the nest site and travel long distances to a variety of early and mid-successional habitats after they fledge (Anders et al. 1998; Vega Rivera et al. 1998). Similarly, studies of post-fledging habitat use in clearcuts found over 50% of adults and fledglings captured in mist nets were forest-interior breeders (Marshall et al. 2003). Among those captured were species frequently observed in this study such as red-eyed vireo, worm-eating warbler, ovenbird, black-and-white warbler, hooded warbler and American redstart.

Hamel suggested that vertical distribution of foliage may be more important than values of percent canopy cover at a given height class (Hamel 2000b). Contrary to my expectations, percent cover in the upper canopy was not identified as a predictor of cerulean warbler territory or nest-site selection. Weakland and Wood (2005) found territories were more likely to be located in stands with higher percent canopy cover in 2 height classes (6-12 m and >24 m). In the younger forest of southern Ontario, Jones (2001) found dense canopy cover at 6-12 m and above 18 m. Although I failed to detect differences in vegetation height between territory and available sites, canopy cover was consistently highest in the upper canopy (12-18 m and 18-24 m), where the cerulean nests and forages. Marshall & Cooper (2004) found foliage density was an accurate predictor of caterpillar density for another canopy forager, the red-eyed vireo, and proposed males may indirectly gauge future food availability based on foliage cover during territory selection.

Some researchers have associated increased foliage density within the nest layer with greater nesting success (Matsuoka et al 1997, Bowman & Harris 1980, Steele 1993, Martin & Roper 1988). Foliage density near the nest site may inhibit transmission of visual or auditory cues related to nest discovery (Martin & Roper 1988). It may also increase predator search time by increasing the number of potential nest sites a predator must examine, reducing the overall chance of finding the nest. (Martin & Roper 1988). Although no studies have correlated foliage density with greater nesting success in cerulean warblers, Jones & Robertson (2001) observed a dramatic reduction in nesting success following a severe ice storm.

Effectiveness of Point Counts, Territory Mapping, and Modeling

AIC modeling ranked only the set of models developed as *a priori* hypotheses prior to analysis. If important variables were missing from the models or were not collected in the field, they would not be identified through this approach. Only the models I suggested as being most important in cerulean warbler habitat selection were considered. Some habitat variables were measured, but not included in the candidate set of models. Other variables that may be important such as distance to edge or distance to gap were not measured in this study and therefore were not considered in the analysis.

For presence and absence data obtained from point counts, several factors may have confounded comparisons of occupied and unoccupied habitat. First, increased habitat heterogeneity due to ice damage may have compromised the ability to detect differences. For example, understory vegetation was abundant throughout the study area due to increased light penetration through storm-created canopy gaps. However, overall basal area (22.2 m^2/ha) and canopy cover (>88%) remained high, which likely provided sufficient nesting and foraging structure that met the needs of cerulean warblers and those of other canopy-dwelling songbirds.

Another explanation for the failure to detect differences in unoccupied and unoccupied areas is that the sampling method did not adequately capture habitat features associated with cerulean warblers. Plots were centered on the point count station rather than on cerulean warbler singing or nesting locations. Although 50-m radius vegetation plots encompass nearly 8000 m^2, cerulean warblers may only use a small fraction of the sampled area. Landscape-level features such as distance to road and distance to edge would have been more appropriate measurements than the microhabitat variables collected in this study.

Finally, cerulean warbler distribution in the study area was patchy and habitat did not appear to be saturated, an observation that has been made throughout its breeding range (Hamel 2000a; Jones & Robertson 2001; Weakland & Wood 2005). If unused but suitable habitat is measured as “unoccupied,” statistical analyses may confound comparisons between used and available habitat (Wiens et al. 1987). On the one hand, the cerulean’s patchy distribution could suggest very narrow habitat preferences (Peck and James 1987). However, it could also intimate a non-structural element to habitat selection, such as conspecific attraction (Stamps 1988). Point counts and territory mapping techniques fail to capture non-habitat or behavioral drivers of habitat choice.

Conclusions

Several key habitat features have been consistently identified as important in cerulean warbler nest-site and/or territory selection throughout the breeding range. This study reinforces these general patterns. The conventional findings that cerulean warblers use large diameter trees in a multi-layered canopy structure with occasional gaps and dense understory appear to be sound management targets for eastern Kentucky. Particular tree species are likely not as important as the structure the trees provide, but east-facing mixed mesophytic conditions seem to be preferred. Although the mechanisms causing cerulean warbler declines are still poorly understood, conservation and management directed toward protecting and establishing large tracts of mature forest with large trees on mesic, sheltered sites should be a reasonable approach to managing cerulean warbler populations on the breeding grounds.

The next task in cerulean warbler management is to understand how these features affect productivity. Identifying the features that exert the strongest influence on the processes of mate attraction, nest predation and parasitism, food availability, and microclimatic differences will refine existing models of cerulean warbler habitat and enhance cerulean warbler conservation.

Table 3-1. Justification for microhabitat and avian community variables used to model cerulean warbler presence-absence in Buffalo Branch, Daniel Boone National Forest, eastern Kentucky.

Variable	Code	Ecological Function	Literature Review
Basal Area (m^2/ha)	BASAL	Nesting substrate and concealment; predator deterrent	Jones & Robertson 2001; Nicholson 2003; Martin 1992
Average dbh	DBH	Nesting substrate; territorial perches	Summarized in Hamel 2000a, b; Barg 2002, Nicholson 2003
% Understory Cover	UC	Canopy gaps; fledgling protection	Jones & Robertson 2001; Nicholson 2003
% Midstory Cover	MC	Distinct canopy layers; increased habitat complexity	Jones & Robertson 2001; Weakland & Wood 2005
% Canopy Cover	CC	Nest concealment; avoid aerial predators	Jones & Robertson 2001; Weakland & Wood 2005;
% Damaged Trees	DAM	Canopy gaps	Hamel 2000a, b; Weakland & Wood 2005
Tree Species Diversity	SPDIV	Food availability	
Aspect (E or W)	ASP	Food availability; thermoregulation	Weakland & Wood 2005; Nicholson 2003
Number of Nest Predators	PRED	Nest predation	Martin 1992
Cowbird Presence	COWBIRD	Brood parasitism	Martin 1992

Table 3-2. Justification for microhabitat variables used to model cerulean warbler territory vs. available habitat in Pioneer Weapons Area, Daniel Boone National Forest, eastern Kentucky.

Variable	Code	Ecological Function	Literature Review
Basal Area (m^2/ha)	BASAL	Nesting substrate and concealment	Jones & Robertson 2001
Dead Tree Basal Area (m^2/ha)	DEAD	Song perches; canopy gaps	Weakland & Wood 2005
DBH (territory tree vs. average-sized tree on random plot)	DBH	Song perches	Summarized in Hamel 2000a, b; Barg 2002, Nicholson 2003
Number of sapling stems	SAP	Canopy gaps; fledgling protection	Jones & Robertson 2001; Nicholson 2003
Number of shrub stems	SHRUB	Canopy gaps; fledgling protection	Jones & Robertson 2001; Nicholson 2003
Percent Canopy Cover 6-12 m	Cover 6-12	YES	Jones & Robertson 2001; Weakland & Wood 2005
Percent Canopy Cover 12-18 m	Cover 12-18	YES	Jones & Robertson 2001; Weakland & Wood 2005
Percent Canopy Cover 18-24 m	Cover 18-24	Food and nest site availability	Jones & Robertson 2001
Percent Canopy Cover >24 m	Cover 24+	Food and nest site availability	Summarized in Hamel 2000a, b; Weakland & Wood 2005
Aspect (E or W)	ASP	Food availability; thermoregulation	Weakland & Wood 2005; Nicholson 2003

Table 3-3. Independent variables for the 9 logistic regression models that predict cerulean warbler presence at point count stations in Buffalo Branch, Daniel Boone National Forest, eastern Kentucky. AIC values, ΔAIC values, and Akaike weights (w) are presented.

Model	**AIC$_c$**	**Δ_{AIC}**	**w$_i$**	**Evidence ratio**
DBH, ASP	100.30	0.00	0.29	1.00
Intercept alone	100.35	0.05	n/a	n/a
BASAL, DBH, CC, MC, ASP*	100.86	0.56	0.22	1.32
DBH, CC, MC, ASP*	101.32	1.02	0.17	1.71
DBH, PRED, ASP, CC, UC	102.22	1.92	0.11	2.64
PRED, CC	102.50	2.20	0.10	2.90
DBH, PRED, ASP	103.23	2.93	0.07	4.14
SPDIV, DAM, CARYA, ASP	105.57	5.27	0.02	14.50
PRED, UC	106.10	5.80	0.02	14.50
PRED, CC, UC, COWBIRDS	108.03	7.73	0.01	29.00

Table 3-4. Comparison of vegetative characteristics of point count stations with cerulean warblers (n=24) and without cerulean warblers (n=76) in Buffalo Branch, Daniel Boone National Forest. Values presented are means ± SE and *t*-test results for equality of means.

Continuous Variables	***Present***	***Absent***	***P-value***
Average DBH	32.51 ± 1.27	30.50 ± 0.9	0.519
Percent Canopy Cover	88.29 ± 1.96	88.49 ± 1.16	0.68
Tree Species Diversity	5.59 ± 0.85	4.82 ± 0.45	0.569
# Snags >12” DBH	2.23 ± 0.42	2.59 ± 0.32	0.993
% Damaged Trees within Basal Area	32.76 ± 6.49	34.83 ± 3.1	0.793
Average % Crown Damage	14.92 ± 2.85	17.52 ± 1.93	0.708
Slope	40.00 ± 3.65	34.49 ± 2.4	0.272

Table 3-5. Comparison of vegetative characteristics of point count stations with cerulean warblers (n=24) and without cerulean warblers (n=76) in Buffalo Branch, Daniel Boone National Forest. Values presented are results of χ^2 tests for equality of proportion.

Categorical Variables	***P-value* *(χ^2 Test)***
% Canopy Cover	0.16
% Midstory Cover	0.46
% Understory Cover	0.51
Slope position	0.39
Landform	0.8
Aspect	0.02

Table 3-6. Independent variables for the 8 logistic regression models that predict cerulean warbler presence at point count stations in the CWTG plots, Daniel Boone National Forest, eastern Kentucky. AIC values, ΔAIC values, and Akaike weights (w) are presented.

Model	**AIC$_c$**	**Δ_{AIC}**	**w$_i$**	**Evidence ratio**
DBH, Aspect	141.260	0.000	0.547	1.00
DBH, Aspect, CC1	142.937	1.677	0.236	2.31
DBH, Aspect, CC1, CC5	144.224	2.964	0.124	4.40
DBH, Aspect, CC1, CC3, CC5	145.976	4.716	0.052	10.57
DBH, Aspect, CC1, CC5, Dead tree basal area	146.433	5.173	0.041	13.28
Aspect, CC1, CC5	165.777	24.517	0.000	210765.2
Aspect, CC1, CC5, Dead tree basal area	167.031	25.771	0.000	394549.5
CC1, CC5	176.293	35.033	0.000	40487344.4

CHAPTER 4: CERULEAN WARBLER NEST-SITE SELECTION AND BREEDING BIOLOGY

Introduction

Nest-site availability is an important factor determining habitat selection in many open-nesting birds (Martin 1993). Individuals may seek territories with an abundance of nest sites in order to reduce predation risk (Martin and Roper 1988). Increasing the number of potential nest sites within a territory may reduce predator efficiency and thereby lower predation rates (Martin & Roper 1988). Because nest predation and brood parasitism are the leading causes of nest failure in open-nesting birds (Martin 1992), an understanding of nesting habitat requirements and of factors that influence nest success is essential to the development of appropriate management plans for species of conservation concern.

The cerulean warbler (*Dendroica cerulea*) is a canopy-nesting Neotropical migrant that breeds in mature, deciduous forests in eastern North America. Over the last 40 years, it has exhibited precipitous range-wide declines (Sauer et al. 2001), especially in historically high-density areas such as Kentucky (Hamel 2000b). Because cerulean warbler nests are placed high in the canopy and often difficult to find, information on productivity and nest-site selection is scarce. The objectives of this study were to provide the first quantitative description of cerulean warbler breeding habitat in Kentucky, to monitor breeding behavior and nesting success, and to examine nest-site selection.

Methods

During the spring of 2005, I searched for cerulean warbler nests on the 4, 20 ha study grids in Pioneer Weapons Area (Figure 2-3) and Clear Creek Management Area (Figure 2-4), Daniel Boone National Forest, eastern Kentucky. Territorial pairs, identified while spot-mapping (Bibby 1992), were visited at least twice a week for 30 to 90 minute periods throughout the breeding season, or until the nest was found. Nest searching efforts followed the protocol outlined by Martin and Geupel (1993). Specifically, nests were found by observing parental behavior (i.e. carrying nest material or food) and systematically scanning branches of large trees within cerulean warbler territories.

Nest Monitoring & Nest Success

Cerulean warbler nests were monitored to determine nest fates, observe parental behavior, and determine the length of nesting stages. Nests were monitored for 45 minute observation periods every 2 days. Nests were watched from the ground with a spotting scope between 0630 and 1400 on days without rain. During each nest watch, I recorded the number of trips to the nest, the activity observed (nest building, incubating, brooding, feeding, etc.), and the sex of the bird making the trip. Other behaviors at the nest, such as male-female interactions and removal of fecal sacs, were also recorded. I used *t*-tests to identify differences in parental activity between males and females and between successful and unsuccessful nests.

Nest stage was determined on each visit and classified into 1 of the following periods: building, laying, incubating, feeding, or fledgling. At the end of the nest cycle, each nest was classified as successful or unsuccessful. Due to the inaccessibility of nest sites, we were unable to determine the exact fates of unsuccessful nests. Therefore, all unsuccessful nests were lumped together without regard to cause of failure. Because brood parasitism has been implicated in declines of forest songbirds (Brittingham & Temple 1983) including cerulean warblers (summarized in Hamel 2000b), I also looked for evidence of brood parasitism by the brown-headed cowbird.

Nest success rates were quantified both as the raw percentage of nests that successfully fledged young, and by the Mayfield method (Mayfield 1961, 1975). Because it is difficult to determine exact transition dates between nest stages in high canopy nests, the full length of the observation period was used in calculations of nest success and a constant survival rate was assumed. For failed nests, we used the midpoint between the last and penultimate nest checks to determine failure date. Based on previous studies (Oliarnyk and Robertson 1996, Nicholson 2003), the nest cycle from laying to fledging was assumed to last 23 days (Roth 2004).

Nest Site-Selection

Seven nest-site and 16 nest-patch characteristics were measured at each nest. Nest-site variables included nest tree species, tree height, nest height, estimated diameter of nest-supporting limb, distance from nest to bole, distance from nest to canopy edge, distance from nest to nearest canopy gap, and gap type. A canopy gap was defined as a break in the canopy if it was >1/2 times the average canopy height (CWTG protocol). Nest-patch measurements were centered directly below the nest, but were otherwise identical to the territory and available plots described in Chapter 3.

Results

The first male cerulean warblers were observed in the study area on 15 April. Female cerulean warblers were observed building nests between 5 May and 12 May. However, hatch dates for nests found during other stages suggest building activity from late April to mid-May. All nests were built entirely by the female. Males frequently sang nearby and occasionally accompanied the female to the nest. The first fledglings were observed on 22 May.

Nest Monitoring and Nest Success

Thirteen nests were found within the 4 study plots. Of these, 12 were near territorial boundaries, making it difficult in some cases to identify the mate of the attending female until feeding began. One nest had had no neighboring territories. Parental behavior (n=11) was the most important cue in finding nests while systematic searches yielded considerably fewer nests (n=2). Nests were watched for an average of 4.2 hours each.

No second nesting attempts were documented, but 3 females from recently failed nests were observed removing material from an old nest and carrying it to a new location (presumably a new nest). In one case, a female was also observed taking material from an inactive nest near the ground in a patch of *Smilax spp.* This nest had probably belonged to a hooded warbler (*Wilsonia citrina*). Although nests were not found, potential re-nesting activity was noted as late as 2 June. As noted by Barg in Ontario (unpublished manuscript), female behavior became increasingly cryptic throughout the breeding season.

Incubation: Incubation was observed between May 5 and June 6. All incubation was performed by the female and lasted 11 (n=1) to 13 (n=2) days. In 25.5 hours (n=10 nests), the female sat on the nest 78.2% of the time for a mean (± SE) incubation time per hour of 47.6 ± 1.3 minutes. No difference was found between incubation rate and time of day or stage of incubation period (Figure 4-1).

As observed by others (Oliarnyk 1996, Barg unpublished manuscript, Nicholson 2003), males and females maintained vocal contact during incubation. On 21 occasions (n=10 nests), the approach or nearby singing of a male elicited call notes from an incubating female. Responding females received food from mates (n=10, 6 nests), remained on the nest (n=6, 7 nests), or left the nest to forage (n=5, 3 nests). No difference in nesting success was observed between nests of males known to provision females during incubation and those where males did not provision (p=0.42), but this test had low statistical power due to small sample size.

Females also vocalized when departing or returning to the nest during incubation without apparent provocation from the male. Females chipped before and during nest departure on 17 out of 54 (31%) observed departures.

Nestlings: I spent 23.5 hours watching nests during the nestling stage. Minimum length of the nestling period was 9 days (n=4). Both males and females fed the young as soon as they hatched, but males fed slightly more for the first 2 days after hatching (1.63 feeding trips per female per hour; 3.26 trips per male per hour; n=7 hours, 7 nests; p=0.06). For the first 2 days after hatch, females spent a mean (± SE) of 45.3 ± 2.7 minutes per hour brooding the nestlings. After day 2, mean brood time waned (Figure 4-2) and feeding rates for the entire nestling period did not differ between sexes (3.2 vs 4.27 trips per hour, p=0.26). Of 168 feeding trips observed, females fed nestlings 72 times (42.86%) while males fed nestlings 96 times (57.14%). Feeding rates increased with increasing number of days since hatch (Figure 4-3).

<u>Nesting success</u>: Fifty-four percent of cerulean warbler nests successfully fledged young and the Mayfield nest success estimate was 49% (Table 4-1).

Six nests failed. Although it is difficult to determine with certainty the cause of nest failure, one nest failure coincided with a heavy afternoon thunderstorm. Predation is the suspected cause of failure of 2 other nests, inasmuch as the nests were clearly disturbed with lining materials found on the ground nearby. Although specific predators could not be identified, potential nest predators such as blue jay (*Cyanocitta cristata*), American crow (*Corvus corax*), and red-bellied woodpecker (*Melanerpes carolinus*) were common throughout the study area.

The brown-headed cowbird (*Molothrus ater*) was present at all study sites, but brood parasitism was not observed. Due to the inaccessibility of nest sites, we were unable to determine whether brood parasitism occurred in nests that failed during the incubation or early nestling stages.

Nest-Site Selection

Nests were found in 6 tree species representing 4 genera (Table 4-2). Most nests were in the upper third of the tree (77%) on a horizontal (n=6) or intermediately angled (n=7) limb (Table 4-3). Nests tended to be closer to the canopy edge than the bole (77%) and were usually located within 20 m of a canopy gap (70%). Treefall gaps (n=4) were the most common gap type identified. Other gap types included steep drop-offs associated with ravines (n=2), an old logging road (n=1), or were of unknown origin (n=6).

Comparisons of vegetative characteristics of nest patches with territory and random patches yielded few differences (Table 4-4). Nest trees were smaller in diameter than territory trees, but were not significantly different in size than randomly available trees. Similarly, percent canopy cover >24 m was greater in territory patches than either nest or random sites. Due to the small sample size of nests and the likelihood of annual variation, however, these results should be interpreted with caution.

Discussion

Breeding Behavior and Nesting Success

For the most part, cerulean warbler breeding and nesting behavior in eastern Kentucky was similar to descriptions by Oliarnyk (1996) and Nicholson (2003). Parental behaviors at the nest including incubation, brooding, and feeding rates were similar to those described by Oliarnyk (1996) and Nicholson (2003) with a few exceptions. Male contributions accounted for about 57% of total feeding trips, greater than observed in Tennessee (40%) and Ontario (50%). Among other species of *Dendroica*, male contribution has been shown to vary between and within species (Morse 1989, 1993).

Males also appeared to interact with incubating females more frequently in eastern Kentucky. While Oliarnyk (n=20 hours) and Nicholson (n=15 hours) observed incubation feeding only twice, I observed males provisioning females on 10 occasions and approaching the nest on at least 11 additional occasions (n=25 hours). Perhaps owing to the scarcity of observations, incubation feeding has received little attention in the literature. Higher rates of incubation feeding have been linked with higher female attentiveness during incubation (Martin and Ghalambor 1999), which in turn positively affects developing embryos (White and Kinney 1974). However, this behavior also increases activity at the nest and may attract the attention of predators. Therefore, incubation feeding may be viewed as a trade-off between nest attentiveness and predation (Martin and Ghalambor 1999).

Although cowbirds were common in the study area, I observed no evidence of brood parasitism. Other studies have found varying and site-specific effects of brood parasitism on cerulean warblers. Oliarnyk (1996) and Nicholson (2003) found 0 and 1 parasitized nests, respectively, but Hamel (2000a) and Peck & James (1987) recorded 13-18% parasitism rates. Due to the inaccessibility of nests, I was unable to determine whether nests that were depredated during the incubation or early nestling stage were parasitized. Therefore, it is possible that brood parasitism occurred, but was not documented.

Nest-site Selection

Eastern Kentucky's mean cerulean warbler nest height of 19.2 m lies on the high end of the range of published values (□= 11.4 ± 0.4; range 4.6 - 19.5 m; compiled in Hamel 2000b) and is most comparable with nest heights in the Mississippi Alluvial Valley (Hamel 2000a) and eastern Tennessee (Nicholson 2003). Despite regional differences in nest height (Hamel 2000b), nests were typically placed at the same height relative to the site of the tree (approximately 70%) as in other studies (Oliarnyk, Nicholson, Hamel 2000a), indicating that nest position with regard to tree structure is more important than its placement in a tree of a particular size. As in eastern Tennessee (Nicholson 2003), the height and diameter of nest trees did not differ from available trees.

Cerulean warbler nests have been found in a variety of tree species. Nicholson's (2003) was the first study to find specific nest tree preferences, where the majority of nests in eastern Tennessee were found in black cherry (*Prunus serotina*), sugar maple, and tulip poplar (Nicholson 2003). Black cherry only occurred rarely if at all in the Kentucky study sites. In contrast, I found over half of the nests in 2 species that were 5th and 6th in basal area: white oak and white ash (Table 8). Due to small sample size, it is too early to say whether these are preferred tree species, but it is suggestive. I also documented a cerulean warbler nest in black oak, which is a new record for the cerulean warbler.

Conclusions

The results of this portion of the study are valuable for their contribution to the growing documentation of cerulean warbler nesting behavior. Cerulean warbler nests are notoriously difficult to find and monitor; therefore any additional clues such as incubation, brooding, and feeding rates will be helpful to researchers who find nests at unknown stages. Similarly, documenting unusual behaviors such as incubation feeding may help nest-searchers in the future.

Table 4-1. Outcomes and success rates of 13 cerulean warbler nests in CWTG plots, Daniel Boone National Forest.

Probable Outcome	
Failed during nest-building	0
Failed during egg-laying	1
Failed during incubation	2
Failed during nestling period	3
Fledged young	7
Outcome unknown	0
Total nest attempts	13
Minimum % successful	53.8%
Minimum number young fledged per successful nest	2.5
Mayfield daily success rate (SE)	0.9697
Nest exposure days	198
Mayfield prob. of success	0.493

Table 4-2. Average basal area (m^2/ha) of individual tree species per vegetation plot in CWTG plots and the number of nests found in each in 2005.

Tree Species	Average Basal Area / Plot	# CERW Nests
Acer saccharum	3.53	2
Liriodendron tulipfera	3.03	1
Quercus prinus	2.47	1
Quercus alba	2.28	0
Fraxinus americana	2.19	3
Quercus alba	2.16	5
Quercus rubra	1.97	0
Quercus velutina	1.19	1
Carya tomentosa	0.75	0
Carya ovata	0.63	0

Table 4-3. Nest site characteristics at 13 cerulean warbler nests in Pioneer Weapons Area, Daniel Boone National Forest. Values presented are means with standard error in parentheses.

Variable	Mean (S.E.)	Minimum	Maximum
Nest height (m)	19.2 (1.73)	6.6	28.2
Tree height (m)	26.8 (1.69)	18.0	34.0
Tree diameter at breast height (cm)	43.5 (3.00)	27.5	65.2
Distance from bole to nest (m)	3.6 (0.54)	1.5	7.5
Distance from nest to canopy edge (m)	2.5 (0.40)	1.5	6.0
Distance from nest to canopy gap (m)	18.8 (3.98)	2.0	43.0
Nest limb diameter (cm)	6.7 (0.74)	3.0	12.0

Table 4-4. Habitat characteristics surrounding 13 cerulean warbler nests in Pioneer Weapons Area, Daniel Boone National Forest. Values presented are means (SE). Differences between nest and territory or nest and random plots are indicated by asterisks ($\alpha = 0.01$).

Variable	Nest	Territory	Random
Basal Area	28.27 (2.39)	25.36	24.01
Average DBH	41.37 (1.53)	54.39**	40.57
Average Height	33.64 (2.51)	30.56	27.00
Sapling height	4.23 (1.13)	2.38	3.39
Sapling % cover	25.38 (7.10)	19.23	18.77
# Sapling stems	1.69 (0.57)	2.58	1.59
Shrub height	1.15 (0.25)	1.17	0.78
Shrub % cover	26.15 (9.71)	29.8	22.2
# Shrub stems	5.23 (1.94)	6.98	3.43
Slope (%)	25.5 (2.63)	31.6	36.1**
Canopy cover 0.5-3 m	23.5 (4.3)	31.7	29.1
Canopy cover 3-6 m	37.3 (4.4)	33.1	43.0
Canopy cover 6-12 m	50.4 (7.5)	45.7	52.3
Canopy cover 12-18 m	63.1 (4.8)	56.1	55.2
Canopy cover 18-24 m	53.5 (6.6)	56.5	55.1
Canopy cover >24 m	10.8 (4.1)	28.0**	15.6

Figure 4-1. Mean minutes per hour of incubation observed during nest watches of female cerulean warblers in Pioneer Weapons Area, Daniel Boone National Forest.

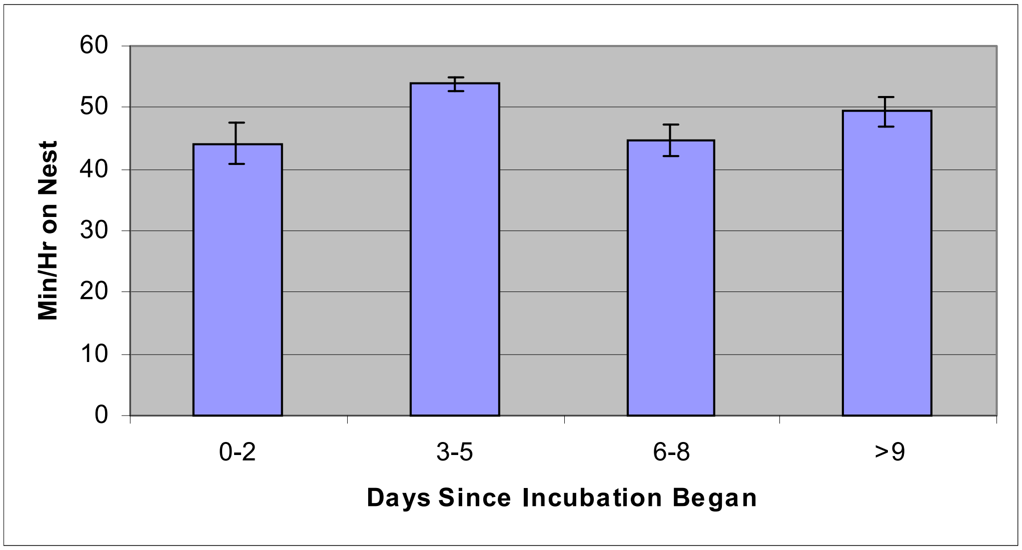


Figure 4-2. Mean minutes per hour of brooding observed during nest watches of female cerulean warblers in Pioneer Weapons Area, Daniel Boone National Forest.

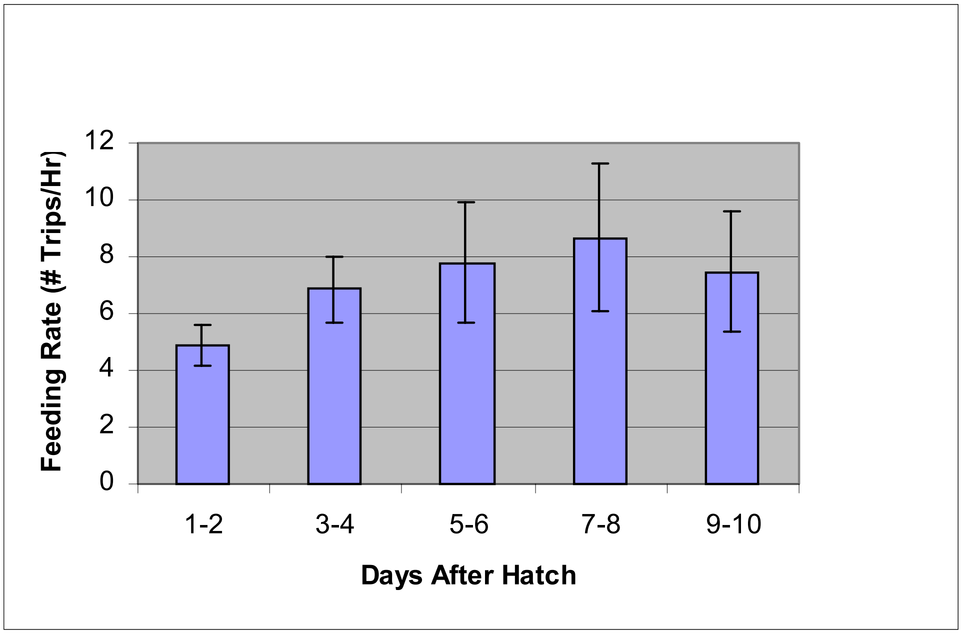
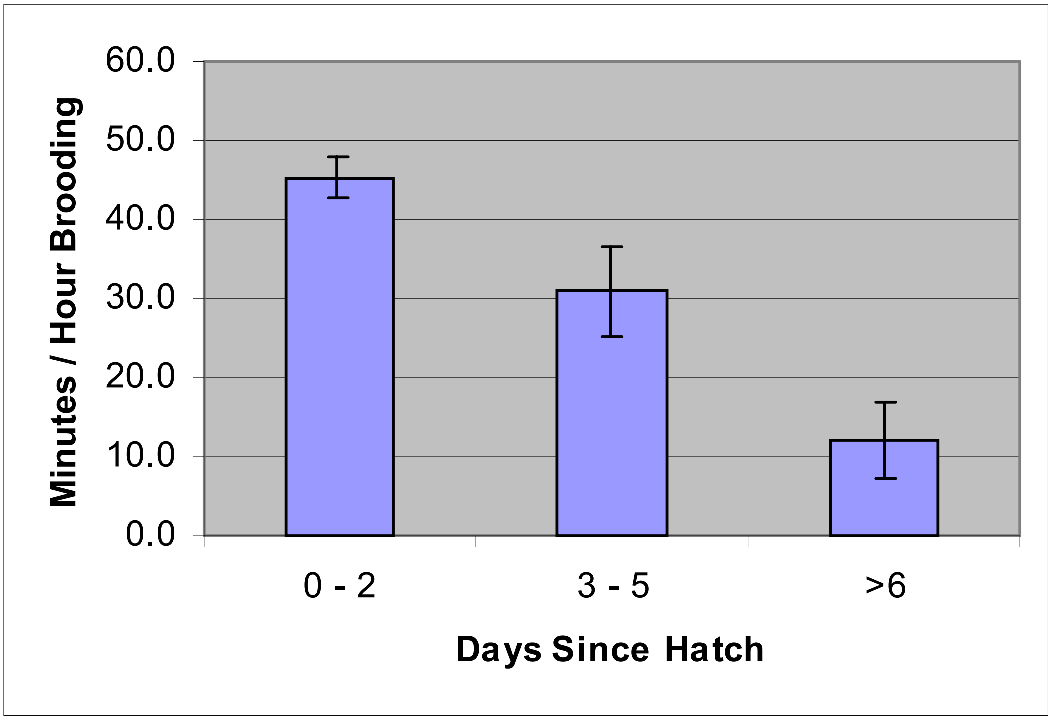


Figure 4-3. Mean number of feeding trips per hour by both parents during nest watches in Pioneer Weapons Area, Daniel Boone National Forest.



CHAPTER FIVE: AVIAN COMMUNITY COMPOSITION IN CERULEAN WARBLER-INHABITED FORESTS IN EASTERN KENTUCKY

Introduction

It is vital to determine features of successful territories and nest sites to develop appropriate management plans. Emphasis is generally placed on habitat features, but the bird community and distribution of nest predators, brood parasites, and heterospecifics may also play a role in the process of habitat selection. For example, birds have been demonstrated to alter territory and nest-site selection patterns in response to previous predation (Jones et al. 2001; Martin & Roper 1988). They may avoid coexistence with species that build nests similar in placement and structure to reduce the density of similar predation targets (MacKenzie et al. 1982; Martin 1993), thereby deterring nest predators from developing reliable search images in an area (Martin 1988). Migratory birds may also select territories based on the density of some resident species (Forsman 1998).

I examined the avian community in eastern Kentucky to look for patterns in cerulean warbler (*Dendroica cerulea*) distribution in relation to other birds. Additionally, I compared avian abundance and community composition in an ice-damaged forest with that of a mature, relatively undisturbed forest.

Methods

I conducted point counts to sample the avian community on 5, 1 km^2 grids in the Buffalo Branch study area (Figure 2-2). In 2004, I conducted 10 minute, 100-m fixed radius point counts (Hamel et al. 1996; Ralph et al. 1993). Each point was surveyed twice during the breeding season (May 20-26 and June 7-11). Observers recorded all individuals detected within 4 distance classes (0-25m, 25-50m, 50-100m, and >100m) and 3 time intervals (0-3, 3-5, and 5-10 minutes). Surveys were conducted between sunrise and 1000 EDT on days without rain or high wind (>20 km/hour). Point counts were conducted by observers skilled in bird identification and trained in distance estimation.

Cerulean warblers (CERW) were classified as "present" if found <100m from point center or "absent" if found >100m from point center at each point count location. Points were visited twice to avoid underestimation of site occupancy (Gu & Swihart 2004).

In 2005, I established point count stations to sample the bird community within the 4 CWTG plots (Figures 2-3 and 2-4). Four point count locations were randomly selected within each study plot for a total of 16 points. Point counts were visited twice (May 15-20 and June 5-10) and were conducted as described above.

I calculated species richness (S; Mcintosh 1967), species diversity (H'; Shannon & Weaver 1949), and evenness (J'; Stiling 1999). Community similarity indices were calculated using the Sorensen index (Sorensen 1948). Individual species abundances were calculated as the maximum number of detections per site divided by the total number of point counts for a mean abundance per point (Faccio 2003). Additionally, species were subdivided into 8 foraging guild categories to obtain mean number of detections of guild members per point (Faccio 2003; Greenberg & Lanham 2001). It is important to note that these are preliminary analyses meant to explore for patterns. These observations will be used to generate testable hypotheses for continuing research, specifically the CWTG silvicultural experiment.

Pre-ice storm data do not exist for Buffalo Branch, which would be the ideal situation to compare community composition between undamaged and damaged forest. Nonetheless, I used data from CWTG plots as "reference" points to compare avian community composition in an intact, relatively undisturbed stand with that of an ice-damaged stand (Buffalo Branch). Due to differences in sampling effort and year, it is problematic to directly compare avian communities in ice-damaged stands in Buffalo Branch (n=200; 2004) with reference sites in Pioneer Weapons Area (n=32; 2005). Diversity indices and mean abundances of individual species and foraging guilds were calculated with these data. As mentioned above, these findings are preliminary observations and will simply be used to identify possible patterns and formulate hypotheses.

Results

In Buffalo Branch, 100 point counts were visited twice during the 2004 breeding season. In 100-m radius point counts, 49 species were detected in sites with ceruleans and 50 in sites without (Appendix E). Diversity values were similar between occupied and unoccupied sites (Table 5-1). The community similarity index for CERW-occupied and unoccupied point count stations was high (0.890), indicating there was a large degree of overlap in species composition. With the exception of the cerulean warbler, all species detected only on CERW-occupied or unoccupied sites (not both) were extremely rare (<5 total detections). The most abundant species in CERW-occupied sites overlapped with those in unoccupied sites within Buffalo Branch. Ovenbird (*Seiurus aurocapillus*), red-eyed vireo (*Vireo olivaceus*), indigo bunting (*Passerina cyanea*), and wood thrush (*Catharus mustelinus*) were identified as 4 of the 5 most abundant species in both areas (Table 5-2). The shrub-inhabiting hooded warbler (*Wilsonia citrina*) was fourth in abundance in CERW-occupied sites while the canopy-dwelling scarlet tanager (*Piranga olivacea*) held that position in unoccupied sites.

Among foraging guilds, the only difference detected between CERW-occupied and unoccupied sites was among early successional species (Figure 5-1). Early successional species were found in much higher numbers on plots with ceruleans than those without. Indigo bunting, yellow-breasted chat (*Icteria virens*), and eastern towhee (*Pipilo erythrophthalmus*) were all detected more frequently on sites with cerulean warblers than without. No other difference was detected among foraging guilds in CERW-occupied and unoccupied sites, but there were differences in individual species within them (Table 5-2). Among forest interior birds, 4 species were lower [Acadian flycatcher (*Empidonax virescens*), ovenbird, scarlet tanager, wood thrush] in abundance in CERW-occupied sites while 2 were higher [hooded warbler, American redstart (*Setophaga ruticilla*)].

In CWTG reference sites, 16 point counts were visited twice during the 2005 breeding season. A total of 42 species were detected in reference sites compared with 55 species in ice-damaged sites (Appendix E). Diversity indices were higher in ice-damaged stands than in reference sites (Table 5-1). Sorenson's similarity index (0.375) indicated that community composition was different between ice-damaged and reference sites. In reference sites, there was still overlap in the most common species, with ovenbird and red-eyed vireo the 2 most abundant species (Table 5-2). However, there was a marked increase in the frequency of the cerulean warbler, which ranked 3rd in abundance. Forest-interior species (scarlet tanager and hooded warbler) occupied the 4th and 5th positions, while the indigo bunting was infrequently observed in undisturbed forest.

At reference sites, early successional species were absent (yellow-breasted chat, eastern towhee) or infrequent (indigo bunting), but forest-interior canopy foragers were more abundant overall (Figure 5-2). Again, species-specific responses were observed. Among canopy foragers, the red-eyed vireo, cerulean warbler, and American redstart appeared to be more abundant than in ice-damaged stands while the scarlet tanager occurred in similar numbers in both areas (Figure 5-3). For ground and shrub foraging interior species, the pattern appear to be the opposite, with lower numbers of Kentucky warbler (*Oporornis formosus*), ovenbird, and wood thrush in reference sites than in ice-damaged sites (Figure 5-4). Similarly, forest-edge species seemed to be higher in ice-damaged than reference sites. Nest predator and brown-headed cowbird abundance did not appear to be different between reference and ice-damaged sites.

Discussion

In this study, preliminary community analysis also may have revealed some vegetative attributes that vegetation sampling failed to detect. Although I measured no difference in habitat between cerulean warbler-occupied and unoccupied sites (Tables 3-3, 3-4, and 3-5), differences in the abundance of certain bird species, particularly early successional species, suggest cerulean warblers were frequently found in more disturbed areas within Buffalo Branch. The presence of these species, especially the yellow-breasted chat, indicates that areas within 100 m of point count stations where ceruleans were observed must have received enough ice damage to create sizable gaps to promote a dense understory.

Previous studies have suggested that early successional bird species tend to increase in response to disturbance while mature forest birds exhibit different species-specific responses (Baker & Lacki 1997; Faccio 2003; Gram et al. 2003; Greenberg & Lanham 2001). In this study, we observed a similar pattern with early successional and forest-interior species. Among canopy species of the forest interior, American redstarts were more common in sites with cerulean warblers while scarlet tanagers were less frequent. When viewed in terms of ice storm damage, this finding makes sense. American redstarts experience lower rates of nest predation and brood parasitism with increasing structural complexity (Sodhi et al. 1999) and frequently occur in secondary forest (Martin 2003). Scarlet tanagers are less tolerant of disturbance (Palmer-Ball 1996) and a reduction in canopy density may negatively affect foraging success or nest-site availability.

Ground and shrub-dwelling species of the forest interior also showed species-specific responses which again, mirrored those of other studies. The hooded warbler was found more frequently in sites with cerulean warblers whereas the wood thrush and ovenbird, though still common, were found less often. Two species, the Kentucky warbler and the worm-eating warbler (*Helmitheros vermivorus*), were found in similar proportions in both areas. Hooded warblers nest and forage in the shrub layer. Therefore, increased light penetration and consequent understory development due to storm damage is likely to increase available nesting and foraging habitat for this species. In contrast, ovenbirds, which forage in dense leaf litter, prefer areas with a closed canopy and less understory development.

The effects of natural disturbance events such as ice storms and tornadoes have been likened to uneven-aged timber management, particularly group-selection and shelterwood cuts (Faccio 2003; Seymour et al. 2002). Both can bring about changes in community patterns, alter diversity and richness values, and result in the addition of new bird species and the loss of others (Baker & Lacki 1997; Faccio 2003; Greenberg & Lanham 2001; King & DeGraaf 2000). We observed higher bird diversity and species richness in storm-damaged sites due to the overlap of mature forest species with early successional species.

Yet, higher densities of forest-interior canopy species were found in the reference sites. Part of this difference can likely be attributed to differences in sampling effort and annual fluctuation, but there were several species absent from the reference sites that occurred frequently in ice-damaged stands. Not surprisingly, early successional species were rare or completely absent while forest-interior canopy species were more abundant in reference sites.

The persistence of the cerulean warbler in disturbed areas may indicate it is better able to respond to disturbance than some other forest obligates. Jones and Robertson (2001) found cerulean warblers experienced a dramatic reduction in nesting success in the year following a severe ice storm. Nevertheless, the birds returned in equal numbers the following year and responded by altering nest-site selection patterns to improve reproductive output in the second post-storm year. These results indicate that the cerulean warbler may possess some level of plasticity with regard to habitat preference at certain scales. Our preliminary observations in Buffalo Branch support the idea that cerulean warblers are somewhat resilient to habitat disturbance; we observed 9 of 15 focal males (60%) feeding fledglings (personal observation) during the second breeding season following the 2003 ice storm.

Although comparisons of ice-damaged and reference sites would be strengthened with pre-storm avian community data and/or temporal consistency between surveys, some interesting inferences may be drawn from observed patterns in these areas. These data provide a baseline for developing hypotheses for continuing research and has implications for the upcoming silivicultural treatments in PWA.

Table 5-1. Diversity indices for CERW-occupied and unoccupied areas in ice-damaged Buffalo Branch (2004) and for reference sites in Pioneer Weapons Area (2005).

	Species Richness (S)	Species Diversity (H')	Species Evenness (J')	Mean # Detections / Point Count
Ice-damaged: CERW present	49	3.4	0.88	20.13
Ice damaged: CERW absent	50	3.38	0.87	18.00
Reference sites	41	3.14	0.85	15.50

Table 5-2. Mean number of individuals detected per point count at stations with (n=24) and without (n=76) cerulean warblers in Buffalo Branch. Values shown are means (SE in parentheses). *P*-values for present vs. absent *t*-tests are presented in the third column. Bold-faced values are significant (α=0.05). The far right columns indicate the mean number of individuals for the entire ice-damaged Buffalo Branch (n=208) site compared with reference sites in Pioneer Weapons Area (n=32).

Foraging guild Species	CERW present (SE)	CERW absent (SE)	*P*	Ice-damaged (SE)	Reference (SE)
Early successional	**2.67 (0.23)**	**1.64 (0.15)**	**<0.001**	1.93 (0.13)	0.41 (0.11)
Yellow-breasted chat	**0.78 (0.13)**	**0.39 (0.06)**	**0.01**	0.50 (0.06)	Not detected
Eastern towhee	**0.55 (0.08)**	**0.36 (0.05)**	**0.04**	0.41 (0.04)	Not detected
Indigo bunting	**1.33 (0.14)**	**0.90 (0.10)**	**0.01**	1.02 (0.08)	0.41 (0.11)
Forest-interior ground/shrub	4.18 (0.30)	4.25 (0.15)	0.86	4.23 (0.14)	3.16 (0.32)
Wood thrush	**1.08 (0.14)**	**1.57 (0.10)**	**0.01**	1.43 (0.09)	0.53 (0.12)
Worm-eating warbler	0.45 (0.10)	0.49 (0.05)	0.75	0.48 (0.05)	0.53 (0.13)
Ovenbird	**2.25 (0.17)**	**2.82 (0.11)**	**0.01**	2.66 (0.10)	1.66 (0.23)
Kentucky warbler	0.23 (0.07)	0.17 (0.04)	0.85	0.19 (0.03)	0.03 (0.03)
Hooded warbler	**1.25 (0.15)**	**0.77 (0.08)**	**0.01**	0.91 (0.07)	0.94 (0.17)
Forest-interior canopy	**4.64 (0.21)**	**3.20 (0.13)**	**<0.001**	3.62 (0.12)	5.41 (0.40)
Yellow-throated vireo	0.23 (0.07)	0.11 (0.03)	0.13	0.15 (0.03)	006 (0.04)
Red-eyed vireo	1.63 (0.13)	1.76 (0.10)	0.41	1.73 (0.08)	2.06 (0.16)
Cerulean warbler	1.50 (0.09)	n/a	n/a	0.63 (0.08)	1.44 (0.25)
American redstart	**0.62 (1.12)**	**0.30 (0.05)**	**0.02**	0.39 (0.05)	0.88 (0.20)
Scarlet tanager	**0.73 (0.11)**	**1.03 (0.09)**	**0.04**	0.95 (0.07)	0.94 (0.16)
Forest-edge ground/shrub	2.18 (0.22)	2.56 (0.14)	0.14	2.45 (0.12)	2.16 (0.27)
Carolina wren	0.37 (0.09)	0.32 (0.05)	0.77	0.33 (0.04)	0.91 (0.15)
Northern cardinal	0.17 (0.06)	0.18 (0.04)	0.41	0.17 (0.03)	0.31 (0.10)
Brown-headed cowbird	0.60 (0.11)	0.48 (0.07)	0.36	0.51 (0.06)	0.41 (0.15)

Table 5-2 (*Continued*)

Foraging guild Species	CERW present □ (SE)	CERW absent □ (SE)	*P*	Ice-damaged □ (SE)	Reference □ (SE)
Forest-edge canopy	1.92 (0.17)	1.75 (0.10)	0.41	1.80 (0.09)	1.09 (0.18)
Yellow-billed cuckoo	0.38 (0.09)	0.41 (0.06)	0.78	0.40 (0.05)	0.28 (0.09)
Carolina chickadee	0.18 (0.16)	0.16 (0.04)	0.21	0.17 (0.03)	0.16 (0.07)
Tufted titmouse	0.67 (0.10)	0.54 (0.06)	0.29	0.58 (0.05)	0.38 (0.12)
Blue-gray gnatcatcher	0.68 (0.10)	0.66 (0.06)	0.86	0.67 (0.05)	0.28 (0.08)
Bark-probers	1.18 (0.16)	0.89 (0.08)	0.11	0.98 (0.07)	0.63 (0.13)
Red-bellied woodpecker	0.33 (0.08)	0.34 (0.05)	0.91	0.34 (0.04)	0.13 (0.06)
Downy woodpecker	0.18 (0.06)	0.14 (0.03)	0.63	0.15 (0.03)	0.16 (0.07)
Hairy woodpecker	0.25 (0.08)	0.09 (0.03)	0.48	0.14 (0.03)	0.13 (0.06)
Northern flicker	0.15 (0.06)	0.09 (0.02)	0.32	0.11 (0.02)	0.03 (0.03)
Pileated woodpecker	0.27 (0.07)	0.23 (0.04)	0.63	0.24 (0.03)	0.19 (0.08)
Bark gleaners	0.50 (0.10)	0.52 (0.06)	0.86	0.51 (0.05)	0.69 (0.15)
White-breasted nuthatch	0.42 (0.09)	0.36 (0.06)	0.58	0.38 (0.05)	0.31 (0.13)
Black-and-white warbler	0.08 (0.04)	0.18 (0.04)	0.12	0.15 (0.03)	0.38 (0.11)
Flycatchers	1.37 (0.16)	1.61 (0.10)	0.10	1.64 (0.09)	0.88 (0.14)
Eastern wood-pewee	0.87 (0.12)	0.77 (0.07)	0.48	0.80 (0.06)	0.53 (0.12)
Acadian flycatcher	**0.52 (0.10)**	**0.86 (0.08)**	**0.01**	0.76 (0.07)	0.34 (0.11)
Corvid nest predators	0.49 (0.12)	0.64 (0.08)	0.32	0.60 (0.07)	0.34 (0.11)
Blue jay	0.18 (0.07)	0.29 (0.05)	0.21	0.26 (0.04)	0.19 (0.08)
American crow	0.32 (0.09)	0.35 (0.06)	0.75	0.34 (0.05)	0.16 (0.08)

Figure 5-1. Mean avian abundance by foraging guild at point count stations with (n=24) and without (n=76) cerulean warblers. Bars represent 1 SE about the mean.

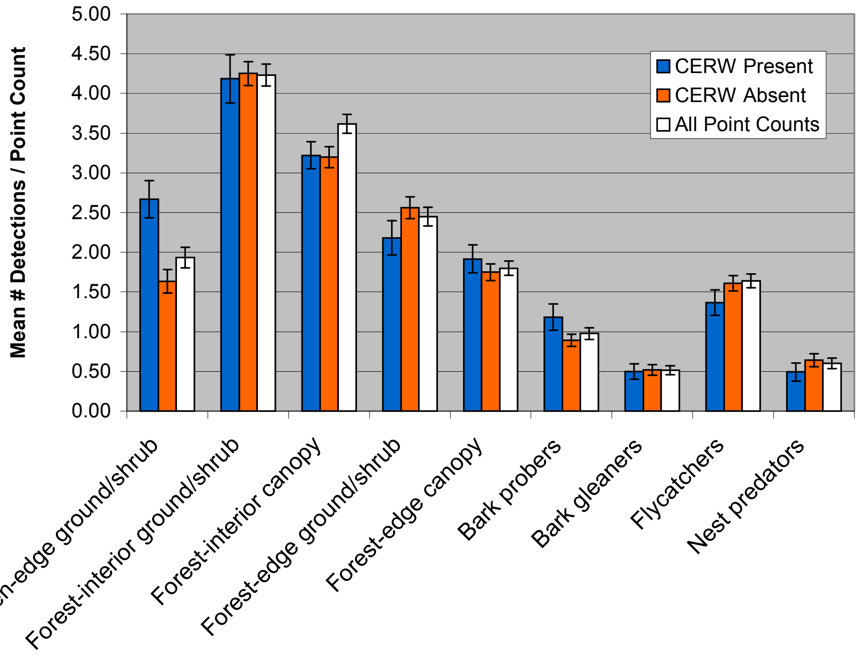


Figure 5-2. Mean avian abundance by foraging guild at point count stations at ice-damaged (n=100) and reference (n=16) sites. Bars represent 1 SE about the mean.

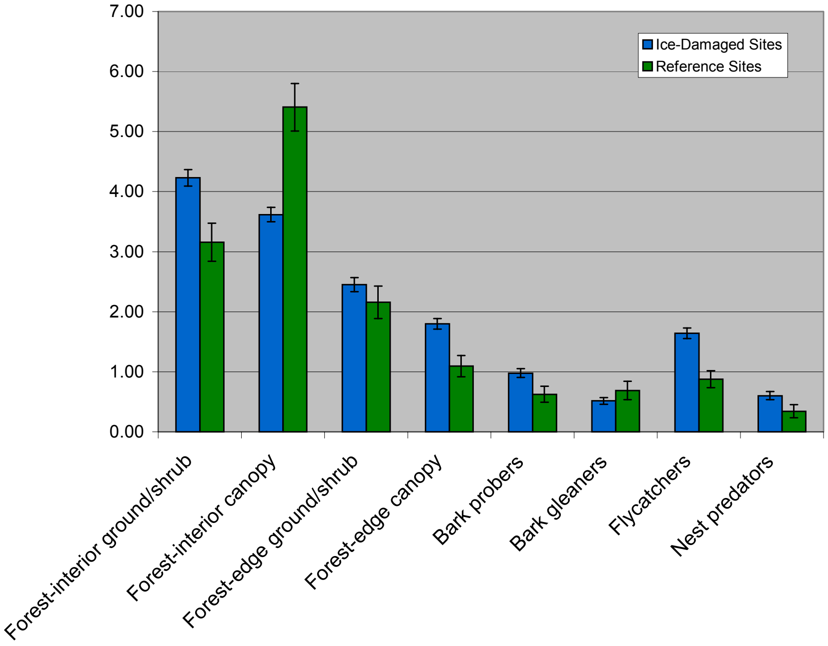


Figure 5-3. Mean abundance of forest-interior species at point count stations in ice-damaged and reference sites. Bars represent 1 SE about the mean.

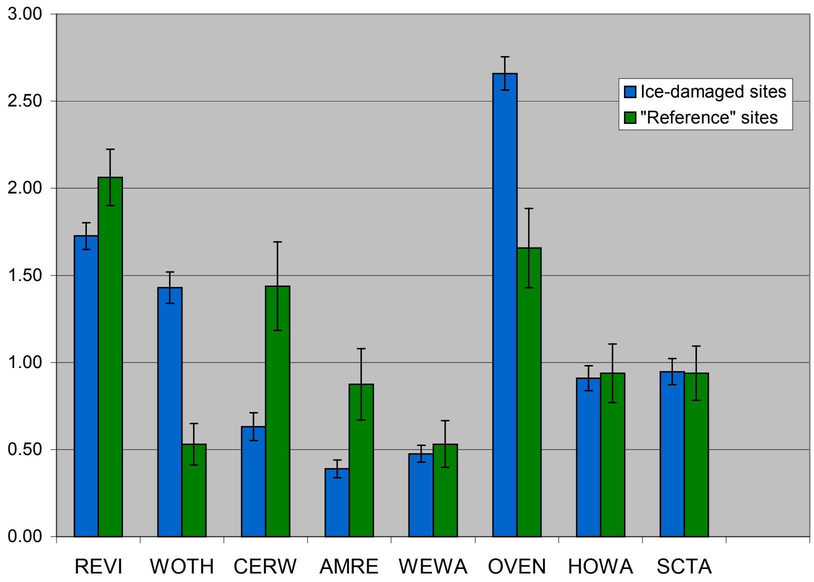
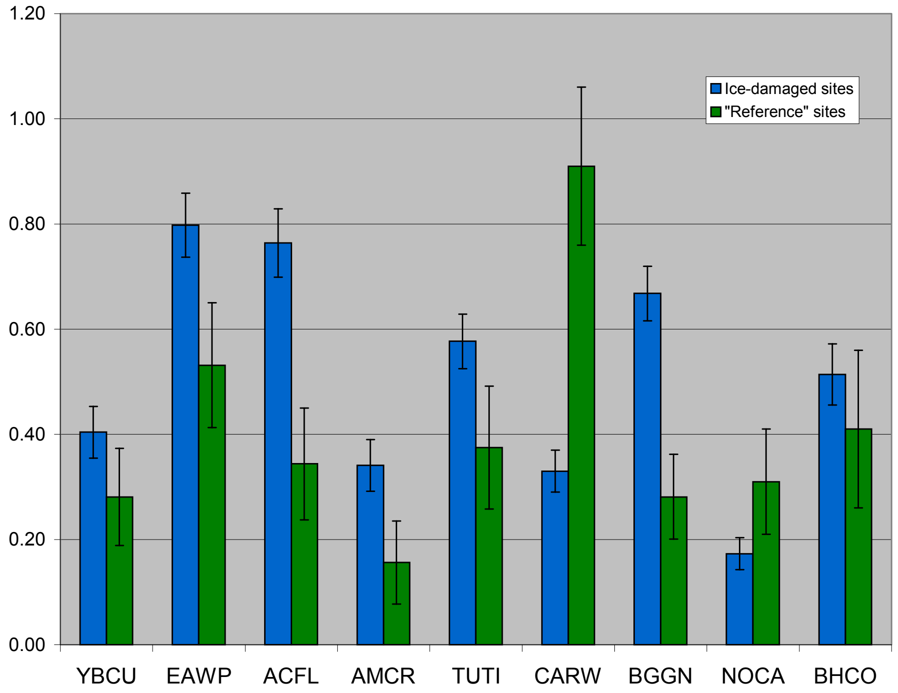


Figure 5-4. Mean abundance of forest-edge species at point count stations in ice-damaged and reference sites. Bars represent 1 SE about the mean.



CHAPTER SIX: BEHAVIORAL CUES IN CERULEAN WARBLER HABITAT SELECTION, A PILOT STUDY

Introduction

Habitat selection theory predicts that individuals should settle in areas with the appropriate combination of resources and environmental conditions to maximize fitness (Morrison et al. 1998). Although this idea is well-established and has been used in management for years, the mechanisms and cues by which animals choose habitat are not well known. Most conservation and management efforts target habitat features thought to be important for a species without recognizing the habitat selection cues that direct an individual to settle in a particular area. For some species, the conservation of habitat features could be made more effective if coupled with an understanding of the kinds of cues a species employs in making a choice of where to live (Reed 2004).

Habitat selection cues may be direct or indirect and differ by species, sex, and age (Reed 2004). Within a species, several cues likely operate in combination and different cues may be more important at different stages of life. For example, inexperienced male house wrens rely more strongly on the presence of conspecifics to choose breeding site, but experienced males are able to judge successful nest sites, irrespective of conspecifics (Muller et al. 1997). Conspecific attraction, the tendency of an individual to settle near other individuals of the same species, has become the focus of considerable attention in recent years for its potential applications in conservation biology.

There are a number of hypotheses regarding the benefits of conspecific cuing. Some of the proposed benefits include reduced predation rates (Gotmark & Andersson 2005; Perry & Anderson 2003), increased nesting success (Stamps 1988; Ward & Schlossberg 2004), improved chances of mate attraction (cite), and better efficiency in assessment of habitat quality (Muller et al. 1997; Shuck-Paim & Alonso 2001). The presence of conspecifics is thought to be particularly important in inexperienced or unsuccessful breeders because they have no personal experience with which to judge habitat quality. To prospecting males, site occupancy could indirectly indicate optimal habitat through the presence of high quality males, which tend to arrive on the breeding grounds earlier than other males (Kokko et al. 2001), or exhibit site fidelity due to past breeding success (Hoover 2003). A potential drawback to using conspecific cuing to select habitat is the potential that birds may not settle in newly available or empty but suitable habitat patches (Reed & Dobson 1993).

Recent evidence suggests that conspecific attraction plays a role in the habitat selection of many bird species, including some territorial songbirds (Muller et al. 1997; Ward & Schlossberg 2004). Breeding colonies of Arctic tern, griffin vulture, and black-capped vireo have been reestablished and expanded by manipulating behavior through the use of decoys, song playbacks, and other indicators of conspecific presence (Podolsky & Kress 1992; Sarrazin et al. 1996; Ward & Schlossberg 2004). With declining numbers in many bird species, particularly neotropical migrants (Peterjohn et al. 1995; Terborgh 1980), artificial attraction to suitable habitat could be a powerful tool in the conservation of imperiled bird species.

The cerulean warbler, *Dendroica cerulea*, is a neotropical migrant of the eastern deciduous forest. Over the last 50 years, the species has experienced range-wide declines (Hamel 2000b; Rosenberg et al. 2000; Sauer et al. 2001) despite an overall increase in the amount of available forest (Yahner 2000). Although it is highly territorial, the cerulean warbler has frequently been observed to occur in clusters, which are sometimes described as loose colonies (Hamel 2000a, 2000b). Another common observation is that suitable habitat is often left vacant (Jones & Robertson 2001; Weakland & Wood 2005). In 2004, I noticed that cerulean warblers in my study area in eastern Kentucky occurred in clusters in some areas but were absent in suitable habitat elsewhere.

In 2005, I conducted a conspecific attraction pilot study on the cerulean warbler in Daniel Boone National Forest, eastern Kentucky. Specifically, I investigated whether cerulean warblers could be attracted to potentially suitable habitat through song playback. Based on the species' semi-colonial tendency and the vacancy of apparently suitable habitat in the study area, I predicted that the cerulean warblers would be attracted to recordings of conspecific song.

Methods

In 2005, 6 playback units were installed in Buffalo Branch, Daniel Boone National Forest (Figure E-1). Playback units were based on the design by Ward and Schlossberg (2005), but were modified for use in the forest canopy (Figure E-2). Each unit consisted of a CD player (Durabrand), a digital timer (Borg General Controls, Elk Grove Village, IL), a 12V deep-cycle marine battery, and a speaker hanging from a tree branch. The CD player, timer, and battery were housed in a heavy duty plastic container placed on the ground and partially camouflaged by woody debris. The speaker was enclosed in plastic (i.e., 2.5 gallon water jug with a side opening) for protection from the elements and supported by a tree limb at least 11 m high. Playback units were situated in areas that contained apparently suitable habitat but did not support cerulean warblers in 2004 and were >500m from previously occupied habitat patches. In one instance (CW1), the playback unit was inadvertently placed approximately 250 m from a 2004 territory.

Three experimental units broadcast cerulean warbler (CW) songs and 3 control units played black-throated green warbler, *Dendroica virens*, songs. The black-throated green warbler (BT) was selected as the control because it is also a canopy-dwelling species, but it usually arrives nearly a month earlier than the experiment was slated to begin (Mengel 1965). Thus, black-throated green warblers would have already established territories and the playbacks should not have affected BT territory placement.

Bird songs were broadcast between 0430 and 0930 and again from 1730 to 1830. Song recordings were obtained from the Macaulay Library, Cornell Lab of Ornithology. To avoid psuedoreplication, each unit played the song of a different individual male cerulean or black-throated green warbler. This also served to mimic the presence of an actual territorial male as closely as possible. Each recording consisted of 55 minutes of singing followed by 15 minutes of silence and was repeated every 70 minutes.

All sites were visited twice a week between April 16 and May 5 during peak arrival times and territory establishment. Thereafter, each site was visited once a week through June 1. During each visit, I recorded the number of cerulean warblers detected and distance of each from the playback unit. I also noted any territorial interactions with the playback unit and/or other neighboring males, as well as any female activity.

Results

In 2005, I observed 4 cerulean warblers at experimental sites and 2 at control sites (Table E-1). In the experimental sites, 3 of the 4 territorial cerulean warblers were first detected at CW1 on April 22 and remained throughout the breeding season. Two males established territories adjacent to the playback while the third was downhill and adjacent to the 2 live birds. Early in the breeding season, the 2 adjacent individuals responded aggressively to the playback unit and frequently hopped on the same branch or even on top of the speaker. Birds typically countersang with the unit and approached during silent periods. On May 4, I found 1 nest under construction approximately 26 m from the playback unit. In contrast, the bird at CW2 set up a territory >100 m from the speaker. On April 18, the bird countersang with the playback unit <5 times and approached within 75 m, but then moved away. No other territorial interactions were observed between that individual and the playback. The third experimental unit (CW3) was stolen before May 1, but no cerulean warblers were observed in the vicinity before then.

At control sites, 2 birds established territories at different sites. At BT2, a cerulean warbler was heard singing on April 15 while the unit was being set up. This was first presumed to be a migrant, but the bird remained nearby throughout the breeding season and was typically heard <50 m from the playback unit. At BT3, a cerulean warbler was first heard on April 18 and established a territory. This individual was usually observed 50-100 m from the playback unit. No cerulean warblers were observed at BT1.

Discussion

The results from this study were inconclusive, but encouraging. My observations at CW1 provided some evidence to suggest that male cerulean warblers were drawn into playbacks. The 3 birds that settled nearby counter-sang with the callbox and treated it like a neighboring territory holder. However, interpretation of results at this site is complicated because the unit was accidentally placed closer to previously occupied habitat than the other units. The results were further confounded by the presence of a cerulean warbler at 2 out of 3 control sites, indicating that new birds settled in previously unoccupied areas or that there was some movement of returning birds between years. Jones et al. (2000) also observed interannual movement of territory clusters.

Despite the equivocal nature of the results, I believe the cerulean warbler is still an appropriate target for conspecific attraction research. There are several study design revisions I would like to suggest in hopes of aiding future researchers in avoiding the pitfalls of this experiment. First, sites should be larger and more isolated from previously occupied areas. In this study, 5-10 ha unoccupied patches were embedded within many occupied areas in the forest. Given this study design, it would be difficult to tease apart the effects of playbacks from the possibility of shifting of territories due to other factors, as I observed this year at the control sites. Ward & Schlossberg's (2004) sites were 15-71 ha in size and isolated from occupied areas. They recommended 1 km as a minimum distance between occupied and playback sites.

A second recommendation is to establish more playback units at each site. Although it will be more expensive and time-consuming, the presence of multiple units per site will increase the opportunity for individuals to encounter them. Further, the number of conspecifics in an area may be important in determining habitat quality (Reed & Dobson 1993). Therefore, a site that appears to support 5 individuals would be more likely to indicate better habitat than would a single male.

Finally, the presentation of visual models along with the playback may be important in this species. Ward & Schlossberg (2004) found that visual models had no effect on territorial responses in the black-capped vireo and attributed it to the vireo's tendency to sing in dense vegetation. In contrast, the cerulean warbler usually sings from a prominent tree, often on an exposed limb, and is probably visible to neighboring conspecifics. Birds in this study did not habituate to the speaker, but continued to countersing and approach the speaker throughout the breeding season, apparently trying to locate the source of the sound. This may have been related to the absence of a visual stimulus to accompany the audio playback.

Conspecific attraction could become an important tool to conservation biologists and land managers. If colonization of newly available habitat by the cerulean warbler is inhibited by a lack of social cues, it may be a more practical and expeditious means of attraction than awaiting natural colonization. More research is warranted to explore the potential role of conspecific cuing in habitat selection and its significance in the development of sound management strategies.

Table 6-1. Number of cerulean warbler territories established within 50, 100, and >100 m from experimental and control playback units.

Site	CW territories <50 m from unit	CW territories 50-100 m from unit	CW territories >100 m from unit
Experimental			
CW1	2	1	0
CW2	0	0	1
CW3	0	0	0
Control			
BT1	0	0	0
BT2	1	0	0
BT3	0	1	0

Figure 6-1. Map of Buffalo Branch study area with playback sites denoted by stars. CW refers to units that played cerulean warbler songs while BT refers to black-throated green warbler song.

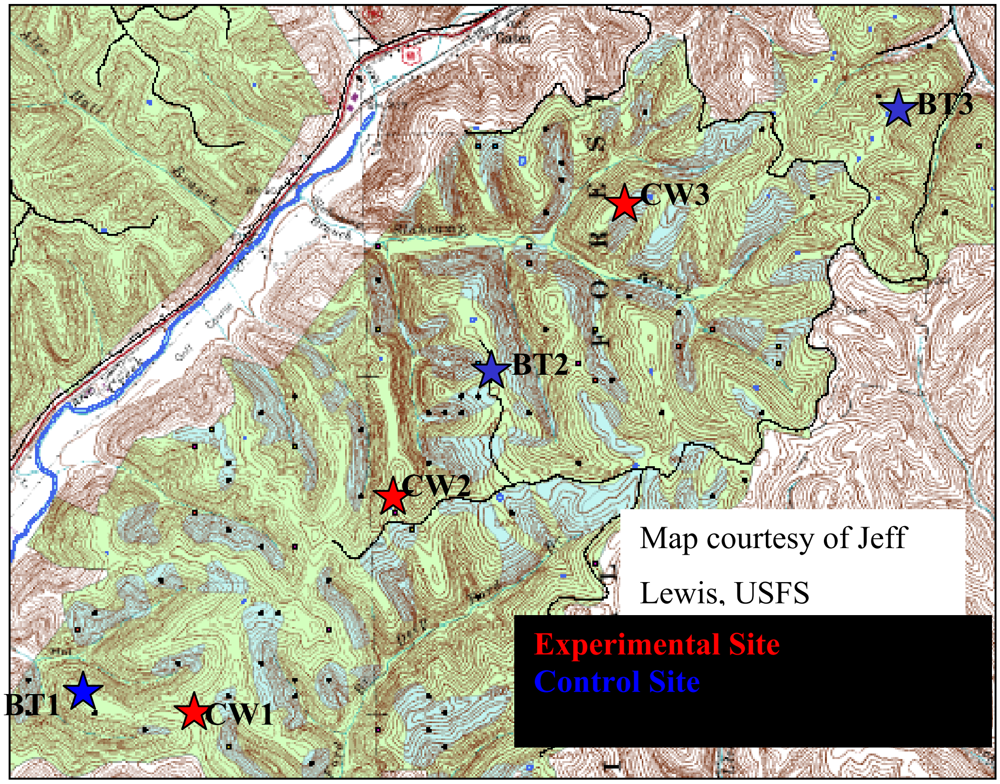
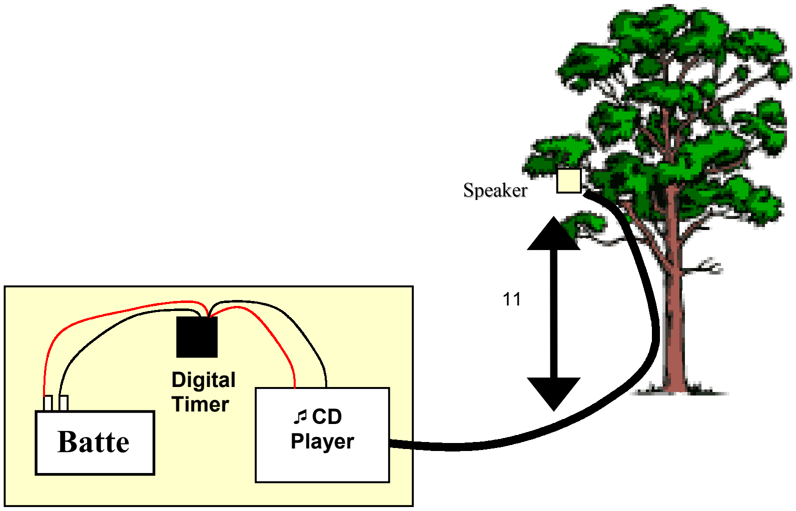


Figure 6-2. Playback system modeled after Ward & Schossberg (2005) with modifications for forest canopy use.



CHAPTER SEVEN: CONCLUSIONS

Several key habitat features have been consistently identified as important in cerulean warbler nest-site and/or territory selection throughout the breeding range. This study reinforces these general patterns. The conventional findings that cerulean warblers use large diameter trees in a multi-layered canopy structure with occasional gaps and dense understory appear to be sound management goals for eastern Kentucky. Particular tree species are likely not as important as the structure the trees provide, but east-facing mixed mesophytic conditions seem to be preferred. The next task in cerulean warbler management is to understand how these features affect productivity. Identifying the features that exert the strongest influence on the processes of mate attraction, nest predation and parasitism, food availability, and microclimatic differences will refine existing models of cerulean warbler habitat and enhance cerulean warbler conservation.

Canopy gaps, for example, are frequently mentioned as important (Bent 1953; Hamel 2000a, 2000b; Harrison 1984; Nicholson 2003; Oliarnyk & Robertson 1996; Suarez et al. 1997; Weakland & Wood 2005), but their role is not clearly understood. Without a clear understanding or definition of canopy gaps, it is premature to recommend their application in management plans. Future research should focus on the types and sizes of gaps used by cerulean warblers, the activities that take place in or near them, and their influence on reproduction and survival. In an Illinois study, indigo buntings experienced higher rates of nest predation in exterior edges (i.e., agriculture) than interior edges (Suarez et al. 1997). Moreover within interior edges, predation rates were higher in abrupt openings (i.e., wildlife clearing) than gradual ones (i.e., treefall gap). Not all gaps are equivalent. Therefore, it should be possible to identify gap dimensions that optimize habitat for the cerulean warbler.

With nearly 275,000 ha of forested habitat in eastern Kentucky, the DBNF is the largest piece of public land in Kentucky. This area contains high cerulean warbler densities and therefore represents an important conservation zone for the species. In fact, >80-year old stands in Pioneer Weapons Area currently support one of the highest known densities of cerulean warbler. By emphasizing the importance of no-harvest zones within forest boundaries and employing uneven-aged management strategies, the DBNF will serve as a refugium for the cerulean warbler and many other forest-interior species. In a recent survey of local residents surrounding the DBNF, 95% of those surveyed agreed protection of critical habitat for plants and wildlife was an important forest value while only 24% placed importance on the forest's utilitarian values for humans (Arndt et al. 2002).

However, silvicultural practices can be employed that mimic the natural processes that created the conditions under which the cerulean warbler evolved. The DBNF contains >530,000 ha of forested private land within the proclamation boundary. If timber extraction is the goal, some silvicultural techniques will be more effective than others in promoting sustainable cerulean warbler populations. In areas actively managed for timber, uneven-aged management practices, particularly single-tree or group-tree selection, should continue to support cerulean warblers. Other management activities that may promote cerulean warbler use or persistence include timber stand improvements such as thinning and crop tree releases, which will provide structural diversity. In areas that have been cut, allowing the understory to develop and gradually shift between habitats should minimize detrimental edge effects while providing habitat for forest-edge species and fledglings.

Single-species conservation is often criticized for ignoring impacts of management on other species or the community. Based on the findings from this study, however, habitat management aimed at the cerulean warbler will likely benefit many other species, including several of conservation importance. Retention of numerous large-diameter trees will provide nesting and foraging habitat for many forest wildlife species. In the ice-damaged Buffalo Branch area, average diameter of trees used for song perches (35.0 cm) was higher than that of available trees (22.2 cm). Current basal areas in ice-damaged stands (22.2 m^2/ha) and in mature, undisturbed forest (24.9 m^2/ha) support high densities of cerulean warbler. The results from the continuing CWTG silvicultural study should provide guidelines for a threshold basal area in which tree density becomes too low to support viable cerulean warbler populations and other forest songbirds.

The maintenance of a complex understory will provide nesting, foraging, and post-fledging habitat for a variety of forest songbirds. Other possible benefits of increased habitat complexity and vertical structure include greater species richness and diversity, increased foraging opportunities, more nest concealment, and reduced predator efficiency. In my study areas, spicebush, pawpaw, and a variety of saplings made up the majority of the shrub layer. Ice-damaged areas also had dense patches of green briar and blackberry.

Due to its simultaneous reliance on large tracts of mature forest and its apparent resilience to moderate levels of disturbance, the cerulean warbler presents an interesting conservation paradox. On the one hand, it offers an umbrella for protection of a suite of forest species. On the other it presents the opportunity to create habitat for early successional species. Species in both groups have urgent conservation needs. Taking this into account, managing for the cerulean warbler may reconcile opposing ecological needs of both groups of species. A cerulean warbler management plan that allows for undisturbed, mature forest interspersed with uneven-aged management may promote conservation of forest-interior and early successional birds.

APPENDIX A. Cerulean Warbler Technical Group Forest Management Research Project Treatment Implementation Guidelines, May 3, 2005

Control: The control stand will remain untreated through the conclusion of the project or at least until August 2008, preferably August 2009. This includes any form of harvest, prescribed burning, or application of herbicides.

Light Treatment: Between July 15, 2006 and April 1, 2007 this stand should be harvested by removing enough of the overstory to leave approximately 75–80 sqft BA/acre (17.2-18.3 m^2/ha). The removal can be a combination of timber stand improvement and value extraction. However, the residual stand should be evenly stocked (i.e., removals should be well-spaced) and the removals should not be strictly a thinning from above as would occur in a diameter limit cut, although such a cut with a high limit (i.e., ≥18” DBH) would give us very similar results and would not be a problem. The marking objective should be designed to roughly mimic a single-tree selection harvest as commonly practiced in the region in question.

Intermediate Treatment: Between July 15, 2006 and April 1, 2007 this stand should be harvested by removing enough of the overstory to leave approximately 55 sqft BA/acre (12.6 m^2/ha). The removal should be conducted such that the residual stand is comprised almost entirely of well-spaced dominants and co-dominants. All other commercial stems (i.e., > 6” DBH) should be felled. The marking objective should be designed to roughly mimic a shelterwood harvest as commonly practiced in the region in question. The cut should NOT be a heavy diameter-limit type harvest. Clearfelling of all stems 2” DBH or larger should be completed within the same time frame as the harvest.

Heavy Treatment: Between July 15, 2006 and April 1, 2007 this stand should be harvested by removing virtually all of the overstory, leaving only approximately 20 sqft BA/acre (4.6 m^2/ha). Residual stems should be well-spaced and be comprised of dominants and co-dominants. All other commercial stems (i.e., > 6” DBH) should be felled. The marking objective should be designed to roughly mimic a deferment or “modified-shelterwood” harvest as commonly practiced in the region in question. Clearfelling of all stems 2” DBH or larger should be completed within the same time frame as the harvest.

All Treatments: No additional timber harvests, burning, or application of herbicides should occur for the remainder of the study or through August 2008, preferably August 2009. This restriction should apply to at least a 50 yard buffer, preferably to a 200 yard buffer. All decks should be located OUTSIDE of the stands if possible. Road and skid trail construction within treatment stands should be minimized.

APPENDIX B. **Protocol for vegetation sampling at point count stations in Buffalo Branch, Daniel Boone National Forest, 2004. Courtesy of Kentucky Department of Fish and Wildlife Resources.**

Methodology for Collecting Habitat Data

(Songbird Point Count Habitat Data Collection Form)

Some general things to remember when completing this form:

- Data should be collected during the songbird breeding season with the same window as for point counts, no earlier than the last week of May and no later than the last week of June.
- Unless otherwise stated, consider only the 50m radius circle around your point when describing a feature.
- Be sure that you complete the entire form (front and back)

<u>Topographic Features</u> (determined from the point center)

Latitude and Longitude	In degrees/minutes/seconds with GPS unit. Make sure the GPS unit has the map datum set to NAD 83 CONUS. **Check your GPS unit before collecting your coordinates!** If you cannot get a reading due to dense canopy, you may have to wait until leaf-off for an accurate reading.
KY PIF Habitat Code	This is a <u>general</u> category for use in the database, which will enable us to group points for analysis. The code you enter will be "letter"-"number" using the following to describe your point: Open Lands "O" 1. Grassland 2. Early successional (barren, glade, old field, scrub/shrub) 3. Row-crop agriculture Forested Lands "F" 1. Deciduous Forest 2. Coniferous Forest 3. Mixed Deciduous and Coniferous Forest 4. Riparian Woodland Wetland "W" 1. Forested Wetland 2. Herbaceous Wetland 3. Open Water

APPENDIX B, continued.

Edge “E”
1. Open Land/Forest
2. Open Land/Wetland
3. Forested Land/Wetland
4. Open Land/Forest/Wetland

Slope	Recorded to the nearest degree slope (0-90º) using a clinometer. This may be 0º for flat terrain. For ridgetops, record the average slope of the 50m radial plot around the point.
Aspect	Recorded to the nearest degree (0-360º) using a compass to measure the direction a slope faces. On flat terrain or ridgetops, enter N/A.
Landform	Circle the landform that best fits your point. If your point does not fit into any of these categories, then circle other and give a description.
Topographic position	If applicable, circle the appropriate slope position for the point.
Water Availability	Circle all that apply. Unless water is absent, you will circle standing or flowing, along with a distance band to represent the closest distance water is to the point. If water is >50m away, record the distance to the nearest tenth of a meter. Record the name or type of water (ie. pond, lake, Green River, etc.)

Vegetation Data

Canopy/Overstory

Dominant Age	Circle one classification.
Dominant Vegetation	List three to five dominant canopy species (generally trees greater than 4 inches in d.b.h.) in order of abundance based upon observations from the point center.
Average Canopy Tree Height	Determine the height of the five canopy trees closest to the point center using a clinometer. Average their heights and record in feet.
Canopy Cover	Circle a percentage cover. Determined by ocular estimate of the canopy from the point center.

APPENDIX B, continued.

Canopy Basal Area	Using a 10 factor prism, *place the prism over the point center and rotate yourself around the plot* noting the number of canopy trees only NOT broken by the prism. Then multiply this number by ten. Do this separately for conifers and hardwoods. Do not count dead trees. Unit will be in ft^2/acre.
Total Basal Area	Use the same process described above, but include all trees NOT broken by the prism. Again, do separately for conifers and hardwoods. Do not count dead trees. Unit will be in ft^2/acre.

Midstory

Dominant Vegetation	List three to five dominant midstory species in order of abundance based upon observations from the point center.
Percent Cover	Circle a percentage cover. Determined by ocular estimate of the midstory from the point center.

Understory/Shrub Layer

Dominant Vegetation	Dominant vegetation of shrub layer (usually 1.5 to 8 feet above the ground) based upon observations from the point center that include deciduous trees, deciduous shrubs, vines, coniferous trees, evergreens, etc. List three to five species in order of abundance.
Percent Cover	Circle a percentage cover. Determined by ocular estimate of the shrub layer cover from the point center.

Herbaceous Layer/Groundcover

Dominant Vegetation	General vegetation categories of the herbaceous layer based upon observations from the point center including woody plants, ferns, forbs/sedges, and grasses (generally less than 1.5 feet). List three to five species in order of abundance.
Total Percent Cover	Circle a percentage cover for all groundcover species. Determined by ocular estimate of the herbaceous layer from the point center.
Percent Grass Cover	Circle a percentage cover for grass species only. Determined by ocular estimate of the herbaceous layer from the point center.

APPENDIX B, continued.

Miscellaneous

Standing Snags	Record the number of trees in each size category within the 50 meter plot.
Live Cavity Trees	Record the number of trees in each size category within the 50 meter plot.

APPENDIX C. Definitions of habitat variables used in analyses of habitat selection in 2005. Comparisons were made between territory and random points within the 4 Pioneer Weapons study grids.

Variable

Basal Area: Used a 2.5x factor metric prism to identify trees (including snags) that counted as "in" the plot. Trees were defined as stems ≥10cm dbh. Tree species and diameters of each "in" tree were recorded. (m^2 / ha)
Acer Basal Area: Basal area of maples within the prism plots
Quercus Basal Area: Basal area of oaks within the prism plots
Average DBH: Average diameter at breast height of all trees within the basal area (cm)
Random or Territory Tree DBH: Diameter at breast height of a representative tree within in the prism plot (random points) OR of a preferred singing perch (territory plots)
Tree Height: The height of a representative tree within the prism plot (random points) OR height of a preferred singing perch tree (territory plots)
Saplings: All stems ≥1.4m in height and measuring 1-10cm dbh within a 3m radius circle centered on a random or territory vegetation plot.

Average Sapling Height: Visually estimated (m)
Percent Sapling Cover: Visually estimated (%)
 # Sapling Stems: Count of individual saplings within the circle (#)
 # Sapling Species: Number of species within the circle (#)

Shrubs: Woody, low-growing plants with multiple stems (includes saplings <1.0 cm dbh) within a 3m-radius circle centered random or territory vegetation plot

Average Shrub Height: Visually estimated (m)
Percent shrub cover: Visually estimated (%)
 # Shrub Stems: Count of individual shrubs within the 3-m circle (#)
 # Shrub Species: Number of species (#)

Slope: Maximum slope measured with a clinometer over a 10-m distance crossing point center (degrees)
Aspect: (degrees)
Canopy Cover: 120 measures of canopy cover were taken using an ocular tube. Readings were taken every 2.26m along 11.3m transects in each of the cardinal directions. 20 readings taken in each of 6 height classes (0.5-3m, 3-6m, 6-12m, 12-18m, 18-24m, >24m), then averaged to estimate percent cover.

Appendix D. Scientific names of species mentioned in the text or tables.

Common name	**Scientific name**
Wood duck	*Aix sponsa*
Broad-winged hawk	*Buteo platypterus*
Ruffed grouse	*Bonasa umbellus*
Wild turkey	*Meleagris gallopavo*
Northern bobwhite	*Colinus virginianus*
American woodcock	*Scolopax minor*
Mourning dove	*Zenaida macroura*
Yellow-billed cuckoo	*Coccyzus americanus*
Great horned owl	*Bubo virginianus*
Barred owl	*Strix varia*
Ruby-throated hummingbird	*Archilochus colubris*
Red-bellied woodpecker	*Melanerpes carolinus*
Downy woodpecker	*Picoides pubescens*
Hairy woodpecker	*Picoides villosus*
Northern flicker	*Colaptes auratus*
Pileated woodpecker	*Dryocopus pileatus*
Eastern wood-pewee	*Contopus virens*
Acadian flycatcher	*Empidonax virescens*
Eastern phoebe	*Sayornis phoebe*
Great-crested flycatcher	*Myiarchus crinitus*
White-eyed vireo	*Vireo griseus*
Blue-headed vireo	*Vireo solitarius*
Yellow-throated vireo	*Vireo flavifrons*
Red-eyed vireo	*Vireo olivaceus*
Blue jay	*Cyanocitta cristata*
American crow	*Corvus brachyrhynchos*
Carolina chickadee	*Poecile carolinensis*
Tufted titmouse	*Baeolophus bicolor*

Appendix D *continued*.

Common name	**Scientific name**
White-breasted nuthatch	*Sitta carolinensis*
Carolina wren	*Thryothorus ludovicianus*
Blue-gray gnatcatcher	*Polioptila caerulea*
Eastern bluebird	*Sialia sialis*
Veery	*Catharus fuscescens*
Gray-cheeked thrush	*Catharus minimus*
Swainson's thrush	*Catharus ustulatus*
Hermit thrush	*Catharus guttatus*
Wood thrush	*Catharus mustelinus*
American robin	*Turdus migratorius*
Gray catbird	*Dumetella carolinensis*
Northern mockingbird	*Mimus polyglottos*
Brown thrasher	*Toxostoma rufum*
Blue-winged warbler	*Vermivora pinus*
Tennessee warbler	*Vermivora peregrine*
Nashville warbler	*Vermivora ruficapilla*
Northern parula	*Parula Americana*
Chestnut-sided warbler	*Dendroica pensylvanica*
Black-throated green warbler	*Dendroica virens*
Blackburnian warbler	*Dendroica fusca*
Yellow-throated warbler	*Dendroica dominica*
Prairie warbler	*Dendroica discolor*
Blackpoll warbler	*Dendroica striata*
Cerulean warbler	*Dendroica cerulea*
Black-and-white warbler	*Mniotilta varia*
American redstart	*Setophaga ruticilla*
Worm-eating warbler	*Helmitheros vermivorus*
Ovenbird	*Seiurus aurocapillus*
Louisiana waterthrush	*Seiurus motacilla*

Appendix D *continued*.

Common name	Scientific name
Kentucky warbler	*Oporornis formosus*
Hooded warbler	*Wilsonia citrine*
Yellow-breasted chat	*Icteria virens*
Summer tanager	*Piranga rubra*
Scarlet tanager	*Piranga olivacea*
Eastern towhee	*Pipilo erythrophthalmus*
Field sparrow	*Spizella pusilla*
Northern cardinal	*Cardinalis cardinalis*
Rose-breasted grosbeak	*Pheucticus ludovicianus*
Indigo bunting	*Passerina cyanea*
Brown-headed cowbird	*Molothrus ater*
Baltimore oriole	*Icterus galbula*
American goldfinch	*Carduelis tristis*

Appendix E. Number of birds recorded by species and by month in Buffalo Branch (2004) and Pioneer Weapons Area (2005) in Daniel Boone National Forest.

	Buffalo Branch, 2004		**Pioneer Weapons Area, 2005**	
Species	**May**	**June**	**May**	**June**
Broad-winged hawk	2	0	0	2
Wild turkey	22	7	0	0
American woodcock	1	1	0	0
Mourning dove	6	5	0	0
Yellow-billed cuckoo	60	22	4	8
Ruby-throated hummingbird	5	3	1	0
Red-bellied woodpecker	29	42	2	2
Downy woodpecker	14	17	4	3
Hairy woodpecker	11	18	3	2
Northern flicker	19	3	1	1
Pileated woodpecker	31	19	2	7
Eastern wood-pewee	84	82	10	16
Acadian flycatcher	82	75	14	9
Eastern phoebe	4	1	2	4
Great-crested flycatcher	6	4	3	0
White-eyed vireo	2	6	0	0
Blue-headed vireo	0	0	1	0
Yellow-throated vireo	11	20	4	3
Red-eyed vireo	199	163	53	50
Blue jay	27	25	1	6
American crow	43	28	0	6
Carolina chickadee	10	25	5	8
Tufted titmouse	72	48	9	11
White-breasted nuthatch	23	55	4	18
Carolina wren	26	43	20	25
Blue-gray gnatcatcher	69	65	10	8
Cedar waxwing	7	2	0	0
Veery	7	0	0	0
Gray-cheeked thrush	0	0	1	0
Swainson's thrush	0	0	3	0
Hermit thrush	1	1	0	0
Wood thrush	118	179	10	14
Gray catbird	5	2	0	0
Brown thrasher	0	1	0	0
Blue-winged warbler	8	1	0	0
Tennessee warbler	0	0	3	0
Nashville warbler	1	0	2	0
Northern parula	1	0	0	0
Chestnut-sided warbler	3	6	0	0
Black-throated green warbler	10	7	5	2

Appendix E (*Continued*)

Species	**Buffalo Branch, 2004** **May**	 **June**	**Pioneer Weapons Area, 2005** **May**	 **June**
Blackburnian warbler	2	0	1	0
Yellow-throated warbler	0	0	1	1
Prairie warbler	1	0	0	0
Blackpoll warbler	0	0	9	0
Cerulean warbler	47	43	29	41
Black-and-white warbler	22	7	7	10
American redstart	48	33	27	22
Worm-eating warbler	41	58	11	16
Ovenbird	267	286	36	42
Louisiana waterthrush	3	2	3	2
Kentucky warbler	12	27	0	1
Hooded warbler	86	103	24	22
Yellow-breasted chat	46	61	0	1
Scarlet tanager	110	87	14	26
Eastern towhee	29	57	0	0
Field sparrow	0	1	0	0
Northern cardinal	18	18	5	11
Rose-breasted grosbeak	2	2	0	0
Indigo bunting	101	112	13	7
Brown-headed cowbird	54	53	15	4
Americn goldfinch	12	14	0	0

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