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Ecology of the Cerulean Warbler in the Cumberland Mountains of East Tennessee

Charles Patrick Nicholson
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a dissertation written by Charles Patrick Nicholson entitled "Ecology of the Cerulean Warbler in the Cumberland Mountains of East Tennessee." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Ecology and Evolutionary Biology.

David A. Buehler, Major Professor

We have read this dissertation and recommend its acceptance:

H. R. DeSelem, M. Boulet, M. Remie

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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

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And recommend its acceptance:

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Acceptance for the Council:

Vice Provost and Dean of Graduate Studies

ECOLOGY OF THE CERULEAN WARBLER IN THE CUMBERLAND MOUNTAINS OF EAST TENNESSEE

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Charles Patrick Nicholson
May 2004

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ABSTRACT

The objective of this study was to describe the distribution, local breeding densities and population trends, breeding biology, and habitat selection of the Cerulean Warbler (*Dendroica cerulea*) in the Cumberland Mountains of Morgan, Campbell, Scott, and Anderson Counties, Tennessee. Point counts were conducted during three years at six study sites. The Cerulean Warbler was detected at 50% of the point counts and was the sixth most frequently encountered bird. Spot-map censuses were conducted on five plots at three study sites. Cerulean Warblers occurred on all census plots at an average density of 84.9 pairs/100 ha. Average density on individual plots ranged from 21.3 to 137.6 pairs/100 ha. Although population trends on the census plots were not uniform, there was an overall decline during the late 1990s.

The breeding biology of the Cerulean Warbler was studied by observing courtship behavior and nest-building, and monitoring a total of 52 nests. Female warblers built nests, incubated eggs, and brooded nestlings. Females fed nestlings more often than males; the rate at which males and females removed fecal sacs from the nest did not differ. Mean clutch size was 3.7 ± 0.13 SE. For the years 1996–1999, nest success, measured by the Mayfield method, averaged 0.3708; the daily nest success rate averaged 0.9685 ± 0.0057 SE. The major cause of nest failure appeared to be weather events, including presumed nestling starvation during unusually cool and wet weather.

Nests were built in 12 taxa of deciduous trees. Although there were some plot-specific preferences, most tree taxa were selected in proportion to their availability. Nests averaged 15.9 m ± 0.81 SE (range 7.0 – 36.3m) above ground. Nest trees averaged 23.6 m ± 0.90 SE (range 10.2 – 42.2 m) tall and 39.6 cm ± 2.53 SE (range 12.3 – 76.2 cm) in diameter at breast height.

Habitat characteristics were sampled at nest sites, territory sites, and random sites on census plots, and at point count locations. Basal area was consistently greater, and both shrub cover and canopy cover consistently less, at nest sites than at random sites, at territory sites than at random sites, and at nest sites than at territory sites. Point count locations where Cerulean Warblers were present had larger diameter live trees and more

sapling cover than locations where the warbler was absent. Logistic regression models successfully classified over 70% of sites on census plots but were less successful in predicting Cerulean Warbler presence at point count locations.

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CHAPTER 1

INTRODUCTION

The Cerulean Warbler (*Dendroica cerulea*) is a small wood-warbler breeding in mature deciduous forests of southern Canada and the United States south to northeast Texas and central Alabama (Hamel 2000a). Within much of this range it inhabits mature floodplain forests with tall trees (Robbins et al. 1992). In the center of its breeding range, which includes the central and southern Appalachians, the Cerulean Warbler also occurs in mature, upland, mesic forests. In both of these habitats, it occupies areas with large-diameter trees, a closed to partially open canopy, and sparse understory. The Cerulean Warbler is often characterized as an area-sensitive species; minimum forest tract sizes of 250 ha and 1600 ha have been suggested for the mid-Atlantic states and Mississippi Alluvial Valley, respectively (Robbins et al. 1989, Hamel 2000a).

As measured by the North American Breeding Bird Survey (BBS), the Cerulean Warbler's rangewide population declined at an average rate of 4.2%/year from 1966-2000 (Sauer et al. 2001). This rate of decline was the greatest for any North American warbler during the 1996-2000 time period. Because of this rapid population decline, the Cerulean Warbler was listed as a Category 2 candidate species for potential listing as Endangered or Threatened under the Endangered Species Act from 1991 to 1996 (USFWS 1991, 1996). Since then, it has been considered a Federal Species of Concern, a designation that carries no regulatory authority but notes the need for its conservation. In October 2000, the Southern Environmental Law Center, on behalf of a coalition of the National Audubon Society and other organizations, petitioned the U.S. Fish and Wildlife Service to list the Cerulean Warbler as a Threatened Species (SELC 2000). On October 23, 2002, the U.S. Fish and Wildlife Service announced its finding that the petition contained information indicating listing may be warranted and initiated a status review of the species (USFWS 2002)

Several factors have been suggested to explain the population decline in the Cerulean Warbler. Commonly cited factors operating within its breeding range include

the loss of breeding habitat through destruction of floodplain forests, fragmentation of remaining forests, and loss of mature forest within otherwise suitable forested areas (Robbins et al. 1992, Hamel 2000b). Potential factors operating outside its breeding range include the loss of wintering and migratory stopover habitat (Robbins et al. 1992).

According to BBS results, the Cerulean Warbler reaches its greatest relative abundance in the Cumberland Plateau physiographic province of southern West Virginia, eastern Kentucky, southwestern Virginia, and eastern Tennessee (Sauer et al. 2001). Its greatest breeding densities have also been reported in this region as well as adjacent portions of the Allegheny Plateau in Ohio and West Virginia (Robbins et al. 1992, censuses published in *American Birds* and *Journal of Field Ornithology*). Although this area is a center of abundance for the Cerulean Warbler, its population in the Cumberland Plateau province declined at the rate of 3.5 %/year from 1966-2000 (Sauer et al. 2001). During the 1980s, the rate of decline was greater in the Cumberland Plateau than in much of the warbler's range (Villard and Maurer 1996).

Much of the biology of the Cerulean Warbler is poorly known (Hamel 2000a). Studies of its habitat preferences, breeding biology, and response to different silvicultural practices have been conducted in bottomland forests of the Mississippi Alluvial Valley in Tennessee, Arkansas, and Mississippi (P.B. Hamel pers. comm., Hamel et al. 1998). The warbler's habitat selection and breeding biology have been studied in southeastern Ontario (Oliarnyk 1996, Oliarnyk and Robertson 1996, Robertson et al. 1998, Jones and Robertson 2001). Robinson et al. (1998) described a statewide survey of its abundance and habitat use in Illinois. A survey of its abundance and distribution across its breeding range was recently published through The Cerulean Warbler Atlas Project (Rosenberg et al. 2000).

Published information on the Cerulean Warbler in the Cumberland Plateau physiographic province is limited to descriptions of its distribution and relative abundance (e.g., Buckelew and Hall 1994, Nicholson 1997, Palmer-Ball 1996). Relative to other parts of the warbler's range, the Cumberland Plateau has a high proportion of interior forest and low level of fragmentation (Hamel 2000b, Wear and Greis 2001). These factors, coupled with the warbler's high density, suggest that the Cumberland

Plateau has great potential for maintaining a dense population of the Cerulean Warbler and preventing its endangerment. This potential is particularly high in the Cumberland Mountains subunit of the Cumberland Plateau. The Cumberland Mountains cover portions of eastern Kentucky, southwestern Virginia, and eastern Tennessee (Fenneman 1938, Smalley 1984). Relative to the rest of the Cumberland Plateau, the Cumberland Mountains have a greater relative density of Cerulean Warblers, as well as a greater diversity and abundance of other Neotropical migrant birds (Nicholson 1997, Sauer et al. 2001). The Cumberland Mountains are relatively unfragmented, and much of the land is in large tracts owned by natural resource agencies and coal and timber companies.

The overall objective of this study is to describe the distribution, local breeding densities and population trends, breeding biology, and habitat selection of the Cerulean Warbler in the Cumberland Mountains of Tennessee. Specific objectives are to:

1. Describe the local distribution, breeding density, and recent population trends of the Cerulean Warbler (Chapter 3).
2. Quantitatively describe and develop models of the breeding habitat of the Cerulean Warbler (Chapter 4).
3. Describe the breeding biology of the Cerulean Warbler (Chapter 5).

CHAPTER 2

STUDY AREAS

This study was conducted in the Cumberland Mountains of eastern Tennessee. The Cumberland Mountains, a section of the Appalachian Plateau Province of Fenneman (1938), cover about 7,500 km^2 in Tennessee, Kentucky, and Virginia. In Tennessee, the Cumberland Mountains cover parts of five counties: Anderson, Campbell, Claiborne, Morgan, and Scott (Figure 2-1). The Cumberland Mountains are differentiated from the adjacent Cumberland Plateau by their greater relief, higher elevations, and higher degree of dissection. Underlying geology consists of layers of sandstones, siltstones, shales, and coal of Pennsylvanian origin. In the eastern part of the region, these strata are folded and faulted into the Cumberland Thrust Block formation, which in Tennessee includes Pine Mountain, Cumberland Mountain, and Walden Ridge (Miller 1974). The area between Pine and Cumberland Mountain, known as the Middlesboro Syncline, and the area west of the thrust block, known as the Wartburg Basin, have relatively horizontal rock strata.

The Cumberland Mountains have a temperate climate with long, moderately hot summers and short, mild to moderately cold winters (Dickson 1975, Smalley 1984). Precipitation averages about 124 cm and is well distributed throughout the year, with December through March the wettest months and August through October the driest months. The frost-free period typically extends from mid-April to mid- to late October (Dickson 1975, Smalley 1984).

REGIONAL VEGETATION

The Cumberland Mountains is one of the most heavily forested regions of Tennessee (Smalley 1984, Schweitzer 2000). Based on her analysis of remnant late-successional forests in the 1930s and 1940s, Braun (1950) included the Cumberland Mountains in her Mixed Mesophytic Forest Region, which she distinguished by the numerous tree species sharing dominance. Common dominant tree species include sugar

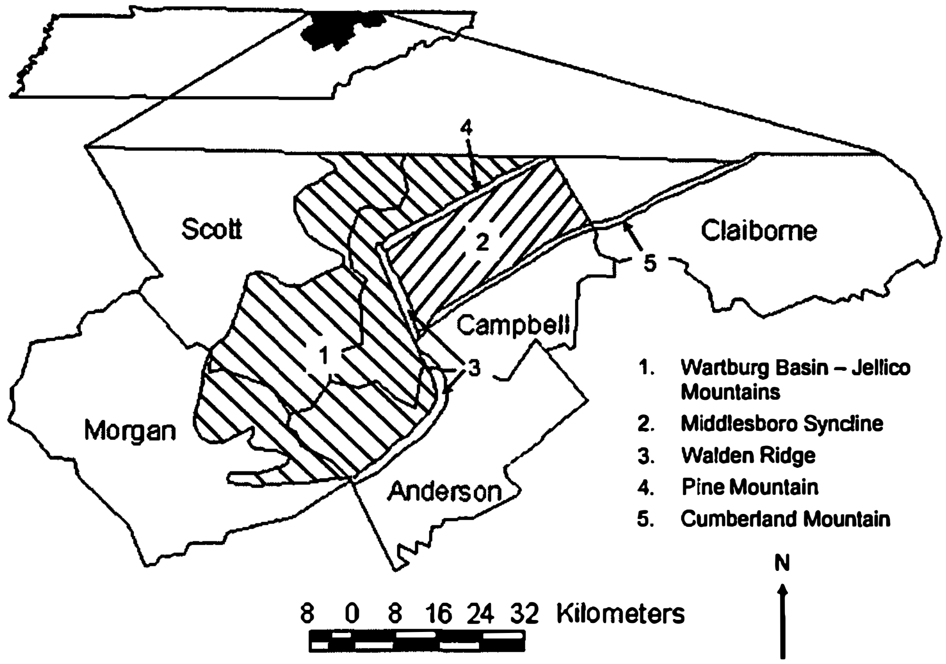


Figure 2-1. Subregions of the Cumberland Mountains in Tennessee. Adapted from Miller (1974) and Smalley (1984).

maple (*Acer saccharum*), white basswood (*Tilia heterophyllum*), yellow-poplar (*Liriodendron tulipifera*), American beech (*Fagus grandifolia*), yellow buckeye (*Aesculus octandra*), northern red oak (*Quercus rubra*), white oak (*Q. alba*), eastern hemlock (*Tsuga canadensis*), and, formerly, American chestnut (*Castanea dentata*).

The importance of the various species in the mixed mesophytic forest varies locally with site conditions. Braun (1950) recognized locally occurring, distinct communities or association-segregates as parts of the mixed mesophytic forest.

Forests dominated by combinations of typical mixed mesophytic species were widespread in the Wartburg Basin, and in ravines and on north slopes of the Cumberland Thrust Block formation. More xeric sites, such as upper southwest slopes and dry ridge tops, support oak and oak-pine forest types; common species on these sites are chestnut oak (*Q. prinus*), scarlet oak (*Q. coccinea*), and black oak (*Q. velutina*). Pines, predominantly shortleaf (*Pinus echinata*), Virginia (*P. virginiana*), and white (*P. strobus*), are fairly common on shallow, sandy soils, especially in the Cumberland Thrust Block formation.

Current forests in the Cumberland Mountains differ greatly from those described by Braun (1950). Almost all of the old-growth stands have been logged, and chestnut blight has eliminated American chestnut from the forest overstory. Many selectively logged stands retain the species composition described by Braun (1950), but lack the large trees she described (Smalley 1984). Coal mining has also affected large areas.

The study was conducted on six different areas within the Cumberland Mountains (Figure 2-2). These individual study sites are described in more detail in the following sections.

FROZEN HEAD STATE PARK AND NATURAL AREA

Elevations in this 3,240-ha park in eastern Morgan County range from 360 to 1,013 m. The area was acquired by the state in 1894 as the location of Brushy Mountain State Prison and for its coal reserves. It became a state forest in 1935 and a state park in 1970. In 1988 most of the park was designated a State Natural Area. The park contains

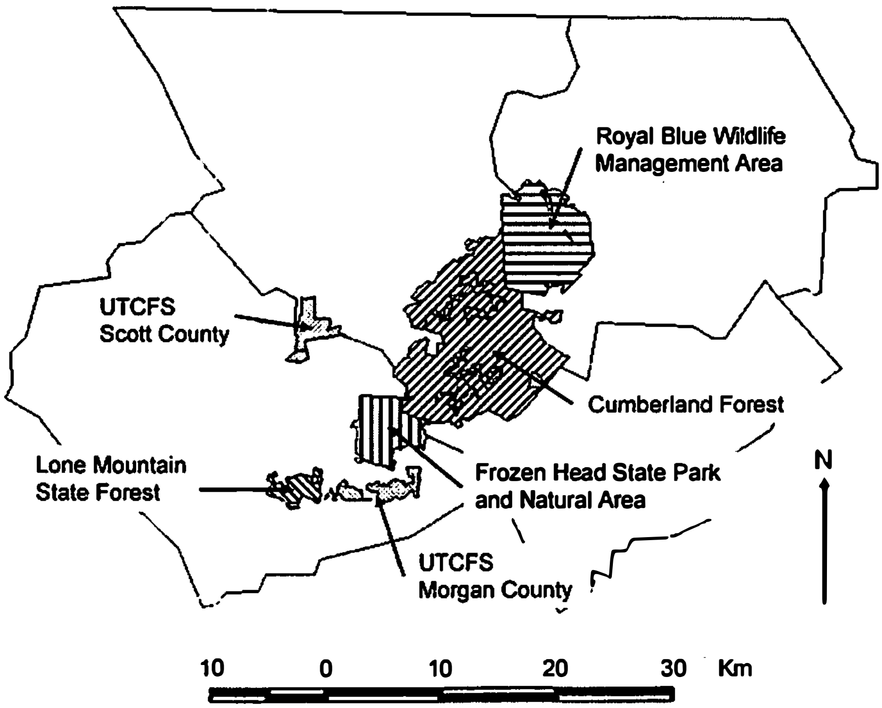


Figure 2-2. Location of Cumberland Mountains study areas.

several of the highest peaks in the Cumberland Mountains of Tennessee, as well as the highest peaks undisturbed by coal surface mining. Virtually all of the area is forested; unforested areas occur along Flat Fork near the western edge, and adjacent to the south and southeastern borders. Regional forest cover was determined from USGS National Land Cover Data (Vogelmann 2001), based on early 1990s remote sensing data with 30 m resolution. Approximately 92% of the area within 10 km of the most intensively studied portion of the park is forested.

The area was heavily cut over and most trees over 35 cm diameter were removed between 1911 and the 1920s (Crownover 1988). Since then, the only major forest disturbance has been occasional forest fires; much of the area burned in 1952. Crownover (1988) gives additional information on the geology and history of Frozen Head. A partial flora of the park was published by Holtzclaw (1977) and the summer avifauna is partially described by Nicholson (1987, 1997).

Crownover (1988) studied the overstory vegetation and soils of Bird Mountain, a part of Frozen Head with elevations of 410 to 990 m. He recognized seven forest community types: chestnut oak, white oak-northern red oak, beech, northern red oak-sugar maple, yellow-poplar, sugar maple-white basswood-yellow-poplar-yellow buckeye, and black cherry-sugar maple. The types segregated by aspect, slope position, elevation, and geomorphic form. All but the yellow-poplar and black cherry-sugar maple types were reproductively stable, with sufficient reproduction to maintain the community type.

ROYAL BLUE WILDLIFE MANAGEMENT AREA

Elevations in this 17,653-ha, mostly forested area in Campbell and Scott Counties range from 350 to 988 m. The dominant vegetation cover is sawtimber-sized upland hardwood forest, which occupies about 85% of the area (TWRA 1998). Numerous surface mines of various ages, size, and state of reclamation occur throughout the area. Large portions of the area were selectively logged in the 1970s, prior to acquisition by the Tennessee Wildlife Resources Agency in 1991. Since then, management efforts have focused on establishing and maintaining wildlife openings, many of which are on former surface mines, and on maintaining roads and trails. The wildlife management area

(WMA) is crossed by powerline corridors and two major highways, and adjoined by other extensive forest. Regional forest cover was determined from USGS National Land Cover Data (Vogelmann 2001), based on early 1990s remote sensing data with 30 m resolution. Approximately 96% of the area within 10 km of the most intensively studied portion of the WMA is forested.

Cabrera (1969) studied the forest cover of a remnant, old growth forest on Ash Log Mountain, elevation 567-989 m, at the edge of the current WMA. He recognized two communities which he identified as mixed mesophytic segregates: 1) sugar maple-yellow-poplar-basswood-buckeye in north coves; and 2) sugar maple-northern red oak-yellow-poplar-black locust on north and west ridges and west and northwest slopes and coves. He also recognized a chestnut oak-black locust community on west and southwest spur ridges and coves; this type is more closely associated with oak forest types than with the mixed mesophytic forest.

Knight (1979) studied soils and vegetation along elevational transects in the Royal Blue area. Mixed oak forests were common on south slopes, while forests on north slopes generally had a higher diversity of canopy trees and more mesophytic species.

Previous ornithological studies at Royal Blue include censuses of breeding birds on forested tracts published by Smith (1977) and by Turner and Fowler (1981a, 1981b). Garton (1973) and Yahner (1972, 1973) censused breeding birds on tracts containing both forested and mined areas.

UNIVERSITY OF TENNESSEE CUMBERLAND FORESTRY STATION, MORGAN COUNTY TRACTS

This study site consists of two nearby tracts, Wilson Mountain and Little Brushy Mountain, totaling about 1,660 ha. At their closest points, the two tracts are about 610 m apart. Much of the area between the two tracts is forested. State Highway 62 bisects the eastern portion of the larger Little Brushy Mountain tract, and farmland adjoins portions of both tracts. Elevations range from 390 to 700 m. Regional forest cover was determined from USGS National Land Cover Data (Vogelmann 2001), based on early

1990s remote sensing data with 30 m resolution. Approximately 89% of the area within 10 km of the centroid of the two tracts is forested.

Most of the high quality timber was cut between 1915 and 1937, when Bryn Mawr Mining and Land Company deeded the two tracts to the University (UT and TVA 1953). Little management, and no timber cutting, occurred between 1937 and the 1950s. A management plan and inventory completed in 1953 found an average sawtimber volume of 26.2 m^3/ha (3,573 bd ft/acre) (UT and TVA 1953). Hardwoods made up 89% of this volume, and almost half of the volume was in defective trees. Much of the tree damage was due to recurrent wildfires, which have been more effectively controlled since the mid-1950s. As recommended by the plan, some harvesting and timber stand improvement work occurred in the 1950s. Narrow contour coal surface mines at 488 m, 548, and 579 m were mined between 1953 and 1957 (DeSelm et al. 1978). The mines were mostly reforested with natural revegetation and loblolly pine (*Pinus taeda*) planted in the 1960s.

Martin (1966, see also DeSelm et al. 1978) identified five forest types on Wilson Mountain between 414 and 689 m elevation. The most common type was chestnut oak. The other types were yellow-poplar, northern red oak, white oak, and shortleaf pine-oak. The yellow-poplar type had the greatest tree species diversity, while the northern red oak type had the highest basal area. Mean tree (stems > 12.7 cm dbh) density and basal area were 309 stems/ha and 18.6 m^2/ha, respectively. Martin (1966) concluded the presence of individual overstory tree species was strongly influenced by slope angle, slope direction, and slope position. Krumpe (1971) used aerial photography and ground truthing to identify 29 vegetation types on Wilson Mountain. Many of these types were subdivisions of Martin's five forest types; others were outside the area sampled by Martin. Eight of the 29 types were dominated by chestnut oak, six by yellow pine, four by white oak, and three by yellow-poplar. The other types were dominated by white pine, northern red oak, black locust, black gum, hickory, or young mixed hardwoods and softwoods (Krumpe 1971). In a further analysis of the data collected by Martin (1966), DeSelm et al. (1978) noted decreases in basal area, tree species diversity, and density in plots arranged on a mesic to xeric axis.

UNIVERSITY OF TENNESSEE CUMBERLAND FORESTRY STATION, SCOTT COUNTY TRACT

This 1,737-ha area straddles the Scott-Morgan County line about 10 km east of Sunbright. Elevations range from 407 to 866 m. Virtually all high quality timber was harvested from 1915 to 1920, and some additional harvesting continued until 1937, when the University acquired the property from Bryn Mawr Mining and Land Company (MacDonald 1964, Rodriguez 1973). Little management took place between 1937 and the 1950s. A few small underground coal mines operated prior to the 1930s, and surface mining occurred in the 1950s. About 2.3 % of the area was mined, and additional areas were disturbed by spoil movement. The surface mines are mostly reforested with natural revegetation and planted loblolly pine. Extensive forest adjoins most of the area. Regional forest cover was determined from USGS National Land Cover Data (Vogelmann 2001), based on early 1990s remote sensing data with 30 m resolution. Approximately 98% of the area within 10 km of the center of the area is forested.

In a forest inventory conducted in 1962, MacDonald (1964) found an average tree (stems > 12.7 cm dbh) density and volume of 270 stems/ha (109.1/acre) and 24 m^3/ha (1775 bd. ft/acre), respectively. Hardwoods comprised 91 % of the volume. Virtually all of the area showed signs of fire damage. Between 1962 and 1972, stem density increased 17 % and basal area increased 22 % (Rodriquez 1973).

LONE MOUNTAIN STATE FOREST

Elevations in this 1,460-ha area in Morgan County range from 243 m along the Emory River to 770 m. The area is dominated by pine-oak and oak-hickory forests; smaller areas of more mesic forest types occur on north and northeast slopes, and along stream drainages. Most of the forests are in the large poletimber and small sawtimber size classes. Forest adjoins most of the west and south borders of the state forest, and farmland and low density residential areas adjoin parts of the north and east borders. Regional forest cover was determined from USGS National Land Cover Data

(Vogelmann 2001), based on early 1990s remote sensing data with 30 m resolution. Approximately 90% of the area within 10 km of the center of the state forest is forested.

CHAMPION INTERNATIONAL CUMBERLAND FOREST

This commercial forest consists of about 34,500 ha in several different tracts in Campbell, Anderson, and Morgan Counties. The tract used in this study is 16,000 ha in size and located at the junction of the 3 counties, between Royal Blue WMA on the east and Frozen Head on the southwest. Elevations in this tract range from about 350 to 950 m. Much of the timber over 40-cm diameter was harvested in the 1980s and early 1990s. The area also has extensive coal surface mines, both former and active, in various stages of reclamation. At the time this study took place, the area was owned by Champion International. It was subsequently sold to International Paper Company and in 2002 was purchased by the Tennessee Wildlife Resources Agency for use as a wildlife management area. Regional forest cover was determined from USGS National Land Cover Data (Vogelmann 2001), based on early 1990s remote sensing data with 30 m resolution. Approximately 99% of the area within 10 km of the approximate center of the area at Stainville is forested.

CHAPTER 3

DISTRIBUTION, DENSITY AND POPULATION TRENDS OF THE CERULEAN WARBLER IN THE CUMBERLAND MOUNTAINS OF TENNESSEE

The Cerulean Warbler breeds in deciduous forests in much of the central and northeastern U.S., as well as parts of southern Canada. Its rangewide breeding population has declined by about 4.4 % per year from 1966 through 2002 (Sauer et al. 2003). Several explanations for the decline have been proposed; these include factors operating within the species' North American breeding range and factors operating within its South American wintering range (Robbins et al. 1992, Hamel 2000b). Analysis of these factors is complicated because the rate of decline has not been uniform temporally or spatially (Villard and Maurer 1996).

The Cerulean Warbler is relatively common and widespread in the Cumberland Mountains, a mountainous portion of the larger Cumberland Plateau physiographic region (Nicholson 1997). The Cumberland Plateau is a center of abundance for the Cerulean Warbler (Hamel 2000a); during the 1980s this area had a greater rate of decline than most other portions of the warbler's range (Villard and Maurer 1996). This chapter describes the results of a study of the distribution, population density, and recent population trends of the Cerulean Warbler in the Cumberland Mountains of Tennessee.

METHODS

Local Distribution

Point count surveys were conducted in the Frozen Head State Park and Natural Area (SP), Royal Blue Wildlife Management Area (WMA), the Morgan and Scott County units of the University of Tennessee Cumberland Forestry Station (UTCFS), Lone Mountain State Forest, and Champion International Cumberland Forest study areas to determine the local distribution and relative abundance of Cerulean Warblers. Each of these study areas is described in Chapter 2.

Ten minute 50-m fixed radius point counts were conducted as recommended by Ralph et al. (1993). Counts were conducted in late May and June of 1995, 1996, and 1997. A point was counted once per year during 1 to 3 years. Counts began shortly after sunrise and were usually completed within 3 hours. Birds were assigned to the following classes according to their distance from the count center: 0-25 m, 25-50 m, and >50 m. Data from all distance classes (unlimited radius) were used for determining the warbler's local distribution.

Points were placed at intervals of 200 to 400 m along transects following woods roads and trails, with 7 to 13 points per transect. The number of transects and points censused each year were as follows: 1995 – 51 transects, 448 points; 1996 – 32 transects, 337 points; and 1997 – 30 transects, 317 points. Transects were located in potential Cerulean Warbler habitat comprised of a variety of hardwood-dominated forest types of pole-sized or larger stand size. Where the presence of the road resulted in an opening in the forest canopy, the point was moved off the road until it was at least 50 m from the forest edge.

Local Density and Population Trend

Spot mapping censuses were used to determine local breeding densities and short-term population trends of Cerulean Warblers. Spot mapping censuses were carried out by making repeated visits to a plot and recording, onto a map of the plot, the location and behavior of each bird observed (Robbins 1970). The observations from each visit were then combined on separate maps for each species. The number of territories of each species was then determined from the clusters of observations.

Five plots in three study areas were censused (Table 3-1). Each plot was nominally 10 ha, the minimum size for forested areas recommended by current standards (Ralph et al. 1993). Plots were originally surveyed with a hand compass and measuring tape, and the boundaries and an internal grid were marked with stakes, plastic flagging, and on some plots, paint. Plot boundaries were later surveyed using global positioning satellite equipment; according to these survey results, actual plot sizes ranged from 10.1 to 11.2 ha. Detailed descriptions of the plots, in the style of Resident Bird Counts

Table 3-1. Locations of spot-map census plots and years censuses were conducted in the Cumberland Mountains of Tennessee.

Study Area	Plot Name	Plot Area (ha)	Years Censused
Frozen Head SP	Upper Plot	10.4	1994-2000
	Lower Plot	11.2	1995-1998
Royal Blue WMA	Turley Mountain	10.3	1995-1998
	Rock Springs Gap	10.3	1995-1998
UTCFS – Scott Co.	Scott. Co.	10.1	1995-1998

published in the *Journal of Field Ornithology* (e.g., Hochadel 1990), are given in Appendices I-V.

Censuses were conducted from mid-May through mid- to late June. Each census visit began by 0700; their length (2.5–4 hours) varied with the terrain and number of birds encountered. The starting points and routes taken through the plots were varied between census visits. Plots were censused 8–10 times each year. The Upper Frozen Head plot was censused by the same individual each year; other plots were censused by different individuals. All spot maps were compiled by the same person.

Local Population Variability

To determine whether the variability in Cerulean Warbler density on the Cumberland Mountains census plots was within the range of variability found on census plots elsewhere, rangewide results of Breeding Bird Censuses repeated at least 3 times from 1965-1995 and reporting Cerulean Warblers on at least 40% of the replications were analyzed. Fourteen plots met these criteria. The mean density and coefficient of variation (CV) were calculated for these plots, as well as the 5 Cumberland Mountains plots. Correlation coefficients were then determined for the relationships between mean density, CV, and the number of years a plot was censused for both the rangewide and Cumberland Mountains data sets.

Regional Population Trends

Regional population trends were determined from the results of the 27 Breeding Bird Survey (BBS) routes in the Cumberland Plateau region (BBS Stratum 21; Figure 3-1). The BBS is a cooperative program established in the mid-1960s to monitor bird populations during the breeding season (Robbins et al. 1986). It consists of randomly located routes 39.2 km in length along lightly and moderately traveled roads. A volunteer observer counts birds along this route by making 50 stops at fixed locations 0.8 km apart and counting all birds heard and seen at each stop during a 3-min period. Counts are begun 30 min before sunrise, and, in the Cumberland Plateau region, conducted during the last few days of May or in June.

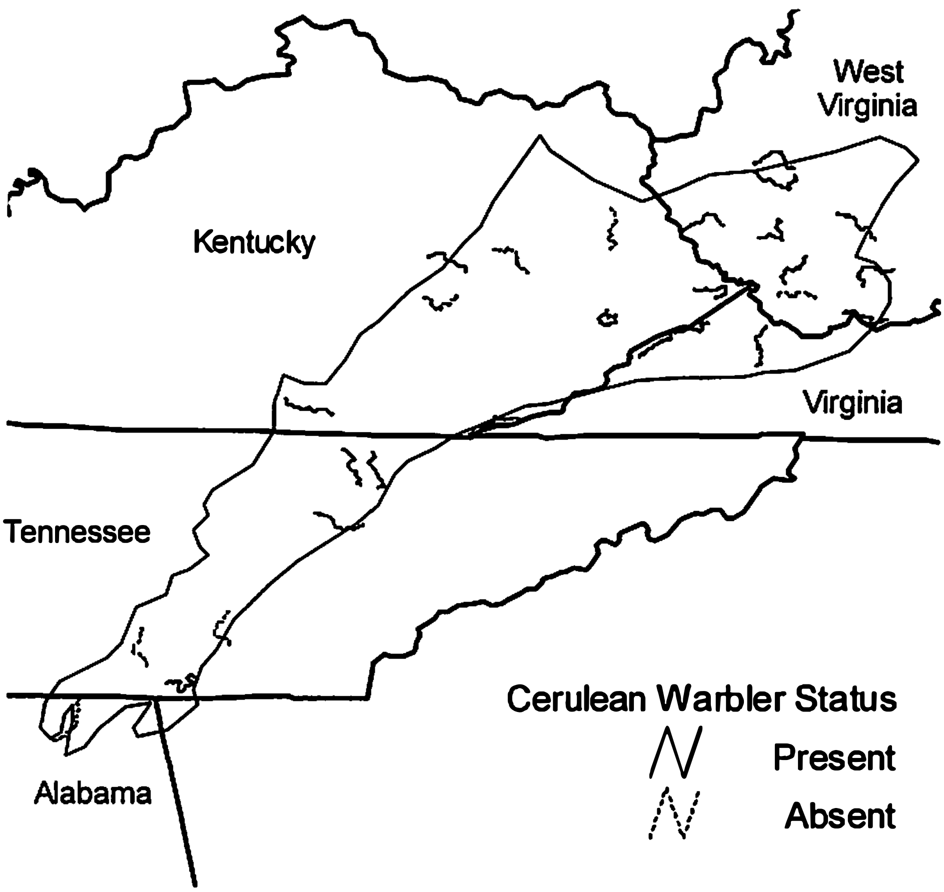


Figure 3-1. Presence/absence of Cerulean Warblers on Breeding Bird Survey routes within Stratum 21, the Cumberland Plateau region, since 1966.

Population trends were calculated by the BBS office, and reflect the mean annual percentage change in numbers of bird per route during a specified time period (Sauer et al. 2003). Trend calculations use a route-regression method, and use weighted averages of trends on individual routes to determine trends for a region (Geissler and Sauer 1990, Link and Sauer 1994). The weighting incorporates effects of missing counts (i.e., years when a route was not surveyed) and observer changes to reduce the bias associated with these factors. The route-regression method also estimates the standard error of a trend and a measure of the statistical significance of that trend.

RESULTS

Local Distribution

Cerulean Warblers were detected at 50 % of all unlimited radius point counts censused during 1995-1997 (Table 3-2). Ceruleans were one of the most common of the 71 different species recorded, and ranked sixth in frequency of occurrence. They ranked third in the total number of individuals recorded, and accounted for 7 % of all individual birds observed. The frequency of occurrence of Ceruleans differed significantly among sites ($F = 8.04$, $P < 0.01$). Because the same points were not censused during all 3 years, between-year differences were not compared.

Local Density

Territorial Cerulean Warblers were present on all of the spot mapping census plots each year; mean density on these censuses was 84.4 pairs/100 ha (SE = 10.4, range 15 - 183) (Table 3-3, Figure 3-2, Appendices I-V). The Upper Frozen Head plot had the greatest average density, 137.6 pairs/100 ha (SE = 16.2), and the UTCFS - Scott Co. plot had the least, 21.3 pairs/100 ha (SE = 3.1). The warbler's density showed a slight declining trend during the study period; this trend was most pronounced on the Upper Frozen Head plot (Figure 3-2a). This declining trend in density was also evident in the total population of all species present on the Upper Frozen Head plot (Figure 3-2b). The total number of species present on the plots did not show any overall trend (Figure 3-2c).

Table 3-2. Summary of results of unlimited-radius point count surveys in the Cumberland Mountains, Tennessee, study areas, 1995-1997.

	Points Surveyed			Percent with Cerulean Warblers			Total number of Cerulean Warblers observed			Total birds observed-all species*			Number of species observed*		
Study Area	1995	1996	1997	1995	1996	1997	1995	1996	1997	1995	1996	1997	1995	1996	1997
Frozen Head SP	104	108	86	34.6	62.0	63.5	51	110	112	733	1380	1069	40	34	43
Lone Mountain	20	25	25	5.0	12.0	5.0	1	2	1	59	240	266	20	19	24
Royal Blue WMA	156	101	100	44.2	87.1	63.0	107	116	96	825	1352	1003	36	37	45
UTCFS – Morgan	37	24	24	2.7	0.0	0.0	1	0	0	158	276	209	25	18	29
UTCFS – Scott	25	26	26	44.0	36.0	42.3	16	11	15	203	311	306	25	25	31
CI Cumberland For.	106	53	56	13..2	60.4	57.1	14	43	55	493	542	699	35	29	44
Total	448	337	317	42.4	59.1	50.7	190	282	279	2471	1640	3552	53	51	67

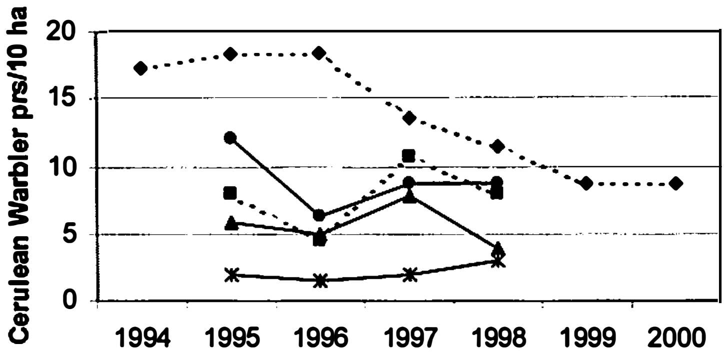
*Excludes migrant species not breeding in region.

Table 3-3. Densities of Cerulean Warblers on spot-mapping census plots in the Cumberland Mountains, Tennessee, study areas, 1994-2000.

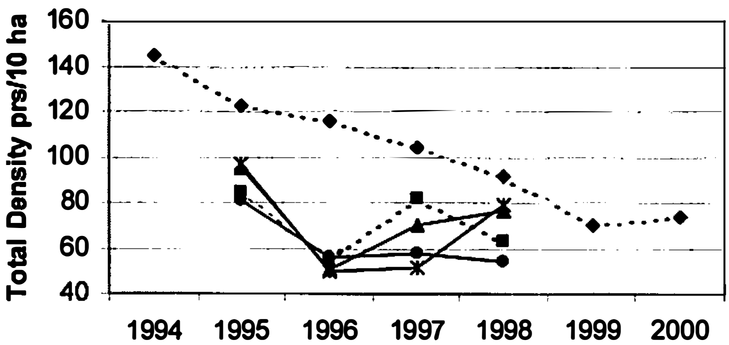
	Frozen Head SP		Royal Blue WMA		UTCFS Forest	All Plots
	Upper	Lower	Turley Mountain	Rock Springs	Scott Co.	
Years censused	1994–2000	1995–1998	1995–1998	1995–1998	1995–1998	
Density (pairs/100 ha)						
Mean	137.6	78.1	56.3	89.8	21.1	84.4
Range	87–183	45–107	39–78	65–125	15–30	15–183
SE	16.2	12.7	8.3	11.9	3.1	10.4
CV (%)	31.1	32.6	29.5	26.7	29.6	5.9

Figure 3-2. Summary of 1994-2000 spot mapping census results. (A) Density of the Cerulean Warbler. (B) Total density of all species. (C) Number of territorial species.

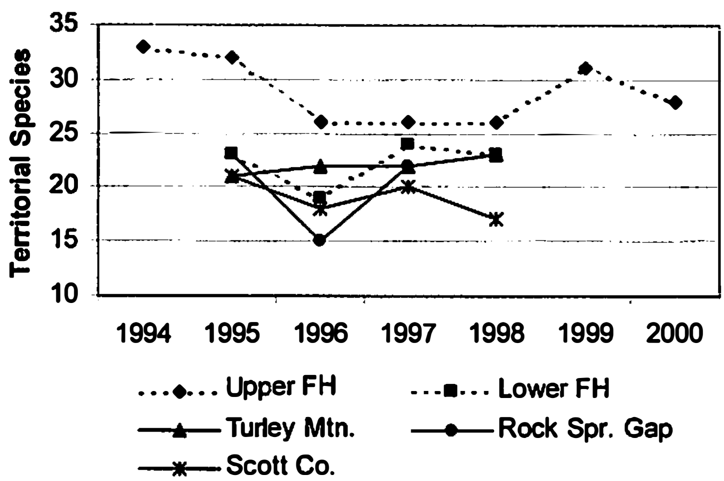
A.


Cerulean Warbler prs/10 ha
20
15
10
5
0
1994 1995 1996 1997 1998 1999 2000

B.


Total Density prs/10 ha
160
140
120
100
80
60
40
1994 1995 1996 1997 1998 1999 2000

C.


Territorial Species
35
30
25
20
15
10
1994 1995 1996 1997 1998 1999 2000
Upper FH
Lower FH
Turley Mtn.
Rock Spr. Gap
Scott Co.

Prior to 1994, Cerulean Warblers were reported on 6 different spot mapping census plots in the Cumberland Mountains of Tennessee (Table 3-4). All of these census plots were in Campbell County, and the plots censused by Garton (1974) and by Turner and Fowler (1981a, 1981b) were within the current Royal Blue WMA. The other plots were in areas of extensive forest interspersed with coal surface mines, similar to Royal Blue WMA. The mean density of Ceruleans on the 6 census plots was 50.2 pairs (SE = 13.2)/100 ha. Some of these census plots contained large areas of strip mines and spoil banks with little or no forest cover. The mean density of Ceruleans on the forested portions of the 6 census plots was 58.4 pairs (SE = 13.7)/100 ha.

Local Population Variability

Fourteen Breeding Bird Census plots in the north-central and northeast breeding range of the Cerulean Warbler met the criteria of having been censused at least 3 times from 1965-1995 and reporting Cerulean Warblers on at least 40% of the replications (Table 3-5, Figure 3-3). Densities on 8 of the 14 plots had a CV of at least 50%. The 5 plots censused in the Cumberland Mountains of Tennessee, in comparison, had CVs of 26.7–32.6% (Table 3-3), well within the range of variability of census results elsewhere. For the plots in Table 3-5, neither the mean density nor the number of years a plot was censused were correlated with the plot's CV ($r < 0.13$, $P(r \neq 0) > 0.68$). For the 5 Cumberland Mountains plots, the mean density was not correlated with the plot's CV ($r = 0.67$, $P(r \neq 0) = 0.21$); the correlation between the number of years a plot was censused and the plot's CV was weakly negative ($r = 0.84$, $P(r \neq 0) = 0.07$).

Regional Population Trends

Cerulean Warblers have been recorded on 23 of the 27 BBS routes censused in the Cumberland Plateau region since 1966 (Figure 3-1) (Sauer et al. 2003). This region (BBS Stratum 21, see Robbins et al. 1986) includes the Cumberland Mountains. The warbler's regional relative abundance of 3.17 birds/route is the greatest of any BBS stratum. The Cerulean Warbler population, as measured by the BBS, declined 3.9%/year from 1966-2002 in the Cumberland Plateau, 5.0%/year in Tennessee, and 4.4%/year rangewide

Table 3-4. Cerulean Warbler densities on spot mapping censuses conducted prior to 1994 in the Cumberland Mountains of Tennessee. Three of the plots contained strip-mined areas and associated spoil banks with little or no forest canopy, and densities are listed for both the whole plots and the forested portion of the plots.

	Area, ha			Density, pairs/100 ha		
Habitat	Whole plot	Forested area	Years	Whole plot	Forested area	Citation
Mixed deciduous forest - strip mine	25.9	22.6	1972–73	66–86	75–97	Yahner 1973
Mixed deciduous forest - strip mine	22.6	16.8	1973	66	89	Garton 1974
Maple-gum-hickory forest*	20	20	1976	110	110	Smith 1977
Deciduous forest - strip mine	23.4	12.9	1978–79	8.5–17	15.5–31	Nicholson 1979, 1980
Oak-maple forest	8.1	8.1	1980	37	37	Turner and Fowler 1981a
Oak-maple forest	8.1	8.1	1980	12.3	12.3	Turner and Fowler 1981b
Deciduous forest	10.1–11.2	10.1–11.2	1994–2000	15–183	15–183	This study

*Partially overlaps the plot censused by Yahner (1973).

Table 3-5. Densities of Cerulean Warbler on Breeding Bird Censuses conducted at least 3 times between 1965 and 1995 and reporting the species on at least 40% of the censuses. Code refers to Figure 3-3 and N is the number of years the census was conducted.

Code	Location	Census Name [Habitat]	Years	N	Density, pairs/100 ha Mean	CV (%)	Citation*
A	Licking Co., OH	Disturbed oak-hickory forest, pine stand, edge and pond	1965–94	24	21.8	55.0	Claugus 1965
B	Brooke Co., WV	Mature northern hardwoods	1971–76	4	57.0	-	Phillips et al. 1971
C	Howard Co., MD	Hickory-oak-ash floodplain forest	1971–77	6	18.1	73.2	Connor et al. 1971a
D	Howard Co., MD	Upland tulip-tree-maple-oak forest	1971–80	8	12.4	63.3	Connor et al. 1971b
E	Kanawha Co., WV	Oak-hickory forest	1972–76	5	46.2	63.9	Katholi 1972
F	Preble Co., OH	Virgin beech-maple forest	1973–81	7	78.6	54.6	Adams and Beissinger 1974
G	Butler Co., PA	Birch-maple-oak forest	1974–80	7	19.8	66.8	Bancroft 1974
H	Ulster Co., NY	Maple-oak forest	1977–79	3	3.3	17.3	Stapleton 1978
I	Hocking Co., OH	Neotoma Valley/Oak-hickory-hemlock-pine forest	1978–87	9	16.7	30.0	Claugus 1979
J	Washington Co., PA	Sugar maple-mixed hardwood forest	1982–86	5	39.0	23.3	Ickes 1983
K	Green Co., VA	Mesophytic forest II	1983–95	9	63.6	50.2	Fisher and Ziegenfus 1984
L	Green Co., VA	Mesophytic forest I	1988–95	8	47.2	30.3	Smith 1989
M	Trumbull Co., OH	Mixed hardwood swamp	1989–95	5	20.7	43.0	Hochadel 1990
N	Middlesex Co., CT	Upland oak and hemlock forest	1989–93	4	35.7	66.7	Zickefoose and Braunfield 1990
	Cumberland Mountains, TN	Deciduous forest	1994–2000	23	84.9	5.9	This study

*Citation for results of the first year presented here. The names of a few of these censuses changed during the years listed.

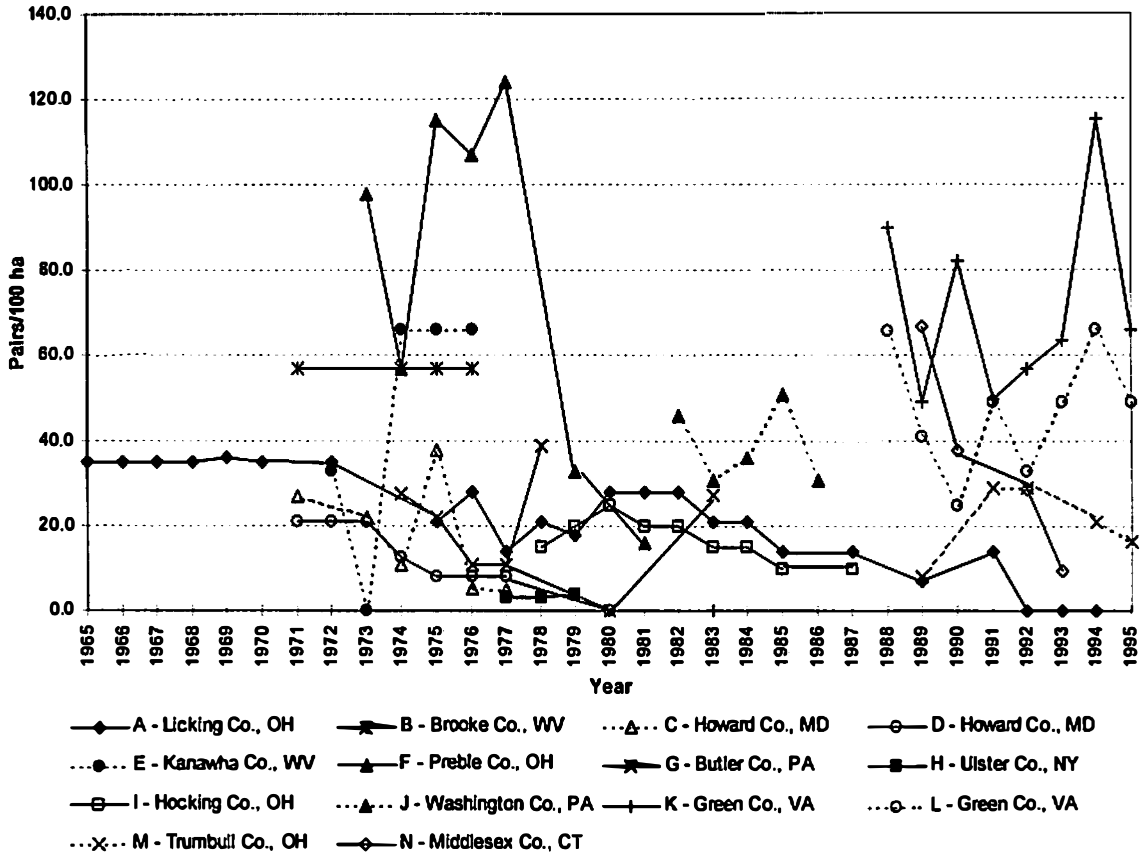


Figure 3-3. Cerulean Warbler densities reported on Breeding Bird Census plots in eastern North America censused at least 3 times between 1965 and 1995 and reporting the species on at least 40% of the censuses.

(Table 3-6). During the years 1966-1979, declining trends were greater than during the subsequent years 1980-2002. Because of small sample sizes (N<14), some of these short- term trends in the Cumberland Plateau and Tennessee should be interpreted with caution. Long-term trends for Tennessee and the rangewide population should also be interpreted with caution because of the low regional abundance (< 1.0 birds/route) of the species in these areas (Sauer et al. 2003).

Three BBS routes are located in the Cumberland Mountains of Tennessee. The recent trend on these routes shows an increase from 1990 to 1994, followed by a decrease (Figure 3-4). Over 90 % of the Cerulean Warblers found on these 3 routes occur on 1 route, a factor which contributes to the large variation in these results. Since 1990, 23 BBS routes, including the 3 study area routes, have been censused in Stratum 21; Cerulean Warblers have been found on 20 of these routes. These routes show a different trend with a slight increase from 1990 to 1996, followed by a decrease. These trends should be interpreted with caution because of the few routes in the Cumberland Mountains of Tennessee, and because for all of Stratum 21, only 5 routes, including the 3 Cumberland Mountain routes, were censused every year from 1990-2001. The average number of routes censused in any single year was 13.

DISCUSSION

The mean density of 84.4 pairs (SE = 10.4, SD = 49.9)/100 ha on the 1994-2000 Cumberland Mountains census plots (Table 3-3) is about twice the mean density of 43 pairs (± 42 pairs SD)/100 ha that Hamel (2000b) found on 332 published Breeding Bird Censuses reporting Ceruleans conducted between 1932 and 1993. The censuses compiled by Hamel included 133 different plots in 15 states and provinces in the Northeast, Midwest, and Appalachians, and individual plots were censused from 1–49 years. The mean density compiled by Hamel is also somewhat lower than the 50.2 pairs (SE = 13.2, SD = 37.3)/100 ha found on the pre-1994 Cumberland Mountains census plots (Table 3-4). The 1994-2000 densities on the Upper Frozen Head plot, the 1997 density on the Lower Frozen Head plot, and the 1995 density on the Rock Springs Gap plot are within the maximum, rangewide densities reported by Robbins et al. (1992) of

Table 3-6. Population trends of the Cerulean Warbler in the Statum 21 - Cumberland Plateau, Tennessee, and eastern North America, as determined from Breeding Bird Survey results. Adapted from Sauer et al. (2003).

Region, Years	N*	Regional Abundance, birds/route	Annual trend, %	Variance of trend	P**
Cumberland Plateau					
1966–2002	23	3.71	-3.9	0.834	<0.01
1966–1979	9	2.84	-2.9	2.322	0.12
1980–2002	18	2.72	-2.9	4.076	0.18
Tennessee					
1966–2002	15	0.83	-5.0	2.817	0.01
1966–1979	10	1.12	-5.2	2.638	0.02
1980–2002	11	0.74	-1.5	6.045	0.56
Rangewide					
1966–2002	262	0.41	-4.4	0.437	<0.01
1966–1979	108	0.27	-5.2	0.918	<0.01
1980–2002	218	0.41	-3.0	0.453	<0.01

*N = number of routes in region recording species during time period. This number does not include non-random routes and a few other routes eliminated from trend analyses.

**P value for test of hypothesis that trend is not different from zero.

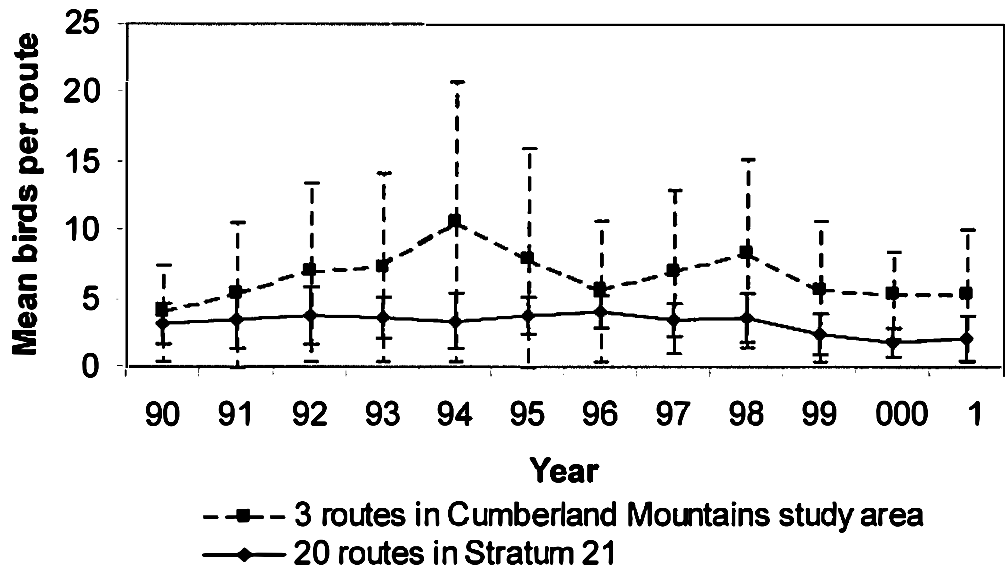


Figure 3-4. Annual means and standard errors of the number of Cerulean Warblers found on Breeding Bird Survey routes within Stratum 21, the Cumberland Plateau, from 1990-2001. Only the 20 routes which recorded Cerulean Warblers at least once during the survey period are included.

82–292 pairs/100 ha. Eight of these 11 high density plots listed by Robbins et al. were in West Virginia and one each was in Indiana, Michigan, and Ohio.

Rangewide Breeding Bird Survey results showed a significant decline in the population of the Cerulean Warbler since 1966. Hamel (2000b) projected that the rangewide population in 1998 was 31–49% of the 1966 population; the lower estimate was based on a uniform 1966–1998 trend, and the higher estimate was based on separate 1966–1979 and 1980–1998 trends. BBS trends also showed a significant decline in the Cumberland Plateau, an area where the bird reaches its greatest relative abundance. The 1998 population in this area was 30–70% of the 1966 population (Hamel 2000b).

Based on both 1994–2000 census results and BBS results, the Cerulean Warbler population in the Cumberland Mountains of Tennessee appears to have declined since 1994. The 1994 population, however, may have been unusually high. During May and early June, 1994, there was a heavy, localized outbreak of the fall cankerworm (Geometridae: *Alsophila pometaria*). This outbreak was evident in Frozen Head SP, and along a portion of a BBS route in Campbell County, Tennessee, just south of Royal Blue WMA (Nicholson pers. obs.). Cerulean Warblers, as well as other birds, fed heavily on cankerworm caterpillars, and may have occurred in unusually high densities in outbreak areas because of this abundant food source.

As a result of the abundant food source, reproductive success in 1994 may have been high, resulting in higher recruitment of yearling birds into the 1995 breeding population. Functional and numeric responses to caterpillar outbreaks have been demonstrated in other species of *Dendroica* warblers, as well as the American Redstart (*Setophaga ruticilla*) (Holmes et al. 1986). Rodenhouse and Holmes (1992) and Sherry and Holmes (1992) observed greater breeding success and recruitment of young into the following year's breeding population in the American Redstart and Black-throated Blue Warblers (*Dendroica caerulescens*) during years of abundant food supply than in years of food limitation. Whether the 1994 fall cankerworm outbreak resulted in any change in the 1995 Cerulean Warbler population is unknown, and no information on nesting success and productivity is available for this time period. The outbreak was not evident at Frozen Head SP or in the Royal Blue area in 1995; no other information is available on

the extent or duration of this outbreak. Fall cankerworm outbreaks often last 2 or 3 years, and may cover large areas (Johnson and Lyon 1991). Little information is available on the recurrence interval of fall cankerworm outbreaks.

Reproductive success and consequently, local population trends in the Cerulean Warbler, were likely also affected by weather during the nesting season. During the years 1996–1998, several nest failures occurred coincidental with rainstorms (Chapter 5). Some of these failures occurred when nests were dislodged from their supporting branches. Other losses were likely due to nestling starvation. From 16 May–15 June, the peak of the nesting season, both the number of days with rain and the total rainfall in all 3 years at Petros, just east of Frozen Head SP, were significantly greater (rain days: $T = 2.2$, $P = 0.02$; total rainfall: $T = 2.06$, $P = 0.03$) than the 1987–2000 average (Tennessee Valley Authority unpubl. data). The greatest weather effect on reproductive success probably occurred in 1997, when nest success was lowest. From 16 May–15 June 1997, there were 15 days with recordable precipitation; the 1987-2000 mean was 8.4 days. The nearest available temperature record is from Oak Ridge, about 23 km SSE of Frozen Head SP, where from 16 May–15 June 1997, there were 18 days with below normal temperatures and a total temperature deficit of 66 degree-days (F) below normal (NCDC 2000). The regional condition of vegetation, as measured by the Normalized Difference Vegetation Index (Wade et al. 1994; USDA-NASS 2000) was poor during this period in 1997, and in early June a fungal infection was evident on understory sugar maple (*Acer saccharum*) leaves at Frozen Head SP (Nicholson pers. obs.). These factors probably reduced insect availability, reduced the prey capture rate of warblers, and increased the need for nestlings to be brooded. Similar weather effects on nesting Black-throated Blue Warblers have been observed in long-term studies in New Hampshire (Holmes et al. 1986, Sillett et al. 2000). During cool, wet summers, caterpillar biomass was lower, as was warbler fecundity. These effects were positively correlated with the El Niño phase of the El Niño Southern Oscillation, as measured by the Southern Oscillation Index (Sillett et al. 2000). The simultaneous weather effects at Frozen Head SP are likely also due to this widespread weather phenomenon. They may have also affected other small insectivorous species such as the Red-eyed Vireo (*Vireo olivaceous*), American Redstart,

and Ovenbird (*Seiurus aurocapillus*), all of which are relatively common in the area, showed similar trends on both the census plots and local Breeding Bird Surveys.

Robbins et al. (1992) proposed 6 factors which may be affecting Cerulean Warbler populations during the breeding season. Four of these factors were related to the reduction in quality and loss of habitat. These 4 habitat factors are loss of forest, especially in floodplains, forest fragmentation, loss of older forest through shift to shorter rotation age, and loss of individual tree species such as elms and American chestnut. While these factors may have affected long-term population trends in the Cumberland Mountains, they have probably had little effect on recent trends. Other than treefalls, there was little evident change in habitat on the Cumberland Mountain study areas from 1994 to 2000. Between 1989 and 1999, the total area of forest land in Campbell, Morgan, and Scott Counties decreased by about 1% while the hardwood forest area classified as large diameter size class (> 11 in. dbh) increased by 7% (Schweitzer 2000, USFS 2002). Thus, at this relatively course scale of measurement, overall habitat conditions probably improved during the 1990s. The lack of apparent habitat change suggests local habitat for the Cerulean Warbler may not be saturated.

The 2 factors proposed by Robbins et al. (1992: 557) that were not habitat related were 1) "pollution and disease problems [which] certainly are not specific to Cerulean Warblers, but these problems seem to be especially severe in the major breeding areas of this warbler," and 2) nest parasitism by the Brown-headed Cowbird (*Molothrus ater*). To support the pollution and disease factor, Robbins et al. cited two articles from a 1983 report on the ecological effects of acid deposition. More recent studies, summarized in the 1996 NAPAP Biennial Report to Congress (NSTC 1998), do not show adverse impacts to forest ecosystems within the Cerulean Warbler's range from sulfur and nitrogen deposition. Hames et al. (2002), however, suggest a negative effect of acid rain on the probability of breeding by the Wood Thrush (*Hylocichla mustelina*).

Nest parasitism by the Brown-headed Cowbird was probably not an important factor in the Cumberland Mountains study area. Only one of the 52 Cerulean Warbler nests found in this study showed evidence of cowbird parasitism (Chapter 5). Less than 15 % of the nests of other potential host species were parasitized (Nicholson unpubl.

data). Cowbirds were uncommon in the study area, and were observed on about 9 % of the unlimited-radius point counts. The maximum cowbird density reported on the census plots was 31 pairs/100 ha and the average density across all the plots was about 7 pairs/100 ha.

The results of this study suggest that short-term trends in the Cerulean Warbler population in the Cumberland Mountains are driven by events during the breeding season, notably fluctuations in food supply and interrelated weather events. Structural changes in breeding habitat were probably not a major factor. Over the long term, events on the warbler's South American wintering range are probably affecting its local population trend. Although its wintering ecology is poorly known, available evidence suggests widespread loss of its montane subtropical forest habitat (Robbins et al. 1992, Hamel 2000a).

CHAPTER 4

HABITAT SELECTION BY THE CERULEAN WARBLER IN THE CUMBERLAND MOUNTAINS OF TENNESSEE

Breeding habitat of the Cerulean Warbler is usually described as extensive tracts of mature deciduous forests with broken canopies (e.g., Robbins et al. 1992, Hamel 2000a). In the late 19th century, Cerulean Warblers were especially abundant in old-growth bottomland forests in the Mississippi River floodplain (Widmann in Hamel 2000a), a habitat that has been mostly eliminated. In more recent decades, some of the greatest densities of the species have been reported in upland deciduous forests in the southern Appalachian Plateaus physiographic province of West Virginia, eastern Kentucky, and eastern Tennessee (Robbins et al. 1992), especially in the Cumberland Mountains (Chapter 3).

The rangewide population of the Cerulean Warbler, as measured by the Breeding Bird Survey, has shown a significant decline since the mid-1960s (Sauer et al. 2001, Link and Sauer 2002). Loss of breeding habitat is frequently mentioned as a primary cause of this decline (Robbins et al. 1992, Hamel 2000a), and is one reason for a recent effort to list the species under the Endangered Species Act (USFWS 2002). Although the Cumberland Plateau is about 73% forested (USFS 2002), the rate of decline of its Cerulean Warbler population is high relative to much of the rest of the warbler's range (Villard and Maurer 1996, Sauer et al. 2001).

The Cerulean Warbler is generally described as requiring large tracts of mature deciduous forest in either wet bottomlands or on mesic upland slopes (Hamel 2000a). Quantitative descriptions of this habitat are limited, especially at the scale of territories and nest sites, and none of the available information is from upland oak-hickory and mixed mesophytic forest types typical of the Cumberland Plateau and Cumberland Mountains (Braun 1950). The objectives of this study were to characterize Cerulean Warbler habitat in the Cumberland Mountains, to determine which habitat characteristics were most important in predicting the species' occurrence, and to develop predictive

models potentially useful in managing forests for the species. Cerulean Warbler habitat was studied at different scales including nest sites, territories as determined by spot-mapping, and a larger landscape scale where its presence was determined by extensive point counts.

METHODS

Field

Habitat characteristics were measured at 52 points centered on trees supporting Cerulean Warbler nests, on 5 spot-mapping census plots, and at 322 point-count locations. On spot-mapping census plots, which ranged from 10.1 to 11.2 ha in size, measurements were taken in 1995 at a sample of 100 randomly selected grid points and in 1995 and 1996 at a total of 66 points within Cerulean Warbler territories. Territory samples were centered on a tree from which the male frequently sang. Between 19 and 21 random points and 8 and 18 territory points were sampled on each plot; the number of territory points was greater on the plots with greater Cerulean Warbler densities. Forty-six nest site samples were in Frozen Head SP and 6 in Royal Blue WMA; 50 nest sites were sampled in 1996-1998, and 2 in 1999. Thirty-one of the Frozen Head nest site samples were on or adjacent to census plots. At point-count locations, samples were classified as having Cerulean Warblers present if the species was recorded within 50 m of the point during at least one of the years the point was censused. 139 samples met this criterion.

The sampling protocol was similar to that of James and Shugart (1970). At each point, trees were sampled with the variable plot sampling technique using a prism with a 2.5 m^2/ha basal area factor (Schreuder et al. 1993). All "in" overstory [$\geq$10 cm diameter at breast height (DBH, 1.37 m above ground)] trees were tallied by species and live or dead status, and measured for diameter and height. Tree density, expressed as the number of trees/ha, was calculated with the formula

$$\text{density} = \sum 1/(\pi(0.3162\text{DBH})^2/10000) \quad (1)$$

where DBH is the diameter in m of each tree in the variable plot sample. Saplings (stems $\geq$1.0 cm and <10 cm diameter and $\geq$1.4 m in height) were tallied by species in a 3-m

diameter circular plot. Percent cover and height of saplings were visually estimated in the same 3-m diameter circular plots.

Habitat variables measured at each sample point, as well as variables derived from the field measurements, are listed in Table 4-1. Additional derived variables, not listed in Table 4-1, were the live density and basal area of 17 tree species and/or species groups present at sample points. All hickories (*Carya* spp.) were combined, as were all pines (*Pinus* spp.). For oaks, density and basal area were derived for both individual species and for the genus *Quercus*. At nest sites, the distance from edge, defined as the distance from the nest to the nearest canopy gap at least as large as the canopy diameter of a dominant tree, was measured in m and assigned to one of 6 distance classes.

Analytical

Univariate Analysis.—Comparisons were made between both nest sites and random points and between nest sites and territory points on the two Frozen Head census plots, between territory points and random points on the five census plots, and between point count locations classified by the presence or absence of the Cerulean Warbler. Because many of the data were nonnormal, nonparametric Wilcoxon rank sum tests were used to test for differences among distribution medians. For the analysis of aspect and distance from edge, the equality of proportions was analyzed with the chi-square goodness-of-fit test.

Multivariate Analysis and Model Development.—Logistic regression (PROC LOGISTIC; SAS Institute 1990) was used to determine which habitat variables were most influential in predicting the occurrence of the Cerulean Warbler, and to develop habitat models. Models were developed to predict suitable nest sites, to predict the occurrence of territorial Cerulean Warblers on spot map census plots, and to predict Cerulean Warbler presence at more extensive point count locations.

Models of nest habitat were developed using nest site samples on and immediately adjacent to the two spot-mapping census plots at Frozen Head, where both a sufficient nest site sample size (31) and nearby randomly located samples were available. The nest habitat models were then tested using 15 nest site samples located off the plots in Frozen Head and 6 nests at Royal Blue.

Table 4-1. Structural habitat variables measured at sample points or derived from field measurements. Underlined variables were used in logistic regression models.

Variable Name	Variable Description	Units
Aspect	Aspect measured at plot center with compass and grouped into eight, 45° classes	categorical
Canopy cover	Average of 4 measurements taken at plot center with sperical densiometer	%
Dead basal area	Basal area of standing dead trees, measured with prism	m^2/ha
Dead tree density	Density of standing dead trees	stems/ha
Distance from edge	Distance from sample point to the nearest canopy gap; measured for nest sites only	m
Live basal area	Basal area of live trees, measured with prism	m^2/ha
Live tree density	Density of live trees	stems/ha
Live tree diameter	Diameter at breast height of live trees	cm
Live tree height	Height of live trees measured by tape and clinometer	m
Sapling cover	Proportion of plot covered by saplings	%
Sapling density	Sapling density	stems/ha
Sapling height	Average height of saplings	m
Shrub cover	Proportion of plot covered by shrubs	%
Slope angle	Slope measured down-slope from plot center with clinometer	%
Total basal area	Basal area of live and dead trees measured with prism	m^2/ha
Total tree density	Density of live and standing dead trees	stems/ha
Total tree diameter	Diameter at breast height of live and standing dead trees	cm
Total tree height	Height of live and standing dead trees measured by tape and clinometer	m

Prior to the use of logistic regression, the explanatory variables were tested for collinearity. For pairs of structural habitat variables with Pearson correlation coefficients of $\geq$0.75, one variable in each pair was eliminated. The results for each data set (nest sites, census plots, and point counts) were very similar, and the same 11 continuous structural explanatory variables were used with each data set (Table 4-1). Aspect was used as an explanatory variable after being recoded into design (dummy) variables, as described by Hosmer and Lemeshow (1989), for each of the eight 45° classes.

Correlations between basal area and density for total trees and for live trees were strongly negative. Correlations between basal area and density for dead trees, and for individual species or genera of live trees tended to be positive, often strongly so. This was likely due to the absence of dead trees, and some individual live tree species and species groups on plots in each data set. Consequently, for individual tree species and species groups, only basal area was used in logistic regression models. Tree species and species groups were selected for use in the models if they occurred at >15% of the sample points. The selected species and species groups cumulatively accounted for 80% of the total basal area of each sample.

Stepwise variable selection was used to develop logistic regression models. The significance level for a variable to enter a model was 0.15 and the significance level for a variable to stay in the model was 0.10. The Hosmer–Lemeshow goodness-of-fit statistic was used to determine how well the data fit the model (Hosmer and Lemeshow 1989). Models were developed using 1) structural variables; 2) structural and individual tree species-specific variables; 3) structural and aspect variables; and 4) structural, individual tree species-specific, and aspect variables. The resulting models are of the form

$$\log_n (P/[1-P]) = \alpha + \beta' X; \qquad (2)$$

where P is the probability of the response being modeled, α is the intercept parameter, β' is the vector of slope parameters, and X is the vector of explanatory variables.

RESULTS

Nest Site Selection

Most continuous structural habitat characteristics of nest sites showed a wide range of values (Table 4-2). Nest sites were not evenly distributed by aspect class (Table 4-3, $X^2 = 27.154$, $P = 0.001$) and were concentrated on NW, N, and NE aspects. Over half of the nests were between 11 and 50 m from an edge (Figure 4-1), although the proportions of nests in the different distance classes did not differ significantly ($X^2 = 9.35$, $P = 0.095$). Of the 15 nests within 10 m of a gap, all but 4 were in trees adjoining the gap.

Univariate Analysis.— Canopy cover, live basal area, sapling density, shrub cover, and total basal area differed significantly (Wilcoxon text, $P < 0.05$) between nest site points and randomly located points on the two Frozen Head census plots (Table 4-4). The differences in dead basal area and dead tree density approached significance ($0.05 < P < 0.10$). Compared to random points, nest sites had lower canopy cover and greater dead basal area, dead tree density, live basal area, sapling density, shrub cover, and total basal area.

Multivariate Analysis.—Only a single logistic regression model was produced for classifying nest and random sites on the two Frozen Head plots; it contained two structural variables, total basal area and canopy cover (Table 4-5). This model correctly classified 77% of the observations; its fit to the data, however, was relatively poor (Hosmer–Lemeshow goodness-of-fit test, $P = 0.0718$). Its general applicability was tested by using it to classify 21 nest sites, 15 at Frozen Head but off the census plots, and 6 at Royal Blue WMA. Nine nests, all at Frozen Head, were correctly classified. This result indicates the model is of little value outside of the Frozen Head study area.

Territory Selection

Univariate Analysis.—Significant differences (Wilcoxon test, $P < 0.05$), and differences approaching significance between territory and random points existed for variables on all 5 plots (Table 4-6). No single habitat variable consistently differed on all 5 plots. Canopy cover, live tree diameter, total tree diameter, red maple basal area, *Carya* basal area and *Carya* density all differed on 3 of the 5 plots. The differences in these

Table 4-2. Structural habitat characteristics of 52 Cerulean Warbler nest sites in the Cumberland Mountains of Tennessee.

Parameter	Mean	SE	Range	95% Confidence Interval
Canopy cover	76.22	1.75	42.3 - 95.1	72.8 - 79.7
Dead basal area	2.36	0.40	0 - 10.0	1.6 - 3.16
Dead tree density	74.98	18.02	0 - 577.3	39.7 - 110.3
Live basal area	32.36	0.95	17.5 - 47.5	30.5 - 34.2
Live tree density	463.06	32.56	133.6 - 966.6	399.2 - 526.9
Live tree diameter	43.12	1.07	28.8 - 65.8	41.0 - 45.2
Live tree height	24.64	0.58	14.2 - 33.6	23.5 - 25.8
Sapling cover	25.56	3.01	0 - 90	19.7 - 31.5
Sapling density	3577.6	440.1	0 - 15208.2	2714.9 - 4440.3
Sapling height	3.29	0.27	0 - 11.0	2.7 - 3.8
Shrub cover	14.17	1.93	0 - 80	10.4 - 17.9
Slope angle	23.02	1.15	3 - 43	19.9 - 26.1
Total basal area	34.71	1.02	17.5 - 52.5	32.72 - 36.71
Total tree density	538.00	38.55	145.0 - 1149.6	499.4 - 576.6
Total tree diameter	42.08	1.08	26.8 - 64.8	40.0 - 44.2
Total tree height	23.93	0.56	14.2 - 33.6	23.0 - 24.8

Table 4-3. Distribution by aspect class of 52 Cerulean Warbler nest sites in the Cumberland Mountains of Tennessee.

N	NE	E	SE	S	SW	W	NW
14	7	2	5	3	0	4	17

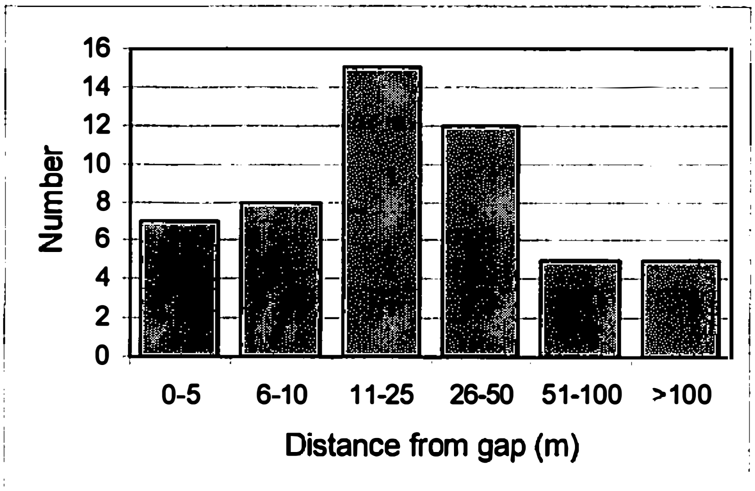


Figure 4-1. Frequency distribution of the distance from the nearest canopy gap for Cerulean Warbler nests in the Cumberland Mountains of Tennessee.

Table 4-4. Comparison of structural habitat parameters on census plots in Frozen Head State Park and Natural Area, Tennessee. Shown are means, standard errors, and P-values for Wilcoxon tests for equality of parameters on nest sites vs. random points and nest sites vs. territory points.

Parameter	Nest (N=31)	Random (N=39)	Territory (N=32)
Canopy cover	74.48 ± 2.48	87.81 ± 1.85 (0.0001)	83.30 ± 1.29 (0.0070)
Dead basal area	2.74 ± 0.55	1.41 ± 0.29 (0.0571)	1.64 ± 0.34 (0.1652)
Dead tree density	88.09 ± 23.74	44.04 ± 14.74 (0.0505)	60.77 ± 15.80 (0.3669)
Live basal area	34.03 ± 1.21	27.44 ± 1.21 (0.0007)	27.58 ± 1.46 (0.0008)
Live tree density	437.97 ± 40.23	424.89 ± 38.56 (0.7495)	375.77 ± 60.48 (0.0820)
Live tree diameter	45.07 ± 1.47	41.80 ± 1.45 (0.2101)	45.04 ± 1.59 (0.9561)
Live tree height	26.01 ± 0.71	26.53 ± 0.80 (0.4214)	26.50 ± 0.84 (0.4173)
Sapling cover	29.29 ± 4.19	30.56 ± 4.28 (0.7306)	32.13 ± 4.13 (0.6241)
Sapling density	3491.14 ± 424.46	2167.41 ± 306.14 (0.005)	2444.15 ± 265.64 (0.0754)
Sapling height	3.27 ± 0.36	2.54 ± 0.10 (0.1027)	2.87 ± 0.19 (0.6924)
Shrub cover	14.87 ± 1.96	23.10 ± 2.49 (0.0297)	39.22 ± 4.27 (<0.0001)
Slope angle	20.64 ± 1.40	18.97 ± 1.32 (0.3376)	19.75 ± 1.52 (0.5866)
Total basal area	36.77 ± 1.29	29.87 ± 1.17 (0.0002)	29.84 ± 1.70 (0.0008)
Total tree density	526.00 ± 51.84	471.54 ± 45.60 (0.3689)	439.44 ± 61.94 (0.1170)
Total tree diameter	43.85 ± 1.52	41.10 ± 1.43 (0.3503)	44.00 ± 1.54 (0.8690)
Total tree height	25.15 ± 0.71	25.86 ± 0.78 (0.3848)	25.73 ± 0.82 (0.4055)

Table 4-5. Logistic regression parameter estimates for distinguishing between Cerulean Warbler nest points and random points, territory points and random points, and nest points and territory points on census plots, and for predicting Cerulean Warbler presence at point count locations in the Cumberland Mountains of Tennessee.

	Nest-Random (N=70)	Territory-Random (N=71)			Nest-Territory (N=63)		Point Count Presence/Absence (N=322)	
Variable	Model 1 Structural	Model 1 Structural	Model 2 Structural and floristic	Model 3 Structural and aspect	Model 1 Structural	Model 2 Structural and floristic	Model 1 Structural and aspect	Model 2 Structural, floristic and aspect
Intercept	-3.0477 (2.9393)	4.8369 (2.1357)	4.0030 (2.1114)	4.4603 (2.1736)	2.8859 (2.8095)	4.0651 (3.3396)	-2.5297 (0.6236)	-3.7441 (1.1658)
Canopy cover	0.1029 (0.0321)	-0.0986 (0.0240	-0.1001 (0.0246)	-0.0959 (0.0243)	-0.0742 (0.0311)	-0.0980 (0.0380)	-	-
Total tree diameter	-	0. 0863 (0.0248)	0.0925 (0.0262)	0.0958 (0.0258)	-	-	0.0400 (0.0142)	0.0706 (0.0220)
Total basal area	-0.1577 (0.0518)	-	-	-	0.0901 (0.0374)	0.1390 (0.0477)	-	0.0011 (0.0006)
Dead basal area	-	-0.4776 (0.1905	-	-0.5271 (0.1957)	-	-	0.1097 (0.0532	-
Dead tree density	-	0.0083 (0.0041)	-	0.0089 (0.0041)	-	-	-	-
Aspect - NW	-	-	-	-	-	-	0.8380 (0.3651)	0.7614 (0.3718)
Sapling cover	-	-	-	-	-	-	0.0151 (0.0050)	0.0168 (0.0054)
Aspect – S	-	-	-	-0.7224 (0.4373)	-	-	-	-
Black cherry density	-	-	-	-	-	-0.0177 (0.0068)	-	-
Black locust basal area	-	-	-	-	-	-0.3904 (0.2162	-	-
Carya basal area	-	-	0.3009 (0.0786)	-	-	-	-	-
Chestnut oak basal area	-	-	-	-	-	-	-	-0.0879 (0.0193)

Table 4-6. Means and standard errors (in parentheses) of structural and tree species-specific habitat variables showing significant differences (P < 0.05) and differences approaching significance (0.10 < P < 0.05) between Cerulean Warbler territory points and random points on census plots in the Cumberland Mountains of Tennessee.

Plot (N_T/N_R)*	Variable	Territory	Random	Z	P-Value
Scott Co. (8/20)	Dead basal area	0	1.25 (0.46)	-1.8474	0.0647
	Dead tree density	0	38.05 (17.51)	-1.8386	0.0660
	Live tree diameter	43.18 (2.15)	38.05 (1.19)	1.9076	0.0564
	Total tree diameter	41.79 (2.13)	37.90 (1.25)	1.9584	0.0502
	Red maple density	0	32.90 (15.13)	-2.0087	0.0446
	Red maple basal area	0	3.25 (1.35)	-2.0108	0.0443
Lower Frozen Head (14/19)	Live tree diameter	43.11 (2.37)	36.32 (1.81)	2.2762	0.0228
	Total tree diameter	41.79 (2.13)	35.78 (1.71)	2.1309	0.0331
	Black cherry density	13.56 (5.20)	4.08 (1.93)	1.7365	0.0825
	Black cherry basal area	2.32 (0.76)	0.66 (0.32)	1.8975	0.0578
	Black locust density	3.06 (3.06)	10.33 (4.15)	2.0306	0.0423
	Black locust basal area	0.13 (0.13)	1.25 (0.51)	2.2246	0.0261
	Chestnut oak density	68.79 (22.74)	173.44 (30.67)	-2.4994	0.0124
	Carya density	16.25 (7.86)	0	2.7436	0.0061
	Carya basal area	1.61 (0.67)	0	2.7448	0.0061
	Quercus density	89.16 (25.08)	211.77 (28.68)	-2.8597	0.0042
	Red maple basal area	1.57 (0.57)	3.37 (0.75)	-1.8197	0.0688
	Sugar maple density	26.91 (19.41)	2.59 (2.59)	1.7804	0.0750
	Sugar maple basal area	1.25 (0.63)	0.26 (0.26)	1.7520	0.0798

Table 4-6. (continued).

Plot (N_T/N_R)*	Variable	Territory	Random	Z	P-Value
Upper Frozen Head(18/20)	Canopy cover	80.77 (1.45)	89.70 (1.12)	-4.1679	0.0001
	Sapling height	2.95 (0.18)	2.36 (0.10)	2.4000	0.0164
	Carya density	21.60 (9.12)	4.68 (3.24)	2.0196	0.0434
	Carya basal area	1.39 (0.41)	0.38 (0.27)	1.9875	0.0469
	Sugar maple density	23.37 (8.04)	73.01 (5.45)	-2.6403	0.0083
	Sugar maple basal area	1.94 (0.72)	3.88 (0.84)	-2.0747	0.0380
	White oak density	2.61 (1.73)	0	1.8441	0.0652
	White oak basal area	0.42 (0.23)	0	1.8549	0.0649
Lower Royal Blue (13/21)	Canopy cover	73.91 (5.16)	85.71 (1.78)	-2.3407	0.0192
	Live tree diameter	38.50 (1.42)	33.52 (1.21)	2.3393	0.0193
	Total tree diameter	37.36 (1.65)	33.56 (1.25)	1.7192	0.0856
	Carya density	35.74 (9.31)	11.38 (5.73)	2.5615	0.0104
	Carya basal area	3.65 (0.92)	0.83 (0.36)	2.8141	0.0049
	Red maple density	12.42 (11.34)	128.36 (38.11)	-2.6908	0.0071
	Red maple basal area	0.54 (0.40)	2.43 (0.60)	-2.5005	0.0124
	White ash density	19.04 (10.73)	9.69 (5.49)	2.0705	0.0384
	White ash basal area	1.35 (0.67)	0.71 (0.35)	2.0211	0.0433
Upper Royal Blue (13/20)	Canopy cover	64.27 (8.38)	89.68 (1.07)	-2.8340	0.0045
	Sapling density	2312.51 (507.52)	1096.40 (249.96)	1.9998	0.0455
	Shrub cover	17.00 (4.93)	6.00 (1.57)	1.8416	0.0655

* N_T = number of territory points sampled on each plot; N_R = number of random points sampled on each plot.

variables were consistent across the plots, with canopy cover and red maple basal area both greater at random points, and live tree diameter, total tree diameter, *Carya* basal area and *Carya* density all greater at territory points.

When the samples from the 5 plots were combined, there were differences ($P < 0.05$) in total tree density, total tree diameter, live tree density, live tree diameter, canopy cover, and shrub cover (Table 4-7). Territory points had lower total and live tree density, greater tree diameter, more shrub cover, and a more open canopy than did randomly located points. Although the points were not equally distributed among the 8 aspect classes ($X^2 = 37.181$, $P = 0.001$), the proportion of territory and random points in each aspect class did not differ ($X^2 = 8.378$, $P = 0.300$) (Table 4-8).

With all 5 plots combined, hickories (*Carya*) and red maples differed ($P < 0.05$) in their density and basal area between territory and random points (Table 4-9). The differences in the density and basal area of black locust and chestnut oak approached significance ($0.05 < P < 0.10$). Compared to random points, territory points had less chestnut oak and red maple, and more hickory and black locust. Dominant tree species/species groups on the plots were oaks, yellow- , chestnut oak, sugar maple, red maple, and northern red oak.

Multivariate Analysis.—Three logistic regression models were developed to classify territory and random points on the 5 combined census plots (Table 4-5). Model 1, using only structural variables, correctly classified 71% of the observations, and explained 30% of the variation. Model 2, based on both structural and tree species variables, correctly classified 72% of the observations and explained 36% of the variation (max rescaled R^2 value). Model 3, based on structural and aspect variables, correctly classified 73% of the observations and explained 32% of the variation. Based on results of Hosmer–Lemeshow goodness-of-fit tests, all three models adequately fit the data (i.e., Model 1: $P = 0.6670$; Model 2: $P = 0.9507$; Model 3: $P = 0.4905$).

Table 4-7. Means, standard errors, and Wilcoxon test results for equality of structural habitat parameters measured at Cerulean Warbler territory points and randomly selected points on census plots in the Cumberland Mountains of Tennessee.

	Territory (N=66)		Random (N=100)			
Parameter	Mean	S.E..	Mean	S.E.	Z	P-Value
Canopy cover	76.08	2.79	88.30	0.86	-5.0318	0.0001
Dead basal area	1.02	0.20	1.48	0.23	-1.1321	0.2576
Dead tree density	40.33	9.79	45.54	10.49	-0.5757	0.5648
Live basal area	24.20	1.03	24.93	0.79	-0.8499	0.3954
Live tree density	358.33	33.88	440.71	24.57	-2.5737	0.0101
Live tree diameter	42.05	0.98	38.20	0.77	3.0340	0.0028
Live tree height	24.44	0.64	24.19	0.53	0.2062	0.8366
Sapling cover	29.67	2.76	24.13	2.24	1.6942	0.0902
Sapling density	2352.49	194.32	2189.26	208.71	1.4413	0.1495
Sapling height	2.89	0.15	2.73	0.12	0.5804	0.5616
Shrub cover	28.70	2.82	19.57	1.74	2.5234	0.0116
Slope angle	21.65	1.18	21.69	1.20	0.1850	0.8533
Total basal area	25.49	1.15	26.73	0.83	-1.1268	0.2598
Total tree density	400.08	35.26	484.19	29.12	-2.1002	0.0357
Total tree diameter	41.26	0.98	37.73	0.76	2.7502	0.0060
Total tree height	23.96	0.63	23.55	0.54	0.3696	0.7117

Table 4-8. Distribution by aspect class of sample points on census plots in the Cumberland Mountains of Tennessee.

	N	NE	E	SE	S	SW	W	NW
Territory (N=66)	13	4	6	3	14	10	9	6
Random (N=100)	13	11	6	12	30	10	12	7
Total	26	15	12	15	44	20	21	13

Table 4-9. Means, standard errors, and Wilcoxon test results for equality of tree species-specific habitat parameters measured at Cerulean Warbler territory points and randomly selected points on census plots in the Cumberland Mountains of Tennessee.

	Territory (N=66)		Random (N=100)			
Variable*	Mean	SE	Mean	SE	Z	P-Value
Am. basswood density	13.66	5.84	11.50	4.89	0.6938	0.4878
Am. basswood basal area	0.95	0.33	0.68	0.21	0.7310	0.4648
Black cherry density	28.25	8.81	20.10	4.28	1.1481	0.2509
Black cherry basal area	3.18	0.79	2.00	0.39	1.3738	0.1695
Black gum density	18.85	7.93	24.01	7.15	-0.6749	0.4998
Black gum basal area	0.68	0.19	0.83	0.17	-0.6274	0.5304
Black locust density	11.46	3.58	11.46	4.82	1.9091	0.0562
Black locust basal area	0.72	0.18	0.65	0.27	1.8776	0.0604
Chestnut oak density	22.28	6.33	61.30	13.07	-1.8234	0.0682
Chestnut oak basal area	2.69	0.68	4.40	0.69	-1.1670	0.0955
Carya density	28.29	5.21	15.44	4.23	3.5714	0.0004
Carya basal area	2.27	0.35	0.88	0.21	3.3972	0.0001
N. red oak density	18.21	3.20	25.93	4.03	-0.6649	0.5061
N. red oak basal area	2.50	0.37	2.88	0.35	-0.4290	0.6679
Quercus density	49.61	8.19	89.92	14.71	-1.5082	0.1315
Quercus basal area	6.06	0.84	7.83	19.55	-1.460	0.1482
Red maple density	49.43	16.29	102.61	19.55	-2.6318	0.0085
Red maple basal area	1.47	0.47	2.85	0.50	-2.6741	0.0075
Sugar maple density	62.40	15.43	60.95	11.44	-0.5107	0.6096
Sugar maple basal area	2.58	0.50	3.00	0.45	-0.6411	0.5215
Yellow-poplar density	34.22	6.46	52.01	7.87	-0.1000	0.9203
Yellow-poplar basal area	4.81	0.75	4.60	0.67	-0.6597	0.5094

Table 4-9. (continued).

Variable*	Territory (N=66) Mean	SE	Random (N=100) Mean	SE	Z	P-Value
White ash density	6.91	2.53	3.56	1.23	1.0707	0.2843
White ash basal area	0.64	0.20	0.50	0.15	0.9086	0.3636
White oak density	6.56	2.59	6.64	2.79	0.6420	0.5209
White oak basal area	0.61	0.19	0.65	0.20	0.5399	0.5893

*Underlining indicates variable used in logistic regression modeling.

Comparison of Nest Site and Territory Selection

Univariate Analysis.—Four structural variables, canopy cover, total basal area, live basal area, and sapling density, differed significantly (Wilcoxon test, $P < 0.05$) in a comparison of nest site points and territory points on the two Frozen Head census plots (Table 4-4). Compared to territory points, nest site points had less canopy cover, greater total basal area, and greater shrub cover. The differences in live tree density and sapling density approached significance ($0.05 < P < 0.10$); live tree density was greater at nest site points and sapling cover was greater at territory points.

Multivariate Analysis.—Two logistic regression models were developed to classify nest and territory points on census plots (Table 4-5). Model 1, using only structural variables, correctly classified 68% of the observations and explained 32% of the variation (max rescaled R^2 value). Model 2, based on both structural and tree species variables, correctly classified 81% of the observations and explained 48% of the variation. Based on results of Hosmer–Lemeshow goodness-of-fit tests, both models adequately fit the data (i.e., Model 1: P = 0 1673; Model 2: P = 0.5608).

Point Count Locations

Univariate Analysis.—Two structural habitat variables, live tree diameter and sapling cover, differed ($P < 0.05$) between points where Ceruleans were present and points where Ceruleans were absent (Table 4-10). The differences in tree diameter, live tree density, sapling height, shrub cover, and canopy cover approached significance ($0.05 > P > 0.10$). Points where Ceruleans were present had larger tree diameter, lower live tree density, more sapling cover, taller saplings, less shrub cover, and slightly more canopy cover. Although the points were not equally distributed among the 8 aspect classes ($X^2 = 115.143$, $P = 0.034$), the proportion of points in each aspect class with Cerulean Warblers present did not differ from random ($X^2 = 10.949$, $P = 0.141$) (Table 4-11).

The density and the basal area of several tree species and species groups differed ($P < 0.05$) between points where Cerulean Warblers were present and

Table 4-10. Structural habitat characteristics at 322 point count locations in the Cumberland Mountains of Tennessee in relation to the presence/absence of Cerulean Warblers.

	Present (N = 139)		Absent (N = 183)			
Variable	Mean	SE	Mean	SE	Z	P-Value
Canopy cover	78.16	0.86	76.33	0.76	1.8866	0.0592
Dead basal area	1.71	0.20	1.33	0.15	1.3902	0.1645
Dead tree density	52.81	8.56	41.96	6.76	1.0555	0.2912
Live basal area	27.75	0.68	28.24	0.58	-0.6690	0.5035
Live tree density	480.33	25.82	520.60	20.93	-1.7252	0.0845
Live tree diameter	39.97	0.78	37.57	0.61	2.0692	0.0385
Live tree height	23.55	0.49	23.22	0.38	0.3481	0.7280
Sapling cover	33.71	2.03	26.47	1.70	2.9035	0.0037
Sapling density	2608.1	169.0	2692.2	151.3	-0.3642	0.7157
Sapling height	3.92	0.16	3.71	0.17	1.7100	0.0873
Shrub cover, %	17.88	1.31	20.52	1.20	-1.6145	0.1064
Slope angle	23.96	0.70	22.45	0.67	1.3191	0.1871
Total basal area	29.46	0.66	29.56	0.59	-0.1852	0.8531
Total tree density	533.14	27.27	562.50	22.90	-1.0001	0.3173
Total tree diameter	39.43	0.78	37.25	0.59	1.8962	0.0579
Total tree height	22.72	0.48	22.83	0.37	-0.4310	0.6664

Table 4-11. Distribution of 322 point counts in the Cumberland Mountains of Tennessee by aspect class in relation to presence/absence of Cerulean Warblers.

CERW Status	N	NE	E	SE	S	SW	W	NW
Present (N=139)	17	25	11	17	12	13	21	23
Absent (N=183)	34	26	18	19	15	30	26	15
Total	51	51	29	36	27	43	47	38

points where Ceruleans were absent (Table 4-12). For most tree species and species groups, density and basal area were strongly correlated. Points where Ceruleans were present had greater density and basal area of American basswood, black cherry, and sugar maple; greater basal area of *Carya* spp. and yellow-poplar; and lower density and basal area of chestnut oak, *Pinus* spp., *Quercus* spp., and red maple. These results suggest selection for more mesic, sheltered sites over xeric, exposed sites. Four of these trees with differences (chestnut oak, red maple, sugar maple, and yellow-poplar) were among the dominant trees at point count locations.

Multivariate Analysis.—The model based solely on structural variables and the model based on structural and tree species-specific variables both poorly fit the data (Hosmer–Lemeshow goodness-of-fit tests, $P = 0.0290$ and $P = 0.0269$) and were rejected. The remaining 2 models, listed in Table 4-5, adequately fit the data (Hosmer–Lemeshow goodness-of-fit tests, $P > 0.15$). Model 1, based on structural and aspect variables, explained 9% of the variation (max rescaled R^2 value), and Model 2, based on structural, aspect, and tree species-specific variables, explained 18% of the variation. These models correctly classified about 66% and 63%, respectively, of the observations. Both models included total tree diameter, sapling cover, and aspect-NW as predictors.

DISCUSSION

Limited quantitative information is available to describe Cerulean Warbler habitat features other than forest-tract size, which was not evaluated in this study. Forest-tract size, however, was likely not an important predictor of the warbler' occurrence, as all of the study sites had a contiguous forest-tract size of at least 700 ha, the minimum suggested by Robbins et al. (1992) in the eastern portion of its range. The study sites were located in heavily forested areas, with the proportion of forest cover within 10 km of the centers of the study sites ranging from 89% for the UTCFS-Morgan County site to 99% for the Cumberland Forest site.

Table 4-12. Means, standard errors, and Wilcoxon test results for equality of tree species-specific habitat parameters measured at point count locations in the Cumberland Mountains of Tennessee in relation to the presence/absence of Cerulean Warblers.

	Present N = 139		Absent N = 183			
Variable*	Mean	SE	Mean	SE	Z	P-Value
Am. basswood density	15.28	4.30	4.97	2.16	2.2501	0.0244
Am. basswood basal area	0.90	0.20	0.36	0.10	2.2475	0.0246
Black birch density	5.50	2.86	5.92	2.38	0.1271	0.8989
Black birch basal area	0.25	0.11	0.20	0.07	0.1763	0.8601
Black cherry density	17.94	4.81	4.97	2.88	3.3297	0.0009
Black cherry basal area	1.38	0.33	0.45	0.18	3.3201	0.0009
Black gum density	19.33	6.60	20.19	4.15	-1.3591	0.1741
Black gum basal area	0.72	0.16	0.81	0.13	-1.1714	0.2415
Black locust density	35.15	12.81	14.63	5.46	1.2318	0.2180
Black locust basal area	0.81	0.23	0.46	0.14	1.2870	0.1981
Black oak density	9.19	3.61	6.68	1.32	-0.6275	0.5303
Black oak basal area	0.63	0.16	0.61	0.11	-0.6107	0.5414
Chestnut oak density	42.30	8.24	85.39	9.03	-5.1822	0.0001
Chestnut oak basal area	3.31	0.48	7.31	0.61	-5.4030	0.0001
Carya density	26.11	3.71	24.39	3.96	1.6951	0.0901
Carya basal area	4.43	0.27	1.89	0.24	2.0358	0.0418
N. red oak density	21.61	3.24	20.81	2.47	1.0274	0.3043
N. red oak basal area	2.90	0.28	2.65	0.28	1.5970	0.1103
Pinus density	3.90	2.99	17.63	4.41	-3.7066	0.0002
Pinus basal area	0.11	0.08	0.87	0.20	-3.7438	0.0002
Quercus density	95.31	12.68	145.84	10.08	-4.6685	0.0001
Quercus basal area	8.74	0.62	12.70	0.65	-4.2232	0.0001
Red maple density	86.44	13.23	137.06	15.27	-3.6284	0.0003
Red maple basal area	2.37	0.32	3.77	0.33	-3.6836	0.0002
Sourwood density	20.23	7.16	21.94	5.45	-0.6093	0.5423
Sourwood basal area	0.40	0.11	0.42	0.09	-0.5309	0.5955

Table 4-12. (continued).

Variable*	Present N = 139		Absent N = 183			
	Mean	SE	Mean	SE	Z	P-Value
Sugar maple density	85.01	12.53	46.36	8.92	3.9572	0.0001
Sugar maple basal area	2.88	0.34	1.65	0.31	4.2153	0.0001
Yellow-poplar density	48.68	6.63	47.68	7.17	1.7388	0.0821
Yellow-poplar basal area	5.14	0.63	3.57	0.42	2.3892	0.0169
White oak density	19.30	4.43	26.76	5.17	-0.3784	0.7052
White oak basal area	1.65	0.26	1.73	0.26	-0.1138	0.9094

*Underlining indicates variable used in logistic regression modeling.

Other than forest-tract size, the most frequently mentioned habitat variable distinguishing occupied from unoccupied or randomly selected sites in previous studies were tree diameter and basal area; occupied sites consistently had larger diameter trees and greater basal area (Robbins et al. 1992, Jones and Robertson 2001). These two variables were also important in distinguishing nest sites from random sites in Ontario (Oliarnyk 1996, Jones and Robertson 2001).

The habitat variables that appeared most important in the various comparisons in this study differed according to the scale of the comparison. This is likely related to a hierarchy of habitat selection decisions by Cerulean Warblers. Males arrive on the breeding grounds before females and soon select territories (Chapter 5; Jones and Robertson 2001). Females later select nest sites within the territories, which likely contain several suitable nest sites.

Canopy cover was the only variable which was an important predictor in all of the comparisons based on the 10-ha census plots. It was consistently greater at random sites than at either territory sites or nest sites. In the comparison of point counts where Cerulean Warblers were present with points where Ceruleans were absent, the difference in canopy cover approached significance. At this scale, canopy cover was somewhat greater at point counts where Ceruleans were present, contrary to the situation on the census plots. Canopy cover, however, averaged lower at the point count locations than on the census plots, and was not an important predictor of occupied point count locations.

Important variables at the largest scale, the point counts, were tree diameter, several floristic variables, and, in the prediction equations, sapling cover and aspect-NW. Points where Cerulean Warblers were present tended to have larger trees, greater sapling cover, and occur on mesic rather than xeric sites. Although the prediction equations correctly classified about two-thirds of the points, the amount of variation they explained was low. This may be due, in part, to the placement of the vegetation sampling point at the center of the 50 m-radius point count circle, and thus not necessarily within the territory of any Cerulean Warblers recorded in the circle.

In the combined sample of five census plots, important variables were tree diameter, tree density, and shrub cover. Compared to random points, territory points had

fewer and larger trees, greater shrub cover, and greater basal area and/or density of a few tree species indicative of mesic sites. The difference in shrub cover may have been related to the difference in canopy cover and was probably not important to Cerulean Warblers which rarely use the shrub layer (Nicholson, pers. obs.). In a similar analysis, Jones and Robertson (2001) found several significant differences between points within and outside territories. Points within territories had greater basal area, greater basal area/tree density ratio, taller trees, and greater upper canopy foliage cover.

At the smallest scale, on the two Frozen Head census plots, basal area, as well as canopy cover and shrub cover, were important in distinguishing nest sites from both random points and territory points. Compared to nest site points, canopy cover was greater and basal area was lower at both random points and territory points. Nest site points also had greater sapling density than did random points. The only variable in the prediction equation for nest sites, in addition to canopy cover, was total basal area.

The prediction equations for nest site points on census plots, for territory points on census plots, and for occupied point count locations correctly classified between about 65 and 77% of the points. The rate of correct classifications increased somewhat as the scale decreased, and the highest rate of correct classifications was for nest site plots on the two Frozen Head plots. This prediction equation, however, had a low success rate in classifying nest site plots off the Frozen Head study area. This may be an artifact of the hierarchy of territory and nest site selection, and the prediction equations for territories and occupied point count locations are probably more applicable to the Cumberland Mountains as a whole.

Some of the randomly selected points used in this study were likely within Cerulean Warbler territories. If territories and known non-territory sites had been compared, the prediction equations would likely have been more robust. Another factor affecting the success of the prediction equations is the degree to which the study areas were saturated by warbler territories. Cerulean Warbler populations fluctuated on all of the census plots (Chapter 3) and territory locations varied from year to year (Nicholson unpubl. data). Portions of each census plot were consistently occupied each year, while other areas were only occupied during some years, which were not necessarily

consecutive. In an apparently unsaturated area of Ontario, Jones and Robertson (2001) found consistent differences between occupied and unoccupied areas in samples taken in different years.

CHAPTER 5

BREEDING BIOLOGY OF THE CERULEAN WARBLER IN EASTERN TENNESSEE

Until recently, available information on the breeding biology of the Cerulean Warbler was limited and mostly anecdotal. Because of its recent population decline (Robbins et al. 1992, Hamel 2000b), information on the warbler's breeding biology, as well as other aspects of its biology, is important in determining the factors limiting its population.

The most detailed study of the breeding biology of the Cerulean Warbler yet published is that of Oliarnyk, who studied the species near the northern limit of its breeding range in southeastern Ontario (Oliarnyk 1996, Oliarnyk and Robertson 1996). Hamel (unpubl. data) and associates have recently studied the breeding biology of the species near the southern limit of its breeding range in the Mississippi Alluvial Valley. This chapter describes the results of a study of the breeding biology of the species in the Cumberland Mountains of Tennessee. The Cumberland Mountains are part of the Appalachian Plateaus province, a core portion of the breeding range of the Cerulean Warbler and an area where it is relatively common (Robbins et al. 1992, Hamel 2000b). The study sites are described in Chapter 2.

METHODS

Most of the observations reported here were made in Frozen Head State Natural Area during 1996, 1997, and 1998. During each of these years, intensive nest searching was carried out from about 7 May to 16 May. Most nests were found by teams of 2 or 3 observers, who often first located a male Cerulean Warbler exhibiting courtship or territorial behavior. If a female warbler was observed near the male, then the female was watched for signs of nest-building. Other females were first located by their distinctive "zeet' call. Females gathering nest material were then followed, often to the nest. A few other nests were found by watching adults carry food to nestlings.

Nests were monitored at intervals of about 3 days, generally following the protocol of Martin et al. (1997). The monitoring interval varied somewhat because of inclement weather and other factors. To determine clutch size, a few nests were inspected by climbing the nest tree or a nearby tree, usually with the help of a portable deer hunting stand, and using a mirror on a pole to view the nest contents. Throughout the nesting cycle, timed observations of variable length were made during which activities at the nest were recorded. A 25x spotting scope was often used for these observations during the nestling period.

Nest success rates were quantified both as the crude percent of nests which successfully fledged young, and by the Mayfield method (Mayfield 1961, 1975). The standard error of daily success rates was calculated as described by Johnson (1979). Because transition dates between nest stages were often difficult to determine, the full length of the observation period, including the nest-building and egg-laying states, was used in nest success calculations, as was a constant survival rate. The full nest cycle was assumed to last 31 days. This included 4 days for nest construction, 4 days for egg-laying, 12 days for incubation, and 11 days the nestling period (Oliarnyk and Robertson 1996, Nicholson, this study). The observation period for nests with uncertain outcomes was terminated on the date the nest was last observed to be active, as recommended by Manolis et al. (2000). Differences in nest success rates among years were tested using the program CONTRAST (Hines and Sauer 1989).

The height of each nest, as well as the total height and height of the base of the live canopy of each nest tree, were measured using a clinometer and measuring tape. The diameter at breast height (dbh) of each tree was measured with a diameter tape. The distance from the nest to both the tree trunk and the outer edge of the tree canopy, and the diameter of the limb supporting the nest were visually estimated. The angle of the limb supporting the nest was measured, relative to vertical, with a clinometer. Characteristics of the surrounding stand were measured as described in Chapter 4.

RESULTS

Spring Arrival

Cerulean Warblers typically arrived in eastern Tennessee in mid-April. Robinson (1990) listed 11 April as the earliest arrival date; this observation was from Chattanooga in 1965. The numbers of migrants passing through Knoxville, about 53 km ESE of the Frozen Head study area, peaked during the last few days of April (Nicholson pers. obs.). The earliest arrival date in the study area was 13 April 1999, and Ceruleans were usually present by about 20 April. Until early May, they were more numerous at low than at high elevations, and males appeared to greatly outnumber females.

Courtship and Territorial Behavior

Male Cerulean Warblers showed territorial behavior soon after their spring arrival. They spent much of their time singing from perches near the outer edge of tree canopies, often adjacent to small openings. Adjacent males often countersang. Physical contact occasionally occurred during territorial establishment, with one male supplanting another from a perch, or through contact in flight. During one such encounter, two males flew from adjacent trees to meet each other in mid-air, and hovered for about 15 sec pecking at each other and loudly chipping. On another occasion, two fighting males locked talons and tumbled more than 10 m to the ground.

On several occasions during the first half of May, males were observed giving the "Moth Flight" (Ficken and Ficken 1962, Nolan 1978, Morse 1993), during which they slowly flew several m, with their tail fanned and wings flapping slowly and shallowly. During this flight, their tail pattern and wing bars were prominently displayed. Following a fight between two males, the dominant male performed a Moth Flight. The Moth Flight was also used in a courtship context. On one occasion, a male terminated this flight by landing next to a female high in a tree holding a nest under construction; the female then flew to the nest and added a piece of nest material she carried in her beak. Males also chased or pounced on females, sometimes in the immediate vicinity of a nest under construction.

Following the establishment of territories, physical combat between males was very rare, and territorial defense was primarily by song. The defense of territory boundaries lessened after nestlings fledged.

Nest Site Selection and Nest Construction

Nest construction began in early May (Table 5-1). Both the male and female selected the nest site. On several occasions, both were observed giving a "Sit-Spin" display, in which one bird would crouch in a potential nest site, spread its wings and tail, and turn back and forth as if shaping the bowl of a nest. One bird would perform this display as its mate perched a few cm away; the birds would then exchange positions and repeat the display. On three occasions, no nest was subsequently built at the display site. On another occasion, a female initiating nest construction made several visits to a fork in a branch, and repeatedly wiped her beak on the branch. She then carried a piece of nest material to the site, dropped it on the fork, and then gave the sit-spin display. After she left the site, the accompanying male briefly sat in the nest site. A nest was subsequently completed at this site.

Nest construction was performed entirely by the female. Males occasionally accompanied females to the nest, and often sang quietly when near the nest. On two occasions, the initial stage of nest construction, during which the female wrapped a long spider web around the supporting tree limb, was observed. The female then added plant material. Once the base of the nest was in place, the female would usually squat in the nest bowl after adding material, and use her body and her beak to shape the bowl.

Nest construction lasted 3 to 6 days, with most nests built in 4–5 days. While nest-building, the female's visits to the nest ranged from 4–43 seconds long, and averaged 16.2 seconds (SE = 1.54, n = 43). During 21 separate bouts of active nest building, involving different nests and totaling 179 min, females brought material to the nest at average intervals of 2 min 18 sec.

Nest Description

The outer shell of the nest was built of bark strips and other plant fibers, woven together and secured with spider webs. Strips of grape (*Vitis* spp.) bark up to 10 cm long

Table 5-1. Nesting chronology of Cerulean Warblers in the Cumberland Mountains of Tennessee, 1995 - 1999.

	Earliest	Latest	Duration, days
Nest-building	5 May	10 June	3–6
Incubation	12 May	23 June	11–12
Nestlings	26 May	30 June	10–11, 18
Fledglings	2 June	7 July	

were commonly used, and on many occasions females pulled strips of bark from grape vines and carried them to the nest. The nest was lined with long (up to 145 mm) thin plant fibers. The walls of the nest were 60–90 mm thick, and curved inward slightly at the rim. The outside of the nest was decorated with varying amounts of gray plant fibers and spider webs. Some nests appeared almost totally gray. A few small plant bud scales, 5–7 mm long, sometimes decorated the outside of the nest. None were decorated with lichens, which Oliarnyk (1996) observed on nests in Ontario.

Following are the dimensions (mean, range) of 4 completed nests which had fallen to the ground at the Frozen Head study area: outside diameter, 65 mm (63–68 mm); height, 42 mm (38–45 mm); inside diameter, 42 mm (40–45 mm); inside depth, 26 mm (22–30 mm); dry weight, 3.24 g (2.50–3.74 g).

Nest Location

All of the 52 nests found during this study were built in deciduous trees. Nests are typically placed in the tree canopy on a lateral limb at the point where the limb forks or a small twig branches off. Most nests had some overhead cover from a few live leaves 10–20 cm above the nest. These leaves were often on a twig branching off of the nest limb close to the nest. An open area in the tree canopy was also present immediately below most nests, and in many cases, the open area extended to the shrub layer or ground cover. Additional nest site characteristics are listed in Table 5-2 and illustrated in Figure 5-1.

Neither the height nor the diameter of nest trees were significantly different from the height and diameter of randomly selected trees on the two Frozen Head study plots ($P>0.05$). Nest trees on these two plots had a mean height of 25.2 m ± 1.00 SE and trees in random samples had a mean height of 26.7 m ± 0.32 SE ($T = 1.31$). The mean diameter of nest trees on these two plots was 43.0 cm ± 2.94 SE and the mean diameter of randomly selected trees was 42.3 cm ± 0.81 SE ($T = 0.22$).

Cerulean Warblers nested in 12 tree taxa, including 11 species and one additional genus. Black cherry and sugar maple were most frequently used (Table 5-3). To test whether the birds selected or avoided certain species, the frequency of use of species on

Table 5-2. Nest site characteristics for 52 Cerulean Warbler nests in the Cumberland Mountains of Tennessee.

Variable	N	Mean	Std. Error	Minimum	Maximum
Nest height, m	52	15.90	0.81	7.0	36.3
Tree height, m	52	23.64	0.90	10.2	42.2
Tree canopy base height, m	51	12.03	0.67	2.8	23.6
Tree diameter, cm	52	39.64	2.53	12.3	76.2
Bole to nest, m	51	3.34	0.21	0.3	7.1
Nest to outer canopy edge, m	51	2.67	0.27	0	9.6
Nest limb diameter, cm	42	3.2	0.3	1.5	15.0
Nest limb angle from vertical, °	42	101.3	3.1	75	150
Distance tree to gap, m	42	44.3	8.1	2	200

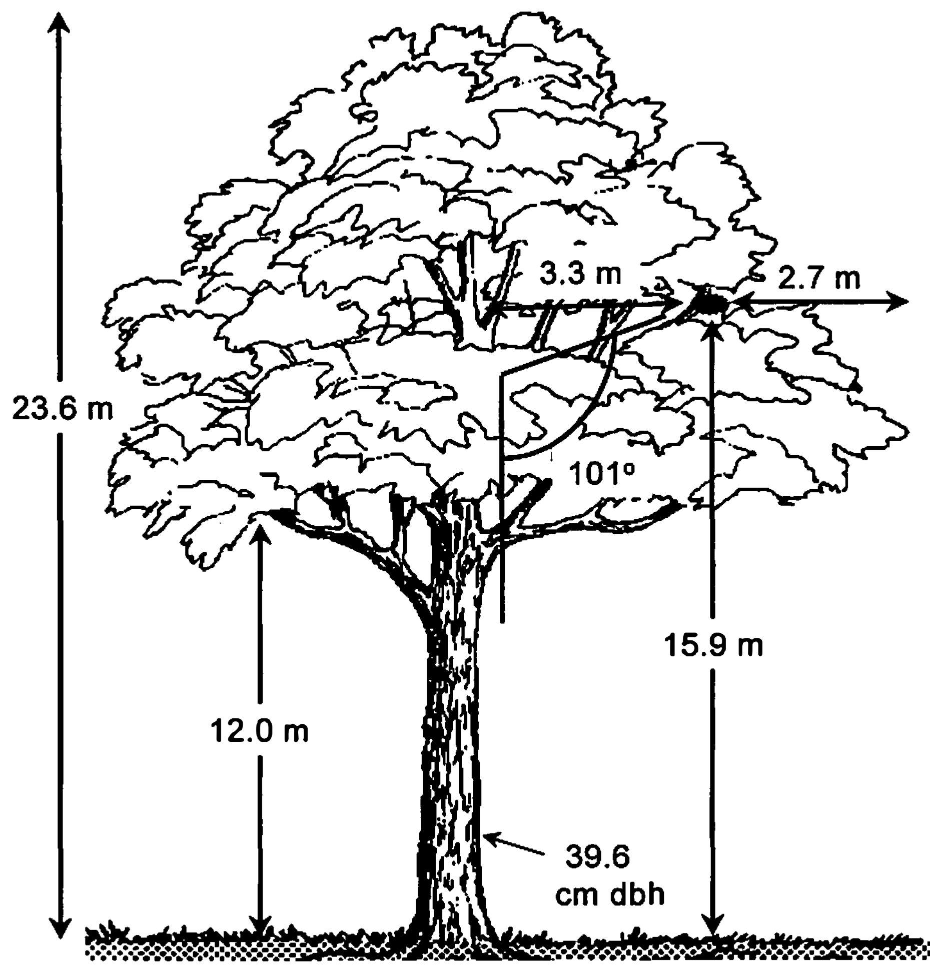


Figure 5-1. Mean nest placement characteristics for Cerulean Warbler nests in the Cumberland Mountains of Tennessee. Sample sizes for individual measurements range from 42 to 52.

Table 5-3. Frequency of occurrence of Cerulean Warbler nests in different tree taxa, and relative abundance (R.A.) of tree taxa on Frozen Head plots. Symbols following relative abundance denote results of tests for selection: +, selection, o, no selection, and –, avoidance.

		Upper Frozen Head		Lower Frozen Head	
Tree Taxa	All Nests	Nests	R.A.	Nests	R.A.
Black cherry, *Prunus serotina*	11	7	1151 +	0	116 o
Sugar maple, *Acer saccharum*	11	2	1460 o	5	105 +
Chestnut oak, *Quercus prinus*	7	0	0 o	7	3293 o
Yellow-poplar, *Liriodendron tulipifera*	7	0	807 o	4	557 +
White oak, *Q. alba*	5	1	0 o	2	47 o
Northern red oak, *Q. rubra*	3	2	422 o	1	678 o
Red maple, *A. rubrum*	2	0	14 o	2	3512 –
Hickory, *Carya* spp.	2	0	93 o	1	0 o
Black gum, *Nyssa sylvatica*	1	0	46 o	1	205 o
American basswood, *Tilia americana*	1	0	604 o	1	81 o
Cucumber tree, *Magnolia acuminata*	1	1	374 o	0	0 o
Sassafras, *Sassafras albidum*	1	0	559 o	1	848 o
Sweet birch, *Betula lenta*	0	0	313 o	0	37 o
Black locust, *Robinia pseudoacacia*	0	0	891 o	0	74 o
Sourwood, *Oxydendrum arboreum*	0	0	0 o	0	364 o
White ash, *Fraxinus americana*	0	0	126 o	0	10 o
Yellow buckeye, *Aesculus flava*	0	0	60 o	0	0 o
Total	52	13	6920	25	9927

the two Frozen Head study plots was compared with the relative abundance of the species (Table 5-3) using Poisson distribution tests (Ludwig and Reynolds 1988). Black cherry was selected on the upper plot, sugar maple and yellow-poplar were selected on the lower plot, and red maple was avoided on the lower plot ($P<0.05$). Other tree species were used in proportion to their availability.

Renesting and Nest Site Reuse

At least 2 nests were renests. One nest was abandoned within a day of the start of its construction. Five days later, an almost complete nest was found on the opposite side of the canopy of the same tree. Another nest was observed tipped on its side about 5 days after the start of its construction. Seven days later, this nest was found on the ground, as was another new nest, 6 m away. This replacement nest was most likely built in a white oak immediately adjacent to the white oak in which the first nest was built. Two other nests were likely renests, as they were found a few days after nearby nests failed. Another nest was found in early June as it was being built by a female who was using material from a previously undiscovered, weathered, probable Cerulean Warbler nest about 25 m away. This was the only observation of the reuse of nest material, which has been observed several times elsewhere (Ganier 1951, Oliarnyk and Robertson 1996, Hamel 2000a).

One nest tree, a 27-cm diameter red maple, was used 2 consecutive years. In 1997, young successfully fledged from the nest in this tree; in 1998, the nesting attempt was unsuccessful.

Clutch Size

Thirteen nests were examined during the incubation period to determine their clutch size. Nine nests held 4 eggs, and four nests held three. Mean clutch size was 3.7 ± 0.13 SE.

Incubation

The female incubated the eggs, and incubation behavior was observed from 11 May through 23 June. Based on observations of fledglings on 3 and 4 June, and

assuming an 11–12 day incubation period and an 10–11 day nestling period (Oliarnyk 1996), incubation on the study area began as early as 12 May.

During a total of 14.3 hours of observations at 15 nests, from early morning through mid-afternoon, the female was on the nest 85.4 % of the time. The attendance rate appeared to be lowest early in the morning, although sample sizes were limited. Attendance did not vary greatly during the rest of the day (Figure 5-2). Females frequently changed position during incubating sessions. The attendance rate was also somewhat greater during the second half of the incubation period than during the first half (Figure 5-3).

Males very rarely visited the nest during incubation. On one occasion, the male arrived at the nest with the female, who had been away from the nest for about 90 sec. The male perched over the nest and looked in it for a few seconds, then flew a few meters and began singing. The female sat in the nest as soon as the male left. A male was twice observed feeding an incubating female; both of these observations were at the same nest.

Males often sang in the nest tree or an adjacent tree, and females often responded with chip notes. On one occasion, the female coordinated her response to the male's song by chipping after each song in a series of about 8 songs. The female then chipped after every 2 or 3 songs.

Nestlings

Nests with young were observed from 26 May though 30 June. Based on the earliest observations of fledglings and an 11–12 day incubation period (Oliarnyk and Robertson 1996), young hatched as early as 24 May on the study area. At the time of hatching, the incubating female was restless and frequently stood on the nest rim and probed in the nest with her bill. Both the female and male occasionally carried food in their beaks to the nest and stood at the nest for a minute or two before swallowing the food.

Both females and males fed the nestlings and removed fecal sacs from nests. During 12.3 hours of observations of nests with young, females fed nestlings 78 times (60%) and males fed nestlings 51 times (40%). An additional 4 feedings were by birds of

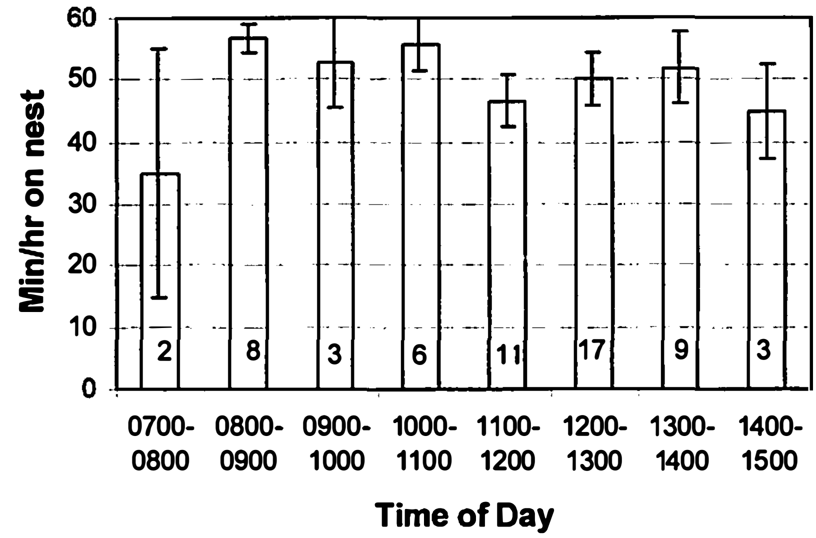


Figure 5-2. Nest attendance (mean ± SE) by incubating Cerulean Warblers in the Cumberland Mountains of Tennessee in relation to time of day. Observation periods were of unequal length and standardized to min/hr. The number of observation periods during each hour is given at the base of each bar; the total min of observation during each hour varied from 43 to 224.

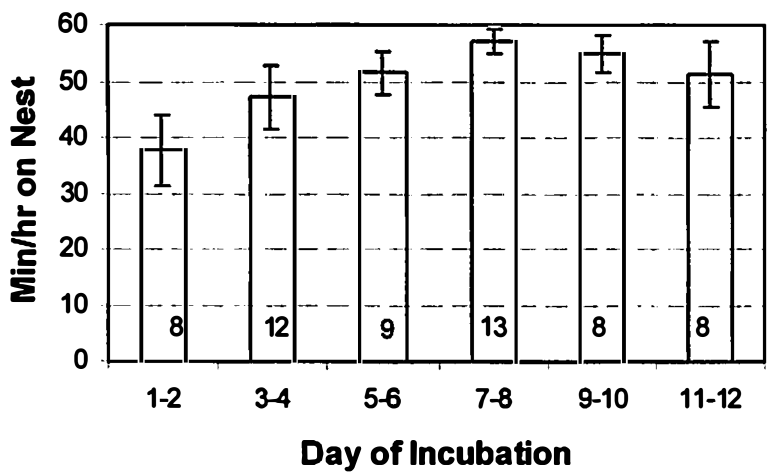


Figure 5-3. Nest attendance (mean ± SE) by incubating female Cerulean Warblers in the Cumberland Mountains of Tennessee in relation to stage of the incubation period. Observation periods were of unequal length and standardized to min/hr. The number of observation periods during each hour is given at the base of each bar; the total min of observation during each two-day period varied from 95 to 195.

unknown sex. On only one occasion did a male Cerulean Warbler give food to a female, which the female then fed to a nestling. Females brooded nestlings during 20 % of the 12.3 hours of observations, and remained at the nest to brood after 21 (27 %) of the feeding visits. Males never brooded nestlings, and their visits were usually brief.

Small nestlings defecated in the nest, while large nestlings, close to fledging, defecated on the nest rim. Females removed fecal sacs from nests during 7 of 78 visits (9%), and males removed fecal sacs during 5 of 51 visits (10%). On only 2 of these occasions did an adult eat the fecal sac.

No vocalizations were heard from nestlings until they were 5–6 days old. Nestlings then gave begging calls when an adult approached the nest; these calls consisted of a short, rapid series of chips, and in large nestlings were audible many meters from the nest. During warm, sunny weather large nestlings often stood up in the nest or perched on the nest rim and stretched or flapped their wings.

Most of the identifiable food brought to nestlings was lepidopteran larvae, 2–4 cm long. Other identifiable food items included a small white moth, a small green grasshopper, and spiders.

Fledging

At the time of fledging, both the adults and young were very vocal, and the adults reacted more vigorously to an observer's presence than earlier in the nesting cycle. Young began leaving the nest early in the day. About an hour after sunrise, one nest contained 3 large young, and a fledgling was perched on a twig about 10 cm from the nest. About 3 hours after sunrise, another nest held at least 1 nestling, and at least 2 fledglings were in nearby tree branches 5–10 m from the nest.

Newly fledged young had down feathers on their head, remiges about a cm in length, and a swollen gape. They were incapable of extended flights and were often found low in saplings or shrubs. Broods soon became mobile, and the family group often left the pair's territory within 4 or 5 days of fledging. Broods were often found in thickets of grape and Virginia creeper (*Parthenocissus quinquefolia*) vines at the edge of or within gaps in the forest. They were also occasionally found in other habitats, such as black locust thickets on surface mines, where adults did not regularly occur earlier in the

nesting cycle. Both male and female parents fed fledglings. There was no evidence of these parents attempting to raise a second brood.

Nest Success

Over the 4 years, at least 37 % of the 52 nests fledged young (Table 5-4). The Mayfield probability of success was 0.37. There were no significant differences (P>0.05) in the Mayfield daily success rate among the years 1996–1998.

The causes of the nest failures could rarely be determined with certainty. Nine nests disappeared from their supporting limbs; four of these nests were found intact on the ground. Most of these losses occurred early in the nesting cycle. An additional seven nests remained in place but were physically damaged. In one case, this damage occurred during nest construction, and was likely the result of storm damage. The other damaged nests contained eggs or nestlings when damaged, possibly by a predator. The few potential predators observed in the vicinity of nests included American Crows (*Corvus brachyrhynchos*), Blue Jays (*Cyanocitta cristata*), and, at lower elevations, black rat snakes (*Elaphe obsoleta obsoleta*). None of these predators were common. The remaining 17 nests appeared intact at the time the warblers quit attending them.

Severe summer storms, as well as extended cool rainy periods, were likely the cause of several nest failures and brood size reductions. Several nest failures were coincident with heavy rain and high winds. During 1997, one nest which originally contained 4 eggs eventually fledged one young, which developed unusually slowly and fledged in 17–18 days. Five of 16 nest failures in 1997, an unusually cool and wet year (NCDC 1997), occurred during the nestling period; the apparent cause of at least 3 of these failures was nestling starvation.

Interspecific Interactions

No evidence of interspecific territoriality was observed. A few interactions, both aggressive and non-aggressive, with other birds were observed.

A female Cerulean building a nest was attacked by a male American Redstart during 3 consecutive trips carrying nest materials to the nest. Several minutes later the

Table 5-4. Outcomes and success rates of 52 Cerulean Warbler nests in the Cumberland Mountains of Tennessee.

Probable Outcome	1996	1997	1998	1999	Total
Failed during nest-building	-	4	-	-	4
Failed during egg-laying	1	2	2	-	5
Failed during incubation	3	4	3	-	11
Failed during nestling period	1	5	5	-	10
Fledged young	5*	5	7	2	19
Outcome unknown	-	1	2	-	3
Total nest attempts	10	21	19	2	52
Minimum % successful	50 %	24 %	37 %	100 %	37 %
Minimum number young fledged per successful nest	2.4	2.8	2.4	3.0	2.6
Mayfield daily success rate (SE)	0.9744 (0.0113)	0.9620 (0.0096)	0.9722 (0.0087)	1.0000	0.9685 (0.0057)
Nest exposure days	195	395	360	3	953
Mayfield prob. of success	0.4476	0.3009	0.4173	1.0000	0.3708

*Includes one nest which fledged a Brown-headed Cowbird (*Molothrus ater*).

Cerulean went to the nest and crouched in the nest bowl. A male redstart perched about 0.5 m away, and the female chased the redstart from the area. About a minute later the female returned and worked on the nest, without interference from the redstart. During observations later in the day, the male redstart sang from an adjacent tree and did not approach the Cerulean nest.

At one Cerulean nest, a male Black-throated Blue Warbler repeatedly fed the nestlings, often in the presence of the female Cerulean. No aggressive interactions were observed between the Black-throated Blue Warbler and the Cerulean pair. This interspecific helping is described in more detail in Nicholson and Buehler (200_).

When nestlings were close to fledging, adult Ceruleans often reacted vigorously to the presence of a human observer and chipped loudly and frequently. This chipping usually attracted other birds to the area. During one such episode, a female Cerulean fed a large nestling. About a minute later, two female Ceruleans were at the nest; one quickly left, and the other briefly looked into the nest, then left. Another minute later, a male American Redstart perched about 10 cm from the nest for about 20 seconds, and then left without being attacked.

DISCUSSION

The courtship behavior, territorial behavior, and nest building of the Cerulean Warbler in the Cumberland Mountains of Tennessee were very similar to the observations of Oliarnyk (1996) and Hamel (2000a) elsewhere in the species' range. Hamel described a flight display similar to the Moth Flight, although he did not describe its context. In the present study, this display was associated with courtship. Nolan (1978) observed Prairie Warblers (*D. discolor*) giving Moth Flights in both territorial and courtship contexts. Morse (1993) observed Black-throated Green Warblers (*D. virens*) performing Moth Flights in territorial contexts.

Oliarnyk (1996) also observed both male and female Cerulean Warblers participating in nest site selection, and performing a display similar to the Sit-Spin, but without the lateral movements. Nolan (1978) observed male and female Prairie Warblers performing a display similar to the Sit-Spin during nest site selection. Only a small

proportion of male Prairie Warblers participated in nest site selection (Nolan 1978). Male participation is common in the Cerulean, although the female apparently makes the final nest site decisions (Jones and Robertson 2001). The role of the male in nest site selection is poorly known in other species of *Dendroica*. Male Cerulean Warblers have not been observed nest building. Males of some other species of *Dendroica* do participate in nest building, although females typically contribute more (e.g., Morse 1993, Hall 1994).

Nest height varies greatly, both locally and regionally (this study, Oliarnyk 1996, Hamel 2000b). The mean height of nests in the Cumberland Mountains, 15.9 m ± 0.81 SE, was greater than the historical rangewide mean of 11.4 m ± 0.4 SE compiled from the literature and egg collection data by Hamel (2000b). Cumberland Mountain nests were, however, intermediate in height between Ontario nests [11.8 m ± 0.6 SE, Oliarnyk (1996)] and Mississippi Alluvial Valley nests [19.5 m ± 0.8 SE, Hamel (2000b)]. As Hamel noted, much of this difference is likely due to differences in stand height across the species' range. In the Cumberland Mountains, the height of nest trees did not differ from those of trees in the surrounding stands.

A consistent, related nest placement characteristic was the height of the nest relative to the height of the nest tree. The heights of Cumberland Mountain nests were 67.0 % ± 0.02 SE of the total heights of the nest trees, and nest height was strongly correlated with tree height ($r^2 = 0.660$). Oliarnyk (1996) found average nest heights in Ontario were an almost identical 66.7% of the total nest tree height in Ontario, although her correlation of nest height with tree height was weaker ($r^2 = 0.138$). Nest heights in the lower Mississippi Alluvial Valley were 66.3% of total tree height (Hamel 2000b).

The mean diameter of nest trees in the Cumberland Mountains, 39.6 cm ± 2.53 SE, was similar to that in Ontario [40.2 cm ± 5.1 SE (Oliarnyk 1996)] and less than in the Mississippi Alluvial Valley [53.2 cm ± 3.0 SE (Hamel 2000b)]. Local variation was high in all three study areas, and in the Cumberlands, the mean diameter of nest trees did not differ from the mean diameter of trees in the surrounding stands.

Cerulean Warblers nested in a variety of tree species in the Cumberland Mountains. In addition to the 12 tree taxa listed in Table 5-3, a nest was found in a black

locust (*Robinia pseudo-acacia*) in 2000 (N. Moore pers. comm.). Some selection for tree species may occur in the Cumberlands. Neither Oliarnyk (1996) nor Jones and Robertson (2001) found evidence of preferential use in their Ontario study area, where both the number of tree species present (12) and species used by Ceruleans (7) were lower than in the Cumberlands. Hamel (2000b) tentatively concluded that on a rangewide basis, Cerulean Warblers do not prefer any particular tree species. Based on the broad range of characteristics of nest sites in the Cumberland Mountains, it is difficult to define a set of characteristics that distinguishes an individual tree likely to hold a nest from other trees in the stand.

The mean clutch size in the Cumberland Mountains, 3.7 ± 0.13 SE, was similar to the rangewide mean of 3.78 ± 0.10 SE (n = 40) compiled by Hamel (2000b). The behavior of the male and female warblers at the nest was generally similar to that described in Ontario by Oliarnyk (1996). The contribution of males feeding nestlings in the Cumberlands was somewhat lower (40 %) than the 50 % observed in Ontario. The contribution by males of other species of *Dendroica* varies greatly between species and within local populations of some individual species (e.g., Nolan 1978; Morse 1989, 1993).

At least 37% of the 52 nesting attempts fledged young, and at least 2.6 young fledged per successful nest. The predominant causes of nest failure were storm damage, followed by apparent predation. Other factors were weather-induced starvation of nestlings in 1997, and cowbird parasitism. Only one nest showed evidence of cowbird parasitism, which did not appear to be a major factor affecting this local Cerulean Warbler population.

Oliarnyk (1996) found a large proportion of the nests (17, including 3 renests, within 18 territories) on her study area; 67% produced fledglings, and 20 of 27 pairs successfully fledged young over two years. Four of her 9 nest losses were likely due to predation; the cause of the others is unknown. Oliarnyk (1966) did not observe any cowbird parasitism. She estimated 3.0–3.5 fledglings per nesting attempt and 3.6 fledglings per successful nest. This annual productivity of about 2.7 young/female, in an

area where the warbler's population is expanding, strongly suggests that her population was functioning as a source (Pulliam 1988).

Hamel (2000a, pers. comm.) found 21 of 66 nests (32 %) in the Mississippi Alluvial Valley fledged young, and estimated 1.7–1.9 fledglings/successful nest. He calculated a Mayfield nest success of 0.9402 ± 0.01 per day for 51 of these nests; this rate is significantly lower ($P = 0.014$) than the rate of 0.9685 ± 0.0057 in the Cumberland Mountains. As in the Cumberlands, Hamel also found substantial annual variation in nest success. At least 9 of 66 nests in Hamel's sample were parasitized by cowbirds, a much greater rate than in the Cumberland Mountains or in Oliarnyk's (1996) Ontario study.

Because it was not possible to find all of the nests (including renests) on the Cumberland Mountain study plots, no definitive measure of seasonal productivity per female was available. Assuming each female made 2 nest attempts/year, and 37% of nesting attempts fledged at least 2.6 young/nest, annual productivity would be about 1.9 fledglings/female/year. The corresponding annual productivity for 3 nest attempts/year is 2.9 fledglings/female/year.

Whether these annual productivity rates are sufficient to maintain a stable local population is questionable, as virtually no information on survival rates of Cerulean Warblers is available. Some survival information is available for other species of wood warblers, and is probably applicable to the Cerulean Warbler. Survival rates from fledging to independence range from 55% for the Ovenbird (Van Horn and Donovan 1994) to 82% for the Prairie Warbler (Nolan et al. 1999). Because the development of fledgling Cerulean Warblers more closely resembles that of the Prairie Warbler than the Ovenbird, the Prairie Warbler's fledgling survival rate is probably more applicable to the Cerulean Warbler. Nolan et al. (1999) estimated 39% of young Prairie Warblers survived from independence to the start of the first breeding season; estimates for other species are lacking. Survival rates of 80% from fledging to independence and 39% from independence to the following breeding season approximate the overall juvenile survival rate of 31% assumed by Donovan et al. (1995) for forest-dwelling Neotropical migrant songbirds.

With an annual productivity of 1.9 young/female/year (2 nest attempts/female/year) and juvenile survival of 31%, an adult survivorship of at least 71% would have been necessary for the Cerulean Warbler population to replace itself. With an annual productivity of 2.9 young/female/year (3 nest attempts/female/year), at adult survivorship of at least 55% would have been necessary for the species to sustain itself. An adult survivorship of at least 71% is improbably high, as most estimates for other wood warblers are in the range of 40–65% (e.g., Ogden and Stutchbury 1994, Van Horn and Donovan 1994, Nolan et al. 1999). Thus, it is unlikely that the productivity of the Cerulean Warbler population in the Cumberland Mountains study area was sufficient to sustain itself during the late 1990s.

CHAPTER 6

SUMMARY AND CONCLUSIONS

This study investigated the distribution, population density and trends, habitat selection, and breeding biology of the Cerulean Warbler in the Cumberland Mountains of East Tennessee. The relatively unfragmented forests in this region support high populations of the Cerulean Warbler, a species of conservation concern because of its declining rangewide population trend.

Cerulean Warblers were common and widespread in the Cumberland Mountains study areas. They were recorded on half of the point counts and were the sixth most frequently encountered bird species. Their average density on individual 10-ha census plots varied from 21.3 to 137.6 pairs/100 ha and averaged 84.9 pairs/100 ha for all five plots combined. Population trends on individual census plots showed an overall declining trend, as did the trends of the total population of all species on the census plots. These trends were not uniform among plots, and the variability in Cerulean Warbler numbers did not differ from that of similar, multi-year censuses elsewhere.

The Cerulean Warbler population, as measured by the Breeding Bird Survey, has declined since 1966 by 4.1%/year rangewide and by 3.5%/year in the BBS Cumberland Plateau subregion, which includes the Cumberland Mountains. The BBS trend on the three routes in the Cumberland Mountains during the 1990s was somewhat similar to that observed on the Cumberland Mountains census plots.

Habitat features important to Cerulean Warblers varied somewhat with scale. Nests are built on a limb of a deciduous tree at a wide range of heights (7–36 m above ground, mean = 15.0 m), and typically about 2/3 of the total tree height. Neither the total height nor diameter of nest trees differed from those of nearby available trees. Nests were found in 12 tree taxa, and there was some plot-specific selection with black cherry and yellow-poplar preferred and red maple avoided. Other taxa were used in proportion to their availability.

In 10-ha plot-based comparisons, basal area was consistently greater, and both shrub cover and canopy cover consistently less, at nest sites than at random sites, at territory sites than at random sites, and at nest sites than at territory sites. When plots from different study areas were combined, canopy cover and tree density were less, and tree diameter and shrub cover greater, at territory sites than at random sites. In the more extensive point count sample, points with Cerulean Warblers present had greater tree diameter and sapling cover and, in contrast to plot-based comparisons, greater canopy cover. This difference was probably due to the greater range of canopy cover at point count locations, which included some points with too little tree cover to support Cerulean Warblers.

Slope angle was not important in any comparisons, and Cerulean Warblers were found through the elevational range of the study areas. Analyses of aspect suggested some avoidance of south and southwest slopes. Comparisons of tree species-specific habitat variables showed some preference for species typical of moister sites such as hickories, sugar maple and yellow-poplar, and avoidance of species typical of dryer sites such as chestnut oak, red maple and pines.

Logistic regression models were developed to classify sites on census plots and point count locations according to their use by Cerulean Warblers. These models correctly classified 63–77% of observations; the classification rate improved as the scale of the analysis decreased. The model developed to distinguish nest sites and random sites on census plots at Frozen Head State Park and Natural Area had the highest correct classification rate but was of little value at other study areas. The other models were more applicable across the study areas. The results of these models indicate that habitat suitable for occupation by territorial Cerulean Warblers is widespread in the study areas and includes a range of mixed age and mature hardwood forests with scattered canopy gaps on moist sites. Suitable nest sites comprise a subset of habitat suitable for territorial birds and have somewhat greater basal area and less canopy cover.

At least 37% of 52 nests fledged at least one young, and an average minimum number of 2.6 young fledged per successful nest. The Mayfield probability of success was 37%, and the Mayfield daily success rate was 0.9685. Nest success varied somewhat

among years; the differences, however, were not significant. Although the causes of many nest failures could not be determined, several were attributable to severe storms and, in 1997, to prolonged wet, cold weather associated with an El Niño event. This unusually wet and cold weather resulted in slow nestling development and brood reductions, as well as nest failures. Because adult females were not individually marked and not all nests on the study plots were found, seasonal productivity per female could not be determined. Females renested after loss of an early season nest and there was no evidence of second broods. Only one nest showed evidence of parasitism by Brown-headed Cowbirds, which does not appear to be an important factor affecting Cerulean Warbler populations in the study area.

The local outbreak of the fall cankerworm in 1994 and weather events probably influenced the local population of the warbler during the 1990s. The fall cankerworm outbreak may have resulted in higher warbler densities and reproductive success in 1994 and subsequent higher densities in 1995. Storms with heavy rain and high winds caused several nest losses each year. Unusually cold, wet weather in 1997 associated with an El Niño event likely reduced reproductive success and populations in subsequent years. Outbreaks of the fall cankerworm do not occur in regular cycles and El Niño events are cyclical with much variation in their recurrence interval and intensity. Neither of these events may therefore have had a long-term effect on the warbler's population trend.

Whether the reproductive success of the species during the late 1990s was sufficient to maintain local populations is difficult to determine. Females fledged at least 2.6 fledglings/successful nest, more than observed by Hamel (2000a) in the Mississippi Alluvial Valley and less than observed by Oliarnyk (1966) in Ontario. The annual productivity in Oliarnyk's study area, where the population was increasing, was about 2.7 fledglings/female. Annual productivity in the Cumberland Mountains study area is estimated to be about 1.9 fledglings/female. If survival rates reported for other species of wood-warblers are applied to this population of Cerulean Warblers, annual productivity during the late 1990s was probably insufficient to maintain the population. This may, however, have been a short-term phenomenon as rainfall was unusually high during the 1996–1998 period when most nests were found.

An important issue in determining the conservation needs of the Cerulean Warbler is the relative importance of events during the breeding and non-breeding seasons in regulating the species' population. None of the six potential breeding season constraints listed by Robbins et al. (1992) appear to be of major importance in the Cumberland Mountains area. Forests in the area are relatively unfragmented, suitable mature and mixed-age stands are widespread and have remained so for many years, and the rate of cowbird parasitism is low. Low breeding success probably affected the local population during the late 1990s. Over the long term, breeding season events are probably less important than non-breeding season events in regulating the Cerulean Warbler population in the Cumberland Mountains of East Tennessee.

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APPENDICES

APPENDIX I

Breeding Bird Census Results

Upper Plot, Frozen Head State Natural Area

Location: Tennessee; Morgan Co.; Frozen Head State Natural Area; 915 m SW of Frozen Head fire tower; 36°07' N, 84°28'W; Petros Quadrangle USGS. Size: 10.4 ha. Description of Plot: A rectangular plot (220 x 460 m) with a mostly closed canopy dominated by uneven-aged black cherry, northern red oak, yellow poplar, and sugar maple. A quantitative vegetation survey modified from the method of James and Shugart (1970) yielded the following results: Trees, 7.6 cm diameter and over, based on 20 plotless prism samples, 403/ha; total basal area 31.8 m^2/ha. Species comprising 100% of the total number of trees [figures after each are trees/ha, relative density (%), basal area in m^2/ha, relative dominance (%), and frequency (%)]: sugar maple 73, 18.1, 3.9, 12.2, 80; black cherry, 58, 14.3, 7.6, 24, 80; standing dead, 57, 14.1, 1.9, 6, 60; black locust, 44.6, 11.1, 2.9, 9.1, 45; yellow poplar, 40, 10, 4, 12.6, 60; sassafras, 28, 6.9, 0.8, 2.4, 10; northern red oak, 21, 5.2, 4.3, 13.4, 65; cucumber tree, 18.7, 4.6, 0.4, 1.1, 15; American basswood, 30.2, 7.5, 2.1, 6.7, 40; black birch, 15.7, 3.9, 1.5, 3.7, 35; white ash, 6.3, 1.6, 1.3, 3.9, 45; hickory spp., 4.7, 1.2, 0.4, 1.2, 10; yellow buckeye, 3, 0.7, 0.5, 1.6, 20; black gum, 2.3, 0.6, 0.3, 0.8, 5; red maple, 0.7, 0.2, 0.1, 0.4, 5; . Trees by diameter size class [figures after each are trees/ha, relative density (%), basal area in m^2/ha, and relative dominance (%)]: A (7.6-15.2 cm) 112, 27.8, 1.4, 4.3; B (15.2-22.9 cm) 92, 22.8, 2.4, 7.5; C (22.9-38.1 cm) 104, 25.8, 7.4, 23.2; D (38.1-53.3 cm) 61.5, 15.3, 9.9, 31.1; E (53.3-68.6 cm) 26.3, 6.5, 7.3, 22.8; F (68.6-83.8 cm) 6.2, 1.5, 2.6, 8.3; G (83.8-101.6 cm) 1.4, 0.4, 0.9, 2.8. Saplings 2016/ha, dominated by sugar maple and yellow buckeye. Shrub cover 21%, average height 0.8 m, stems/ha, dominated by wild hydrangea, sugar maple, and buffalo nut. Canopy cover 89%; average tree height 27.4 m. The plot contains two springs and headwater sections of four intermittent streams with maximum widths < 1 m. Edge: The plot is bordered on all sides by similar habitat, and lies within a forested area > 3000 ha in size. Topography and Elevation: The plot is on a ridge crest and NW slope; average grade on plot of 22%. Minimum elevation 812 m, maximum elevation 924 m. A

rock bluff up to 15 m tall runs lengthwise across most of the plot. The densities in the following table are expressed as pairs/10 ha.

Species	1994	1995	1996	1997	1998	1999	2000
Turkey Vulture						V	
Broad-winged Hawk	+	V	+	V		V	
Red-tailed Hawk			V				
Ruffed Grouse	1	+	+	+		+	+
Wild Turkey	V						
Yellow-billed Cuckoo	+	+	V		V		V
Barred Owl	+		V	+		V	
Chimney Swift	V	V				V	
Ruby-throated Hummingbird		V					V
Red-bellied Woodpecker	+						
Downy Woodpecker	1.5	1.5	+	1	+	1	1.5
Hairy Woodpecker	1	1	1	1	0.5	1	1
Pileated Woodpecker	+	+	+	+	+	1	+
Eastern Wood-Pewee	3	2	3	2	2	1	2
Acadian Flycatcher	V		V				
Eastern Phoebe		1					V
Great-crested Flycatcher							
Yellow-throated Vireo	1	1	2.5	1	V	1	2
Blue-headed Vireo	5.5	5	2.5	1.5	3.5	3	3.5
Red-eyed Vireo	11	13.5	17	16	14	10	6.5
Blue Jay		V	V		+	+	
Carolina Chickadee	1	1	V	V	+	1	+
Tufted Titmouse	+	+	0.5	0.5	1	2	1.5
White-breasted Nuthatch	2	1.5	1	2	1.5	1.5	1
Carolina Wren	V					1	1
Winter Wren		V				+	
Veery	1	2	1	+	1.5	0.5	2
Wood Thrush	2	+	+	1	1	2.5	2
Cedar Waxwing	+			V			V
Chestnut-sided Warbler	1.5	0.5	1.5	V	+		
Black-throated Blue Warbler	7	7	6.5	4	2.5	2.5	2.5
Black-throated Green Warbler	V	1.5	1	1	1.5	1	1
Blackburnian Warbler	V	+	+	V	1	1	2
Cerulean Warbler	18	19	19	14	12	9	9
Black-and-white Warbler	2.5	2	1.5	2.5	2.5	0.5	1
American Redstart	22	21	20.5	22	17	8	9
Worm-eating Warbler	1.5	V		V		+	V
Ovenbird	30	23	22.5	23	20	14	16
Kentucky Warbler	2	1.5	2	1			
Hooded Warbler	15	11.5	12.5	8	5.5	6	6
Canada Warbler	2.5	1.5	V	1.5	2	+	+
Scarlet Tanager	6	3	1.5	3.5	3.5	4	3
Eastern Towhee	3	2	V	1	0.5	0.5	+
Northern Cardinal	V	+				+	+
Rose-breasted Grosbeak	1.5	2.5	3	1	2	2.5	2
Indigo Bunting	7	+	V		+	+	1
Brown-headed Cowbird	1.5	2	+	+	V		
Total	151	127.5	120	108.5	95	75.5	76.5
Territorial Species	33	32	26	26	26	31	28

APPENDIX II

Breeding Bird Census Results

Lower Plot, Frozen Head State Natural Area

Location: Tennessee, Morgan Co.; Frozen Head State Natural Area; Rough Ridge, 900 m SSE of Natural Area headquarters; 36°07' N, 84°30' W; Camp Austin and Petros Quadrangles USGS. Size: 11.2 ha. Description of Plot: A rectangular plot (245 x 420 m) with a mostly closed canopy dominated by chestnut oak, yellow poplar, red maple, and northern red oak. A quantitative vegetation survey modified from the method of James and Shugart (1970) by the use of plotless tree sampling yielded the following results: Trees, 7.6 cm diameter and over, based on 20 plotless prism samples, 532/ha; total basal area 28.6 m^2/ha. Species comprising 100% of the total number of trees [figures after each are trees/ha, relative density (%), basal area in m^2/ha, relative dominance (%), and frequency (%)]: red maple, 176, 33, 3.5, 12.2, 75; chestnut oak, 165, 30.9, 12.1, 42.3, 90; sassafras, 42.4, 8, 0.5, 1.7, 10; northern red oak, 34, 6.4, 3.1, 10.9, 65; standing dead, 33, 6.7, 0.8, 2.6, 30; yellow poplar, 28, 5.2, 4.3, 14.9, 40; sourwood, 18.2, 3.4, 0.4, 1.3, 10; black gum, 10.2, 1.9, 0.6, 2.1, 20; black cherry, 5.8, 1, 1, 3.4, 25; black birch, 5.8, 1.1, 0.3, 0.9, 5; sugar maple 5.2, 1, 0.4, 1, 10; white oak, 2.9, 0.5, 0.6, 2.1, 15; American basswood, 4, 0.8, 0.6, 2.1, 5; black locust, 3.7, 0.7, 0.3, 0.9, 10; white ash, 0.5, 0.1, 0.1, 0.4, 5. Trees by diameter size class [figures after each are trees/ha, relative density (%), basal area in m^2/ha, and relative dominance (%)]: A (7.6-15.2 cm) 195.4, 36.7, 2.1, 7.4; B (15.2-22.9 cm) 116.8, 21.9, 3.3, 11.4; C (22.9-38.1 cm) 154.4, 29.0, 11, 38.4; D (38.1-53.3 cm) 51.0, 9.6, 7.9, 27.5; E (53.3-68.6 cm) 12.7, 2.4, 3.4, 11.8; F (68.6-83.8 cm) 1.8, 0.3, 0.8, 2.6; G (83.8-101.6 cm) 0.2, 0.03, 0.1, 0.4; H (> 101.6 cm) 0.2, 0.03, 0.1, 0.4. Saplings 2193/ha, dominated by red maple and sugar maple. Shrub cover 25%, average height 1.3 m, dominated by buffalo nut, red maple, and *Vaccinium* spp. Canopy cover 82%; average tree height 25.6 m. The plot contains two springs and an intermittent stream with maximum width of 1 m. Edge: The plot is bordered on all sides by similar habitat, and lies within a forest area > 3000 ha in size. The NE border of the plot bisects a canopy gap about 1 ha in size. Topography and Elevation: The plot straddles a ridgetop

running SE-NW, and has an average grade of about 14%. Minimum elevation 642 m, maximum 709 m. The densities in the following table are expressed as pairs/10 ha.

Species	1995	1996	1997	1998
Turkey Vulture	V			
Cooper's Hawk		V		
Broad-winged Hawk			V	
Ruffed Grouse	V			
Mourning Dove	V		+	+
Yellow-billed Cuckoo	V		V	V
Barred Owl	+			
Ruby-throated Hummingbird	V	V	+	V
Red-bellied Woodpecker	V		+	
Downy Woodpecker	2	1.5	+	V
Hairy Woodpecker	1		+	1
Northern Flicker		V		V
Pileated Woodpecker	+	V	0.5	0.5
Eastern Wood-Pewee	V			
Acadian Flycatcher	1	+	+	
Great-crested Flycatcher		V		
Yellow-throated Vireo	V	+	0.5	0.5
Blue-headed Vireo	2.5	1.5	2	3.5
Red-eyed Vireo	11	8	12.5	11.5
Blue Jay	+			+
American Crow				+
Carolina Chickadee	2		+	+
Tufted Titmouse		0.5	0.5	0.5
White-breasted Nuthatch	1.5	0.5	1.5	0.5
Wood Thrush	+		V	V
Cedar Waxwing	V		V	
Chestnut-sided Warbler			+	
Black-throated Blue Warbler			V	
Black-throated Green Warbler	2.5	1.5	1.5	1
Blackburnian Warbler	V	V	0.5	+
Cerulean Warbler	9	5	12	9
Black-and-white Warbler	2	1		1.5
American Redstart	7	8.5	14	10
Worm-eating Warbler	5.5	3	2	2
Ovenbird	27	16.5	20	18.5
Hooded Warbler	8.5	5.5	10	6
Scarlet Tanager	5.5	3.5	4.5	4
Eastern Towhee				V
Northern Cardinal	0.5	+	0.5	+
Rose-breasted Grosbeak	1	+		
Indigo Bunting	2	2		0.5
Brown-headed Cowbird	3.5	2	2	0.5
Total	95	60.5	84.5	71
Territorial Species	23	19	24	23

APPENDIX III

Breeding Bird Census Results

Rock Springs Gap Plot, Royal Blue Wildlife Management Area

Location: Tennessee, Campbell Co.; Royal Blue Wildlife Management Area; Adkins Mountain, immediately NW of Rock Springs Gap; 36°22' N, 84°18'W; Block Quadrangle USGS. Size: 10.3 ha. Description of Plot: A rectangular plot (250 x 400 m) with a mostly closed canopy dominated by red maple, tulip poplar, sugar maple, and northern red oak. Two dirt roads with closed canopies cross the plot. A small portion of the plot was disturbed by coal mining many years ago and is now reforested. A quantitative vegetation survey modified from the method of James and Shugart (1970) by the use of plotless tree sampling yielded the following results: Trees, 7.6 cm diameter and over, based on 20 plotless prism samples, 570/ha; total basal area 25.9 m^2/ha. Species comprising 100% of the total number of trees [figures after each are trees/ha, relative density (%), basal area in m^2/ha, relative dominance (%), and frequency (%)]: red maple, 169, 30, 9.8, 38, 50; sugar maple 111, 19.4, 4, 15.4, 70; standing dead, 74, 13, 1.6, 6.3, 30; yellow poplar, 54, 9.4, 4.6, 17.9, 70; black cherry, 28, 4.9, 1.3, 4.8, 35; white oak, 20.2, 3.5, 1.9, 7.2, 30; black gum, 19, 3.3, 0.5, 1.9, 50; northern red oak, 16.7, 2.9, 2.5, 9.7, 50; hickory spp., 48.3, 8.5, 2, 7.7, 40; chestnut oak, 6.2, 1.1, 1, 3.9, 10; American basswood, 43.7, 7.7, 0.4, 1.4, 15; white ash, 4.7, 0.8, 0.5, 2, 10; yellow buckeye, 1, 0.2, 0.1, 0.5, 5; cucumber tree, 0.5, 0.1, 0.1, 0.5, 5. Trees by diameter size class [figures after each are trees/ha, relative density (%), basal area in m^2/ha, and relative dominance (%)]: A (7.6-15.2 cm) 234, 41.1, 3, 11.6; B (15.2-22.9 cm) 175, 30.7, 4.9, 18.8; C (22.9-38.1 cm) 101, 17.7, 7.4, 28.5; D (38.1-53.3 cm) 50.9, 8.9, 7.9, 30.4; E (53.3-68.6 cm) 6.6, 1.2, 1.8, 6.8; F (68.6-83.8 cm) 1.7, 0.3, 0.8, 2.9; G (83.8-101.6 cm) 0.3, 0.1, 0.3, 1. Saplings, 1096/ha, dominated by sugar maple, red maple, and black cherry. Shrub cover 15%, average height 0.4 m, dominated by sugar maple and black cherry. Canopy cover 90%; average tree height 21.3 m. The plot contains short headwater stretches of two intermittent streams. Edge: The plot is bordered on all sides by similar habitat, and lies within an area > 15,000 ha in size of forest interspersed with surface mines of various size and state of reclamation. Topography and Elevation: The plot straddles an E-W spur

ridge of Adkins Mountain, and has an average grade of about 21%. Minimum elevation 782 m, maximum 879 m. The densities in the following table are expressed as pairs/10 ha.

Species	1995	1996	1997	1998
Wild Turkey	+	V	1	V
Yellow-billed Cuckoo	V			+
Barred Owl		V		
Chimney Swift				V
Ruby-throated Hummingbird	V		V	V
Downy Woodpecker	1		+	1
Hairy Woodpecker	V	V	+	
Pileated Woodpecker	V	+	+	+
Eastern Wood-Pewee			V	1
Acadian Flycatcher	1	1	0.5	+
Yellow-throated Vireo	3.5		+	1
Blue-headed Vireo	3	1	2	4.5
Red-eyed Vireo	19.5	11	13	12.5
Blue Jay	+		V	+
American Crow	V			
Carolina Chickadee	+	0.5	0.5	V
Tufted Titmouse	2	+	1	1
White-breasted Nuthatch	1	V	+	+
Wood Thrush	+		+	1
Cedar Waxwing			V	
Black-throated Green Warbler	8.5	7	7.5	9
Blackburnian Warbler				+
Cerulean Warbler	12.5	6.5	9	9
Black-and-white Warbler	2.5	2	3	2.5
American Redstart	9.5	8	9.5	8.5
Worm-eating Warbler	2	1	V	1
Ovenbird	20	11	17	19
Kentucky Warbler	2		1	
Hooded Warbler	6	1.5	3	3
Yellow-breasted Chat				
Scarlet Tanager	4	1.5	2.5	4
Northern Cardinal	+	+	+	+
Indigo Bunting	+		V	0.5
Brown-headed Cowbird	1		1.5	V
Total	99	52	72	78.5
Territorial Species	23	15	22	23

APPENDIX IV

Breeding Bird Census Results

Turley Mountain Plot, Royal Blue Wildlife Management Area

Location: Tennessee, Campbell Co.; Royal Blue Wildlife Management Area; Turley Mountain, Mountain, immediately NW of Muse Gap; 36°22'N, 84°17'W; Block Quadrangle, USGS. Size: 10.3 ha. Description of Plot: A rectangular plot (~250 x 400 m) with a mostly closed canopy dominated by chestnut oak, northern red oak, red maple, and black gum. Portions of the plot were logged in the early 1970s. A dirt road with mostly closed canopy runs lengthwise across the plot. A quantitative vegetation survey modified from the method of James and Shugart (1970) by the use of plotless tree sampling yielded the following results: Trees, 7.6 cm diameter and over, based on 21 plotless prism samples, 531/ha; total basal area 21.9 m^2/ha. Species comprising 100% of the total number of trees [figures after each are trees/ha, relative density (%), basal area in m^2/ha, relative dominance (%), and frequency (%)]: red maple, 128, 24.1, 2.6, 11.3, 62; chestnut oak, 122, 23.0, 7.1, 30.7, 81; black gum, 63.6, 11.9, 1.8, 7.7, 48; northern red oak, 50.6, 9.5, 3.8, 16.9, 76; standing dead, 32.5, 6.1, 1.8, 7.7, 52; yellow poplar, 28.2, 5.3, 1.2, 5.1, 24; sourwood, 27.0, 5.1, 0.5, 2.0, 14; Florida dogwood, 24.3, 4.6, 0.4, 1.5, 10; sassafras, 16.1, 3.0, 0.2, 1.0, 10; sugar maple 15.7, 3.0, 0.8, 3.6, 24; hickory spp., 11.4, 2.1, 0.8, 3.8, 24; white oak, 9.7, 1.8, 0.7, 3.1, 19; white ash, 1.2, 0.2, 0.1, 0.5, 5; black walnut, 0.7, 0.1, 0.1, 0.5, 5; American basswood, 0.1, 0.1, 0.1, 0.5, 5. Trees by diameter size class [figures after each are trees/ha, relative density (%), basal area in m2/ha, and relative dominance (%)]: A (7.6-15.2 cm) 233, 43.8, 2.5, 11.3; B (15.2-22.9 cm) 156, 29.3, 4.3, 19.4; C (22.9-38.1 cm) 90, 16.9, 6.4, 29; D (38.1-53.3 cm) 45, 8.5, 6.8, 30.1; E (53.3-68.6 cm) 7, 1.4, 1.9, 8.6; F (68.6-83.8 cm) 0.6, 0.1, 0.2, 1. Saplings, 3098/ha, dominated by red maple, black gum, and chestnut oak. Shrub cover 19%, average height 0.6 m, dominated by chestnut oak, *Vaccinium* spp., and sassafras. Canopy cover 86%; average tree height 19.5 m. Edge: More than 90% of the plot's permineter is bordered by similar habitat; an electrical transmission line borders part of the SW edge. It lies within an area > 15,000 ha in size of forest interspersed with coal surface mines of various size and state of reclamation. Topography and Elevation: The plot straddles a N-

S spur ridge of Turley Mountain and has an average grade of about 22%. Minimum elevation 582 m, maximum 691 m. The densities in the following table are expressed as pairs/10 ha.

Species	1995	1996	1997	1998
Broad-winged Hawk			V	
Red-tailed Hawk				V
Ruffed Grouse	V	V		
Wild Turkey		+		
Yellow-billed Cuckoo	V		+	+
Eastern Screech-Owl	V	V		
Ruby-throated Hummingbird				V
Red-bellied Woodpecker	+	+		
Downy Woodpecker	1	1		+
Hairy Woodpecker	+	+	+	
Pileated Woodpecker	V	+	V	+
Eastern Wood-Pewee		V	V	
Acadian Flycatcher	+		V	
Eastern Phoebe	V	1	+	1
Yellow-throated Vireo			1	2
Blue-headed Vireo	1		1.5	4.5
Red-eyed Vireo	10	11.5	12	12
Blue Jay		V		V
American Crow				V
Carolina Chickadee	1	+	+	+
Tufted Titmouse	5	1	0.5	+
White-breasted Nuthatch	2	1.5	2	2
Carolina Wren	1.5			
Blue-Gray Gnatcatcher	V	V	+	
Wood Thrush	+		1.5	+
Black-throated Green Warbler	6.5	3	5	2
Blackburnian Warbler	2		1	1
Cerulean Warbler	6	5	8	4
Black-and-white Warbler	2.5	4	3	4
American Redstart	2	1.5	1.5	2
Worm-eating Warbler	5.5	5.5	4	5
Ovenbird	12.5	6	6.5	6
Kentucky Warbler	1.5	1		
Hooded Warbler	7.5	4.5	5.5	3.5
Yellow-breasted Chat	2			
Scarlet Tanager	8	7	3.5	3
Eastern Towhee	1			
Northern Cardinal		1	0.5	2
Indigo Bunting	3.5	3	2.5	1
Brown-headed Cowbird	V			
Total	83	57.5	59.5	55
Territorial Species	21	22	22	23

APPENDIX V

Breeding Bird Census Results

Scott County Plot, UT Cumberland Forestry Experiment Station

Location: Tennessee, Scott Co.; UT Cumberland Forestry Experiment Station; Young Mountain; 36°14'N, 84°34'W; Gobey Quadrangle USGS. Size: 10.1 ha. Description of Plot: A rectangular plot (250 x 400 m) with a mostly closed canopy dominated by tulip poplar, sugar maple, and red maple. A quantitative vegetation survey modified from the method of James and Shugart (1970) by the use of plotless tree sampling yielded the following results: Trees, 7.6 cm diameter and over, based on 21 plotless prism samples, 382/ha; total basal area 26.1 m^2/ha. Species comprising 100% of the total number of trees [figures after each are trees/ha, relative density (%), basal area in m2/ha, relative dominance (%), and frequency (%)]: sugar maple 105.5, 27.5, 6.1, 23.3, 76; yellow poplar, 104.3, 27.2, 8.5, 32.4, 71; standing dead, 36.2, 9.5, 1.2, 4.6, 33; red maple, 31.3, 8.2, 3.2, 12.3, 38; chestnut oak, 7.3, 1.9, 1.4, 5.5, 38; black gum, 25, 6.5, 1.2, 4.6,29; black birch, 19, 5, 0.7, 2.7, 19; hickory spp., 11.7, 3.0, 0.7, 2.7, 24; black cherry, 10.1, 2.8, 0.5, 1.8, 10; American basswood, 8.8, 2.3, 0.6, 2.3,10; northern red oak, 4.9, 1.3, 0.6, 2.3, 19; black locust, 9.3, 2.4, 0.2, 0.9, 5; white ash, 5.3, 1.4, 0.6, 2.3,10; ironwood, 2.4, 0.6, 0.1, 0.5, 5; yellow buckeye, 1.2, 0.3, 0.1, 0.5, 5. Trees by diameter size class [figures after each are trees/ha, relative density (%), basal area in m2/ha, and relative dominance (%)]: A (7.6-15.2 cm) 68.6, 16.2, 1.0, 3.6; B (15.2-22.9 cm) 140, 33, 3.8, 14.6; C (22.9-38.1 cm) 140, 33 9, 34.7; D (38.1-53.3 cm) 61.7, 14.6, 8.7, 33.3; E (53.3-68.6 cm) 11.3, 2.7, 2.9, 10.9; F (68.6-83.8 cm) 1.6, 0.4, 0.6, 2.3; G (83.8-101.6 cm) 0.2, 0.04, 0.1, 0.5. Saplings 2179 stems/ha, dominated by sugar maple, sourwood, and red maple. Shrub cover 26%, average height 0.7 m, dominated by sugar maple, sassafras, and wild hydrangea. Canopy cover 86%; average tree height 27.3 m. A semi-permanent stream with a maximum width of about 1.5 m runs lengthwise across most of the plot. Edge: The plot is bordered on all sides by similar habitat, and lies within an area > 15,000 ha in size of forest interspersed with surface mines of various size and state of reclamation. Topography and Elevation: The plot is on a N-NE slope and has an average grade of

26%. Minimum elevation 600 m, maximum elevation 776 m. The densities in the following table are expressed as pairs/10 ha.

Species	1995	1996	1997	1998
Red-shouldered Hawk				V
Ruffed Grouse			V	
Wild Turkey			+	V
Yellow-billed Cuckoo	+			+
Red-bellied Woodpecker			+	
Downy Woodpecker	+	+	+	+
Hairy Woodpecker		1	0.5	1
Pileated Woodpecker	+	+	0.5	0.5
Eastern Wood-Pewee		+		
Acadian Flycatcher	2	2	V	+
Eastern Phoebe	1		1	
Yellow-throated Vireo	V			
Blue-headed Vireo	3.5	0.5	+	2
Red-eyed Vireo	17	9.5	10	14
Blue Jay	+	V	+	1
American Crow				V
Carolina Chickadee	0.5		+	1
Tufted Titmouse	V			0.5
White-breasted Nuthatch	+	+	1	1.5
Carolina Wren	+			V
Wood Thrush	4	2	1	2
Cedar Waxwing			V	
Black-throated Green Warbler	13	4.5	4	6
Cerulean Warbler	2	1.5	2	3
Black-and-white Warbler	2	3	2	5.5
American Redstart	8	3	4.5	13
Worm-eating Warbler	1.5	+	2.5	V
Ovenbird	29.5	18.5	15.5	21
Kentucky Warbler	V			
Hooded Warbler			V	V
Yellow-breasted Chat				7
Scarlet Tanager	12.5	4	5	
Eastern Towhee				
Northern Cardinal				
Rose-breasted Grosbeak	+	1		1
Indigo Bunting		V	3	V
Brown-headed Cowbird	1	+	V	+
Total	97.5	50.5	52.5	80
Territorial Species	21	18	20	17

VITA

Charles Patrick Nicholson was born in Knoxville, Tennessee on August 5, 1953. He grew up in Oak Ridge, Tennessee, Mol, Belgium, and Knoxville, where he graduated from Bearden High School in 1971. He attended the University of Tennessee, where he earned a B.S. in wildlife and fisheries science in 1975. He then attended the University of Maine where he earned a M.S. in wildlife management in 1977. He has been employed by the Tennessee Valley Authority since 1978 in a variety of positions involved with wildlife management and endangered species. He is presently Senior National Environmental Policy Act/Endangered Species Act Specialist in TVA's Environmental Policy & Planning group.