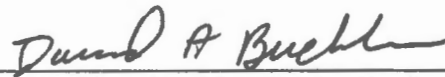


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**Relative Abundance of Breeding Birds and Habitat Associations of Select Neotropical  
Migrant Songbirds on the Cherokee National Forest, Tennessee.**

**A Thesis**

**Presented for the**

**Master of Science**

**Degree**

**The University of Tennessee, Knoxville**

**John G. Bartlett**

**August 1995**

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## ABSTRACT

Concern over apparent population declines of inland neotropical migrant birds in the United States has focused attention on the relationship between songbird habitat and forest management. To develop songbird habitat models and to assess the effects of forest management on songbirds, I surveyed breeding bird populations between 15 May and 1 July 1992 and 1993, using 20-minute, 50-m fixed-radius point counts on the Cherokee National Forest in eastern Tennessee. To assess habitat associations, I measured vegetation and physical habitat parameters at each point-count location on 0.04-ha circular plots. A sample of ~200 census points were randomly selected from the U.S. Forest Service Continuous Inventory of Stand Conditions (CISC) database for the Tellico Ranger District. Census points were stratified into 6 broad forest type classes and 3 stand condition classes.

We recorded 60 and 65 species of birds within 50 m on point counts in 1992 and 1993, respectively. Neotropical migrants comprised 73% of all species observed in 1992 and 78% of all species observed in 1993.

Optimal predictive models of habitat selection patterns by seven of the ten neotropical migrant songbird species deemed highest priority for management in the Southern Blue Ridge Mountains (acadian flycatcher (*Empidonax virescens*), black-throated blue warbler (*Dendroica caerulescens*), Canada warbler (*Wilsonia canadensis*), chestnut-sided warbler (*Dendroica pensylvanica*), hooded warbler (*Wilsonia citrina*), wood thrush (*Hylocichla mustelina*), and worm-eating warbler (*Helmitheros vermivorus*), were generated through stepwise logistic regression and best-subset selection

techniques and evaluated using Hosmer and Lemeshow's goodness-of-fit test and Wald's chi-square test. Unbiased correct classification (jackknife) rates for the final species models varied, with chestnut-sided warbler showing the strongest model (93.5% correct classification) and hooded warbler showing the weakest model (64.5% correct classification).

The best predictive model of acadian flycatcher distribution on the Tellico Ranger District contained five habitat variables - elevation, litter depth, basal area of saplings, stand age, and 38-53 cm dbh tree size class. The best black-throated blue warbler model contained six variables - elevation, % cover by *Vaccinium spp.*, litter depth, 53-68 cm dbh tree size class, ground cover %, and % cover by rhododendron (*Rhododendron maximum*). The Canada warbler model consisted of six variables - elevation, % cover by rhododendron, # of conifer trees, # tree species, % slope, and # standing snags. Chestnut-sided warbler distribution was best predicted by three habitat variables - elevation, canopy height, and litter depth. The hooded warbler stepwise model contained five variables - 15-23 cm dbh tree size class, % shrub cover, elevation, % slope and forest type. The wood thrush model contained three variables - 30-38 cm dbh tree size class, 53-68 cm dbh tree size class, and canopy height. The worm-eating warbler model contained six habitat variables - elevation, slope, # tree species, forest type, # deciduous trees, and total basal area.

Overall, elevation was the most important ( $P \leq 0.05$  - Wald Chi-square test) variable in predicting species' distributions, occurring in six of the seven priority species

models. Three of seven models contained ( $P \leq 0.05$  - Wald Chi-square test) slope and litter depth components.

I also used habitat parameters to develop predictive models for patterns of avian species richness and abundance. Models of species richness and abundance containing all measured and derived habitat variables ( $n=62$  variables) for neotropical migrant and resident songbirds explained 29 to 35% of the variation in the data ( $R^2 = 0.29 - 0.35$ ). Patterns of avian diversity, therefore, could not be predicted with a high degree of accuracy at this scale using standard forest vegetation variables.

I also used habitat variables available in the CISC database to develop models to predict the seven priority species' distributions (logistic regression) and avian species richness and abundance (linear regression). The CISC database yielded well-fitting models for the seven priority species ( $P \leq 0.05$ ) with correct classification rates (jackknife) ranging from 63% to 92%. Elevation was important ( $P \leq 0.05$  - Wald Chi-square test) in six of the seven priority species models. Selection patterns in cove hardwood, northern hardwood, and oak/hickory forest types were important ( $P \leq 0.05$  - Wald Chi-square test) in four of the seven CISC species models. CISC models for neotropical migrant and permanent resident richness and abundance had moderate predictive power ( $R^2 = 0.21 - 0.48$ ). The CISC database, thus, may not be useful for modeling patterns of avian diversity at the district level, although it worked well for single-species models.

## TABLE OF CONTENTS

| CHAPTER                                                                                                                                 | PAGE |
|-----------------------------------------------------------------------------------------------------------------------------------------|------|
| I. INTRODUCTION .....                                                                                                                   | 1    |
| II. STUDY AREA AND METHODS .....                                                                                                        | 6    |
| Study Area .....                                                                                                                        | 6    |
| Sampling Methods .....                                                                                                                  | 8    |
| Statistical Methods .....                                                                                                               | 19   |
| III. RESULTS .....                                                                                                                      | 34   |
| Descriptive Analysis .....                                                                                                              | 34   |
| Songbird-Habitat Models .....                                                                                                           | 39   |
| Richness and Abundance Models .....                                                                                                     | 71   |
| IV. DISCUSSION AND MANAGEMENT CONSIDERATIONS .....                                                                                      | 76   |
| Descriptive Analysis .....                                                                                                              | 76   |
| Selected Species Habitat Associations .....                                                                                             | 79   |
| Models of Avian Diversity .....                                                                                                         | 96   |
| Current Forest Management Practices .....                                                                                               | 97   |
| V. SUMMARY .....                                                                                                                        | 100  |
| LITERATURE CITED .....                                                                                                                  | 101  |
| APPENDIXES .....                                                                                                                        | 111  |
| APPENDIX A. Common and scientific names of woody plant species recorded on<br>vegetation plots .....                                    | 112  |
| APPENDIX B. Common and scientific names of avian species recorded on point ..<br>count surveys, 1992 and 1993 .....                     | 114  |
| APPENDIX C. Mean and standard error for physical and vegetative parameters<br>across six forest types and three condition classes ..... | 117  |
| APPENDIX D. Avian species occurrence and density across condition class<br>categories for six USFS forest types .....                   | 130  |
| VITA .....                                                                                                                              | 143  |



## LIST OF TABLES

| TABLE                                                                                                                                                                                                                                                                                     | PAGE |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 1. U.S. Forest Service CISC database forest types for the Tellico Ranger District and major forest type classes developed for this study, Cherokee National Forest, Tennessee.....                                                                                                        | 10   |
| 2. U.S. Forest Service CISC data for number of suitable and unsuitable hectares in each forest type and age category for both managed and wilderness portions, Tellico Ranger District, Cherokee National Forest, Tennessee .....                                                         | 10   |
| 3. Tree diameter classes for three USFS condition class categories and CISC codes included in our analysis for each, Cherokee National Forest, Tennessee .....                                                                                                                            | 12   |
| 4. Number of point counts conducted in each forest type/condition class combination during the 1992 and 1993 breeding seasons, Cherokee National Forest, Tennessee.....                                                                                                                   | 12   |
| 5. Physical and vegetative habitat variables derived from parameters measured at each point (n = 214) using a 11.3-m radius circular plot technique, Cherokee National Forest, Tennessee.....                                                                                             | 16   |
| 6. Number of points incorrectly classified by forest type in the CISC database according to global satellite positioning (GPS) ground-truthed locations and basal area dominance data gathered on 11.3-m radius vegetation plots at each point, Cherokee National Forest, Tennessee ..... | 19   |
| 7. Sample sizes for CISC forest-stand age categories, Cherokee National Forest, Tennessee.....                                                                                                                                                                                            | 21   |
| 8. Results of multicollinearity tests between 51 continuous physical and habitat variables used for model selection, Tellico Ranger District, Cherokee National Forest, Tennessee .....                                                                                                   | 25   |
| 9. Hypothetical classification table for 4 points, adapted from SAS (1990) .....                                                                                                                                                                                                          | 29   |
| 10. Analysis of variance test results for comparison of avian richness and abundance among forest type, condition class, and age class categories, Cherokee National Forest, Tennessee.....                                                                                               | 36   |

|     |                                                                                                                                                                                                                                                                                        |    |
|-----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| 11. | Result of model selections for response variable - acadian flycatcher. ....                                                                                                                                                                                                            | 44 |
| 12. | Result of model selections for response variable - black-throated blue warbler. .                                                                                                                                                                                                      | 48 |
| 13. | Result of model selections for response variable - Canada warbler. ....                                                                                                                                                                                                                | 52 |
| 14. | Result of model selections for response variable - chestnut-sided warbler. ....                                                                                                                                                                                                        | 56 |
| 15. | Result of model selections for response variable - hooded warbler. ....                                                                                                                                                                                                                | 60 |
| 16. | Result of model selections for response variable - wood thrush. ....                                                                                                                                                                                                                   | 65 |
| 17. | Result of model selections for response variable - worm-eating warbler. ....                                                                                                                                                                                                           | 69 |
| 18. | Linear regression analysis and resulting $R^2$ values for six diversity indices when<br>all predictor variables are included in the model ( $n = 62$ ), Cherokee National<br>Forest, Tennessee. ....                                                                                   | 72 |
| 19. | Results of model selections for six diversity indices using stepwise linear<br>regression techniques, Cherokee National Forest, Tennessee. ....                                                                                                                                        | 73 |
| 20. | Linear regression analysis and resulting $R^2$ values for the CISC database variables<br>with the elevation component included, Cherokee National Forest,<br>Tennessee. ....                                                                                                           | 74 |
| 21. | Estimated logits or predictive equations for calculating odds ratios ( $\psi$ ) and<br>habitat use probabilities based on final predictive habitat models and USFS<br>CISC database variables for seven species of neotropical songbirds, Cherokee<br>National Forest, Tennessee. .... | 92 |



## LIST OF FIGURES

| FIGURE                                                                                                                                                                                                                                                                | PAGE |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| 1. Study area location in the southern portion of the Cherokee National Forest, Tennessee.....                                                                                                                                                                        | 7    |
| 2. Procedures for developing predictive models of avian habitat relationships for high priority neotropical migrants and richness/abundance indices, Cherokee National Forest, Tennessee.....                                                                         | 22   |
| 3. Mean species richness and abundance per point for neotropical migrants, residents, and combined across six forest types, Cherokee National Forest, Tennessee.....                                                                                                  | 35   |
| 4. Mean species richness and abundance per point for neotropical migrants, residents, and combined across three condition classes, Cherokee National Forest, Tennessee.....                                                                                           | 38   |
| 5. Mean species richness and abundance per point for neotropical migrants, residents, and combined across nine stand age categories, Cherokee National Forest, Tennessee.....                                                                                         | 40   |
| 6. Percentage of points where acadian flycatcher was present and absent in 1992, 1993 or in both years, across five continuous habitat variables deemed best predictors of acadian flycatcher distribution, Cherokee National Forest, Tennessee.....                  | 41   |
| 7. Percentage of points where black-throated blue warbler was present and absent in 1992, 1993 or in both years, across six continuous habitat variables deemed best predictors of black-throated blue warbler distribution, Cherokee National Forest, Tennessee..... | 46   |
| 8. Percentage of points where Canada warbler was present and absent in 1992, 1993 or in both years, across six continuous habitat variables deemed best predictors of Canada warbler distribution, Cherokee National Forest, Tennessee.....                           | 50   |

|     |                                                                                                                                                                                                                                                            |    |
|-----|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| 9.  | Percentage of points where chestnut-sided warbler was present and absent in 1992, 1993 or in both years, across three continuous habitat variables deemed best predictors of chestnut-sided warbler distribution, Cherokee National Forest, Tennessee..... | 55 |
| 10. | Percentage of points where hooded warbler was present and absent in 1992, 1993 or in both years, across seven continuous habitat variables deemed best predictors of hooded warbler distribution, Cherokee National Forest, Tennessee.....                 | 58 |
| 11. | Percentage of points where wood thrush was present and absent in 1992, 1993 or in both years, across three continuous habitat variables deemed best predictors of wood thrush distribution, Cherokee National Forest, Tennessee .....                      | 64 |
| 12. | Percentage of points where worm-eating warbler was present and absent in 1992, 1993 or in both years, across five continuous habitat variables deemed best predictors of worm-eating warbler distribution, Cherokee National Forest, Tennessee.....        | 67 |

## CHAPTER I

### INTRODUCTION

Over the last decade, protection of neotropical migrant land birds has become a major conservation issue (Robbins et al. 1989b, Askins et al. 1990) because long-term studies of trends in songbird densities have revealed significant declines for many avian species occupying small forest tracts (Lynch and Whitcomb 1978, Robbins 1979, Butcher et al. 1981, Leck et al. 1981 and 1988, Ambuel and Temple 1982, Johnston and Winings 1987, Robbins et al. 1989b, Terborgh 1989, Askins et al. 1990, Finch 1991). Lynch and Whitcomb (1978) and Robbins (1979) attributed population declines of forest-interior birds to local forest fragmentation, leading to increased nest predation and parasitism associated with increased edge. In addition, local changes in presence, size, and distribution of forested habitats on the breeding grounds have been shown to affect populations of songbirds (Askins and Philbrick 1987, Holmes and Sherry 1988). Ongoing destruction of overwintering habitat in the neotropics may serve to hasten the population declines of many neotropical migrants (Briggs and Criswell 1978). Along with forest fragmentation and loss of winter habitat, human development of migratory stopover habitat may also be contributing to neotropical migrant declines (Moore and Simons 1992). My research addresses the individual habitat requirements of seven of these apparently declining species<sup>1</sup> in the Southern Appalachian portion of their range.

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<sup>1</sup> Bird species deemed highest priority for management and research in the Southern Blue Ridge Physiographic Province due to evidence of significant population declines and/or significant trends in habitat loss (Hunter et al. 1993).

Songbirds are a richly diverse and well-studied non-game resource. Their continued study and management is important for a variety of reasons, including: (1) to ensure quality wildlife recreational experiences for nonconsumptive forest users, (2) to maintain vital ecological links in the forest food chain, (3) to ensure control of forest insect pests and regulation of insect pest population eruptions (Dickson and Segelquist 1979), and (4) to more fully understand the community-level population dynamics of the ecosystem.

Increased public interest in nongame wildlife and non-consumptive recreational opportunities on federal and state-owned lands has challenged forest managers to develop an ecosystem approach to forest and rangeland management in the United States (Norse et al. 1986, Norton 1986). The 1985 National Survey of Fishing, Hunting and Wildlife-Associated Recreation (USDI 1989) showed that there are nearly 61 million bird-watchers in the U.S. (Wiedner and Kerlinger 1990). Only 3% of this number, however are strictly committed to viewing birds (Kellert 1985). The rest include birding as one of many outdoor activities and likely includes many of the estimated 46.6 million fishermen and 16.7 million hunters who consider presence of birds an essential part of the overall outdoor experience (USDI 1989). Thusly, avian species other than those threatened, endangered or showing trends towards minimum viable population levels should be incorporated into the forest management regime to ensure quality wildlife recreational experiences for consumptive and non-consumptive users.

Habitat selection by breeding forest birds is largely a function of vegetative structure (Anderson and Shugart 1974, Crawford et al. 1981, Kendeigh and Fawver

1981). If a given habitat supplies the individual bird with proximal cues that are correlated with the habitat's ultimate suitability and if accurate identification of a species' habitat requirements is possible, then bird communities can be managed for by managing habitat (Noon et al. 1980). Moreover, a bird species' distribution can be predicted by accurately quantifying components of the bird species' habitat that are deemed important correlates to its distribution.

Intensive timber management practices may drastically alter the vegetative structure of a forest with concomitant changes in the vertebrate community (Gauthreaux 1978, Noon et al. 1980, Maurer et al. 1981). By measuring the vegetative structure across the entire spectrum of successional stages and primary vegetation types on the Tellico District and by building predictive models of avian species' distributions, I linked avian species' distributions to vegetative structure. Also, because timber management is linked to vegetative structure, I can determine how timber management will affect breeding bird species diversity on the Tellico Ranger District.

Most attempts to characterize habitat in conjunction with studies of avian populations have been descriptive in nature (Capen et al. 1986). Building predictive models of avian habitat relationships is a recent trend in avian ecology (Robbins 1978, Rice et al. 1984, Capen et al. 1986, Rottenberry 1986, Smith and Connors 1986). The concept of quantifying components of a species' habitat is rooted in the theoretical perception that an animal's niche is a multidimensional space (Hutchinson 1958). One portion of a species' niche is the habitat in which it lives. Green (1971) suggested that the habitat niche can be accurately described by measuring appropriate environmental



variables and reducing the number of variables to those that describe important dimensions of the niche. I used vegetative sampling, point count surveys, and subsequent habitat modeling with multivariate statistical techniques to identify the habitat variables that most accurately predict the distributions of several neotropical migrant songbirds. Thus, future impacts of timber management can be predicted for these select species and management alternatives can be weighed according to their relative impacts.

Establishing baseline population densities, relative abundance, and forest habitat models for breeding songbirds within the framework of existing forest management protocols and resources is an important step in assessing future population and habitat-use trends. Currently, knowledge of how different bird species respond to variations in forest type and timber size class (condition class) is useful to USFS land managers because they manage size distribution of trees by forest type and must account for the effects of forest management practices on a wide variety of other resources, especially wildlife. In fact, the USFS is legally mandated to maintain and enhance current levels of biological diversity on their lands through the National Forest Management Act of 1976. My baseline data on avian densities and relative abundance across several key vegetation classes currently being used by the USFS for maintaining timber inventories provides the Tellico Ranger District with information vital to the future assessment of timber management impacts on breeding bird populations.

The objectives of this two-year study on the habitat relationships of breeding songbirds on the Cherokee National Forest were: (1) to document the relative abundance of songbirds by forest type, timber size class, and forest stand age, (2) to use habitat

characteristics to develop models that accurately predict the distributions of seven high priority neotropical migrant species, and (3) to use habitat characteristics to develop models that accurately predict patterns of avian richness and abundance.

## **CHAPTER II**

### **STUDY AREA AND METHODS**

#### **STUDY AREA**

##### **History**

The study area was the Tellico Ranger District, located in the southern portion of the Cherokee National Forest in Monroe County, Tennessee (Figure 1). The area was first logged in the 1890's by the Smoky Mountain Timber and Improvement Company. By 1925, only small pockets of uncut timber remained (Lambert 1961, Sulzer 1975). Federal funds became available for purchasing the denuded Tellico and Citico river drainages as well as much of the Unaka Mountains in 1911 through the Weeks Law. The forested lands were consolidated into the Cherokee National Forest on July 8, 1936 (Maughan 1939).

##### **Description**

The 49,928-ha Tellico District, located in the Southern Appalachian Mountains, has elevations ranging from 244 m to 1668 m above sea level (USGS 1985). The Little Tennessee River forms the northern boundary of the district, while the Nantahala National Forest in North Carolina constitutes the east - southeast boundary. The Great Smoky Mountains National Park (GSMNP) bisects the three northern and three southern Cherokee National Forest Ranger Districts. The Tellico Ranger District lies directly



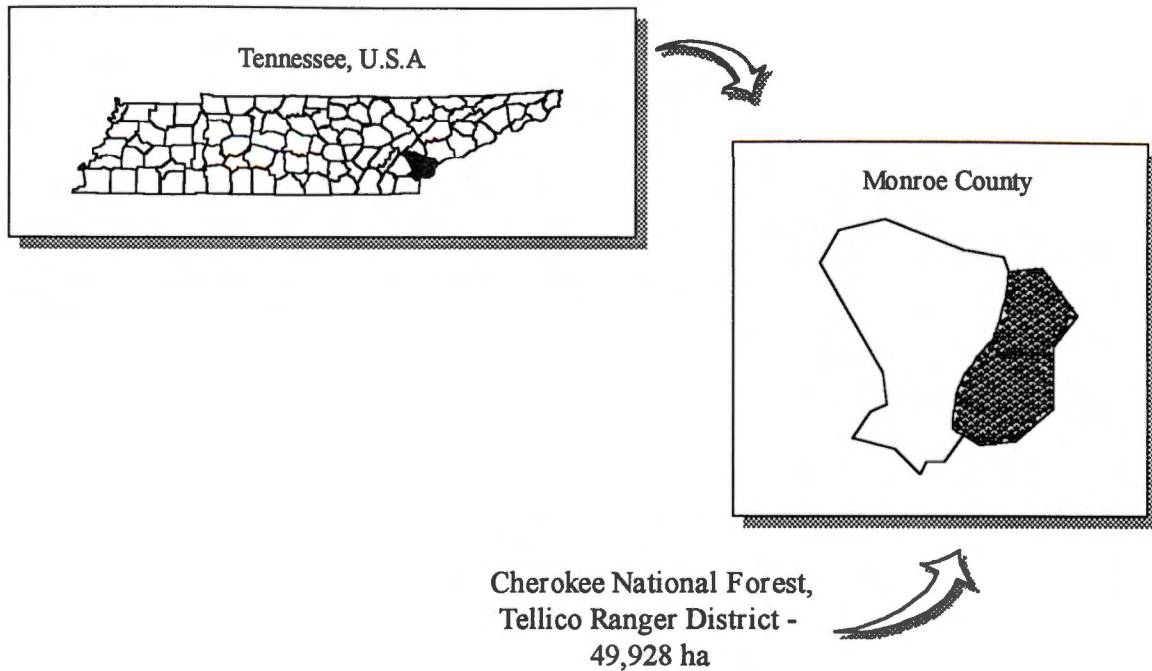


Figure 1. Study area location in the southern portion of the Cherokee National Forest, Tennessee.

southwest of the park. The Tellico District is bisected by two main river drainages: the Tellico River drainage to the south and the Citico Creek drainage to the north. Each river drainage supports a wilderness area: the Bald River Gorge Wilderness (Tellico drainage) and the Citico Creek Wilderness (Citico drainage) (USGS 1985).

Yearly average precipitation for the Citico Creek drainage in an earlier 11-year study was 178 cm, with runoff 56 % of total precipitation. Air temperatures varied from -25° C to 34° C ( $\bar{x}$  = 12.4° C) and average relative humidity was 86.1% (TVA 1972).

The principal rock type of the area is Thunderhead Sandstone (Ocoee Series) and the underlying metamorphic bedrock is granitic gneiss (TVA 1963). Soils of the area have been placed into five major series, depending on texture, percent slope, and slope angle

(Bowman 1911, Robinson 1963, TVA 1968, U.S. Soil Conservation Service 1974, U.S. Dept. of Trans. 1976, Malter 1977):

- *Barbourville Series*, 20%. These are well-drained, slightly acid soils found on flat ridge tops, wide slopes, and at the base of mountains. These soils are dominated by northern red oak (*Quercus rubra*), sugar maple (*Acer saccharum*), and yellow poplar (*Liriodendron tulipifera*).
- *Jefferson Series*, 7%. These are very acid soils, typically found on well-drained east and south slopes at the base or on lower slopes. Trees most commonly associated with this series are hickory (*Carya spp.*), sweet birch (*Betula lenta*), white oak (*Quercus alba*), yellow birch (*Betula alleghaniensis*), and yellow poplar.
- *Matney Series*, 27%. These soils are very strongly acid and occur at high elevations, particularly on flat ridges and on the shallower slopes associated with these ridges. Common tree species are black gum (*Nyssa sylvatica*), chestnut oak (*Quercus prinus*), pitch pine (*Pinus rigida*), yellow birch, and Virginia pine (*Pinus virginiana*).
- *Ramsey Series*, 31%. These soils are sandy, well-drained, and strongly acid. This series occurs at high elevations on the district, particularly on steep slopes and ridges. These sites are highly susceptible to landslide and erosion from unstable weather conditions or human use. The ericaceous shrubs (Appendix A) occur here, along with American beech (*Fagus grandifolia*), chestnut oak, red maple (*Acer rubrum*), and table mountain pine (*Pinus pungens*).
- *Stony Colluvium, Ramsey Soil Material*, 14%. These are strongly acid, well-drained types occurring on 60% to 90% slopes. Trees in this series are generally reduced in stature and a dense layer of ericaceous shrubs is often present.

## SAMPLING METHODS

I made two important assumptions regarding my general approach to randomly surveying avian populations, quantifying habitat characteristics, and assessing habitat-use trends:

- the district-wide avian species assemblage was influenced primarily by the resources and other conditions at the breeding site as opposed to the proximity and type of other potential habitat in the region (source-sink dynamics) (Pulliam 1988).

- within-stand characteristics of a forest stand were relatively homogenous.

## Stand Selection

**Forest Type Categories-** The Tellico District is comprised of predominately even-aged stands of several forest types. Forest types are classified by the USFS based on  $\geq 50\%$  dominance of a single tree species or  $\geq 70\%$  dominance of two tree species. The forest stand, a plant community with sufficient uniformity of structure and composition to distinguish it from adjacent stands, is the primary management unit. I grouped all stands from all existing forest types into six major forest type categories using the CISC database - cove hardwood, eastern hemlock (*Tsuga canadensis*<sup>1</sup>)/white pine (*Pinus strobus*), mixed hardwood/yellow pine, northern hardwood, oak/hickory, and yellow pine (Table 1).

Typical stands range in size from 2 ha to over 160 ha.

Cove hardwood types were dominated primarily by yellow poplar and secondarily by eastern hemlock, northern red oak, white oak, and white pine (Table 1). For cove hardwood types, 51% of the stand area on the Tellico District was suitable for timber management according to the CISC database (Table 2) (Fryer 1994). For eastern hemlock/white pine types (Table 1), 74% of the stand area was suitable for management (Table 2). Mixed hardwood/pine types were co-dominated by hardwood and softwood tree species. Dominant mixed hardwood/pine species included: chestnut oak, northern red oak, pitch pine, shortleaf pine (*Pinus echinata*), table mountain pine, Virginia pine, white oak, and/or white pine (Table 1). For mixed hardwood/pine types, 51% of the stand area was suitable for management (Table 2). The northern hardwood forest type was

---

<sup>1</sup> Scientific names of tree species are listed in Appendix A.

Table 1. U. S. Forest Service CISC database forest types for the Tellico Ranger District and major forest type classes developed for this study, Cherokee National Forest, Tennessee. Specific scientific names are listed in Appendix A.

| USFS CISC Forest Types                   | Major Forest Types - This Study | Acronym |
|------------------------------------------|---------------------------------|---------|
| Cove Hardwoods - White Pine - Hemlock    | Cove Hardwood                   | COVEHD  |
| Yellow Poplar - White Oak - N. Red Oak   | Cove Hardwood                   |         |
| Hemlock                                  | Eastern Hemlock / White Pine    | HEMLCK  |
| White Pine                               | Eastern Hemlock / White Pine    |         |
| White Pine - Hemlock                     | Eastern Hemlock / White Pine    |         |
| Chestnut Oak - Scarlet Oak - Yellow Pine | Mixed Hardwood / Yellow Pine    | MXEDHP  |
| N. Red Oak - Hickory - Yellow Pine       | Mixed Hardwood / Yellow Pine    |         |
| Pitch Pine - Oak                         | Mixed Hardwood / Yellow Pine    |         |
| Shortleaf Pine - Oak                     | Mixed Hardwood / Yellow Pine    |         |
| Table Mountain Pine - Hardwood           | Mixed Hardwood / Yellow Pine    |         |
| Virginia Pine - Oak                      | Mixed Hardwood / Yellow Pine    |         |
| White Oak - Black Oak - Yellow Pine      | Mixed Hardwood / Yellow Pine    |         |
| White Pine - Upland Hardwood             | Mixed Hardwood / Yellow Pine    |         |
| Sugar Maple - Beech - Yellow Birch       | Northern Hardwood               | NORHWD  |
| Chestnut Oak                             | Oak / Hickory                   | OAKHIC  |
| Chestnut Oak - Scarlet Oak               | Oak / Hickory                   |         |
| N. Red Oak                               | Oak / Hickory                   |         |
| Scarlet Oak                              | Oak / Hickory                   |         |
| Scrub Oak                                | Oak / Hickory                   |         |
| White Oak                                | Oak / Hickory                   |         |
| White Oak - N. Red Oak - Hickory         | Oak / Hickory                   |         |
| Pitch Pine                               | Yellow Pine                     | YEPINE  |
| Shortleaf Pine                           | Yellow Pine                     |         |
| Table Mountain Pine                      | Yellow Pine                     |         |
| Virginia Pine                            | Yellow Pine                     |         |

Table 2. U.S. Forest Service CISC data for number of suitable (suitable for timber management) and unsuitable (not suitable for timber management) hectares in each forest type and age category for both managed and wilderness portions, Tellico Ranger District, Cherokee National Forest, Tennessee.

| Forest Type                 | Suitable Hectares |                  |               | Unsuitable Hectares |                  |               |
|-----------------------------|-------------------|------------------|---------------|---------------------|------------------|---------------|
|                             | 0 - 20<br>years   | 21 - 60<br>years | > 60<br>years | 0 - 20<br>years     | 21 - 60<br>years | > 60<br>years |
| Cove Hardwood               | 432               | 141              | 5,728         | 143                 | 591              | 5,241         |
| Eastern Hemlock/ White Pine | 412               | 532              | 410           | 113                 | 12               | 341           |
| Mixed Hardwood / Pine       | 320               | 738              | 3,618         | 207                 | 244              | 4,119         |
| Northern Hardwood           | 96                | 42               | 199           | 68                  | 505              | 871           |
| Oak/Hickory                 | 248               | 183              | 4,584         | 109                 | 597              | 6,180         |
| Yellow Pine                 | 2,707             | 2,126            | 2,772         | 102                 | 756              | 2,813         |
| <b>TOTALS</b>               | <b>4,215</b>      | <b>3,763</b>     | <b>17,310</b> | <b>743</b>          | <b>2,706</b>     | <b>19,566</b> |

dominated by sugar maple, American beech (*Fagus grandifolia*), and yellow birch. Only 19% of the northern hardwood stand area was suitable for forest management.

Oak/hickory forest types were dominated by chestnut oak, northern red oak, scarlet oak, and/or white oak (Table 1). For oak/hickory forest types, 42% of the area was suitable for management. Yellow pine forest types were dominated by pitch pine, shortleaf pine, table mountain pine, and/or Virginia pine (Table 1). For yellow pine stands, 67% of the area was suitable for management (Table 2).

***Condition Class Categories-*** Forest stands within a particular forest type were subdivided according to the sizes of the dominant trees in the stand. These size class categories or condition classes were based on the USFS tree diameter classification scheme: seedling/sapling, poletimber, and sawtimber (Table 3). Tree diameter groupings for these classes were different for hardwoods and softwoods. Forest stands dominated by hardwood or softwood trees < 10 cm diameter at breast height (dbh) were classed as seedling/saplings stands. Poletimber stands were those dominated by 10-30 cm dbh hardwood trees or 10-25 cm dbh softwood trees. Sawtimber stands were dominated by >30 cm dbh hardwoods or >25 cm dbh softwoods.

My goal was to randomly select 30 stands from those available in each of the six major forest types, stratified evenly into the three condition classes. There were 18 combinations of forest type and condition class; thus I wanted to select a total of 180 stands for evaluation (Table 4). The Tellico Ranger District contains 2,858 stands. In several cases, 10 stands were not available on the district within a given forest type-condition class combination. In these cases, I located two or more point count sites in a single stand. Additionally, in a few cases, the survey point location based on global

Table 3. Tree diameter classes for three USFS condition class categories and CISC codes included in our analysis for each, Cherokee National Forest, Tennessee.

| Condition Class | Hardwood Types | Softwood Types | USFS CISC Codes                                                              | Acronym |
|-----------------|----------------|----------------|------------------------------------------------------------------------------|---------|
| seed/sapling    | < 10 cm dbh    | < 10 cm dbh    | 1 (regeneration)<br>13 (adequately stocked)<br>14 (inadequately stocked)     | SEEDLG  |
| poletimber      | 10-30 cm dbh   | 10-25 cm dbh   | 2 (damaged)<br>5 (sparse)<br>7 (low quality)<br>9 (mature)<br>11 (immature)  | POLTMB  |
| sawtimber       | >30 cm dbh     | >25 cm dbh     | 3 (damaged)<br>6 (sparse)<br>8 (low quality)<br>10 (mature)<br>12 (immature) | SAWTMB  |

Table 4. Number of point counts conducted in each forest type/condition class combination during the 1992 and 1993 breeding seasons, Cherokee National Forest, Tennessee.

| Forest Type                    | Condition Class  | 1992 season | 1993 season |
|--------------------------------|------------------|-------------|-------------|
| Cove Hardwood                  | seedling/sapling | 9           | 13          |
|                                | poletimber       | 12          | 13          |
|                                | sawtimber        | 15          | 15          |
| Eastern Hemlock/<br>White Pine | seedling/sapling | 10          | 12          |
|                                | poletimber       | 8           | 12          |
|                                | sawtimber        | 10          | 11          |
| Mixed Hardwood / Pine          | seedling/sapling | 10          | 14          |
|                                | poletimber       | 9           | 11          |
|                                | sawtimber        | 13          | 12          |
| Northern Hardwood              | seedling/sapling | 11          | 12          |
|                                | poletimber       | 9           | 10          |
|                                | sawtimber        | 12          | 12          |
| Oak / Hickory                  | seedling/sapling | 5           | 6           |
|                                | poletimber       | 7           | 11          |
|                                | sawtimber        | 11          | 12          |
| Yellow Pine                    | seedling/sapling | 8           | 15          |
|                                | poletimber       | 11          | 13          |
|                                | sawtimber        | 13          | 9           |
| Total # of Counts =            |                  | 183         | 213         |



positioning system (GPS) technology placed the point in a different forest stand than that which I thought I was surveying. This resulted in changing the forest type and/or condition class for a few points. In 1993, I added additional randomly-selected stands as time and availability permitted. Thus, sample sizes among forest type-condition class combinations and between years were slightly unequal (Table 4). Sampling within each of the forest type-condition class combinations was further stratified based on 5 stand size categories to eliminate potential biases among different stand sizes (Robbins 1979): 5-10 ha, 10-15 ha, 15-25 ha, 25-40 ha, and >40 ha. Selected stands were located by navigating with USFS stand maps from known locations with compass bearings and pacing prior to avian censuses. CISC forest type and condition class listings were visually verified during original location. Incorrectly typed stands were replaced.

### **Avian Surveys**

I conducted 50-m radius, 20-minute duration point counts (Hutto et al. 1986) to survey breeding bird populations from 15 May-5 July, 1992 and 13 May-1 July, 1993.

Two assumptions coincided with the use of this technique:

- the distribution of birds during counts was unaffected by the observer's approach to and presence at the point count location.
- there was no error in estimating the distances of birds relative to plot center.

I conducted point counts in the interior of each selected stand, at least 100 meters inside the outer edge of the stand to eliminate edge/ecotone effects (Elliott 1987). To eliminate potential seasonal sampling biases associated with condition class, elevation, forest type,



and/or species-specific life histories, I scheduled approximately three points within each forest type-condition class group for census every ten days of the six-week breeding season.

I conducted point counts from 0600 to 1000 EST for a duration of 20 minutes. Hutto et al. (1986) and Verner and Ritter (1986) found no hourly variation in avian species richness or abundance over the first 4-5 hours after sunrise. Gauthreaux (1971) suggested that early morning counts may tend to reduce the number of spring migrants or 'contaminants' that may otherwise bias the breeding sample. To ensure compatibility with a wide range of count durations currently being used by other researchers, I divided my 20-minute counts into 0-3 minute, 3-5 minute, 5-10 minute, and 10-20 minute time interval data. I visually divided the 50-m count radius into 25 m and 50 m radius concentric circles and I recorded birds in the following distance categories: 0-25 m, 26-50 m, and >50 m. Counts began immediately upon arrival at plot center and all birds seen or heard were recorded in their respective time interval and distance category. Counts were not conducted during periods of precipitation. In a few instances, weather conditions deteriorated after the survey began. Data for those counts were not used, and the point count was repeated. I report descriptive and statistical analyses based only on data recorded within 50 m for 20 minutes on point counts. Birds observed flying over the area were recorded but not included in the analysis. All bird species recorded within 50 m on point counts for both 1992 and 1993 are listed in Appendix B.

## **Habitat Evaluation**

I assumed that the area around the point count location represented breeding habitat for the bird species detected at a given point. I characterized the habitat associated with each location by measuring a wide range of physical and vegetative parameters within 11.3-m radius (0.04-ha) circular plots centered on the point count location. I measured the following habitat variables: (1) all woody stems were identified to species, (2) diameters of trees and snags >10 cm dbh were measured, (3) all saplings < 10 cm dbh were counted, (4) percent shrub cover was estimated across each plot (ocular estimate), (5) litter depth (cm), percent canopy cover (spherical densiometer), and percent ground cover (ocular estimate) were estimated in each cardinal direction 3 m from plot center, (6) percent ground cover of dominant herbaceous species and shrub species were recorded, (7) average canopy height was measured in meters (clinometer), and (8) percent slope (clinometer) and aspect (compass) were recorded. I derived many habitat parameters from the preceding list of field measurements (Table 5). I calculated means and standard errors for all physical and vegetative parameters across each forest type-condition class combination (Appendix C).

## **Global Satellite Positioning**

I revisited 193 point count locations (90% of total) in winter 1993 and used global satellite positioning technology to establish Universal Transverse Mercator (UTM) coordinates for each point. I overlaid these coordinates on USFS maps to determine which stand within a compartment was actually censused. I performed all statistical analyses using the adjusted forest type and condition class parameters provided by the

Table 5. Physical and vegetative habitat variables derived from parameters measured at each point (n = 214) using a 11.3-m radius circular plot technique, Cherokee National Forest, Tennessee. Basal area is per 0.04 hectares. Asterisks denote variables used initially in high priority species' models; all variables were used to model species richness and abundance.

| Abbreviation | Variable Name                               | Description of Measured or Derived Variable                                     |
|--------------|---------------------------------------------|---------------------------------------------------------------------------------|
| 10-15DBH *   | # of trees in 10-15 cm dbh range            | total number of trees between 10 and 14.9 cm dbh counted on 0.04-ha plots       |
| 15-23DBH *   | # of trees in 15-23 cm dbh range            | total number of trees between 15 and 22.9 cm dbh counted on 0.04-ha plots       |
| 23-30DBH *   | # of trees in 23-30 cm dbh range            | total number of trees between 23 and 29.9 cm dbh counted on 0.04-ha plots       |
| 30-38DBH *   | # of trees in 30-38 cm dbh range            | total number of trees between 30 and 37.9 cm dbh counted on 0.04-ha plots       |
| 38-53DBH *   | # of trees in 38-53 cm dbh range            | total number of trees between 38 and 52.9 cm dbh counted on 0.04-ha plots       |
| 53-68DBH *   | # of trees in 53-68 cm dbh range            | total number of trees between 53 and 67.9 cm dbh counted on 0.04-ha plots       |
| AMBECH       | # of American beech trees                   | number of American beech trees counted per 0.04 hectares                        |
| ASPECT *     | aspect                                      | eight directional categories measured once per point at plot center in degrees  |
| BLAGUM       | # of blackgum trees                         | number of blackgum trees counted per 0.04-ha plot                               |
| BLAOAK       | # of black oak trees                        | number of black oak trees counted per 0.04-ha plot                              |
| BKBRCH       | # of black birch trees                      | number of black birch trees counted per 0.04-ha plot                            |
| BKLCST       | # of black locust trees                     | number of black locust trees counted per 0.04-ha plot                           |
| BSLSAP *     | basal area of saplings (m <sup>2</sup> /ha) | (0.5 cm dbh per sapling) x (number of saplings counted on 0.04-ha plots)        |
| CHTOAK       | # of chestnut oak trees                     | number of chestnut oak trees counted per 0.04-ha plot                           |
| CNDCLS *     | condition class                             | CISC inventory category - seed/sapling, poletimber, sawtimber                   |
| CNPYCR *     | % canopy cover                              | average of four measured locations per point using a spherical densiometer      |
| CNPYHT *     | canopy height                               | average tree height per 0.04-ha plot measured by clinometer                     |
| CONFRQ *     | # of conifer trees                          | total number of coniferous trees (> 10 cm dbh) counted on 0.04-ha plots         |
| COVEHD *     | cove hardwood forest type                   | design (dummy) variable derived from the CISC inventory                         |
| CSLVRB       | # of Carolina silverbell trees              | number of Carolina silverbell trees counted per 0.04-ha plot                    |
| DECFRQ *     | # of deciduous trees                        | total number of deciduous trees (> 10 cm dbh) counted on 0.04-ha plots          |
| ELEVTN *     | elevation (meters)                          | elevation above sea level measured with a Global Positioning System unit (feet) |
| FDGWOD       | # of flowering dogwood trees                | number of flowering dogwood trees counted per 0.04-ha plot                      |
| FORTYP *     | forest type                                 | CISC inventory category - six forest types                                      |
| GRNDCV *     | ground cover percent                        | average of four measured locations per point (ocular estimate)                  |
| HEMLCK *     | e. hemlock / w. pine forest type            | design (dummy) variable derived from the CISC inventory                         |
| HEMTRE       | # of eastern hemlock trees                  | number of eastern hemlock trees counted per 0.04-ha plot                        |
| LITDPH *     | litter depth                                | average of four measured locations per point (cm)                               |
| MHCKRY       | # of mockernut hickory trees                | number of mockernut hickory trees counted per 0.04-ha plot                      |
| MXEDHP *     | mixed hardwood / pine forest type           | design (dummy) variable derived from the CISC inventory                         |

Table 5. (continued)

| Abbreviation | Variable Name                                              | Description of Measured or Derived Variable                                          |
|--------------|------------------------------------------------------------|--------------------------------------------------------------------------------------|
| NORHWD       | * northern hardwood forest type                            | design (dummy) variable derived from the CISC inventory                              |
| NOTRSP       | * tree species count                                       | total number of tree species counted on 0.04-ha plots                                |
| NRDOAK       | * # of n. red oak trees                                    | number of n. red oak trees counted per 0.04-ha plot                                  |
| OAKHIC       | * oak / hickory forest type                                | design (dummy) variable derived from the CISC inventory                              |
| POLTMB       | * poletimber age class                                     | design (dummy) variable derived from the CISC inventory                              |
| PTCHPN       | * # of pitch pine trees                                    | number of pitch pine trees counted per 0.04-ha plot                                  |
| RDMAPL       | * # of red maple trees                                     | number of red maple trees counted per 0.04-ha plot                                   |
| RHODCR       | * % cover by rhododendron                                  | ocular estimate of area covered by the dominant shrub species                        |
| RHODDN       | * # of rhododendrons (>10 cm dbh)                          | number of stems counted per 0.04-ha plot                                             |
| SAPNUM       | * sapling count                                            | total number of saplings counted on 0.04-ha plots                                    |
| SAWTMB       | * sawtimber age class                                      | design (dummy) variable derived from the CISC inventory                              |
| SCTOAK       | * # of scarlet oak trees                                   | number of scarlet oak trees counted per 0.04-ha plot                                 |
| SEEDLG       | * seedling / sapling age class                             | design (dummy) variable derived from the CISC inventory                              |
| SGRMPL       | * # of sugar maple trees                                   | number of sugar maple trees counted per 0.04-ha plot                                 |
| SHRBCV       | * % cvr of all shrubs                                      | mean ocular estimate by two observers of percent of 0.04-ha plot covered by shrubs   |
| SHRTLF       | * # of shortleaf pine trees                                | number of shortleaf pine trees counted per 0.04-ha plot                              |
| SLOPE%       | * slope                                                    | measured down-slope at plot center using a clinometer (%)                            |
| SNGBDM       | * % basal dominance by snags (m <sup>2</sup> /ha)          | (total basal area of standing snags) / (total basal area on plot) x 100% (ha)        |
| SNGBSM       | * basal sum of snags (m <sup>2</sup> /ha)                  | total basal area for all standing snags (>10 cm dbh) (ha)                            |
| SNGFRQ       | * # of standing snags                                      | total number of standing snags (> 10 cm dbh) counted on 0.04-ha plots                |
| STENDX       | * site quality index                                       | index of avg. tree growth relative to avg. tree age / stand - from the CISC database |
| STNDGE       | * stand age (years after cutting)                          | years since last harvest, CISC inventory                                             |
| STNDSZ       | * stand size                                               | area (ha) of stand, CISC inventory                                                   |
| TOTBSL       | * total basal area/point (>10 cm dbh) (m <sup>2</sup> /ha) | total basal area for all trees (>10 cm dbh) on 0.04-ha plots                         |
| TOTNTR       | * total frequency of trees (>10 cm dbh)                    | total number of trees (>10 cm dbh) counted on 0.04-ha plots                          |
| VACCVR       | * % cover by vaccinium spp.                                | ocular estimate of area covered by the vaccinium shrubs on 0.04-ha plots             |
| VAPINE       | * # of Virginia pine trees                                 | number of Virginia pine trees counted per 0.04-ha plot                               |
| WHTOAK       | * # of white oak trees                                     | number of white oak trees counted per 0.04-ha plot                                   |
| WHTPNE       | * # of white pine trees                                    | number of white pine trees counted per 0.04-ha plot                                  |
| YBIRCH       | * # of yellow birch trees                                  | number of yellow birch trees counted per 0.04-ha plot                                |
| YEPINE       | * yellow pine forest type                                  | design (dummy) variable derived from the CISC inventory                              |
| YPOPLR       | * # of yellow poplar trees                                 | number of yellow poplar trees counted per 0.04-ha plot                               |

CISC database. I used a Trimble® Pathfinder Professional GPS unit (Trimble Corp., Sunnyvale, CA) and a base station to differentially correct locations. Jasumback and Luepke (1992) tested the accuracy of the Pathfinder model under a dense hardwood tree canopy in Indiana and recorded an average horizontal position error of 3.7 meters for a similar approach to what I used. I used the 3D positioning mode on the unit to establish permanent elevation readings. I used point elevations in subsequent habitat modeling.

I used the GPS-corrected point locations to compare the CISC forest type grouping (i.e...cove hardwood) for each sampled forest stand to the percent basal area ( $\text{m}^2/\text{ha}$ ) of the trees actually recorded during vegetation surveys at each point (Table 6). I then classified each point count location based on the top two dominant tree species at each point. If the dominant species failed to fall within the CISC forest type grouping for that point, I labeled the point as 'incorrectly classified' by the CISC database. Of the 193 points corrected with a GPS location, 19% were incorrectly classified by the CISC database according to my vegetation measurements. This estimated misclassification rate may be inaccurate, however, because the CISC forest type signified what a given stand was expected to develop into upon maturity. Approximately one-third of our stands were seedling/sapling stands that may ultimately develop into the CISC forest type. Therefore, two reasons for misclassification existed: (1) a given stand had yet to mature into the CISC forest type and/or (2) a given stand will never mature into the CISC forest type because it was misclassified. For my purposes, I used the original CISC forest type classification for the descriptive analysis and for the 'forest type' modeling variable. I also



Table 6. Number of points incorrectly classified by forest type in the CISC database according to global satellite positioning (GPS) ground-truthed locations and basal area dominance data gathered on 11.3-m radius vegetation plots at each point, Cherokee National Forest, Tennessee.

| Forest Type                | % Incorrectly Classified | Total Number of Points Visited - (1992 and 1993) |
|----------------------------|--------------------------|--------------------------------------------------|
| Cove Hardwood              | 24                       | 42                                               |
| Eastern Hemlock/White Pine | 23                       | 35                                               |
| Mixed Hardwood/Pine        | 0                        | 38                                               |
| Northern Hardwood          | 3                        | 34                                               |
| Oak / Hickory              | 28                       | 29                                               |
| Yellow Pine                | 27                       | 37                                               |

included dominant tree species as individual variables in the modeling portion of my analysis (see Table 5).

## STATISTICAL METHODS

### Relative Abundance

All birds recorded within 50 m on point counts were included in this analysis. I assigned species to two groups (neotropical migrant (migrant) and short-distant migrant/permanent resident (resident)) based on the Southeastern Working Group-Partner's in Flight designations (Hamel 1992). The following indices were calculated from each point count:

- *migrant species richness* (number of neotropical migrant species observed at each point)
- *resident species richness* (number of resident species observed at each point)
- *combined species richness* (number of neotropical migrant and resident species observed at each point)
- *migrant species abundance* (number of individual neotropical migrant birds observed at each point)

- *resident species abundance* (number of individual resident birds observed at each point)
- *combined species abundance* (total number of individual birds observed at each point)

I used a one-way analysis of variance (ANOVA) test to determine if within-group differences ( $P \leq 0.05$ ) occurred for each descriptive avian index (e.g. migrant richness) when analyzed across forest type, condition class, and age class. If significant differences in means were present for a given index ( $P \leq 0.05$ ), I used Duncan's multiple range test for pairwise comparisons (SAS 1990). The stand age category was derived by assigning each stand age from CISC to the appropriate 10-year age intervals (Table 7). The age category variable was not used in subsequent habitat modeling. Instead, I used the CISC condition class variable and stand age variable, which directly represent the CISC database.

## **Predictive Models**

The main objective of the model-building portion of my research was to find the best fitting, most parsimonious models to accurately predict the avian species' distribution or richness/abundance indices with a set of explanatory habitat variables, within the context of sound biological principles (Hosmer and Lemeshow 1989). This was achieved by obtaining the best 'fitting' model for each high priority species or diversity index while minimizing the number of parameters or independent variables in the model. The best fitting models for high priority species were defined as those that had high correct classification rates (concordance and jackknife tests), acceptable ( $P > 0.05$ ) goodness-of-fit scores (Hosmer-Lemeshow test), and acceptable ( $P \leq 0.05$ ) Wald



Table 7. Sample sizes for CISC forest-stand age categories, Cherokee National Forest, Tennessee.

| Stand Age Category | Sample Size |            |
|--------------------|-------------|------------|
|                    | 1992        | 1993       |
| 0-10 years         | 21          | 29         |
| 11-20 years        | 32          | 35         |
| 21-30 years        | 19          | 23         |
| 31-40 years        | 9           | 13         |
| 41-50 years        | 4           | 7          |
| 51-60 years        | 20          | 26         |
| 61-70 years        | 18          | 18         |
| 71-80 years        | 28          | 29         |
| 81-90 years        | 23          | 22         |
| >90 years          | 9           | 11         |
| <i>TOTALS =</i>    | <i>183</i>  | <i>213</i> |

chi-square scores. For richness/abundance models, high  $R^2$ 's (on a scale of 0 to 1) indicate that much of the variation in the index was explained by the chosen independent variables. Because regression techniques were used in the entire analysis, the underlying null hypothesis for all model selections was: *the slope coefficients for the independent variables in any given model were equal to zero*. If I successfully rejected the null hypothesis ( $P \leq 0.05$ ), it indicated a significant relationship between any given independent variable or group of variables and the dependent variable. I decided not to incorporate interaction or quadratic terms into the model selection process because of the large number of models and habitat variables involved. A more detailed description of the model development procedures used follows (Figure 2).

**General.** I combined the 1992 and 1993 datasets for model development. To define high priority species' distributions, I recorded a species as 'present' at a point location if it was ever observed there (1992 or 1993 or both years). For richness and abundance indices, the combined dataset contained the average of 1992 and 1993 richness

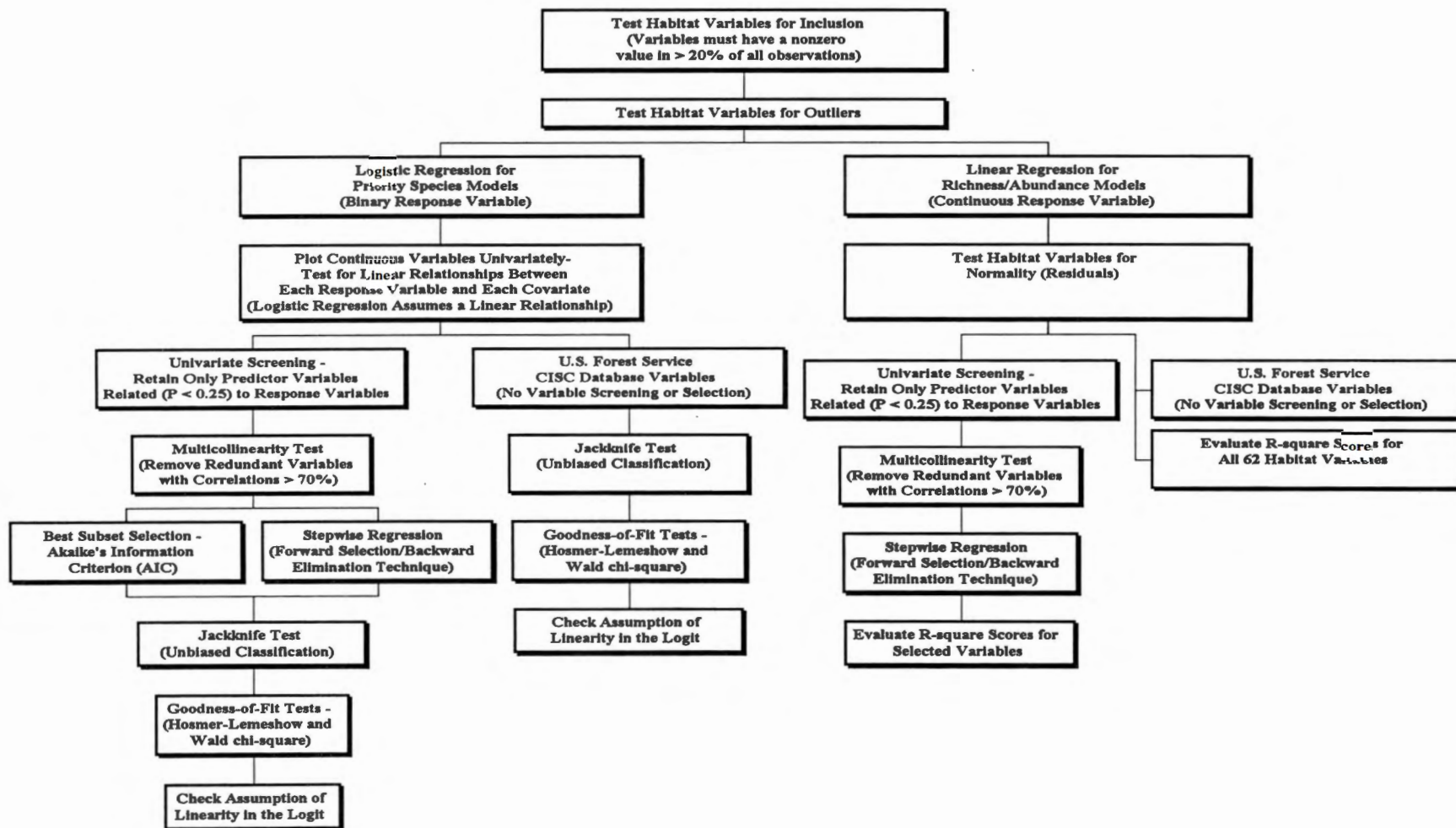


Figure 2. Procedures for developing predictive models of avian habitat relationships for high priority neotropical migrants and richness/abundance indices, Cherokee National Forest, Tennessee.

and abundance scores for each point. My general approach to model development was to first screen all variables for inclusion, then test each variable univariately against the given response variable. Next, I placed all significant ( $P \leq 0.25$ ) variables into a multiple logistic regression (species models) or a multiple linear regression (richness/abundance models) model selection process. Finally, I tested the fit of each resulting logistic regression model using Hosmer-Lemeshow and Wald tests.

***Tests for Inclusion and Outliers.*** I excluded independent variables with zero values in  $\geq 80\%$  of the total observations from the habitat analyses. A preponderance of zeros for a variable indicated that: (1) differences in a given variable were too difficult to detect accurately with our sampling technique (the technique was not able to detect fine-scale differences across a variable) and/or (2) non-zero values for a variable were too rare to be an accurate predictor of species' distribution or avian diversity.

I evaluated all habitat variables for the presence of outliers. For richness/abundance models, I simply looked at the distribution of each variables' residuals (normality test) and determined if the skewness (length of the tails) in the distribution was significant ( $>3$  standard deviations from the mean). For priority species models, I sorted the data in each habitat variable, determined the mean for the sample, and looked for values that were  $>3$  standard deviations from the mean. I did not observe any extreme outliers within the habitat variables in either model-development approach.

***Multicollinearity Tests.*** I calculated Pearson correlation coefficients for all continuous independent variables in SAS to determine if correlations were present (SAS 1990). Variable pairs with correlation coefficients  $\geq 0.70$  were considered redundant (explaining the same variance) and one variable in the pair was removed from the analysis

(Table 8). I removed redundant variables that were: (1) relatively difficult to measure, and/or (2) variables that were less likely to have a sound biological link to the given response variable. This approach was consistent with Capen et al's (1986) recommendations and reduced potential for model failure from multicollinearity.

***Univariate Screening.*** I performed univariate tests between each remaining independent variable (covariate) and each response variable to determine the relative importance of each covariate (Hosmer and Lemeshow 1989). I defined 'importance' as variables that showed the greatest probability of being different ( $P \leq 0.05$ ) across points where a species was present versus points where a species was absent.

For high priority species' models, all variables with a P-value  $\leq 0.25$  in the univariate test along with other variables of known biological importance were included in the stepwise multivariate analysis; the top ten variables with the lowest P-values in univariate tests were used in the best subset selection procedure (Hosmer and Lemeshow 1989).

If categorical variables (e.g. forest type, condition class) were identified by the univariate procedure as important, I created design variables or 'dummy' variables for each forest type and/or condition class variable. This procedure was necessary because stepwise regression does not distinguish between the forest type or condition class sublevels (i.e. ...cove hardwood or seedling/sapling) in the selection process. For example, if the cove hardwood forest type was very important (very small P-value) to acadian flycatcher distribution and no other forest types were important, then the stepwise



Table 8. Results of multicollinearity tests (correlations >70%) between 51 continuous physical and habitat variables used for model selection, Tellico Ranger District, Cherokee National Forest, Tennessee. See Table 5 for variable descriptions.

| <b>Redundant Variables</b> | <b>Eliminated Variable</b> | <b>Remaining Variable</b> |
|----------------------------|----------------------------|---------------------------|
| SNGBSM, SNGFRQ             | SNGBSM                     | SNGFRQ                    |
| SNGBDM, SNGBSM             | SNGBDM                     | SNGBSM                    |
| 10-15DBH, 15-23DBH, TOTNTR | 10-15DBH and/or 15-23DBH   | TOTNTR                    |
| CNPYHT, STNDGE             | CNPYHT                     | STNDGE                    |

procedure would probably have removed the forest type variable from the analysis and the effects of the cove hardwood sublevel would not have been included in the final model. Design variables allowed each forest type and condition class to be evaluated separately and independent from the effects of the other forest types or condition classes in the group (Hosmer and Lemeshow 1989).

For the richness and abundance models, all variables with a P-value  $\leq 0.25$  in the univariate test were included in the stepwise linear regression analysis. By using a less conservative P-value (0.25 as opposed to 0.05), I allowed for the inclusion of variables that may be important collectively in the interactive stage of multivariate analysis, even though they may be weakly associated with the response variable in the univariate stage ( $P > 0.05$ ) (Mickey and Greenland 1989).

### **Logistic Regression for High Priority Species Models**

I used logistic regression to predict high priority species' distributions by developing predictive models that were derived from measured habitat parameters. Logistic regression was used because my response variables (species' presence (1) or absence (0)) were binary in nature (Hosmer and Lemeshow 1989). Logistic regression fits

linear logistic regression models for binary or ordinal response data by the maximum likelihood method (SAS 1990). Analysis of habitat use often involves data sets that contain both continuous and categorical variables (Capen et al. 1986). Use of categorical variables such as aspect, condition class, and forest type (Table 5) violate the assumption of multivariate normality necessary to conduct linear discriminant function analysis, an alternative to logistic regression (Press and Wilson 1978, Anderson 1981, James and McCulloch 1990). Logistic regression is an appropriate technique for mixed data sets because it does not require equal variance-covariance matrices or multivariate normality and because it can incorporate discrete variables (through BMDP) into the analysis (Press and Wilson 1978, James and McCulloch 1990). Hosmer and Lemeshow (1989) provide an excellent review of this technique.

**Initial Plots.** Logistic regression assumes a linear relationship with a constant slope between continuous independent variables and response variables (Hosmer and Lemeshow 1989). I screened independent variables for this assumption by plotting the mean response (species' presence or absence) across each individual independent variable and assessed the nature of the relationship. To do this, I divided each independent variable into 8-10 intervals and calculated the mean response value (the proportion of individuals present) within each interval using a sliding mean (i.e...intervals: 1-2, 2-3, 3-4 etc...) in Microsoft® Excel (Microsoft Corp., Redmond, WA). I then plotted the mean of each variable within each interval against the mean response for each interval. I excluded independent variables that resulted in nonlinear plots for each high priority species from further analysis (Hosmer and Lemeshow 1989). On average, 36% of the remaining habitat variables for all priority species were removed due to non-linear distributions.

→ in the form of the logit.  
Best to transform the response to the logit and then check for linearity

→ but they say not to use stepwise - they do not advocate using stepwise selection

**Stepwise Logistic Regression.** I used a stepwise selection method as a traditional approach to selecting final habitat models because the technique is widely used and reported in the literature (James and McCulloch 1990). Stepwise regression indicated which variables, in association with others, appeared to be most commonly associated with the bird distributions. Stepwise selection has been criticized for producing biologically implausible models and for selecting irrelevant (noise) variables (Flack and Chang 1987, Griffiths and Pope 1987). In these studies, noise variables were selected as important simply because they were measured in many of the same areas in which the birds were found. The stepwise approach is useful, however, because it builds models sequentially, allows for examination of a collection of predictive models, and allows for the initial inclusion of many potentially important variables (Hosmer and Lemeshow 1989). I used a forward selection technique with a test for backward variable elimination. I used a significance level of  $P = 0.25$  for variable entry into the selection process and a stay level of  $P = 0.15$  (SAS 1990). I used both SAS and BMDP statistical software (BMDP) for building predictive models of species' distribution because I wanted to check for consistency across software packages. Because model selection was virtually identical across packages, I reported results for only those developed in SAS. I created design (dummy) variables for my categorical variables (Table 5) when using stepwise regression in SAS (SAS 1990).

**Best Subset Selection.** To better understand the robustness of the stepwise analyses, I used a best subset selection method based on the minimum of Akaike's Information Criterion (AIC) to select variable subsets that best describe species' presence or absence (Akaike 1973, Bozdogan 1987). AIC is an information-based or entropic



measure used for identifying an 'optimal statistical model'. An optimal model is supported by the data, adheres to the principle of parsimony, and has enough parameters to provide a trade-off between precision and bias (Burnham and Anderson 1992). In the best subset selection method, an AIC score is calculated for all possible independent variable combinations. The combination of variables that results in the minimum AIC score represents the optimal model (Akaike 1973). This approach requires extensive computer time. For example, a model selection process starting with 20 independent variables would require the generation of 1,048,576 AIC scores. To avoid excessive computer costs, I limited my analysis to the ten habitat variables with the lowest P-values in the univariate tests. The AIC was calculated for each competing model combination and the model with the smallest AIC was identified. AIC scores were calculated for a total of 1,024 possible variable combinations for each species model.

*Classification and Jackknife Tests.* To assess model performance, I conducted classification and jackknife tests in SAS and BMDP. The classification test classified each point count location, using the logistic regression equation obtained from all point count locations including the one currently being classified. This test was thus biased because it simultaneously used the data to build and to test the model. The jackknife test systematically selected one observation, built the model without it and used the excluded observation to check classification accuracy. This process was repeated with each observation in the data set to generate an overall correct classification rate (Lachenbruch 1975). This test was considered unbiased because the model was tested with data independent of the model developed. For both tests, a 2x2 frequency table of observed and predicted responses was generated (Table 9) and the response variable for each point

Table 9. Hypothetical classification table for 4 points, adapted from SAS (1990).

| Point No.                                      | Observed | Predicted | Classification         |
|------------------------------------------------|----------|-----------|------------------------|
| 1                                              | present  | present   | Classified Correctly   |
| 2                                              | present  | absent    | Classified Incorrectly |
| 3                                              | absent   | present   | Classified Incorrectly |
| 4                                              | absent   | absent    | Classified Correctly   |
| <i>Correct classification rate = 2/4 = 50%</i> |          |           |                        |

count was classified either as an 'event' (presence) or as 'no event' (absence) according to: (1) whether or not the point had the species recorded at it, and (2) whether or not the collective independent variables correctly predicted the presence or absence of that particular species at that given point (SAS 1990). I reported the percentage of points that were correctly classified for each model in the species' distribution. I ran each jackknife test using the arbitrary predictive probability cut-off point of 0.5 (SAS 1990). At a given point, if the response (present or absent) had a predicted probability  $\geq$  the cut-off value (0.5), then the response was classified as an 'event' (presence) (Table 9). After evaluating the graphs of percent correct classification versus cut-off point, I determined that the percentage of correct classification for all species models peaked within a range that included the 0.5 cut-off value. Therefore, I did not adjust the cut-off point for any model. If the percentage of correct classification had peaked in a range outside of the 0.5 cut-off, then I would have adjusted the cut-off point to where it peaked on the graph. This adjustment would make evaluation of model performance more reliable because it assures better adherence to the  $\chi^2$  (g-2) distribution (Hosmer et al. 1988). These classification tests were thus useful in assessing how accurately a land manager can predict the distribution of a given species using the habitat variables that make up the models (BMDP

1992).

***Goodness-of-Fit Tests.*** In addition to the classification tests, I used two internal validation tests (Hosmer-Lemeshow test and Wald chi-square test) to: (1) assess the fit of each model to the data (Hosmer and Lemeshow); and (2) determine if the slopes of the estimated correlation coefficients (parameter estimates) for each continuous variable and categorical parameter-level (i.e...cove, hemlock/white pine, mixed) were different from zero (Wald chi-square test).

The Hosmer-Lemeshow test used 'deciles of risk' grouping to categorize points into 10 groups - ranked and separated according to their estimated probabilities. Based on the differences between observed and expected frequencies in each group, models that fit the data showed small differences between the frequency types and generally had P-values that were large ( $>0.05$ ) (Hosmer and Lemeshow 1989). Small P-values ( $<0.05$ ) indicated large differences between within-group observed and expected frequencies and signified a poor fit of the model to the data.

The Wald chi-square test was defined as the variable parameter estimate (coefficient of variation) / (standard error of the estimate). Under the hypothesis that an individual variable's slope coefficient was zero, I used the Wald test to select variables that had slopes that were significantly different from zero. Using an approximate significance level of 0.05, which assumes a critical value of 2, I screened each variable's Wald score. Those variables with scores  $>2$  were considered significantly different from zero. The Wald test was especially useful in determining the significance of each level of a categorical variable such as forest type (i.e...cove, hemlock/white pine, mixed...) that used design (dummy) variables in the model.

**Assumption of Linearity.** I checked the assumption of linearity in the logit for all continuous variables in the final species' models by plotting the log-odds or logit ratios (dependent) against each covariate (independent) (Hosmer and Lemeshow 1989). For all models, this assumption was adequately met. *what is "adequate"??*

### **Multiple Linear Regression for Avian Species Richness Responses**

I chose a multiple linear regression technique to relate habitat variables to indices of avian diversity because response variables were continuous. For response variables, I used the six richness and abundance indices listed previously. The linear regression analysis used the principle of least squares to produce estimates that were the 'best linear unbiased estimates' (SAS 1990) under the following classical statistical assumptions (Ott 1988):

- All important explanatory variables were included in the model.
- Regressor variables were measured without error.
- The expected value of the errors was zero.
- The variance of the errors was a constant across observations.
- The errors were uncorrelated across observations.
- The errors were normally distributed.

It was unlikely that all of the above assumptions were strictly met in my analysis. The use of strong biological and empirical evidence supporting or refuting the inclusion of each habitat variable in the final model, however, added strength to this technique and made it a good first step in the process of selecting biologically plausible models.

**Normality Test of Residuals.** A Shapiro-Wilk test for normality was performed on all response variables (y) across all habitat variables (x) and the skewness, kurtosis, and probability plots of each combination were examined (SAS 1990). I calculated and plotted the residuals from the estimated regression equations as actual minus predicted (SAS 1990). I eliminated habitat variables without normal distributions from the rest of the analysis because subsequent ANOVA's require an assumption of normality.

**Full and Final Models.** I built full regression models for each response variable that included all 62 of the habitat variables. After the initial univariate screening of important predictor variables ( $P \leq 0.25$ ), I generated a final model for each diversity index that contained all important predictor variables as determined by the univariate screening. I determined the predictive 'quality' of both full and final models by reviewing the  $R^2$  statistic in the ANOVA procedure for each model.  $R^2$  was defined as the proportion of variance in the response (y) that was explained by (that was predictable from) the predictor variables (x's) (SAS 1990). For example, an  $R^2 = 0.75$  indicated that 75% of the variation in the response variable was explained by the given independent variable(s).

**Stepwise Linear Regression.** I built regression models that contained all univariately important ( $P \leq 0.25$ ) variables for each diversity index (SAS 1990). I used a forward selection technique with a test for backward variable elimination. I used a significance level of  $P = 0.25$  for variable entry into the selection process and a stay level of  $P = 0.15$ . I created design variables for each categorical variable, similar to my approach with the logistic regression models (SAS 1990).

## **Predictive Power of CISC Variables**

Six habitat variables (condition class, elevation<sup>1</sup>, forest type, site index, stand age, and stand size) were characterized for all forest stands in the CISC database (Table 5). Use of these variables in developing habitat models for predicting high priority species' distributions and for predicting avian species richness and abundance was desirable because model results could readily be applied to all stands on the Tellico District. For high priority species' distributions, I used logistic regression, as described previously, with all six CISC variables. For richness and abundance, I used multiple linear regression with the same six CISC variables. I used a jackknife test and two goodness-of-fit tests (Hosmer-Lemeshow test and Wald chi-square test) to assess the predictive strength and model quality of these variables for all seven high priority species (Hosmer and Lemeshow 1989). For richness and abundance, I used the multiple linear regression  $R^2$  statistic to determine how much of the variation in each richness and abundance response variable was explained by the six CISC variables. For both series of analysis, I used design (dummy) variables for the categorical variables - forest type and condition class.

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<sup>1</sup> The elevation variable was developed from U.S. Geological Survey digital elevation model data for the Tellico Ranger District.



## CHAPTER III

### RESULTS

#### DESCRIPTIVE ANALYSIS

##### Overview

I recorded 60 and 65 species of birds within 50 m on point counts in 1992 and 1993, respectively. Neotropical migrants (migrants) comprised 73% of all species observed in 1992 and 78% in 1993. Avian species recorded in each forest type-condition class combination are listed (Appendix D).

##### Avian Richness and Abundance Across Forest Types

**Species Richness.** Mean species richness per point differed across forest types for migrants in 1992 and 1993 and for migrants and residents (combined) in 1993 ( $P \leq 0.05$ ) (Figure 3, Table 10). In 1992, migrant richness was greater in hemlock/white pine, northern hardwood, and oak/hickory stands than migrant richness in yellow pine stands ( $P \leq 0.05$ ). In 1993, migrant richness was greater in cove hardwood, northern hardwood, and oak/hickory stands than in mixed or yellow pine stands ( $P \leq 0.05$ ). Also in 1993, migrant richness and combined richness were less in yellow pine stands than in all other stand types except mixed ( $P \leq 0.05$ ). I was unable to detect differences ( $P \leq 0.05$ ) in resident richness across forest types for either 1992 or 1993.

**Species Abundance.** Mean number of individuals per point differed across forest types for migrants and combined in 1992 and for migrants, residents and combined in 1993 ( $P \leq 0.05$ ) (Figure 3, Table 10). In 1992, migrants were more abundant in northern

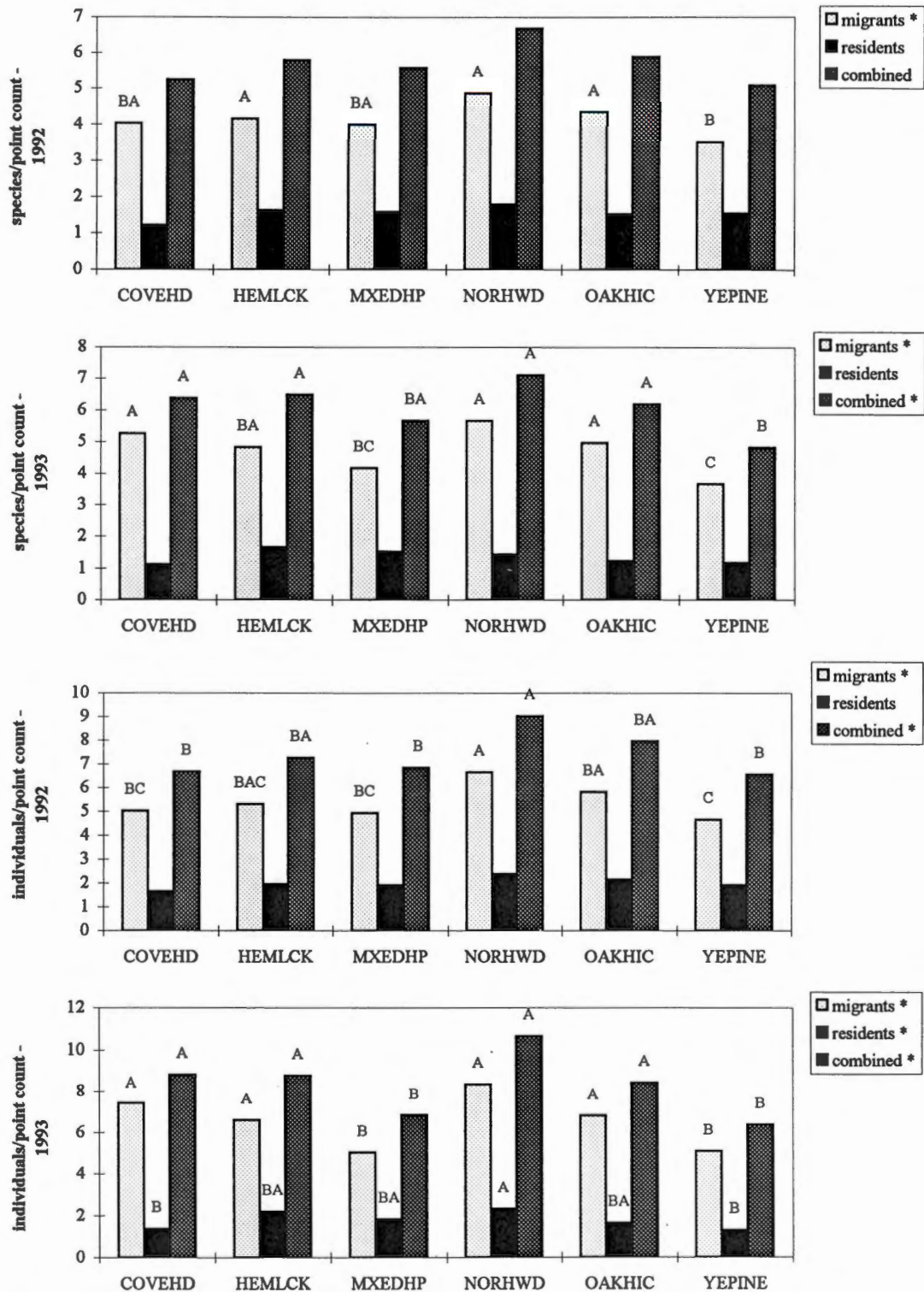


Figure 3. Mean species richness and abundance per point for neotropical migrants, residents, and combined across six forest types, Cherokee National Forest, Tennessee. \* Indicates a difference across the forest types ( $P \leq 0.05$ ), based on analysis of variance tests. Forest types within years and within species groups (migrants, residents, and combined) with different letters differ based on Duncan's multiple range tests, ( $P \leq 0.05$ ). Sample sizes for each category are listed in Table 3.



hardwood and oak/hickory stands than in yellow pine stands ( $P \leq 0.05$ ). In 1993, migrants were less abundant in mixed and yellow pine stands than in all other forest types ( $P \leq 0.05$ ). In 1993, residents were more abundant in northern hardwood stands than in cove hardwood and yellow pine stands ( $P \leq 0.05$ ). In 1992, combined migrants and residents were more abundant in northern hardwood stands than in cove hardwood, mixed, and yellow pine stands ( $P \leq 0.05$ ). In 1993, combined migrants and residents were less abundant in mixed and yellow pine stands than all other forest types ( $P \leq 0.05$ ).

#### **Avian Richness and Abundance Across Condition Classes**

***Species Richness.*** Mean species richness per point differed across condition classes for migrants, residents, and combined in 1993 (Table 10, Figure 4). I did not detect differences ( $P \leq 0.05$ ) in migrant richness, resident richness, or combined richness across condition classes in 1992. In 1993, migrant richness was greater in seedling/sapling stands than in poletimber stands ( $P \leq 0.05$ ). Also for 1993, resident richness and combined richness were greater in seedling/sapling stands than in poletimber and sawtimber stands ( $P \leq 0.05$ ).

***Species Abundance.*** Mean species abundance per point differed across condition classes for migrants, residents, and combined in 1993 ( $P \leq 0.05$ ) (Table 10, Figure 4). I did not detect differences ( $P \leq 0.05$ ) in migrant abundance, resident abundance, or combined abundance across condition classes in 1992. In 1993, migrants were more abundant in seedling/sapling stands than in poletimber stands ( $P \leq 0.05$ ). Also in 1993, residents and combined migrants and residents were more abundant in seedling/sapling stands than in poletimber and sawtimber stands ( $P \leq 0.05$ ).

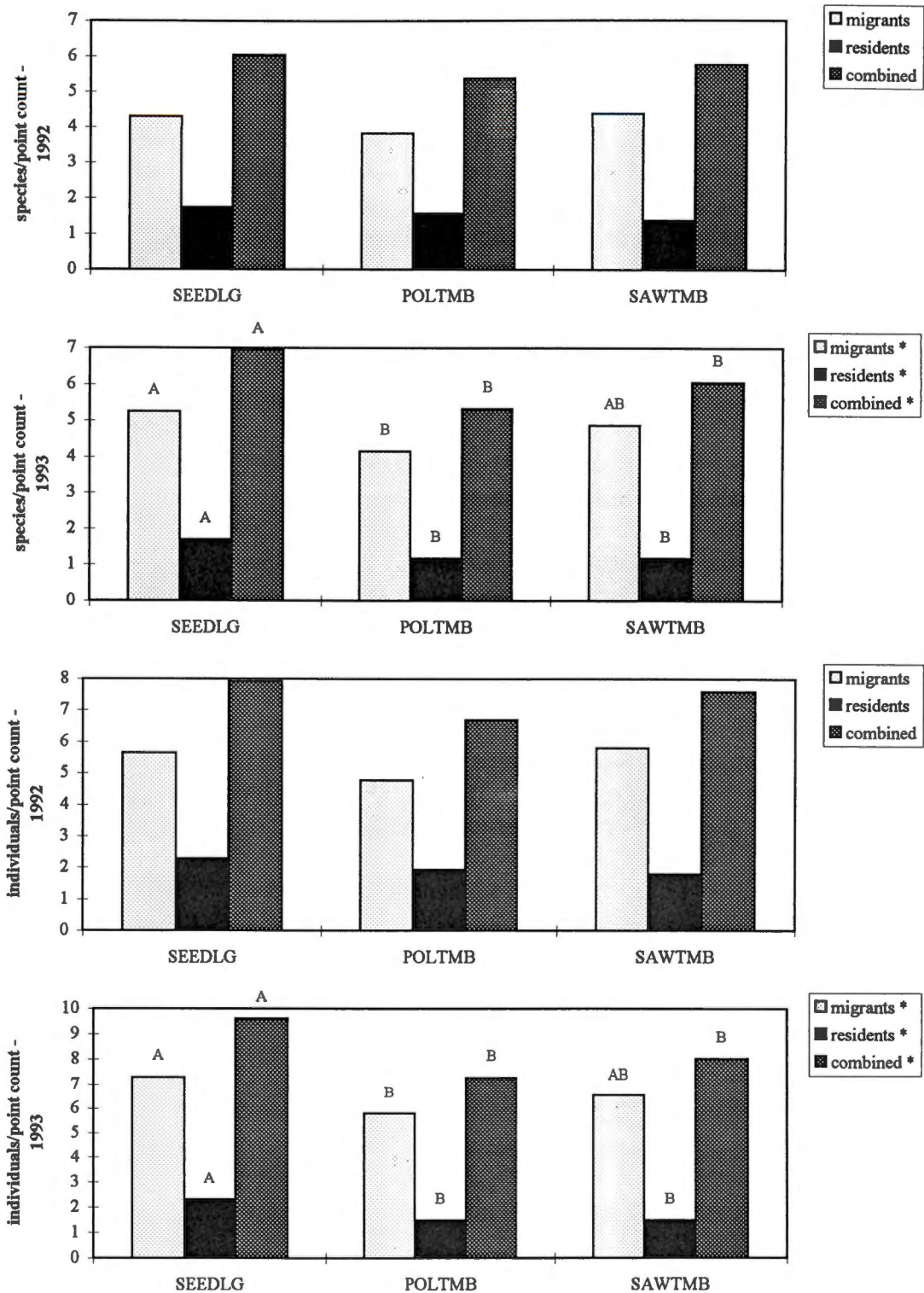


Figure 4. Mean species richness and abundance per point for neotropical migrants, residents, and combined across three condition classes, Cherokee National Forest, Tennessee. \* Indicates a difference across the condition classes ( $P \leq 0.05$ ), based on analysis of variance tests. Condition classes within years and within species groups (migrants, residents, and combined) with different letters differ based on Duncan's multiple range tests, ( $P \leq 0.05$ ). Sample sizes for each category are listed in Table 3.



## **Avian Richness and Abundance Across Age Categories**

***Species Richness.*** Mean species richness per point differed across stand age categories for residents and combined in 1992, and for migrants, residents, and combined in 1993 (Table 10, Figure 5). In 1993, migrant richness and combined richness were greater in the 0-10 age category than in the 31-40 age category ( $P \leq 0.05$ ), and resident richness was greater in the 21-30 age category than in the 51-60 and >90 age categories ( $P \leq 0.05$ ).

***Species Abundance.*** Mean species abundance per point differed among stand age categories for residents in 1992 and for migrants, residents, and combined in 1993 ( $P \leq 0.05$ ) (Table 10, Figure 5). In 1993, migrants were more abundant in the 0-10 age category than in all other age categories except 21-30, 71-80, and >90,  $P \leq 0.05$ ). Also in 1993, combined migrants and residents were more abundant in the 0-10 age category than in all other age categories ( $P \leq 0.05$ ). In 1993, residents were more abundant in the 0-10 age category than in the 31-40, 41-50, 51-60, and >90 categories ( $P \leq 0.05$ ).

## **SONGBIRD-HABITAT MODELS**

### **Acadian Flycatcher**

***Predictive Models - Top Ten Predictors.*** I observed acadian flycatchers at low to mid elevation sites with low sapling densities and moderate to high litter depths (Figure 6). These sites were older riparian stands with mid to large-sized trees present. The top ten sampled predictor variables of acadian flycatcher distribution selected by the univariate analysis were (from lowest P-value to highest): elevation, litter depth, slope, saplings



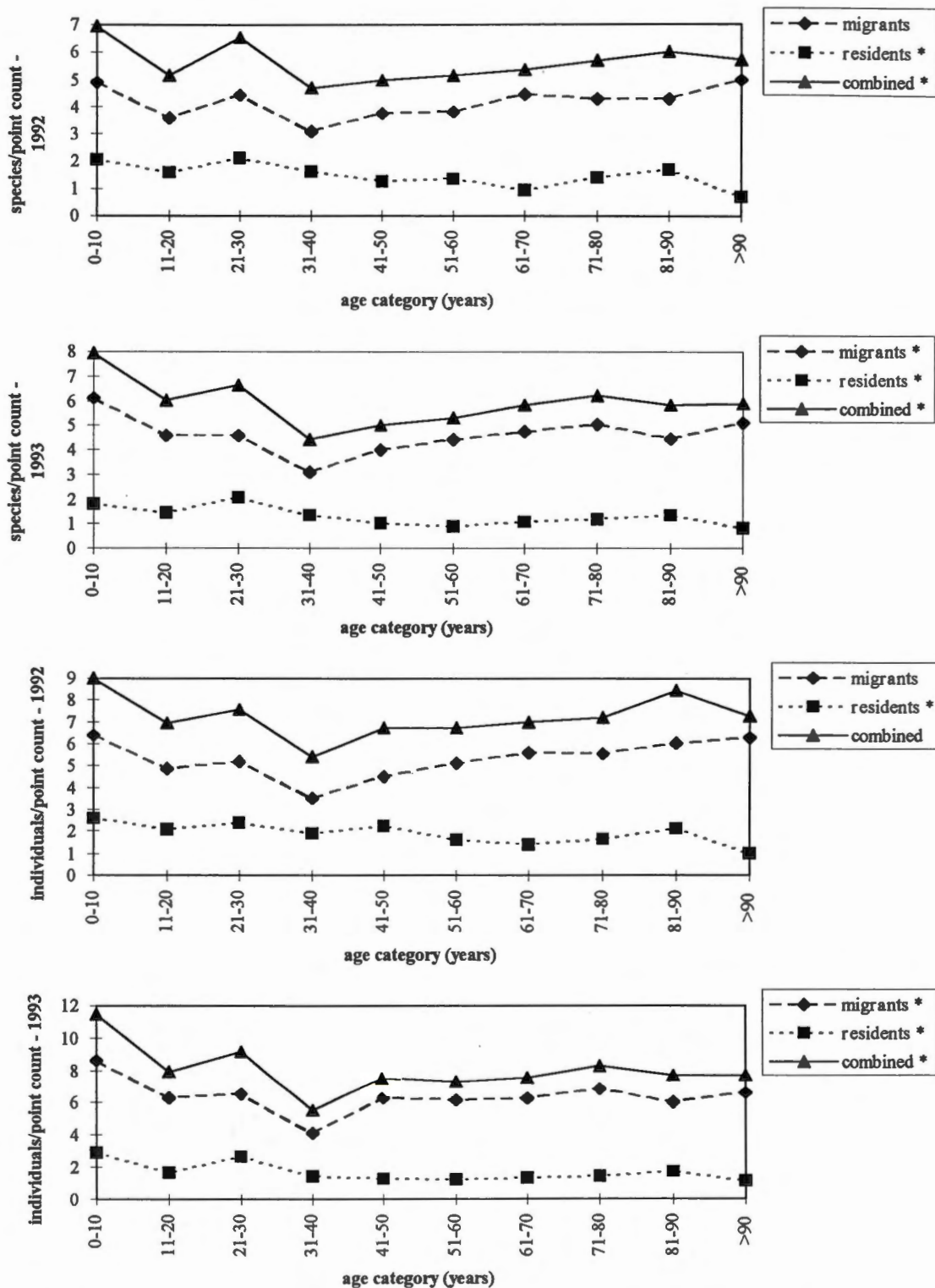


Figure 5. Mean species richness and abundance per point for neotropical migrants, residents, and combined across nine stand age categories, Cherokee National Forest, Tennessee.\* Indicates a difference across the age categories ( $P \leq 0.05$ ), based on analysis of variance tests. Sample sizes for each category are listed in Table 7.

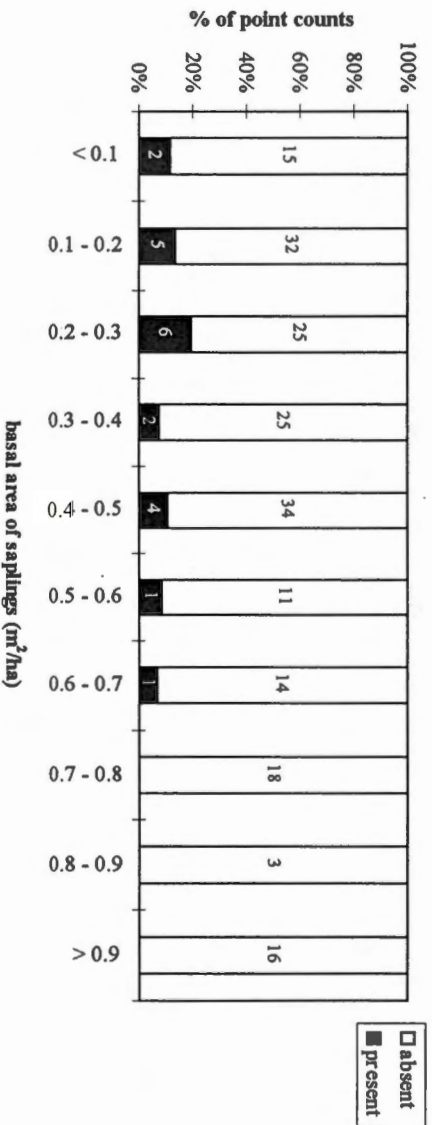
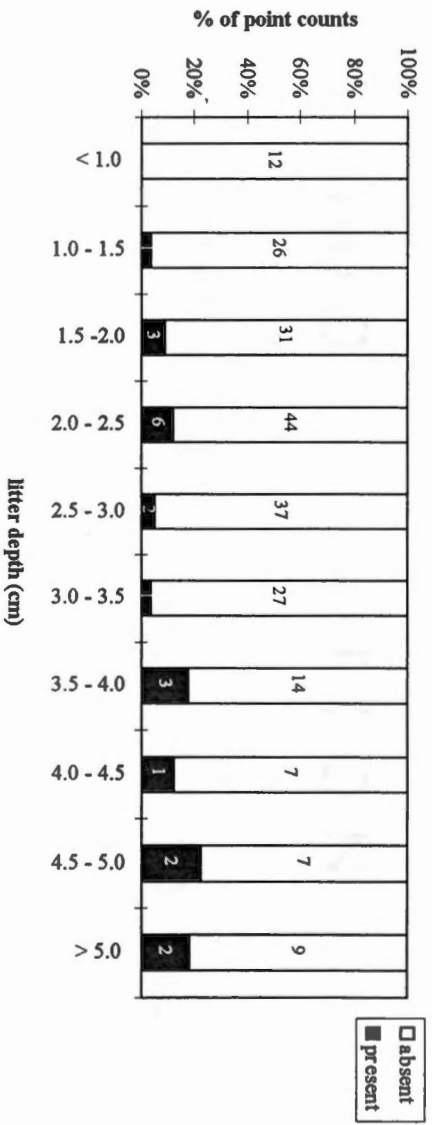
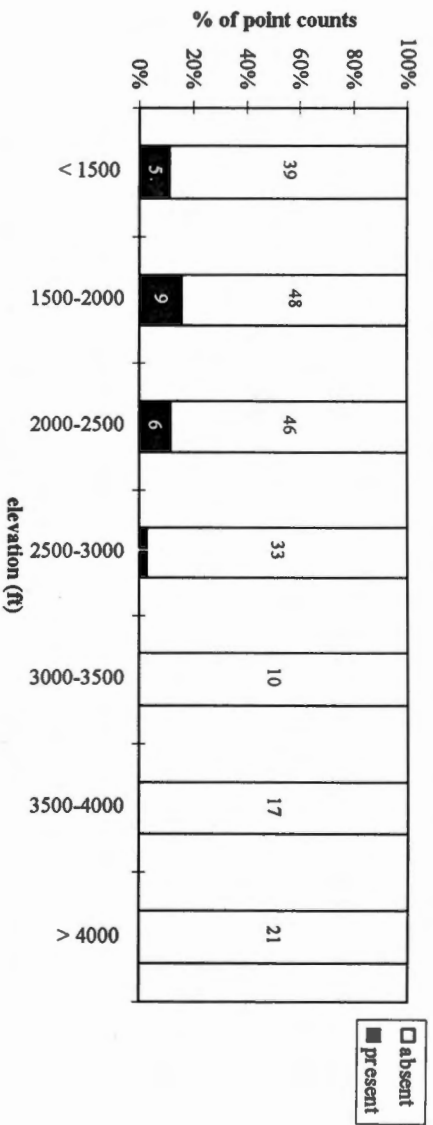


Figure 6. Percentage of points where acadian flycatcher was present and absent in 1992, 1993 or in both years, across five continuous habitat variables deemed best predictors of acadian flycatcher distribution, Cherokee National Forest, Tennessee.

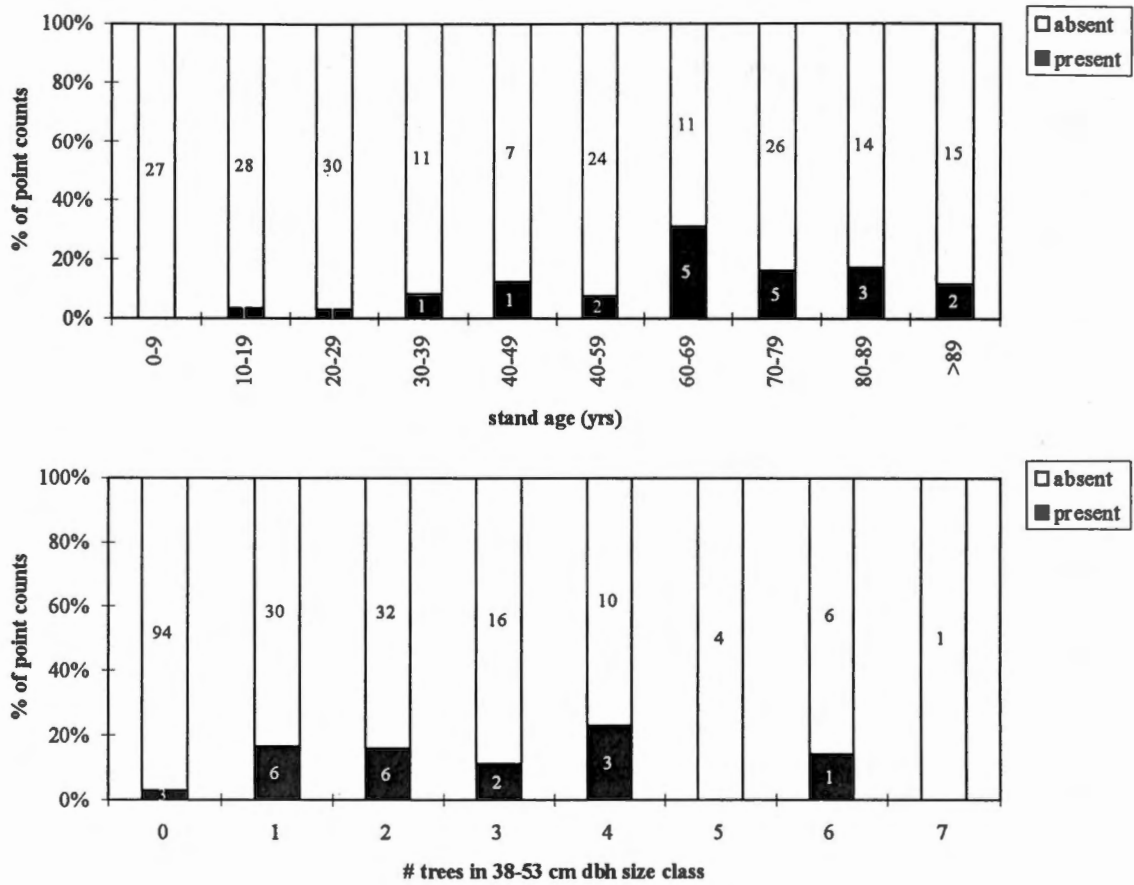


Figure 6. (continued)

count, basal area saplings, condition class, stand age, 30-38 dbh, 38-53 dbh, and # tree species (Table 11). Wald chi-square scores indicated that elevation, litter depth, stand age, and 38-53 dbh had estimated “slope” coefficients (parameter estimates) that were different ( $P \leq 0.05$ ) from zero, thus indicating a relationship between these covariates and acadian flycatcher distribution on the Tellico District (Hosmer and Lemeshow 1989). This combination of habitat variables resulted in a correct classification rate of 87.3% for the biased test (concordance) and 86.9% for the unbiased test (jackknife). The Hosmer-Lemeshow goodness-of fit-test indicated that the model fit the data ( $P = 0.31$ ). There were 21 observed acadian flycatcher-present points and 193 observed acadian flycatcher-absent points.

***Predictive Models - AIC and Stepwise.*** Five variables (elevation, litter depth, basal area saplings, stand age, and 38-53 dbh) were selected by both procedures (AIC and stepwise) as the best predictors among sampled variables of acadian flycatcher presence/absence on the Tellico Ranger District (Table 11). Elevation and basal area of saplings were negatively correlated with acadian flycatcher distribution; litter depth, stand age, and 38-53 dbh were positively correlated (Table 11). Wald scores indicated that the estimated slope coefficients of all five variables were different ( $P \leq 0.05$ ) from zero. The correct classification rates by the concordance and jackknife tests for this model were 85.4% and 89.7%, respectively. The Hosmer-Lemeshow goodness-of-fit test for this model indicated that the model fit the data well ( $P = 0.57$ ).

***Predictive Models - CISC Variables.*** The USFS CISC database variables (forest type, condition class, stand age, site index, stand size, and elevation) (Table 11) correctly classified acadian flycatcher distribution 85.1% of the time (concordance) and 88.3% of

Table 11. Result of model selections for response variable - acadian flycatcher. Final variables were selected from 38 habitat variables, Cherokee National Forest, Tennessee. Underlined variables are categorical. Asterisks denote variables with significant ( $P \leq 0.05$ ) Wald chi-square test scores (see Table 5 for variable descriptions).

| Model Type        | Variables Selected         | Parameter Estimate <sup>1</sup> | Pr. > $\chi^2$ | Probability Tests of Correct Classification |            | Goodness-of-Fit Indicator<br>Hosmer / Lemeshow |
|-------------------|----------------------------|---------------------------------|----------------|---------------------------------------------|------------|------------------------------------------------|
|                   |                            |                                 |                | Concordance                                 | Jack-knife |                                                |
| FULL <sup>2</sup> | CONSTANT                   | -3.829                          | 0.174          |                                             |            |                                                |
|                   | ELEVTVN                    | -0.002                          | 0.000*         |                                             |            |                                                |
|                   | LITDPH                     | 0.387                           | 0.057*         |                                             |            |                                                |
|                   | SLOPE%                     | 0.007                           | 0.796          |                                             |            |                                                |
|                   | NOSAPS                     | 3.591                           | 0.729          |                                             |            |                                                |
|                   | BSLSAP                     | -1831.5                         | 0.728          | 87.3 %                                      | 86.9 %     | C = 7.16<br>P = 0.31                           |
|                   | <u>CNDCLS</u> <sup>3</sup> |                                 |                |                                             |            |                                                |
|                   | STNDAG                     | 0.058                           | 0.041*         |                                             |            |                                                |
|                   | 30-38DBH                   | 0.198                           | 0.228          |                                             |            |                                                |
|                   | 38-53DBH                   | 0.285                           | 0.127*         | 0.127 > 0.05                                |            |                                                |
|                   | NOTRSP                     | 0.035                           | 0.758          |                                             |            |                                                |
| CISC              | CONSTANT                   | -0.341                          | 0.890          |                                             |            |                                                |
|                   | <u>COVEHD</u>              | 0.752                           | 0.526          |                                             |            |                                                |
|                   | <u>HEMLCK</u>              | 1.225                           | 0.215          |                                             |            |                                                |
|                   | <u>MXEDHP</u>              | 0.175                           | 0.807          |                                             |            |                                                |
|                   | <u>NORHWD</u>              | -1.435                          | 0.241          |                                             |            |                                                |
|                   | <u>OAKHIC</u>              | -0.841                          | 0.384          |                                             |            |                                                |
|                   | <u>YEPINE</u> <sup>4</sup> | 0.124                           | 0.807          | 79.3 %                                      | 88.8 %     | C = 11.71<br>P = 0.17                          |
|                   | <u>SEEDLG</u>              | 0.631                           | 0.713          |                                             |            |                                                |
|                   | <u>POLTMB</u>              | 0.641                           | 0.506          |                                             |            |                                                |
|                   | <u>SAWTMB</u> <sup>5</sup> | -1.272                          | 0.713          |                                             |            |                                                |
|                   | STNDAG                     | 0.046                           | 0.058*         |                                             |            |                                                |
|                   | STENDX                     | 0.072                           | 0.042*         |                                             |            |                                                |
|                   | STNDSZ                     | 0.002                           | 0.502          |                                             |            |                                                |
|                   | ELEVTVN <sup>6</sup>       | -0.002                          | 0.001*         | 85.1 %                                      | 88.3 %     |                                                |
| AIC & STEP-WISE   | CONSTANT                   | -0.268                          | 0.845          |                                             |            |                                                |
|                   | ELEVTVN                    | -0.001                          | 0.000*         |                                             |            |                                                |
|                   | LITDPH                     | 0.292                           | 0.132*         | 85.4 %                                      | 89.7 %     | C = 4.78<br>P = 0.57                           |
|                   | BSLSAP                     | -2.431                          | 0.096*         |                                             |            |                                                |
|                   | STNDAG                     | 0.026                           | 0.030*         |                                             |            |                                                |
|                   | 38-53DBH                   | 0.268                           | 0.104*         | 0.104 > 0.05 not < 0.05                     |            |                                                |

<sup>1</sup> Unstandardized coefficients - these estimates do not indicate the relative weight of each variable.

<sup>2</sup> Variables are listed in decreasing order of the significance of their F-statistic.

<sup>3</sup> 'SEEDLG' subgroup (parameter est. = 3.206,  $P = 0.123$ ) recorded a significant ( $P \leq 0.05$ ) Wald score.

<sup>4</sup> Reference group for the forest type design (dummy) variable group.

<sup>5</sup> Reference group for the condition class design (dummy) variable group.

<sup>6</sup> Correct classification rate for the CISC variables with the ELEVTVN component included.

the time (jackknife). Estimated slope coefficients for stand age, site index, and elevation were different ( $P \leq 0.05$ ) from zero (Wald test). The Hosmer-Lemeshow statistic indicated an acceptable fit of the model to the data ( $P = 0.17$ ).

### **Black-throated Blue Warbler**

***Predictive Models - Top Ten Predictors.*** On the Tellico District, black-throated blue warblers occurred on mid to high elevation points, in stands with rhododendron but not vaccinium in the shrub layer, with large-diameter trees (Figure 7). The ten most important sampled predictor variables of black-throated blue warbler distribution were (from lowest P-value to highest): elevation, forest type, conifer frequency, rhododendron cover, vaccinium cover, litter depth, 53-68 dbh, total basal area, 10-15 dbh, and 38-53 dbh (Table 12). Wald chi-square scores indicated that elevation, rhododendron cover, vaccinium cover, and litter depth had estimated slope coefficients that were different ( $P \leq 0.05$ ) from zero. This model resulted in a correct classification rate of 95.6% (concordance) and 90.7% (jackknife). The Hosmer-Lemeshow test indicated an acceptable fit of the model to the data ( $P = 0.14$ ). There were 55 observed black-throated blue warbler-present points and 159 observed black-throated blue warbler-absent points.

***Predictive Models - AIC and Stepwise.*** A six variable model (elevation, vaccinium cover, litter depth, 53-68 dbh, ground cover %, and rhododendron cover) was the best model to explain variation in habitat use by black-throated blue warbler on the district; all six variables had significant coefficients ( $P \leq 0.05$ ; Table 12). Ground cover



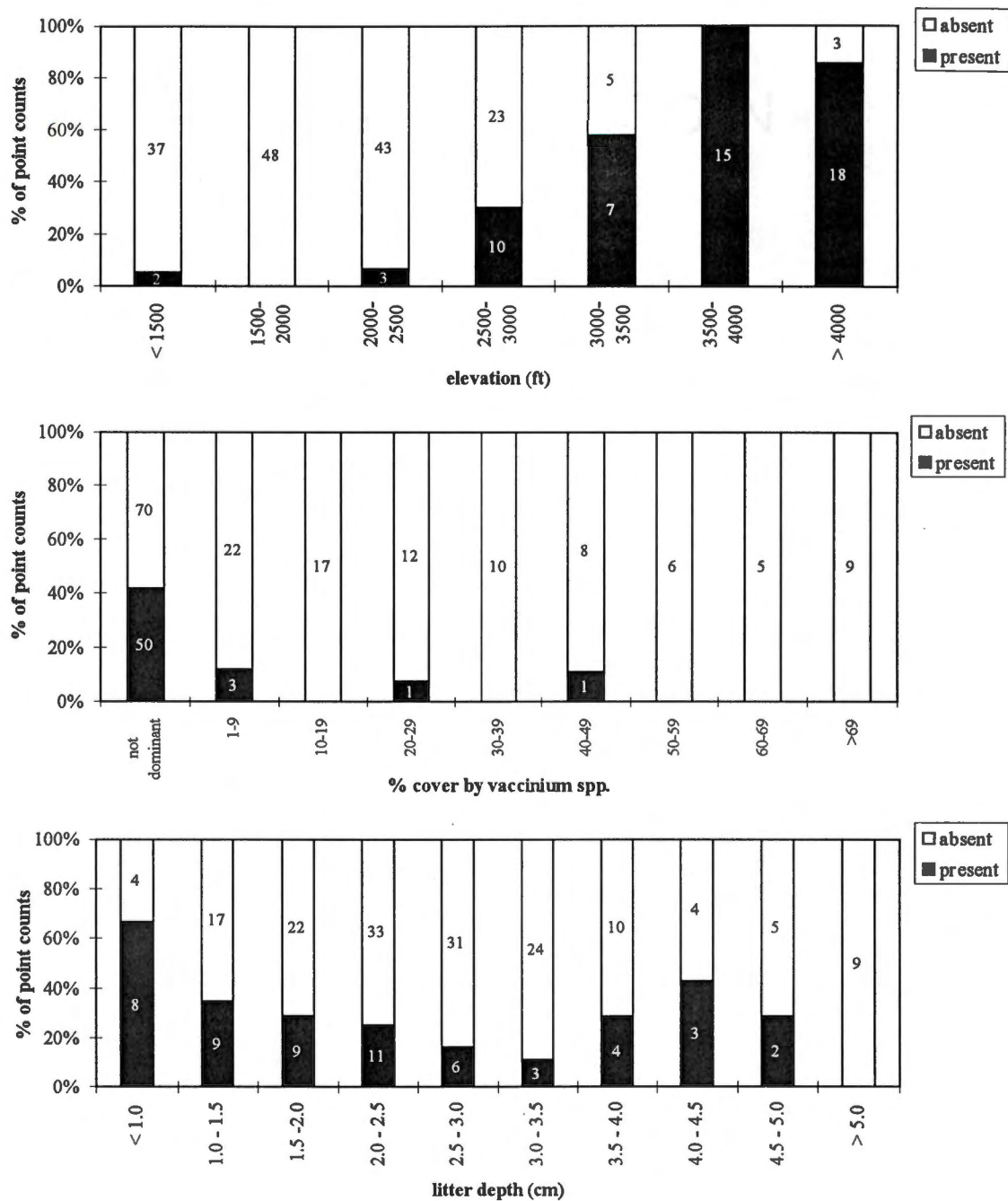


Figure 7. Percentage of points where black-throated blue warbler was present and absent in 1992, 1993 or in both years, across six continuous habitat variables deemed best predictors of black-throated blue warbler distribution, Cherokee National Forest, Tennessee.

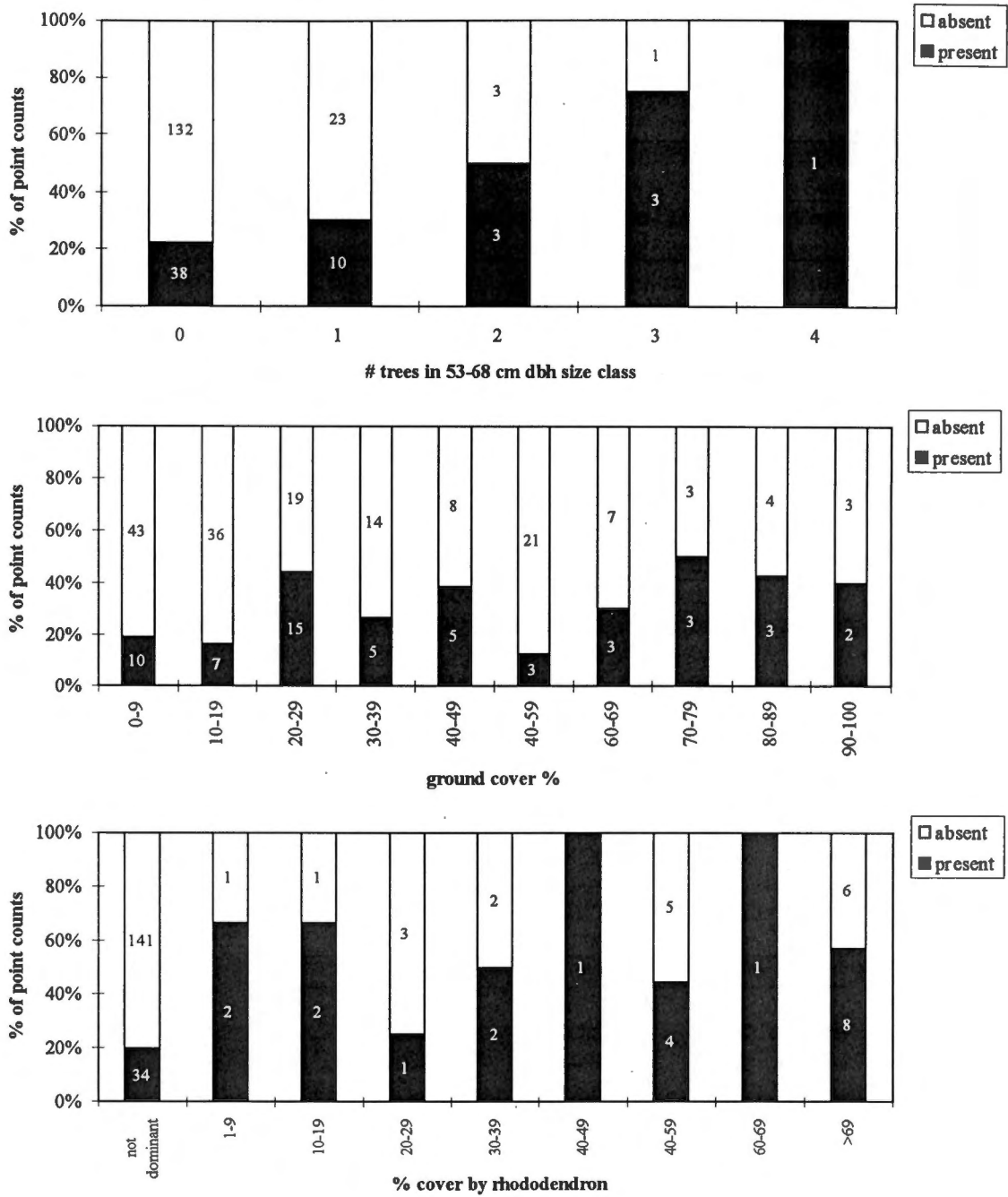


Figure 7. (continued)

Table 12. Result of model selections for response variable - black-throated blue warbler. Final variables were selected from 38 habitat variables, Cherokee National Forest, Tennessee. Underlined variables are categorical. Asterisks denote variables with significant ( $P \leq 0.05$ ) Wald chi-square test scores (see Table 5 for variable descriptions).

| Model Type        | Variables Selected         | Parameter Estimate <sup>1</sup> | Pr. > $\chi^2$ | Probability Tests of Correct Classification |            | Goodness-of-Fit Indicator<br>Hosmer / Lemeshow |
|-------------------|----------------------------|---------------------------------|----------------|---------------------------------------------|------------|------------------------------------------------|
|                   |                            |                                 |                | Concordance                                 | Jack-knife |                                                |
| FULL <sup>3</sup> | <i>CONSTANT</i>            | -5.620                          | 0.001          |                                             |            |                                                |
|                   | ELEVTN                     | 0.002                           | 0.000*         |                                             |            |                                                |
|                   | <u>FORTYP</u> <sup>2</sup> |                                 |                |                                             |            |                                                |
|                   | CONFRQ                     | -0.037                          | 0.607          |                                             |            |                                                |
|                   | RHODCR                     | 0.021                           | 0.058*         |                                             |            |                                                |
|                   | VACCVR                     | -0.038                          | 0.135*         | 95.6 %                                      | 90.7 %     | C = 8.31                                       |
|                   | LITDPH                     | -0.602                          | 0.064*         |                                             |            | P = 0.14                                       |
|                   | 53-68DBH                   | 0.558                           | 0.326          |                                             |            |                                                |
|                   | TOTBSL                     | 0.375                           | 0.651          |                                             |            |                                                |
|                   | 10-15DBH                   | 0.003                           | 0.956          |                                             |            |                                                |
|                   | 38-53DBH                   | -0.162                          | 0.507          |                                             |            |                                                |
| CISC              | <i>CONSTANT</i>            | -4.718                          | 0.058          |                                             |            |                                                |
|                   | <u>COVEHD</u>              | 1.928                           | 0.159*         |                                             |            |                                                |
|                   | <u>HEMLCK</u>              | 0.522                           | 0.697          |                                             |            |                                                |
|                   | <u>MXEDHP</u>              | 0.568                           | 0.651          |                                             |            |                                                |
|                   | <u>NORHWD</u>              | 5.841                           | 0.000*         |                                             |            |                                                |
|                   | <u>OAKHIC</u>              | 2.731                           | 0.015*         | 89.0 %                                      | 84.6 %     | C = 8.16                                       |
|                   | <u>YEPINE</u> <sup>4</sup> | -11.590                         | 0.652          |                                             |            | P = 0.42                                       |
|                   | <u>SEEDLG</u>              | 0.160                           | 0.916          |                                             |            |                                                |
|                   | <u>POLTMB</u>              | -0.134                          | 0.873          |                                             |            |                                                |
|                   | <u>SAWTMB</u> <sup>5</sup> | -0.026                          | 0.916          |                                             |            |                                                |
|                   | STNDAG                     | 0.009                           | 0.667          |                                             |            |                                                |
|                   | STENDX                     | 0.017                           | 0.521          |                                             |            |                                                |
|                   | STNDSZ                     | -0.006                          | 0.072*         |                                             |            |                                                |
|                   | ELEVTN <sup>6</sup>        | 0.002                           | 0.000*         | 93.9 %                                      | 88.8 %     |                                                |
| AIC & STEP-WISE   | <i>CONSTANT</i>            | -5.864                          | 0.000          |                                             |            |                                                |
|                   | ELEVTN                     | 0.008                           | 0.000*         |                                             |            |                                                |
|                   | VACCVR                     | -0.046                          | 0.081*         | 95.0 %                                      | 92.1 %     | C = 14.01                                      |
|                   | LITDPH                     | -0.559                          | 0.040*         |                                             |            | P = 0.05                                       |
|                   | 53-68DBH                   | 0.572                           | 0.103*         |                                             |            |                                                |
|                   | GRNDCV                     | -0.021                          | 0.080*         |                                             |            |                                                |
|                   | RHODCR                     | 0.015                           | 0.130*         |                                             |            |                                                |

<sup>1</sup> Unstandardized coefficients - these estimates do not indicate the relative weight of each variable.

<sup>2</sup> 'OAKHIC' subgroup (parameter est. = 1.869,  $P = 0.151$ ) recorded a significant ( $P \leq 0.05$ ) Wald score.

<sup>3</sup> Variables are listed in decreasing order of the significance of their F-statistic.

<sup>4</sup> Reference group for the forest type design (dummy) variable group.

<sup>5</sup> Reference group for the condition class design (dummy) variable group.

<sup>6</sup> Correct classification rate for the CISC variables with the ELEVTN component included.

%<sup>1</sup>, litter depth, and vaccinium cover were negatively correlated, whereas elevation, rhododendron cover, and 53-68 dbh were positively correlated with black-throated blue warbler distribution (Table 12). The correct classification rates by the concordance and jackknife tests were 95.0% and 92.1%, respectively. The Hosmer-Lemeshow goodness-of-fit test indicated a marginal fit of the model to the data ( $P = 0.05$ ).

***Predictive Models - CISC Variables.*** The CISC model (forest type, condition class, stand age, site index, stand size, and elevation) (Table 12) correctly predicted black-throated blue warbler presence/absence 93.9% (concordance) and 88.8% (jackknife) of the time. Slope coefficients for design variables - cove hardwood, northern hardwood, and oak/hickory and continuous variables - stand size and elevation were different ( $P \leq 0.05$ ) from zero (Wald test). The Hosmer-Lemeshow test indicated a good fit of the model to the data ( $P = 0.42$ ).

## **Canada Warbler**

***Predictive Models - Top Ten Predictors.*** I recorded Canada warblers in high elevation stands with rhododendron present, with few conifers and few snags (Figure 8). The univariate test selected the following ten variables with the highest probability of being different ( $P \leq 0.05$ ) across 32 observed Canada warbler-present points and 182 observed Canada warbler-absent points (lowest P-value to highest): elevation, rhododendron cover, conifer frequency, # tree species, vaccinium cover, ground cover %, litter depth, total # trees, slope, and 53-68 dbh (Table 13). The Wald test indicated that

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<sup>1</sup> Ground cover % was not a top ten predictor variable but passed the univariate test ( $P \leq 0.25$ ).

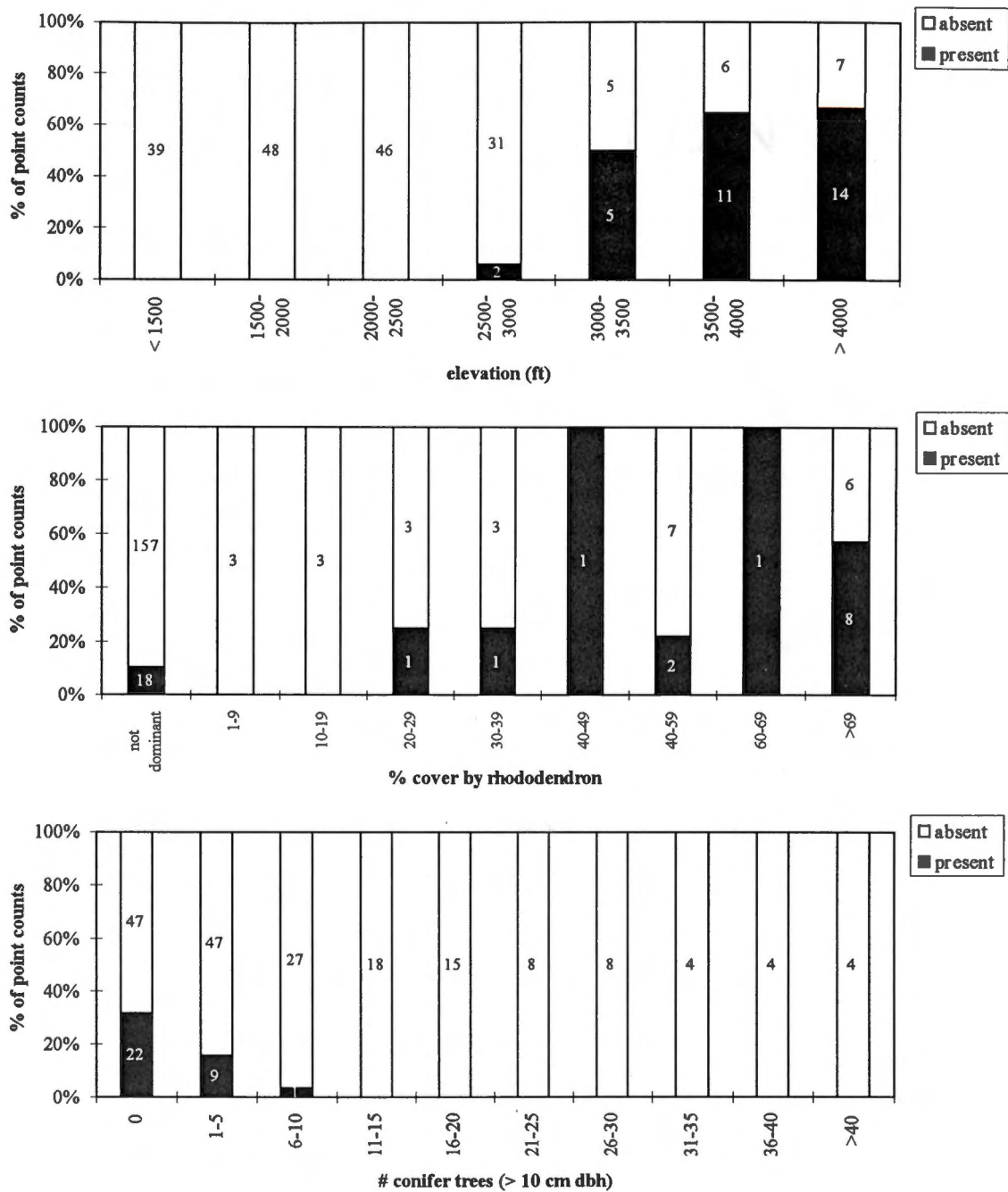


Figure 8. Percentage of points where Canada warbler was present and absent in 1992, 1993 or in both years, across six continuous habitat variables deemed best predictors of Canada warbler distribution, Cherokee National Forest, Tennessee.

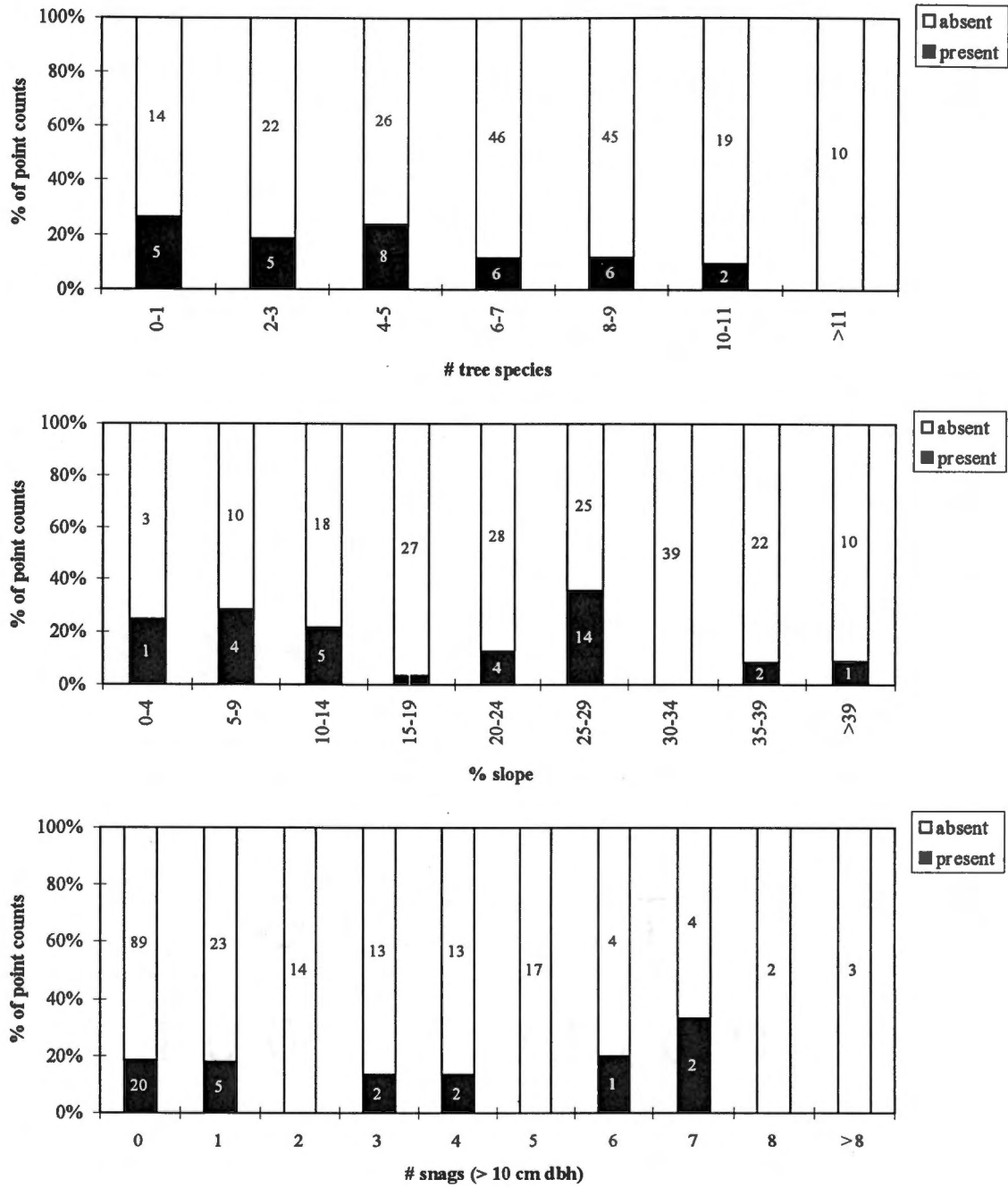


Figure 8. (continued)



Table 13. Result of model selections for response variable - Canada warbler. Final variables were selected from 38 habitat variables, Cherokee National Forest, Tennessee. Underlined variables are categorical. Asterisks denote variables with significant ( $P \leq 0.05$ ) Wald chi-square test scores (see Table 5 for variable descriptions).

| Model Type        | Variables Selected         | Parameter Estimate <sup>1</sup> | Pr. > $\chi^2$ | Probability Tests for Correct Classification |            | Goodness-of-Fit Indicator<br>Hosmer / Lemeshow |
|-------------------|----------------------------|---------------------------------|----------------|----------------------------------------------|------------|------------------------------------------------|
|                   |                            |                                 |                | Concordance                                  | Jack-knife |                                                |
| FULL <sup>2</sup> | <i>CONSTANT</i>            | -8.220                          | 0.001          |                                              |            |                                                |
|                   | ELEVTN                     | 0.003                           | 0.000*         |                                              |            |                                                |
|                   | RHODCR                     | 0.091                           | 0.001*         |                                              |            |                                                |
|                   | CONFRQ                     | -0.504                          | 0.072*         |                                              |            |                                                |
|                   | NOTRSP                     | -0.442                          | 0.073*         |                                              |            |                                                |
|                   | VACCVR                     | 0.036                           | 0.335          | 98.3 %                                       | 92.1 %     | C = 2.40                                       |
|                   | GRNDCV                     | -0.023                          | 0.227          |                                              |            | P = 0.66                                       |
|                   | LITDPH                     | -0.485                          | 0.177          |                                              |            |                                                |
|                   | TOTNTR                     | 0.002                           | 0.971          |                                              |            |                                                |
|                   | SLOPE%                     | -0.079                          | 0.125*         |                                              |            |                                                |
|                   | 53-68DBH                   | 0.433                           | 0.411          |                                              |            |                                                |
| CISC              | <i>CONSTANT</i>            | -31.900                         | 0.000          |                                              |            |                                                |
|                   | <u>COVEHD</u>              | 28.752                          | 0.000*         |                                              |            |                                                |
|                   | <u>HEMLCK</u>              | 28.236                          | 0.000*         |                                              |            |                                                |
|                   | <u>MXEDHP</u>              | 28.040                          | 0.000*         |                                              |            |                                                |
|                   | <u>NORHWD</u>              | 31.643                          | 0.000*         |                                              |            |                                                |
|                   | <u>OAKHIC</u>              | 28.820                          | 0.000*         |                                              |            |                                                |
|                   | <u>YEPINE</u> <sup>3</sup> | -145.50                         | 0.000*         | 88.3%                                        | 86.4 %     | C = 6.34                                       |
|                   | <u>SEEDLG</u>              | 1.128                           | 0.511          |                                              |            | P = 0.61                                       |
|                   | <u>POLTMB</u>              | 0.052                           | 0.960          |                                              |            |                                                |
|                   | <u>SAWTMB</u> <sup>4</sup> | -1.180                          | 0.511          |                                              |            |                                                |
|                   | STNDAG                     | 0.014                           | 0.538          |                                              |            |                                                |
|                   | STENDX                     | 0.001                           | 0.984          |                                              |            |                                                |
|                   | STNDSZ                     | -0.004                          | 0.207          |                                              |            |                                                |
|                   | ELEVTN <sup>5</sup>        | 0.000                           | 0.001*         | 95.8 %                                       | 90.2 %     |                                                |
| AIC               | <i>CONSTANT</i>            | -7.560                          | 0.000          |                                              |            |                                                |
|                   | ELEVTN                     | 0.002                           | 0.000*         | 95.6 %                                       | 89.7 %     | C = 4.66                                       |
|                   | CONFRQ                     | -0.129                          | 0.175          |                                              |            | P = 0.21                                       |
|                   | LITDPH                     | -0.102                          | 0.691          |                                              |            |                                                |
| STEP-WISE         | <i>CONSTANT</i>            | -9.529                          | 0.000          |                                              |            |                                                |
|                   | ELEVTN                     | 0.003                           | 0.000*         |                                              |            |                                                |
|                   | RHODCR                     | 0.107                           | 0.001*         | 96.1 %                                       | 91.6 %     | C = 1.05                                       |
|                   | CONFRQ                     | -0.672                          | 0.036*         |                                              |            | P = 0.71                                       |
|                   | NOTRSP                     | -0.315                          | 0.063*         |                                              |            |                                                |
|                   | SLOPE%                     | -0.093                          | 0.072*         |                                              |            |                                                |
|                   | SNGFRQ                     | -0.494                          | 0.035*         |                                              |            |                                                |

<sup>1</sup> Unstandardized coefficients - these estimates do not indicate the relative weight of each variable.

<sup>2</sup> Variables are listed in decreasing order of the significance of their F-statistic.

<sup>3</sup> Reference group for the forest type design (dummy) variable group.

<sup>4</sup> Reference group for the condition class design (dummy) variable group.

<sup>5</sup> Correct classification rate for the CISC variables with the ELEVTN component included.

elevation, rhododendron cover, conifer frequency, # tree species, and slope had significant slope coefficients ( $P \leq 0.05$ ). This model resulted in correct classification rates of 98.3% (concordance) and 92.1% (jackknife). The Hosmer-Lemeshow goodness-of-fit test indicated that the model fit the data well ( $P = 0.66$ ).

***Predictive Models - AIC.*** Three variables (elevation, conifer frequency, and litter depth) were chosen by the best-subset selection procedure as best predictors among sampled variables of Canada warbler presence/absence on the Tellico District (Table 13). Conifer frequency and litter depth were negatively correlated, whereas elevation was positively correlated with Canada warbler distribution (Table 13). Wald scores indicated that elevation was significant ( $P \leq 0.05$ ). The correct classification rates by the concordance and jackknife tests for this model were 95.6% and 89.7%, respectively. The Hosmer-Lemeshow statistic indicated the model fit to the data was acceptable ( $P = 0.21$ ).

***Predictive Models - Stepwise.*** Elevation, rhododendron cover, conifer frequency, # tree species, slope, and snag frequency were selected by the stepwise procedure as best predictors of Canada warbler distribution (Table 13). Elevation and rhododendron cover were positively correlated with Canada warbler distribution, whereas conifer frequency, # tree species, slope and snag frequency were negatively correlated (Table 13). Slope coefficients for all six variables were different ( $P \leq 0.05$ ) from zero (Wald test). Correct classification rates for this model were 96.1% (concordance) and 91.6% (jackknife). The Hosmer-Lemeshow test indicated a very good fit of the model to the data ( $P = 0.71$ ).

***Predictive Models - CISC Variables.*** Concordance and jackknife values for the CISC database variables (forest type, condition class, stand age, site index, stand size, and elevation) (Table 13) were 95.8% and 90.2%, respectively. Slope coefficients for design

variables - cove hardwood, hemlock/white pine, mixed, northern hardwood, oak/hickory, and yellow pine and continuous variable - elevation were significant ( $P \leq 0.05$ ). The Hosmer-Lemeshow test for the CISC model indicated that the model fit the data well ( $P = 0.61$ ).

### **Chestnut-sided Warbler**

***Predictive Models - Top Ten Predictors.*** I recorded chestnut-sided warblers in high elevation clearcuts (Figure 9), natural forest openings, and along roads generally > 3,000 ft MSL. The ten most important sampled predictor variables of chestnut-sided warbler distribution were (from lowest P-value to highest): elevation, # tree species, canopy height, total # trees, 10-15 dbh, conifer frequency, condition class, litter depth, stand age, and ground cover % (Table 14). Wald scores indicated that elevation, canopy height, total # trees, 10-15 dbh, litter depth, and ground cover % had slope coefficients that were different ( $P \leq 0.05$ ) from zero in the full model. This model resulted in a correct classification rate of 98.2% (concordance) and 93.5% (jackknife). The Hosmer-Lemeshow test indicated that the model fit the data well ( $P = 0.61$ ). There were 27 observed chestnut-sided warbler-present points and 187 observed chestnut-sided warbler-absent points.

***Predictive Models - AIC and Stepwise.*** Three variables (elevation, canopy height, and litter depth) were selected as best predictors among sampled variables of chestnut-sided warbler presence/absence (Table 14). Parameter estimates for canopy height and litter depth indicated negative correlations to chestnut-sided warbler distribution, whereas elevation was positively correlated (Table 14). Wald scores for the

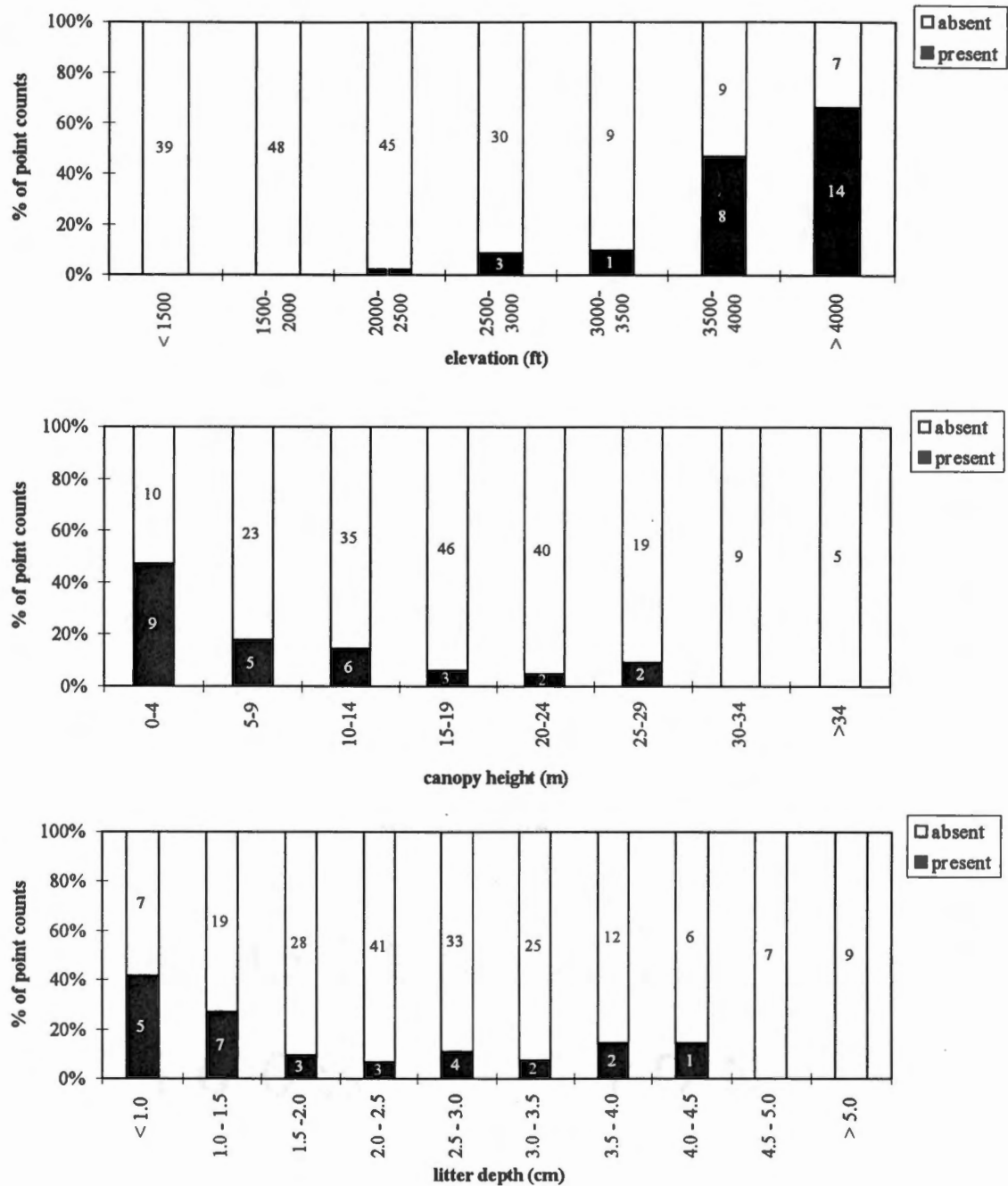


Figure 9. Percentage of points where chestnut-sided warbler was present and absent in 1992, 1993 or in both years, across three continuous habitat variables deemed best predictors of chestnut-sided warbler distribution, Cherokee National Forest, Tennessee.

Table 14. Result of model selections for response variable - chestnut-sided warbler. Final variables were selected from 38 habitat variables, Cherokee National Forest, Tennessee. Underlined variables are categorical. Asterisks denote variables with significant ( $P \leq 0.05$ ) Wald chi-square test scores (see Table 5 for variable descriptions).

| Model Type        | Variables Selected         | Parameter Estimate <sup>1</sup> | Pr. > $\chi^2$ | Probability Tests of Correct Classification |            | Goodness-of-Fit Indicator<br>Hosmer / Lemeshow |
|-------------------|----------------------------|---------------------------------|----------------|---------------------------------------------|------------|------------------------------------------------|
|                   |                            |                                 |                | Concordance                                 | Jack-knife |                                                |
| FULL <sup>2</sup> | <i>CONSTANT</i>            | -6.048                          | 0.198          |                                             |            |                                                |
|                   | ELEVTVN                    | 0.003                           | 0.000*         |                                             |            |                                                |
|                   | NOTRSP                     | 0.059                           | 0.825          |                                             |            |                                                |
|                   | CNPYHT                     | -0.221                          | 0.034*         |                                             |            |                                                |
|                   | TOTNTR                     | 0.155                           | 0.158*         |                                             |            |                                                |
|                   | 10-15DBH                   | -0.395                          | 0.025*         | 98.2 %                                      | 93.5 %     | C = 2.25                                       |
|                   | CONFRQ                     | -0.272                          | 0.213          |                                             |            | P = 0.61                                       |
|                   | <u>CNDCLS</u>              |                                 |                |                                             |            |                                                |
|                   | LITDPH                     | -0.811                          | 0.099*         |                                             |            |                                                |
|                   | STNDAG                     | -0.001                          | 0.981          |                                             |            |                                                |
|                   | GRNDCV                     | -0.044                          | 0.043*         |                                             |            |                                                |
| CISC              | <i>CONSTANT</i>            | -3.735                          | 0.362          |                                             |            |                                                |
|                   | <u>COVEHD</u>              | 0.843                           | 0.656          |                                             |            |                                                |
|                   | <u>HEMLCK</u>              | 0.046                           | 0.976          |                                             |            |                                                |
|                   | <u>MXEDHP</u>              | -11.223                         | 0.944          |                                             |            |                                                |
|                   | <u>NORHWD</u>              | 6.174                           | 0.001*         |                                             |            |                                                |
|                   | <u>OAKHIC</u>              | 2.132                           | 0.108*         |                                             |            |                                                |
|                   | <u>YEPINE</u> <sup>3</sup> | 2.028                           | 0.000          | 94.7 %                                      | 87.4 %     | C = 0.98                                       |
|                   | <u>SEEDLG</u>              | 1.535                           | 0.537          |                                             |            | P = 0.91                                       |
|                   | <u>POLTMB</u>              | -1.527                          | 0.338          |                                             |            |                                                |
|                   | <u>SAWTMB</u> <sup>4</sup> | -0.008                          | 0.537          |                                             |            |                                                |
|                   | STNDAG                     | -0.024                          | 0.448          |                                             |            |                                                |
|                   | STENDX                     | 0.007                           | 0.870          |                                             |            |                                                |
|                   | STNDSZ                     | -0.012                          | 0.008*         |                                             |            |                                                |
|                   | ELEVTVN <sup>5</sup>       | 0.000                           | 0.001*         | 98.2 %                                      | 91.6 %     |                                                |
| AIC & STEP-WISE   | <i>CONSTANT</i>            | -5.731                          | 0.000          |                                             |            |                                                |
|                   | ELEVTVN                    | 0.003                           | 0.000*         | 97.5 %                                      | 93.5 %     | C = 1.20                                       |
|                   | CNPYHT                     | -0.187                          | 0.000*         |                                             |            | P = 0.52                                       |
|                   | LITDPH                     | -0.629                          | 0.063*         |                                             |            |                                                |

<sup>1</sup> Unstandardized coefficients - these estimates do not indicate the relative weight of each variable.

<sup>2</sup> Variables are listed in decreasing order of the significance of their F-statistic.

<sup>3</sup> Reference group for the forest type design (dummy) variable group.

<sup>4</sup> Reference group for the condition class design (dummy) variable group.

<sup>5</sup> Correct classification rate for the CISC variables with the ELEVTVN component included.



slope coefficients of this model indicated that all three covariates were significant ( $P \leq 0.05$ ). The classification tests indicated correct classification rates of 97.5% (concordance) and 93.5% (jackknife) for this model. The Hosmer-Lemeshow goodness-of-fit test indicated a good fit of this model to the data ( $P = 0.52$ ).

***Predictive Models - CISC Variables.*** Correct classification rates for the CISC model (forest type, condition class, stand age, site index, stand size, and elevation) (Table 14) were 98.2% (concordance) and 91.6% (jackknife). Wald scores indicated differences ( $P \leq 0.05$ ) in slope coefficients for design variables - northern hardwood and oak/hickory and continuous variables - stand size and elevation. The Hosmer-Lemeshow test indicated an excellent fit of the model to the data ( $P = 0.91$ ).

## **Hooded Warbler**

***Predictive Models - Top Ten Predictors.*** On the Tellico District, hooded warblers occurred across the entire spectrum of most habitat variables deemed important as distribution predictors (Figure 10). The univariate test selected the following ten variables with the highest probability of being different ( $P \leq 0.05$ ) across 125 observed hooded warbler-present points and 89 observed hooded warbler-absent points (lowest P-value to highest): 15-23 dbh, site index, total # trees, forest type, conifer frequency, condition class, canopy cover, 10-15 dbh, total basal area, and 23-30 dbh (Table 15). Wald chi-square scores indicated that 15-23 dbh and conifer frequency had estimated coefficients that were different ( $P \leq 0.05$ ) from zero. This model resulted in correct classification rates of 77.1% (concordance) and 64.5% (jackknife). The Hosmer-Lemeshow test indicated an acceptable fit of the model to the data ( $P = 0.19$ ).



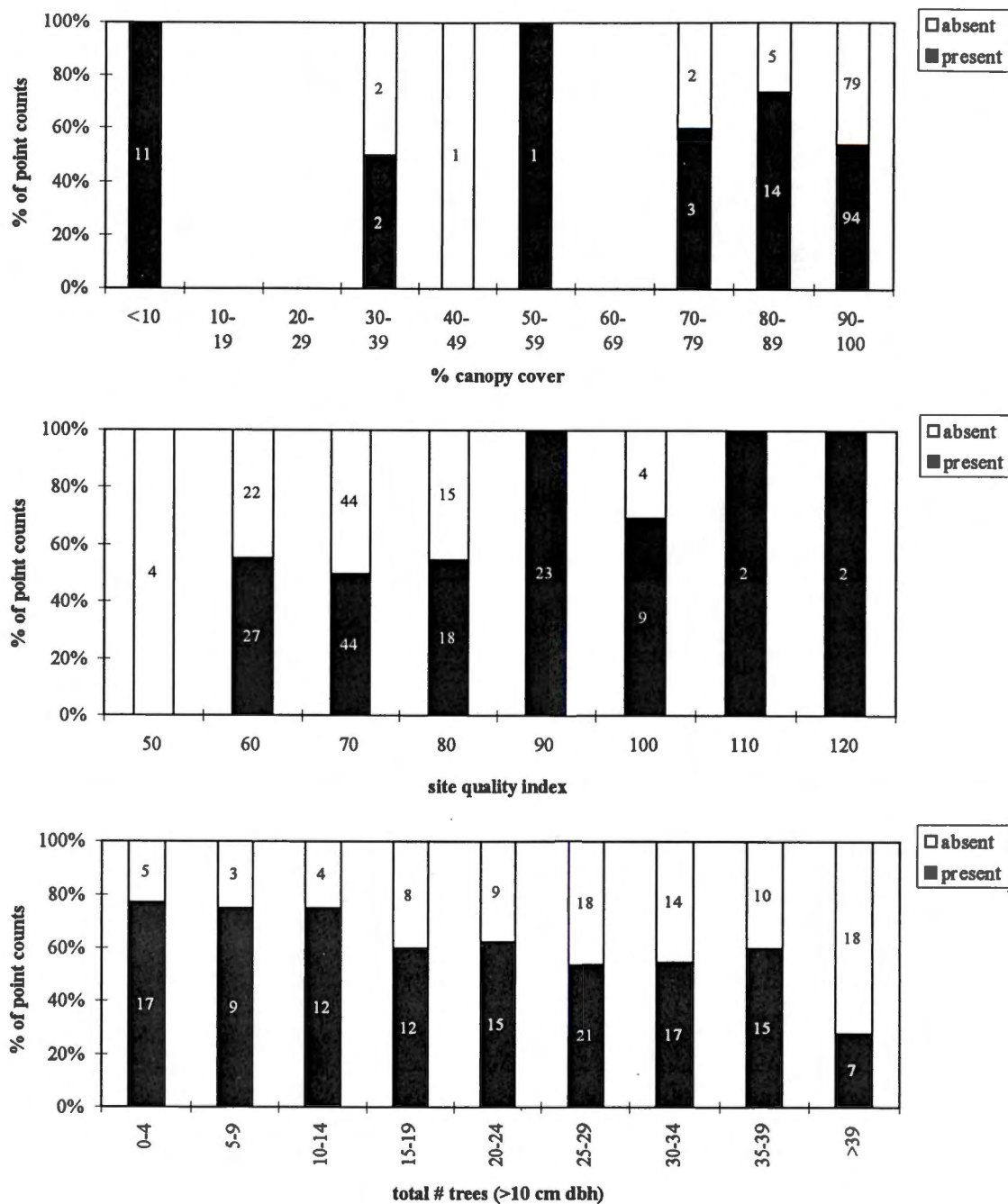


Figure 10. Percentage of points where hooded warbler was present and absent in 1992, 1993 or in both years, across seven continuous habitat variables deemed best predictors of hooded warbler distribution, Cherokee National Forest, Tennessee.

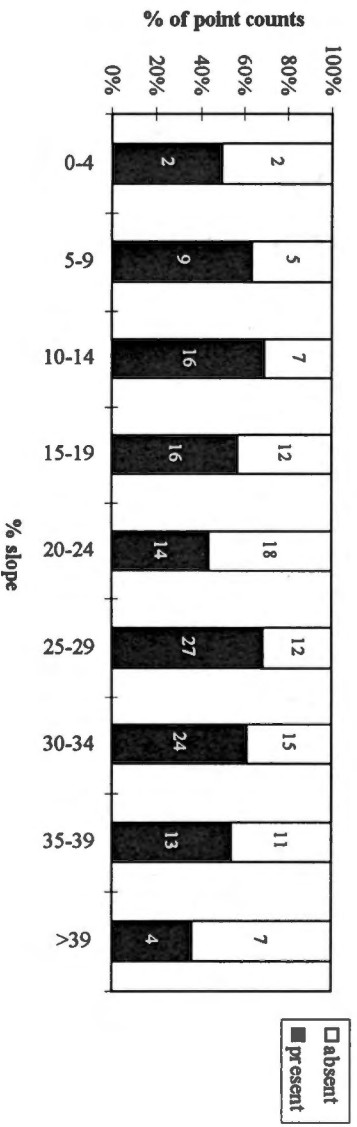
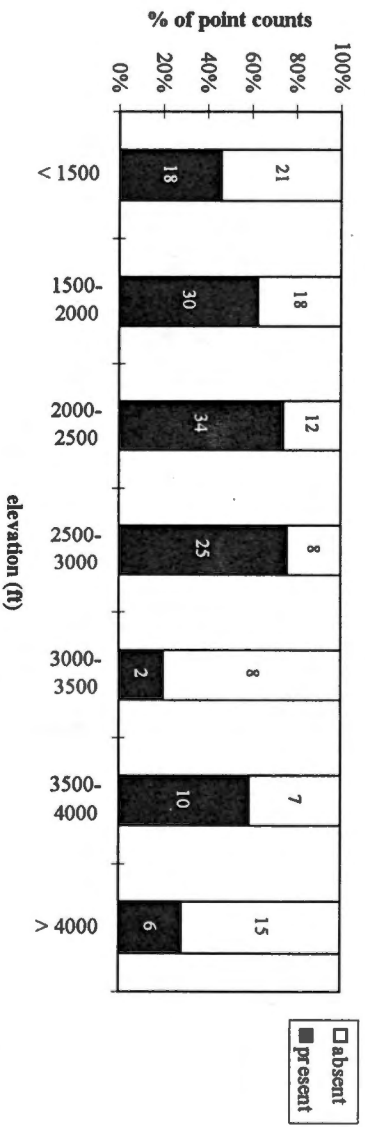
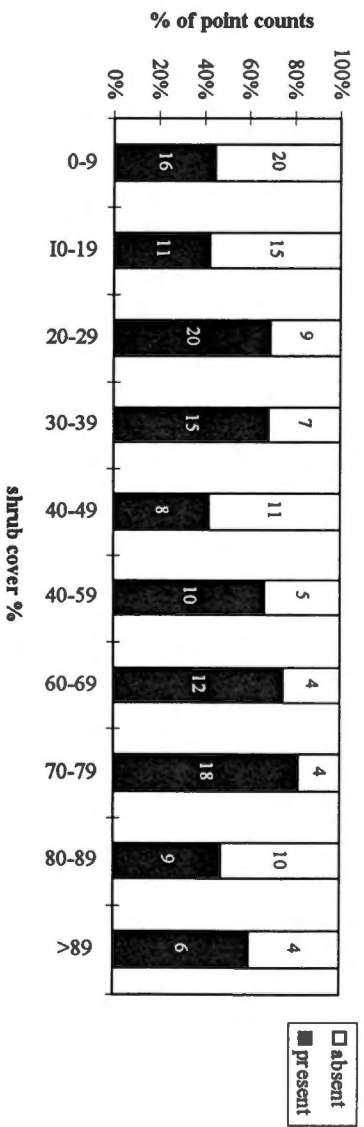
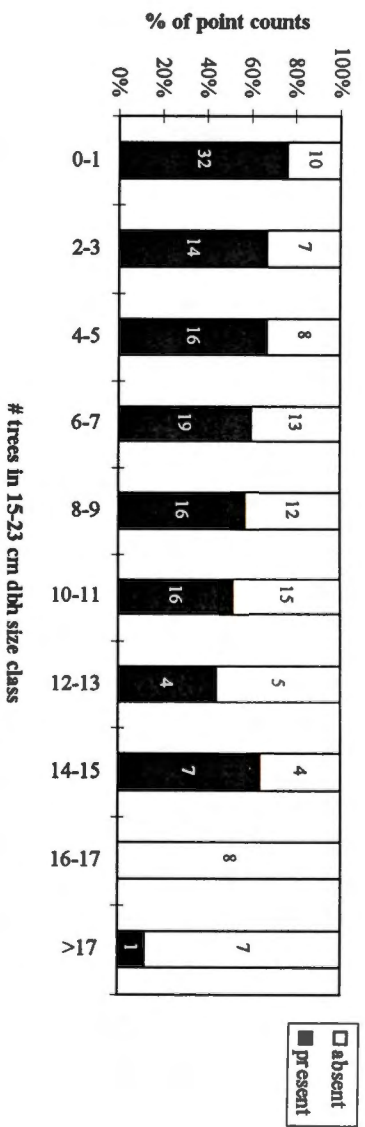


Figure 10. (continued)

Table 15. Result of model selections for response variable - hooded warbler. Final variables were selected from 38 habitat variables, Cherokee National Forest, Tennessee. Underlined variables are categorical. Asterisks denote variables with significant ( $P \leq 0.05$ ) Wald chi-square test scores (see Table 5 for variable descriptions).

| Model Type        | Variables Selected         | Parameter Estimate <sup>1</sup> | Pr. > $\chi^2$ | Probability Tests of Correct Classification |            | Goodness-of-Fit Indicator<br>Hosmer / Lemeshow |
|-------------------|----------------------------|---------------------------------|----------------|---------------------------------------------|------------|------------------------------------------------|
|                   |                            |                                 |                | Concordance                                 | Jack-knife |                                                |
| FULL <sup>3</sup> | CONSTANT                   | 0.606                           | 0.730          |                                             |            |                                                |
|                   | 15-23DBH                   | -0.166                          | 0.139*         |                                             |            |                                                |
|                   | STENDX                     | 0.006                           | 0.796          |                                             |            |                                                |
|                   | TOTNTR                     | 0.102                           | 0.399          |                                             |            |                                                |
|                   | <u>FORTYP</u> <sup>2</sup> |                                 |                |                                             |            |                                                |
|                   | CONFRQ                     | -0.033                          | 0.156*         | 77.1 %                                      | 64.5 %     | C = 11.21<br>P = 0.19                          |
|                   | <u>CNDCLS</u> <sup>4</sup> |                                 |                |                                             |            |                                                |
|                   | CNPYCR                     | -0.012                          | 0.201          |                                             |            |                                                |
|                   | 10-15DBH                   | -0.075                          | 0.526          |                                             |            |                                                |
|                   | TOTBSL                     | -0.187                          | 0.769          |                                             |            |                                                |
|                   | 23-30DBH                   | -0.064                          | 0.631          |                                             |            |                                                |
| CISC              | CONSTANT                   | -1.789                          | 0.332          |                                             |            |                                                |
|                   | <u>COVEHD</u>              | 2.643                           | 0.002*         |                                             |            |                                                |
|                   | <u>HEMLCK</u>              | 0.939                           | 0.132*         |                                             |            |                                                |
|                   | <u>MXEDHP</u>              | 0.712                           | 0.149*         |                                             |            |                                                |
|                   | <u>NORHWD</u>              | 0.149                           | 0.797          |                                             |            |                                                |
|                   | <u>OAKHIC</u>              | 0.552                           | 0.325          | 74.6 %                                      | 64.0 %     | C = 6.20<br>P = 0.63                           |
|                   | <u>YEPINE</u> <sup>5</sup> | -4.994                          | 0.152*         |                                             |            |                                                |
|                   | <u>SEEDLG</u>              | 1.618                           | 0.128*         |                                             |            |                                                |
|                   | <u>POLTMB</u>              | -0.121                          | 0.854          |                                             |            |                                                |
|                   | <u>SAWTMB</u> <sup>6</sup> | -1.497                          | 0.131*         |                                             |            |                                                |
|                   | STNDAG                     | 0.014                           | 0.340          |                                             |            |                                                |
|                   | STENDX                     | 0.004                           | 0.858          |                                             |            |                                                |
|                   | STNDSZ                     | -0.001                          | 0.560          |                                             |            |                                                |
|                   | <u>ELEVTN</u> <sup>7</sup> | -0.000                          | 0.132*         | 75.6 %                                      | 63.1 %     |                                                |
| AIC               | CONSTANT                   | 0.897                           | 0.565          |                                             |            |                                                |
|                   | CNPYCR                     | -0.012                          | 0.167*         |                                             |            |                                                |
|                   | <u>COVEHD</u>              | 1.998                           | 0.027*         |                                             |            |                                                |
|                   | <u>HEMLCK</u>              | 0.538                           | 0.376          |                                             |            |                                                |
|                   | <u>MXEDHP</u>              | 0.517                           | 0.296          | 74.0 %                                      | 64.5 %     | C = 1.11<br>P = 0.99                           |
|                   | <u>NORHWD</u>              | -0.107                          | 0.851          |                                             |            |                                                |
|                   | <u>OAKHIC</u>              | 0.242                           | 0.664          |                                             |            |                                                |
|                   | <u>YEPINE</u>              | -3.188                          | 0.296          |                                             |            |                                                |
|                   | STENDX                     | 0.012                           | 0.559          |                                             |            |                                                |
|                   | TOTNTR                     | -0.031                          | 0.011*         |                                             |            |                                                |

<sup>1</sup> Unstandardized coefficients - these estimates do not indicate the relative weight of each variable.

<sup>2</sup> 'COVEHD' subgroup (parameter est. = 2.041,  $P = 0.034$ ) recorded a significant ( $P \leq 0.05$ ) Wald score.

<sup>3</sup> Variables are listed in decreasing order of the significance of their F-statistic.

<sup>4</sup> 'SEEDLG' subgroup (parameter est. = 0.773,  $P = 0.157$ ) recorded a significant ( $P \leq 0.05$ ) Wald score.

<sup>5</sup> Reference group for the forest type design (dummy) variable group.

<sup>6</sup> Reference group for the condition class design (dummy) variable group.

<sup>7</sup> Correct classification rate for the CISC variables with the ELEVTN component included.

Table 15. (continued)

| Model Type | Variables Selected | Parameter Estimate | Pr. > $\chi^2$ | Probability Tests of Correct Classification |            | Goodness-of-Fit Indicator<br>Hosmer / Lemeshow |
|------------|--------------------|--------------------|----------------|---------------------------------------------|------------|------------------------------------------------|
|            |                    |                    |                | Concordance                                 | Jack-knife |                                                |
| STEP-WISE  | <i>CONSTANT</i>    | 1.300              | 0.094          |                                             |            |                                                |
|            | 15-23D             | -0.118             | 0.000*         |                                             |            |                                                |
|            | SHRBCV             | 0.014              | 0.020*         |                                             |            |                                                |
|            | ELEVTN             | -0.000             | 0.100*         |                                             |            |                                                |
|            | SLOPE%             | -0.025             | 0.124*         |                                             |            |                                                |
|            | <u>COVEHD</u>      | 2.761              | 0.000*         | 77.6 %                                      | 66.8 %     | C = 9.30                                       |
|            | <u>HEMLCK</u>      | 0.870              | 0.101*         |                                             |            | P = 0.37                                       |
|            | <u>MXEDHP</u>      | 0.711              | 0.162*         |                                             |            |                                                |
|            | <u>NORHWD</u>      | 1.065              | 0.156*         |                                             |            |                                                |
|            | <u>OAKHIC</u>      | 0.659              | 0.243          |                                             |            |                                                |
|            | <u>YEPINE</u>      | -6.066             | 0.224          |                                             |            |                                                |

***Predictive Models - AIC.*** Canopy cover, forest type, condition class, site index, and total # trees were selected as best sampled predictors of hooded warbler distribution by Akaike's Information Criterion (Table 15). Canopy cover, northern hardwood, yellow pine, and total # trees were negatively correlated with hooded warbler distribution, while cove hardwood, hemlock/white pine, mixed, oak/hickory, and site index were positively correlated (Table 15). Wald scores indicated that coefficients for canopy cover, total # trees and design variable - cove hardwood were different ( $P \leq 0.05$ ) from zero.

Concordance and jackknife tests correctly classified points 74.0% and 64.5% of the time, respectively. The Hosmer-Lemeshow statistic indicated the AIC model fit to the data was exceptional ( $P = 0.99$ ).

***Predictive Models - Stepwise.*** Five variables (15-23 dbh, shrub cover, elevation, slope, and forest type) were chosen by the stepwise procedure as best predictors among sampled variables of hooded warbler presence/absence on the district (Table 15). Slope, 15-23 dbh, and yellow pine showed negative correlations; shrub cover, elevation, cove hardwood, hemlock/white pine, mixed, northern hardwood, and oak/hickory were positively correlated with hooded warbler distribution (Table 15). Wald scores indicated that coefficients for all continuous variables and all design variables excluding oak/hickory and yellow pine were different ( $P \leq 0.05$ ) from zero. The correct classification rates by the concordance and jackknife tests for this model were 77.6% and 66.8%, respectively. The Hosmer-Lemeshow test for this model indicated a good model fit to the data ( $P = 0.37$ ).

***Predictive Models - CISC Variables.*** Concordance and jackknife values for the CISC database variables (forest type, condition class, stand age, site index, stand size, and



elevation) (Table 15) were 75.6% and 63.1%, respectively. Elevation and forest types - cove hardwood, hemlock/white pine, mixed and yellow pine and condition classes - seedling/sapling and sawtimber were different ( $P \leq 0.05$ ) from zero (Wald test). The Hosmer-Lemeshow goodness-of-fit test indicated a good fit of the model to the data ( $P = 0.61$ ).

### **Wood thrush**

***Predictive Models - Top Ten Predictors.*** I recorded wood thrushes in stands with large diameter trees and well-established canopies (Figure 11). Univariate tests chose the following ten variables as best predictors of wood thrush presence/absence among sampled variables (smallest P-value to largest): canopy height, saplings count, basal area saplings, condition class, stand age, 30-38 dbh, 38-53 dbh, 53-68 dbh, # tree species, and total basal area (Table 16). Wald chi-square scores indicated that 30-38 dbh had an estimated slope coefficient that was different ( $P \leq 0.05$ ) from zero. Correct classification rates were 71.9% (concordance) and 86.9% (jackknife), respectively. The Hosmer-Lemeshow statistic indicated the full model fit to the data was poor ( $P = 0.03$ ). There were 29 observed wood thrush-present points and 185 observed wood thrush-absent points.

***Predictive Models - AIC.*** The AIC best-subset selection procedure chose the following two variables as best sampled predictors of wood thrush distribution: 30-38 dbh and 53-68 dbh (Table 16). Both 30-38 dbh and 53-68 dbh were positively correlated with wood thrush distribution (Table 16). All slope coefficients were significant ( $P \leq 0.05$ ) (Wald scores). A concordance rate of 67.6% and jackknife rate of 86.4% were recorded,



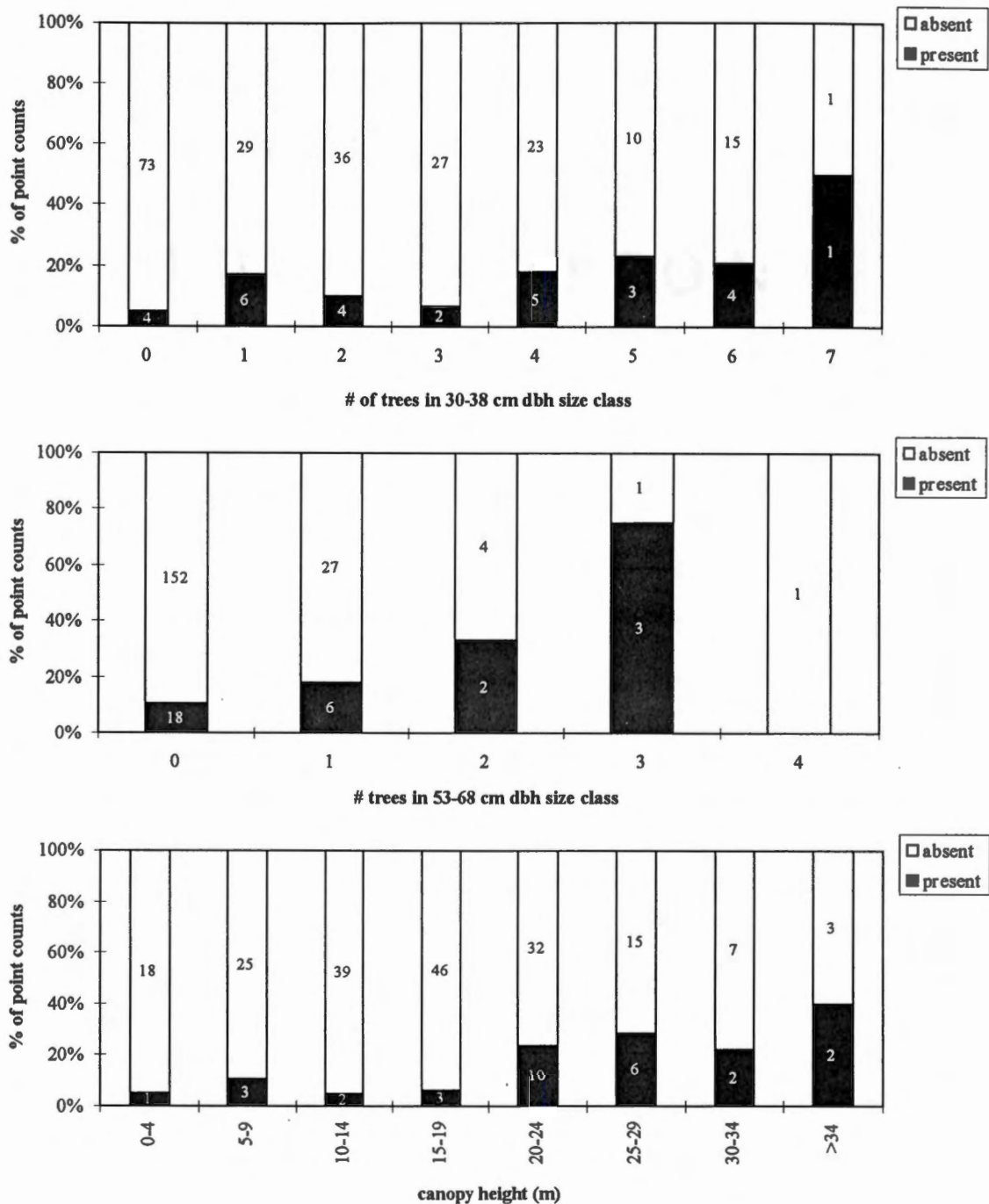


Figure 11. Percentage of points where wood thrush was present and absent in 1992, 1993 or in both years, across three continuous habitat variables deemed best predictors of woodthrush distribution, Cherokee National Forest, Tennessee.

Table 16. Result of model selections for response variable - wood thrush. Final variables were selected from 38 habitat variables, Cherokee National Forest, Tennessee. Underlined variables are categorical. Asterisks denote variables with significant ( $P \leq 0.05$ ) Wald chi-square test scores (see Table 5 for variable descriptions).

| Model Type        | Variables Selected          | Parameter Estimate <sup>1</sup> | Pr. > $\chi^2$ | Probability Tests of Correct Classification |            | Goodness-of-Fit Indicator<br>Hosmer / Lemeshow |
|-------------------|-----------------------------|---------------------------------|----------------|---------------------------------------------|------------|------------------------------------------------|
|                   |                             |                                 |                | Concordance                                 | Jack-knife |                                                |
| FULL <sup>2</sup> | <i>CONSTANT</i>             | -2.401                          | 0.199          |                                             |            |                                                |
|                   | CNPYHT                      | 0.049                           | 0.232          |                                             |            |                                                |
|                   | NOSAPS                      | 4.022                           | 0.694          |                                             |            |                                                |
|                   | BSLSAP                      | -2048.90                        | 0.694          |                                             |            |                                                |
|                   | <u>CNDCLS</u>               |                                 |                |                                             |            |                                                |
|                   | STNDAG                      | -0.022                          | 0.278          | 71.9 %                                      | 86.9 %     | C = 17.38                                      |
|                   | 30-38DBH                    | 0.241                           | 0.109*         |                                             |            | P = 0.03                                       |
|                   | 38-53DBH                    | 0.038                           | 0.805          |                                             |            |                                                |
|                   | 53-68DBH                    | 0.504                           | 0.182          |                                             |            |                                                |
|                   | NOTRSP                      | 0.078                           | 0.383          |                                             |            |                                                |
| CISC              | TOTBSL                      | 0.063                           | 0.916          |                                             |            |                                                |
|                   | <i>CONSTANT</i>             | -1.411                          | 0.513          |                                             |            |                                                |
|                   | <u>COVEHD</u>               | 1.923                           | 0.089*         |                                             |            |                                                |
|                   | <u>HEMLCK</u>               | 1.786                           | 0.069*         |                                             |            |                                                |
|                   | <u>MXEDHP</u>               | 1.010                           | 0.258          |                                             |            |                                                |
|                   | <u>NORHWD</u>               | -0.467                          | 0.719          |                                             |            |                                                |
|                   | <u>OAKHIC</u>               | 1.488                           | 0.103*         |                                             |            |                                                |
|                   | <u>YEPINE</u> <sup>3</sup>  | -5.740                          | 0.258          | 73.2 %                                      | 84.6 %     | C = 2.05                                       |
|                   | <u>SEEDLG</u>               | -1.228                          | 0.373          |                                             |            | P = 0.98                                       |
|                   | <u>POLTMB</u>               | -0.326                          | 0.679          |                                             |            |                                                |
|                   | <u>SAWTMB</u> <sup>4</sup>  | 1.554                           | 0.373          |                                             |            |                                                |
|                   | STNDAG                      | 0.006                           | 0.762          |                                             |            |                                                |
|                   | STENDX                      | -0.017                          | 0.498          |                                             |            |                                                |
|                   | STNDSZ                      | -0.004                          | 0.352          |                                             |            |                                                |
| AIC               | <u>ELEVTVN</u> <sup>5</sup> | 0.000                           | 0.130          | 74.0 %                                      | 86.4 %     |                                                |
|                   | <i>CONSTANT</i>             | -2.842                          | 0.000          |                                             |            |                                                |
|                   | 30-38DBH                    | 0.293                           | 0.005*         | 67.6 %                                      | 86.4 %     | C = 18.91                                      |
| STEP-WISE         | 53-68DBH                    | 0.700                           | 0.004*         |                                             |            | P = 0.00                                       |
|                   | <i>CONSTANT</i>             | -3.472                          | 0.000          |                                             |            |                                                |
|                   | 30-38DBH                    | 0.229                           | 0.047*         | 72.2 %                                      | 86.0 %     | C = 11.12                                      |
|                   | 53-68DBH                    | 0.547                           | 0.037*         |                                             |            | P = 0.13                                       |
|                   | CNPYHT                      | 0.044                           | 0.152*         |                                             |            |                                                |

<sup>1</sup> Unstandardized coefficients - these estimates do not indicate the relative weight of each variable.

<sup>2</sup> Variables are listed in decreasing order of the significance of their F-statistic.

<sup>3</sup> Reference group for the forest type design (dummy) variable group.

<sup>4</sup> Reference group for the condition class design (dummy) variable group.

<sup>5</sup> Correct classification rate for the CISC variables with the ELEVTVN component included.

whereas the Hosmer-Lemeshow goodness-of-fit test indicated a poor fit of the model to the data ( $P = 0.00$ ).

***Predictive Models - Stepwise.*** The stepwise procedure chose 30-38 dbh, 53-68 dbh and canopy height as best predictors (Table 16). All three variables were positively correlated with wood thrush presence/absence (Table 16). Wald scores indicated that all slope coefficients were significant ( $P \leq 0.05$ ). Correct classification rates were 72.2% (concordance) and 86.0% (jackknife), respectively, and the Hosmer-Lemeshow goodness-of-fit test indicated a marginal fit of the model to the data ( $P = 0.13$ ).

***Predictive Models - CISC Variables.*** Concordance and jackknife test results for the CISC database variables (forest type, condition class, stand age, site index, stand size, and elevation) (Table 16) were 74.0% and 86.4% correct classification, respectively. Wald scores of slope coefficients for elevation and design variables - cove hardwood, hemlock/white pine, and oak/hickory were significant ( $P \leq 0.05$ ) (Wald score). The Hosmer-Lemeshow test indicated that the data fit the model exceptionally well ( $P = 0.98$ ).

### **Worm-eating Warbler**

***Predictive Models - Top Ten Predictors.*** I recorded worm-eating warblers in low to mid elevation deciduous forests on the Tellico District across a broad range of habitat conditions (Figure 12). The top ten sampled predictor variables of worm-eating warbler distribution selected by the univariate analysis were (from lowest P-value to highest): elevation, ground cover %, slope, # tree species, forest type, rhododendron cover, deciduous frequency, total basal area, 53-68 dbh, and 10-15 dbh (Table 17). Wald chi-square scores indicated that elevation, # tree species, rhododendron cover, deciduous

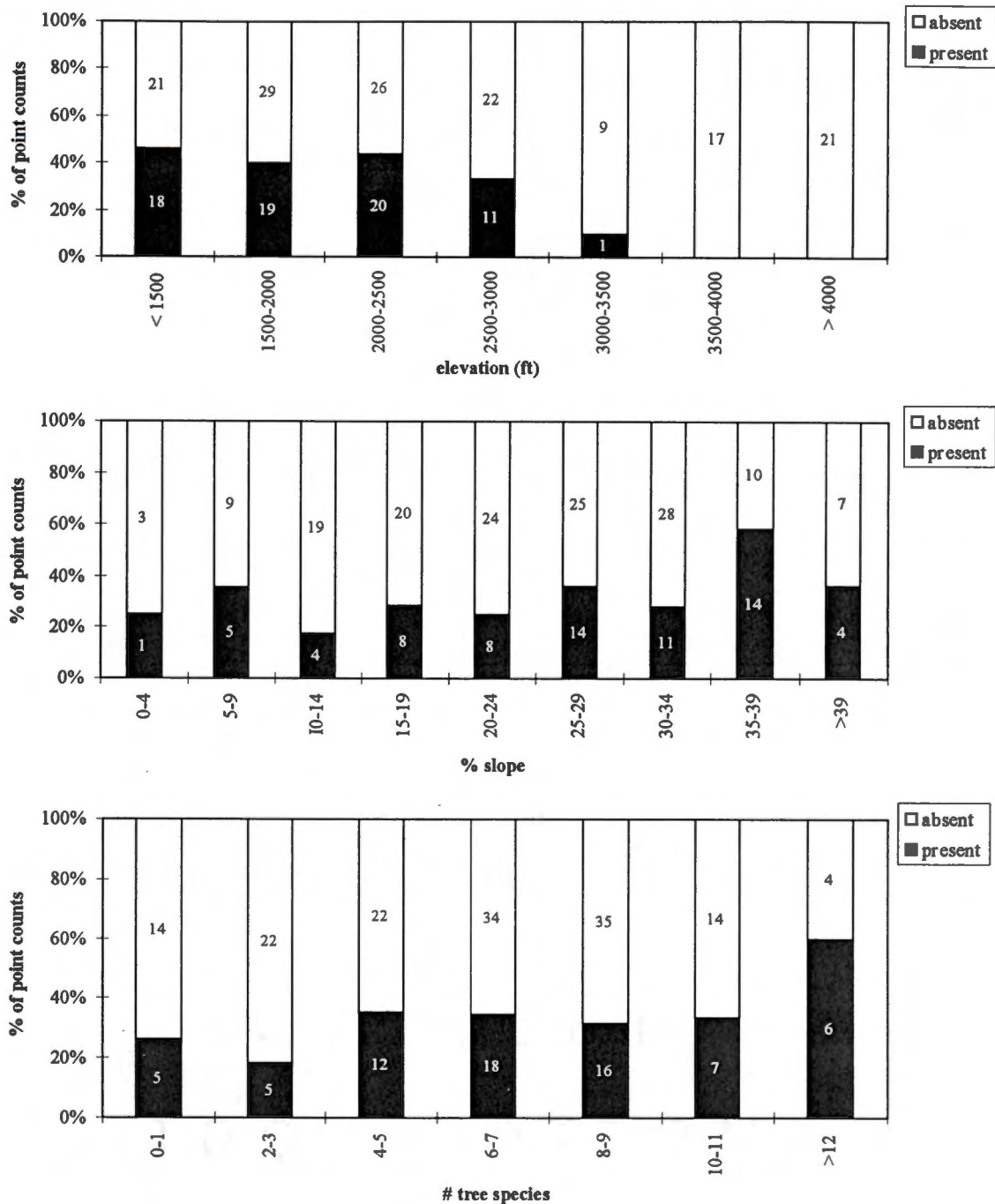


Figure 12. Percentage of points where worm-eating warbler was present and absent in 1992, 1993 or in both years, across five continuous habitat variables deemed best predictors of worm-eating warbler distribution, Cherokee National Forest, Tennessee.

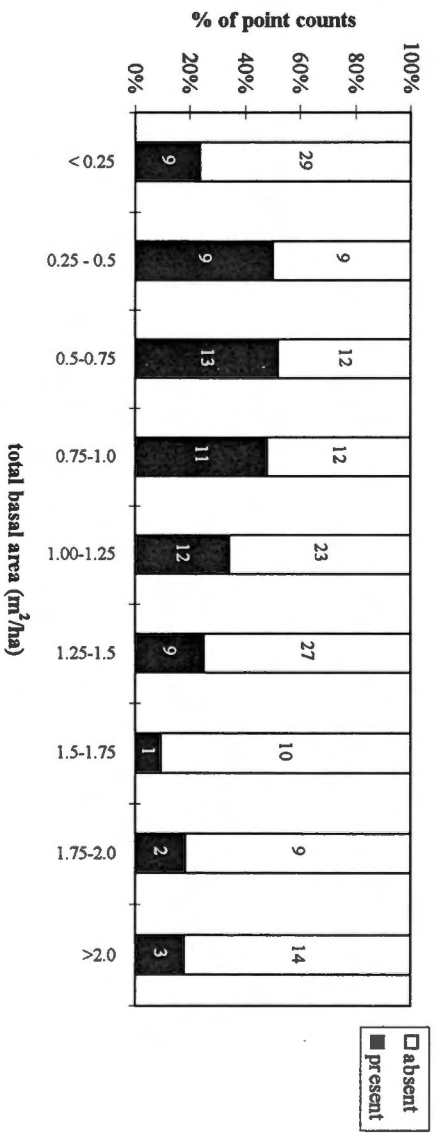
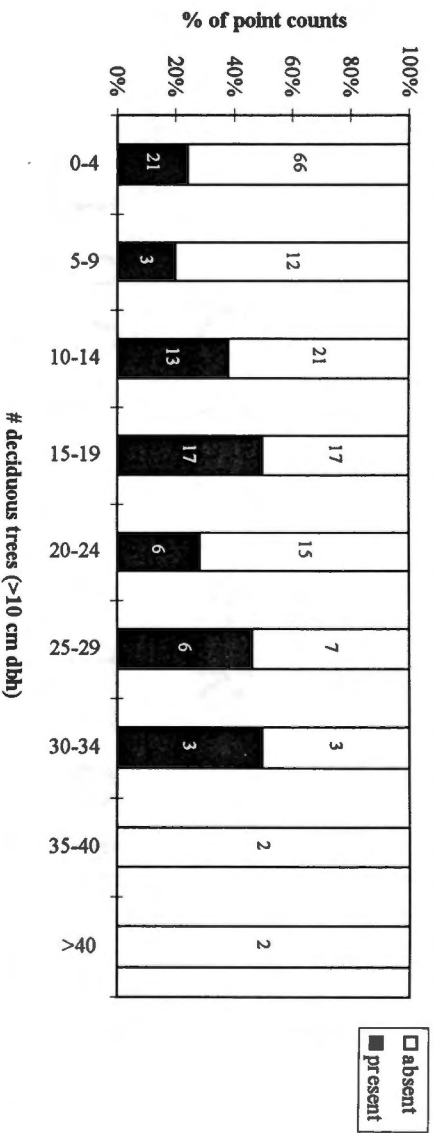


Figure 12. (continued)

Table 17. Result of model selections for response variable - worm-eating warbler. Final variables were selected from 38 habitat variables, Cherokee National Forest, Tennessee. Underlined variables are categorical. Asterisks denote variables with significant ( $P \leq 0.05$ ) Wald chi-square test scores (see Table 5 for variable descriptions).

| Model Type        | Variables Selected         | Parameter Estimate <sup>1</sup> | Pr. > $\chi^2$ | Probability Tests of Correct Classification |            | Goodness-of-Fit Indicator<br>Hosmer / Lemeshow |
|-------------------|----------------------------|---------------------------------|----------------|---------------------------------------------|------------|------------------------------------------------|
|                   |                            |                                 |                | Concordance                                 | Jack-knife |                                                |
| FULL <sup>2</sup> | <i>CONSTANT</i>            | 0.495                           | 0.610          |                                             |            |                                                |
|                   | ELEV TN                    | -0.001                          | 0.011*         |                                             |            |                                                |
|                   | GRNDCV                     | -0.011                          | 0.230          |                                             |            |                                                |
|                   | SLOPE%                     | 0.020                           | 0.254          |                                             |            |                                                |
|                   | NOTRSP                     | 0.146                           | 0.082*         |                                             |            |                                                |
|                   | <u>FORTYP</u> <sup>3</sup> |                                 |                | 77.7 %                                      | 64.5 %     | C = 13.40<br>P = 0.14                          |
|                   | RHODCR                     | -0.014                          | 0.146*         |                                             |            |                                                |
|                   | DECFRQ                     | 0.033                           | 0.173*         |                                             |            |                                                |
|                   | TOTBSL                     | -1.154                          | 0.014*         |                                             |            |                                                |
|                   | 53-68DBH                   | 0.188                           | 0.628          |                                             |            |                                                |
|                   | 10-15DBH                   | -0.012                          | 0.637          |                                             |            |                                                |
| CISC              | <i>CONSTANT</i>            | -2.314                          | 0.180          |                                             |            |                                                |
|                   | <u>COVEHD</u>              | -0.056                          | 0.943          |                                             |            |                                                |
|                   | <u>HEMLCK</u>              | 0.607                           | 0.306          |                                             |            |                                                |
|                   | <u>MXEDHP</u>              | 0.165                           | 0.741          |                                             |            |                                                |
|                   | <u>NORHWD</u>              | -2.356                          | 0.008*         |                                             |            |                                                |
|                   | <u>OAKHIC</u>              | 0.522                           | 0.345          |                                             |            |                                                |
|                   | <u>YEPINE</u> <sup>4</sup> | 1.118                           | 0.741          | 66.7 %                                      | 66.4 %     | C = 9.29<br>P = 0.32                           |
|                   | <u>SEEDLG</u>              | 1.319                           | 0.215          |                                             |            |                                                |
|                   | <u>POLTMB</u>              | 0.697                           | 0.277          |                                             |            |                                                |
|                   | <u>SAWTMB</u> <sup>5</sup> | -2.016                          | 0.215          |                                             |            |                                                |
|                   | STNDAG                     | 0.015                           | 0.334          |                                             |            |                                                |
|                   | STENDX                     | -0.000                          | 0.974          |                                             |            |                                                |
|                   | STNDSZ                     | 0.004                           | 0.113*         |                                             |            |                                                |
|                   | ELEV TN <sup>6</sup>       | -0.000                          | 0.000*         | 72.4 %                                      | 65.9 %     |                                                |
| AIC & STEP-WISE   | <i>CONSTANT</i>            | -0.013                          | 0.987          |                                             |            |                                                |
|                   | ELEV TN                    | -0.001                          | 0.004*         |                                             |            |                                                |
|                   | SLOPE%                     | 0.028                           | 0.094*         |                                             |            |                                                |
|                   | NOTRSP                     | 0.130                           | 0.102*         |                                             |            |                                                |
|                   | <u>COVEHD</u>              | 0.378                           | 0.477          | 77.1 %                                      | 65.0 %     | C = 12.10<br>P = 0.30                          |
|                   | <u>HEMLCK</u>              | 0.435                           | 0.413          |                                             |            |                                                |
|                   | <u>MXEDHP</u>              | 0.049                           | 0.927          |                                             |            |                                                |
|                   | <u>NORHWD</u>              | -0.159                          | 0.875          |                                             |            |                                                |
|                   | <u>OAKHIC</u>              | 1.131                           | 0.057*         |                                             |            |                                                |
|                   | <u>YEPINE</u>              | -1.834                          | 0.763          |                                             |            |                                                |
|                   | DECFRQ                     | 0.029                           | 0.197          |                                             |            |                                                |
|                   | TOTBSL                     | -1.035                          | 0.010*         |                                             |            |                                                |

<sup>1</sup> Unstandardized coefficients - these estimates do not indicate the relative weight of each variable.

<sup>2</sup> Variables are listed in decreasing order of the significance of their F-statistic.

<sup>3</sup> 'OAKHIC' subgroup (parameter est. = 1.117,  $P = 0.062$ ) recorded a significant ( $P \leq 0.05$ ) Wald score.

<sup>4</sup> Reference group for the forest type design (dummy) variable group.

<sup>5</sup> Reference group for the condition class design (dummy) variable group.

<sup>6</sup> Correct classification rate for the CISC variables with the ELEV TN component included.



frequency, and total basal area had slope coefficients that were different ( $P \leq 0.05$ ) from zero. This combination of habitat variables resulted in correct classification rates of 77.7% (concordance) and 64.5% (jackknife). The Hosmer-Lemeshow goodness-of-fit test indicated a marginal fit of the model to the data ( $P = 0.10$ ). There were 69 observed worm-eating warbler-present points and 145 observed worm-eating warbler-absent points.

***Predictive Models - AIC and Stepwise.*** Six variables (elevation, slope, # tree species, forest type, deciduous frequency, and total basal area) were selected by both procedures as the best predictors among sampled variables of worm-eating warbler presence/absence on the Tellico District (Table 17). Elevation, northern hardwood, yellow pine, and total basal area were negatively correlated with worm-eating warbler distribution; slope, # tree species, cove hardwood, hemlock/white pine, mixed, oak/hickory, and deciduous frequency were positively correlated (Table 17). Wald tests indicated that slope coefficients for elevation, slope, # tree species, total basal area, and design variable - oak/hickory, were significant ( $P \leq 0.05$ ). The correct classification rates by the concordance and jackknife tests for this model were 77.1% and 65.0%, respectively. The Hosmer-Lemeshow statistic indicated the model fit to the data was acceptable ( $P = 0.30$ ).

***Predictive Models - CISC Variables.*** The USFS CISC database variables (forest type, condition class, stand age, site index, stand size, and elevation) (Table 17) correctly classified worm-eating warbler distribution 72.4% of the time (concordance) and 65.9% of the time (jackknife), respectively. Wald scores indicated significant ( $P \leq 0.05$ ) slope coefficients for stand size and elevation and design variable - northern hardwood. The

Hosmer-Lemeshow goodness-of-fit test indicated an acceptable fit of the model to the data ( $P = 0.32$ ).

## **RICHNESS AND ABUNDANCE MODELS**

### **Full and Final Models**

*Full Models.* Before I began the univariate screening process for each response variable (migrant richness, resident richness, combined richness, migrant abundance, resident abundance, and combined abundance), I built a regression model for each response that included all 62 sampled and derived habitat variables (Table 18). The  $R^2$  scores indicated that these models, which included all of our data describing the vegetative and physical components of the sampled stands, explained from 29% to 35% of the variation in our avian richness and abundance response variables for the district. Univariate tests showed that, on average, a given variable with a  $P$ -value  $\leq 0.25$  explained only 2.9% of the variation in the richness or abundance data for respective migrant, resident, or combined models.

*Stepwise Linear Regression.* Final stepwise richness and abundance models for migrants, residents, and combined explained 13% to 29% of the variation in their respective response variables (Table 19). The hemlock/white pine forest type variable occurred in all six diversity models and elevation occurred in five of the final models.

### **CISC Database Models**

Six habitat variables (condition class, elevation, forest type, site index, stand age, and stand size) characterized for all forest stands in the CISC database, were used to build

Table 18. Linear regression analysis and resulting  $R^2$  values for six diversity indices when all predictor variables are included in the model ( $n = 62$ ), Cherokee National Forest, Tennessee.

| <b>Diversity Index</b> | <b><math>R^2</math></b> |
|------------------------|-------------------------|
| Migrant Richness       | 0.32                    |
| Resident Richness      | 0.30                    |
| Combined Richness      | 0.29                    |
| Migrant Abundance      | 0.35                    |
| Resident Abundance     | 0.31                    |
| Combined Abundance     | 0.35                    |

predictive models of avian diversity (Table 20). Models with and without the elevation component were generated to assess the additive predictive strength of the variable.  $R^2$  scores for these models ranged from 21% to 48%.

Table 19. Results of model selections for six diversity indices using stepwise linear regression techniques, Cherokee National Forest, Tennessee. See Table 5 for variable descriptions.

| Diversity Index    | Habitat Variable | Parameter Estimate | F      | Prob > F | R <sup>2</sup>                     |
|--------------------|------------------|--------------------|--------|----------|------------------------------------|
| Migrant Richness   | CONSTANT         | 2.517              | 10.57  | 0.001    | <b>Model R<sup>2</sup> = 0.261</b> |
|                    | ELEVTVN          | 0.000              | 14.54  | 0.000    | 0.098                              |
|                    | TOTNTR           | 0.019              | 5.55   | 0.019    | 0.059                              |
|                    | STENDX           | 0.016              | 3.91   | 0.050    | 0.025                              |
|                    | OAKHIC           | 0.882              | 9.91   | 0.002    | 0.023                              |
|                    | HEMLCK           | 0.616              | 5.13   | 0.025    | 0.021                              |
|                    | VACCVR           | -0.348             | 2.50   | 0.116    | 0.014                              |
|                    | SEEDLG           | 0.515              | 4.80   | 0.030    | 0.012                              |
|                    | 53 68D           | 0.241              | 2.41   | 0.122    | 0.009                              |
| Resident Richness  | CONSTANT         | 3.080              | 58.83  | 0.000    | <b>Model R<sup>2</sup> = 0.149</b> |
|                    | NOTRSP           | -0.070             | 11.32  | 0.001    | 0.076                              |
|                    | STENDX           | -0.016             | 10.79  | 0.001    | 0.031                              |
|                    | SHRBCV           | -0.006             | 6.07   | 0.015    | 0.020                              |
|                    | HEMLCK           | 0.328              | 3.51   | 0.063    | 0.011                              |
|                    | GRNDCV           | 0.006              | 3.67   | 0.057    | 0.011                              |
| Combined Richness  | CONSTANT         | 5.627              | 124.67 | 0.000    | <b>Model R<sup>2</sup> = 0.129</b> |
|                    | CONFRQ           | -0.031             | 6.04   | 0.015    | 0.045                              |
|                    | NOTRSP           | -0.115             | 7.58   | 0.006    | 0.032                              |
|                    | HEMLCK           | 1.026              | 8.17   | 0.005    | 0.031                              |
|                    | ELEVTVN          | 0.000              | 8.46   | 0.004    | 0.021                              |
| Migrant Abundance  | CONSTANT         | 2.632              | 5.68   | 0.018    | <b>Model R<sup>2</sup> = 0.262</b> |
|                    | ELEVTVN          | 0.001              | 26.29  | 0.000    | 0.146                              |
|                    | HEMLCK           | 1.074              | 7.69   | 0.006    | 0.030                              |
|                    | VACCVR           | -0.729             | 5.54   | 0.020    | 0.026                              |
|                    | OAKHIC           | 1.407              | 12.37  | 0.001    | 0.023                              |
|                    | TOTNTR           | -0.020             | 3.02   | 0.084    | 0.019                              |
|                    | SEEDLG           | 0.696              | 4.67   | 0.032    | 0.010                              |
|                    | STENDX           | 0.023              | 4.23   | 0.041    | 0.008                              |
| Resident Abundance | CONSTANT         | 3.838              | 27.72  | 0.000    | <b>Model R<sup>2</sup> = 0.132</b> |
|                    | ELEVTVN          | 0.000              | 13.33  | 0.000    | 0.027                              |
|                    | STENDX           | -0.036             | 10.86  | 0.001    | 0.026                              |
|                    | SHRBCV           | -0.010             | 9.30   | 0.003    | 0.023                              |
|                    | HEMLCK           | 0.905              | 10.00  | 0.002    | 0.019                              |
|                    | GRNDCV           | 0.011              | 6.85   | 0.010    | 0.014                              |
|                    | TOTBSL           | -0.461             | 12.51  | 0.001    | 0.012                              |
|                    | COVEHD           | 0.596              | 2.76   | 0.098    | 0.011                              |
| Combined Abundance | CONSTANT         | 5.508              | 52.85  | 0.000    | <b>Model R<sup>2</sup> = 0.292</b> |
|                    | ELEVTVN          | 0.001              | 36.22  | 0.000    | 0.156                              |
|                    | TOTNTR           | -0.033             | 5.16   | 0.024    | 0.063                              |
|                    | HEMLCK           | 1.788              | 13.38  | 0.000    | 0.060                              |
|                    | SEEDLG           | 0.983              | 5.80   | 0.017    | 0.014                              |
|                    | OAKHIC           | 1.465              | 7.78   | 0.006    | 0.013                              |
|                    | VACCVR           | -0.804             | 4.45   | 0.036    | 0.011                              |

Table 20. Linear regression analysis and resulting  $R^2$  values for the CISC database variables with the elevation component included, Cherokee National Forest, Tennessee. See Table 5 for variable descriptions.

| Diversity Index   | Habitat Variable | Parameter Estimate | F     | Prob > F | $R^2$                                 |
|-------------------|------------------|--------------------|-------|----------|---------------------------------------|
| Migrant Richness  | <i>CONSTANT</i>  | 2.129              | 3.57  | 0.060    | <b>Model <math>R^2 = 0.394</math></b> |
|                   | OAKHIC           | 1.281              | 11.26 | 0.001    | 0.022                                 |
|                   | ELEV TN          | 0.000              | 8.59  | 0.004    | 0.098                                 |
|                   | HEMLCK           | 0.968              | 6.16  | 0.014    | 0.001                                 |
|                   | MXEDHP           | 0.459              | 1.96  | 0.163    | 0.018                                 |
|                   | YEPINE           | -3.968             | 1.96  | 0.163    | 0.085                                 |
|                   | NORHWD           | 0.617              | 1.60  | 0.207    | 0.036                                 |
|                   | COVEHD           | 0.643              | 1.59  | 0.208    | 0.006                                 |
|                   | POLTMB           | -0.490             | 1.48  | 0.225    | 0.044                                 |
|                   | STENDX           | 0.013              | 1.12  | 0.290    | 0.049                                 |
|                   | STNDAG           | -0.004             | 0.19  | 0.663    | 0.005                                 |
|                   | STNDSZ           | -0.001             | 0.18  | 0.673    | 0.000                                 |
|                   | SEEDLG           | 0.228              | 0.12  | 0.732    | 0.029                                 |
|                   | SAWTMB           | 0.262              | 0.12  | 0.732    | 0.001                                 |
| Resident Richness | <i>CONSTANT</i>  | 4.299              | 33.70 | 0.000    | <b>Model <math>R^2 = 0.209</math></b> |
|                   | STNDAG           | -0.023             | 14.64 | 0.000    | 0.065                                 |
|                   | POLTMB           | -0.879             | 11.03 | 0.001    | 0.009                                 |
|                   | STENDX           | -0.023             | 7.93  | 0.005    | 0.031                                 |
|                   | SEEDLG           | -1.222             | 7.80  | 0.006    | 0.038                                 |
|                   | SAWTMB           | 2.101              | 7.80  | 0.006    | 0.010                                 |
|                   | ELEV TN          | 0.000              | 3.02  | 0.084    | 0.007                                 |
|                   | HEMLCK           | 0.420              | 2.69  | 0.103    | 0.007                                 |
|                   | COVEHD           | 0.471              | 1.97  | 0.162    | 0.013                                 |
|                   | MXEDHP           | 0.225              | 1.10  | 0.296    | 0.002                                 |
|                   | YEPINE           | -1.242             | 1.10  | 0.296    | 0.000                                 |
|                   | NORHWD           | 0.177              | 0.31  | 0.581    | 0.010                                 |
|                   | STNDSZ           | 0.000              | 0.25  | 0.617    | 0.001                                 |
|                   | OAKHIC           | -0.051             | 0.04  | 0.840    | 0.016                                 |
| Combined Richness | <i>CONSTANT</i>  | 6.427              | 18.44 | 0.000    | <b>Model <math>R^2 = 0.311</math></b> |
|                   | ELEV TN          | 0.001              | 9.39  | 0.003    | 0.079                                 |
|                   | HEMLCK           | 1.388              | 7.17  | 0.008    | 0.004                                 |
|                   | POLTMB           | -1.369             | 6.55  | 0.011    | 0.043                                 |
|                   | OAKHIC           | 1.231              | 5.87  | 0.016    | 0.003                                 |
|                   | STNDAG           | -0.028             | 4.93  | 0.027    | 0.031                                 |
|                   | COVEHD           | 1.114              | 2.70  | 0.102    | 0.000                                 |
|                   | MXEDHP           | 0.684              | 2.47  | 0.118    | 0.006                                 |
|                   | YEPINE           | -5.211             | 2.47  | 0.118    | 0.049                                 |
|                   | NORHWD           | 0.794              | 1.50  | 0.222    | 0.037                                 |
|                   | SEEDLG           | -0.994             | 1.26  | 0.263    | 0.051                                 |
|                   | SAWTMB           | 2.363              | 1.26  | 0.263    | 0.000                                 |
|                   | STENDX           | -0.010             | 0.35  | 0.552    | 0.007                                 |
|                   | STNDSZ           | 0.000              | 0.00  | 0.944    | 0.001                                 |



Table 20. (continued)

| Diversity Index    | Habitat Variable | Parameter Estimate | F     | Prob > F | R <sup>2</sup>                     |
|--------------------|------------------|--------------------|-------|----------|------------------------------------|
| Migrant Abundance  | <i>CONSTANT</i>  | 1.689              | 1.10  | 0.296    | <b>Model R<sup>2</sup> = 0.476</b> |
|                    | ELEVTVN          | 0.001              | 14.08 | 0.000    | 0.146                              |
|                    | OAKHIC           | 1.760              | 10.38 | 0.002    | 0.028                              |
|                    | HEMLCK           | 1.375              | 6.07  | 0.015    | 0.001                              |
|                    | NORHWD           | 0.796              | 1.30  | 0.255    | 0.058                              |
|                    | STENDX           | 0.020              | 1.18  | 0.279    | 0.053                              |
|                    | COVEHD           | 0.777              | 1.13  | 0.288    | 0.006                              |
|                    | SEEDLG           | 0.929              | 0.95  | 0.331    | 0.028                              |
|                    | SAWTMB           | -0.694             | 0.95  | 0.331    | 0.000                              |
|                    | STNDSZ           | -0.002             | 0.81  | 0.371    | 0.001                              |
|                    | POLTMB           | -0.235             | 0.17  | 0.684    | 0.031                              |
|                    | MXEDHP           | 0.148              | 0.10  | 0.752    | 0.047                              |
|                    | YEPINE           | -4.856             | 0.10  | 0.752    | 0.072                              |
|                    | STNDAG           | 0.002              | 0.01  | 0.910    | 0.005                              |
| Resident Abundance | <i>CONSTANT</i>  | 5.299              | 25.33 | 0.000    | <b>Model R<sup>2</sup> = 0.241</b> |
|                    | STNDAG           | -0.031             | 12.95 | 0.000    | 0.059                              |
|                    | POLTMB           | -1.213             | 10.39 | 0.002    | 0.015                              |
|                    | STENDX           | -0.032             | 7.46  | 0.007    | 0.021                              |
|                    | ELEVTVN          | 0.000              | 7.14  | 0.008    | 0.039                              |
|                    | SEEDLG           | -1.556             | 6.25  | 0.013    | 0.043                              |
|                    | SAWTMB           | 2.769              | 6.25  | 0.013    | 0.007                              |
|                    | HEMLCK           | 0.744              | 4.17  | 0.043    | 0.005                              |
|                    | COVEHD           | 0.739              | 2.40  | 0.123    | 0.014                              |
|                    | MXEDHP           | 0.310              | 1.03  | 0.312    | 0.000                              |
|                    | YEPINE           | -2.452             | 1.03  | 0.312    | 0.003                              |
|                    | NORHWD           | 0.410              | 0.81  | 0.369    | 0.031                              |
|                    | OAKHIC           | 0.249              | 0.49  | 0.486    | 0.003                              |
|                    | STNDSZ           | 0.000              | 0.06  | 0.813    | 0.001                              |
| Combined Abundance | <i>CONSTANT</i>  | 6.988              | 11.70 | 0.001    | <b>Model R<sup>2</sup> = 0.464</b> |
|                    | ELEVTVN          | 0.001              | 18.81 | 0.000    | 0.156                              |
|                    | HEMLCK           | 2.119              | 8.97  | 0.003    | 0.003                              |
|                    | OAKHIC           | 2.010              | 8.41  | 0.004    | 0.010                              |
|                    | POLTMB           | -1.448             | 3.93  | 0.049    | 0.038                              |
|                    | STNDAG           | -0.030             | 3.12  | 0.079    | 0.030                              |
|                    | COVEHD           | 1.515              | 2.69  | 0.103    | 0.000                              |
|                    | NORHWD           | 1.206              | 1.86  | 0.174    | 0.075                              |
|                    | MXEDHP           | 0.458              | 0.60  | 0.441    | 0.030                              |
|                    | YEPINE           | -7.308             | 0.60  | 0.441    | 0.055                              |
|                    | STNDSZ           | -0.002             | 0.34  | 0.559    | 0.001                              |
|                    | STENDX           | -0.013             | 0.30  | 0.582    | 0.012                              |
|                    | SEEDLG           | -0.627             | 0.27  | 0.604    | 0.053                              |
|                    | SAWTMB           | 2.075              | 0.27  | 0.604    | 0.001                              |



## **CHAPTER IV**

### **DISCUSSION AND MANAGEMENT CONSIDERATIONS**

#### **DESCRIPTIVE ANALYSIS**

##### **Avian Diversity Across Forest Types.**

On the Tellico District, the yellow pine forest type supported fewer numbers and species of neotropical migrants than all other forest types except the mixed hardwood/pine type. Species richness and abundance for migrants, residents and combined were similar across cove hardwood, eastern hemlock/white pine, northern hardwood, and oak/hickory forest types. Kendeigh and Fawver (1981) reported similar results for Great Smoky Mountains National Park (GSMNP), where species richness for cove forests, chestnut oak forests, and hemlock-deciduous forests did not differ. Fewer species and lower abundance occurred in the pine-oak forest type than in the other three forest types.

One possible reason for the lack of discernible differences across four of our forest types was that avian preferences for individual forest types may have been overshadowed by the effects of foliage structure and habitat heterogeneity (Bond 1957, James 1971, Whitmore 1975). Foliage structure is important to birds because productivity of foliage insects decreases from moist cove forests to dry oak and pine forests (Whittaker 1952). Thus, birds that glean foliage for insects decrease in density from moist to dry forests (Bond 1957).

Hamilton and Noble (1975) argued that the precise plant species of a given vegetative life form, like those that form our forest type delineations, is not particularly important when considering avian communities. Furthermore, MacArthur (1971) claimed

that “a many-layered forest of a single tree species can support as many bird species as one of similar structure composed of many tree species.” Therefore, on the Tellico District, differences in species richness and abundance may be more a factor of habitat structure than of tree species composition. Furthermore, the lack of discernible differences across four of the forest types suggests that these forest types may be structurally similar. In fact, two structural variables (canopy height and total basal area) showed no differences ( $P \leq 0.05$ ) across these four forest types. Alternatively, even if structural differences exist, if there is a similar number of niches available, species richness and abundance would be comparable across forest types.

#### **Avian Diversity Across Condition Classes.**

*Overview.* Many studies of succession and avian populations in eastern deciduous forests have reported a general increase in bird species richness and abundance with increasing age of the forest (Kendeigh 1944, Odum 1950, Johnston and Odum 1956, Karr 1968, Shugart and James 1973) and increased structural diversity of the habitat (MacArthur and MacArthur 1961). In contrast, Hopper (1967), Ambrose (1975), and Conner and Adkisson (1975) observed highest avian richness and abundance in clearcuts 3 to 12 years old in eastern oak/hickory forests. Conner et al. (1979) reported that 3 year-old clearcuts in southwest Virginia pine-oak forests had the highest avian abundance and mature pine-oak stands had the highest avian richness. Both Conner and Adkisson (1975) and Conner et al. (1979) studied avian diversity within a single forest type. Thompson et al. (1992) reported peak densities of several neotropical migrants in clearcut

areas and high densities in surrounding poletimber stands and suggested that surplus individuals were 'spilling-over' into the suboptimal poletimber habitat.

From this study, avian richness was highest for residents in the seedling/sapling condition class in 1993 and highest for migrants in the seedling/sapling and sawtimber classes. More specifically, in 1993 this translated into peak combined richness and abundance scores for the 0-10 year class.

It is important to note that I have *described* the observed relationships between forest type and condition class and avian richness and abundance but I have *not* inferred any causal relationships. For example, I did not assume that higher habitat quality was reflected by higher avian abundance. Birds may be more numerous in a given habitat for a variety of reasons other than higher habitat quality: (1) avian populations may exhibit multi-annual variability in local densities due to small-scale variability in insect densities (Van Horne 1983) and/or (2) avian populations may support social interactions between conspecifics that prevent subdominant animals from entering the desirable habitat while jointly suppressing reproduction in the desirable habitat (Lidicker 1975). These subdominant (surplus), nonbreeding "floaters" may then collect in undesirable habitat "sinks" where densities are unstable. Thus, when densities are high, real density-habitat quality relationships are difficult to assess and when densities are low, a more representative view of avian density-habitat quality relationships are obtainable. In the final analysis, using avian abundance as a measure of habitat suitability is often retrospective in nature and can give misleading trends without any possibility of explaining causation (Van Horne 1983).

## SELECTED SPECIES HABITAT ASSOCIATIONS

### Overview

The goal of this portion of my analysis was to develop habitat-use models for high priority species that predict their occurrences across the landscape. According to Kendeigh and Fawver (1981), the predominant factor controlling bird distribution in the GSMNP was the relation of bird species to plant communities. It may be easy to distinguish between the habitat structure of two distinct plant communities such as forest and field, but accurate comparisons of habitat structure with the presence or absence of an individual bird species may be difficult when comparing two *forest* communities. If the goal is to design predictive models of species' distribution to determine which exact features of the habitat are responsible for a species being present in that habitat, then we must review the published literature to determine the biological plausibility of each variable and ask: *Is this variable important to the survivability of this species or may this variable merely systematically occur or fail to occur in the same places where our modeled species occurs?* Interpreting the literature with respect to identifying key habitat requirements for a given species is often difficult because different researchers examine these relationships on different scales. For example, small study areas such as those examined by James (1971) and Anderson and Shugart (1974) may be more likely to identify the micro-scale structural features of the vegetation that were consistently present where a given species occurred (the niche-gestalt) in a single vegetation type. These important small-scale habitat features, however, may vary across vegetation types. Therefore, to capture avian species' response under a variety of vegetation types, a broad-scale analysis across a large study area like the Tellico Ranger District is needed.



Furthermore, habitat-use models built from larger study areas are more applicable on a regional basis because they potentially identify important broad-scale features that likely occur in other parts of the species' range.

Even though I compare habitat requirements for bird species across a broad range of study areas in the following sections, the habitat requirements as characterized by my final habitat models may be variable over the geographic range of the species. Therefore, site-specific external validation tests for each model will add strength to their overall applicability.

### **Acadian Flycatcher**

***Habitat Requirements.*** Hamel (1992) described the primary breeding habitat of the acadian flycatcher as riparian, deciduous forests with a moderate understory. Acadian flycatchers perch on middlestory branches 3-12 meters above streams and attack their insect prey on the wing (Hamel 1992). Hamel (1992) placed acadian flycatcher in "tree nesting, arboreal hawking insectivore" guilds. Stupka (1963) generally recorded the species below 3,500 ft above sea level (MSL) in GSMNP. Other researchers have reported similar habitat associations for predicting acadian flycatcher distribution. Smith (1977) found the following three variables to be correlated to acadian flycatcher distribution in an Ozark watershed: a positive correlation with large sized trees ( $> 38$  cm dbh) and negative correlations with intermediate and small sized trees ( $< 38$  cm dbh). In the middle Atlantic region, Robbins et al. (1989a) reported the following five variables as significant predictors of acadian flycatcher relative abundance: positive correlation with canopy height, area of surrounding forest, moisture gradient, and stands with a moderate

foliage density, while % canopy cover by conifers was negatively correlated with its relative abundance.

**Final Model.** The distribution of acadian flycatchers on the Tellico Ranger District was consistent with Hamel's (1992) description of primary breeding habitat according to my final habitat model - older stands at low elevations with an open understory and large-sized trees. It is not apparent why litter depth was significantly correlated to acadian flycatcher distribution. Overall, the model performance was good at predicting acadian flycatcher distributions with the existing dataset (jackknife test) and the goodness-of-fit for this model was very good. Larger sample sizes for the acadian flycatcher-present category ( $n = 21$ ) may improve the model because the correct classification rates for the biased and unbiased tests were inconsistent (the unbiased [jackknife] score was greater than the biased [concordance] score). For all other models excluding the wood thrush models (which also had low sample sizes for the 'observed - present' category), the classification rates were greater for the concordance test as expected.

**CISC Model.** From the CISC model, only three variables were significantly correlated to acadian flycatcher distribution - stand age, site index, and elevation. The model performance was good and the goodness-of-fit was marginally acceptable. The relatively small number of acadian flycatcher-present points ( $n = 21$ ) likely led to the higher correct classification rate for the unbiased (jackknife) test. No forest types or condition classes were significantly correlated to acadian flycatcher distribution but I recorded peak % occurrence and peak densities of acadian flycatchers in the hemlock/white pine - sawtimber habitat combination. Kendeigh and Fawver (1981)



reported peak breeding densities of acadian flycatchers in mature pine-oak forests and in hemlock-deciduous forests in GSMNP. Robbins et al. (1989a) reported a negative correlation between acadian flycatcher relative abundance and percent canopy cover by conifer trees. In contrast, acadian flycatchers in the Southern Appalachians occurred consistently in forest stands with conifer trees in the overstory. Conner and Adkisson (1975) reported maximum relative abundance for acadian flycatchers in mature oak/hickory stands in southwestern Virginia.

### **Black-throated Blue Warbler**

**Habitat Requirements.** Black-throated blue warblers occupy a variety of montane forest types in the Southeast; favoring “medium-growth forests with a moderate to dense understory, especially rhododendron (*Rhododendron maximum*) or mountain laurel (*Kalmia latifolia*)” (Hamel 1992). In GSMNP, Stupka (1963) generally found black-throated blue warblers breeding above 2,800 ft MSL. This bush-nester gleans insects from twigs and leaves of hardwoods or conifers and commonly forages from the middle of the crown down to the shrub and sapling layer (Hamel 1992). Robbins et al. (1989a) reported the following two variables as significant predictors of black-throated blue warbler relative abundance for the middle Atlantic region: positive correlations with foliage density for the shrub/sapling layer and area of surrounding forest.

**Final Model.** The final black-throated blue warbler model for the Tellico District indicated that this species occurred in mid to high-elevation stands with a rhododendron component and large trees, and with little vaccinium cover or ground cover and generally shallow litter depths. Overall, the model performance was very good at predicting

black-throated blue warbler distribution with the existing dataset (jackknife test) but the goodness-of-fit for this model was barely adequate.

**CISC Model.** From the CISC model, five variables were significantly correlated to black-throated blue warbler distribution - cove hardwood forest type, northern hardwood forest type, oak/hickory forest type, stand size and elevation. The model performance was very good and the goodness-of-fit was acceptable. I recorded peak % occurrence and density levels for black-throated blue warblers in the northern hardwood-poletimber habitat combination. Kendeigh and Fawver (1981) reported peak breeding densities of black-throated blue warblers in cove forests and high breeding densities in hemlock-deciduous forests in GSMNP. Webb et al. (1977) reported that black-throated blue warblers responded equally at all logging intensities in a northern hardwood forest, and therefore were unaffected by increased logging activity.

### **Canada Warbler**

**Habitat Requirements.** Canada warblers occupy a variety of montane forest types in the Southern Appalachians, preferring dense, moist understory layers and shrub tangles (rhododendron and mountain laurel) on northerly aspects beneath hemlock and hardwood canopies or in forest openings (Bent 1953, Hamel 1992). Hamel (1992) placed Canada warbler in “ground nesting, bush gleaning or hawking insectivore” guilds. Stupka (1963) generally recorded Canada warblers above 3,400 ft MSL in GSMNP. In the middle Atlantic region, Robbins et al. (1989a) reported the following six variables as significant predictors of Canada warbler relative abundance: positive correlations with basal area of

trees, foliage density of shrubs and seedlings, surrounding area of the forest, and a moisture gradient, and negative correlations with canopy height and % ground cover.

***Final Model.*** Hamel's (1992) description of preferred habitat for Canada warbler fit my final model well. Canada warblers on the Tellico District occurred in mid to high elevation stands with rhododendron present, few conifer trees present, a low diversity of tree species, relatively little slope, and low frequencies of standing snags. Overall, the model performance was excellent at predicting Canada warbler distribution with the existing dataset (jackknife test) and the goodness-of-fit for this model was very good.

***CISC Model.*** From the CISC model, forest type and elevation were significantly correlated to Canada warbler distribution. The model performance was excellent for the CISC variables. All forest types were significantly correlated to Canada warbler distribution, with yellow pine being negatively correlated to its distribution. I recorded peak % occurrence and densities for Canada warblers in the northern hardwood-poletimber habitat combination. Poletimber stands were preferred by Canada warblers in northern New England as well (DeGraaf and Chadwick 1987). Kendeigh and Fawver (1981) reported peak breeding densities of Canada warblers in hemlock-deciduous forests in GSMNP. Webb et al. (1977) reported that Canada warbler populations in an Adirondack northern hardwood forest increased progressively with increased logging intensity.

### **Chestnut-sided Warbler**

***Habitat Requirements.*** Primary breeding habitat for this shrub-nesting, shrub-gleaning insectivore is second-growth woods and overgrown fields (Robinson 1990,

Hamel 1992). For the mid-Atlantic region, chestnut-sided warbler relative abundance was best predicted by (1) the number of standing snags > 3 cm dbh (negative correlation) and (2) total basal area of trees (negative correlation) (Robbins et al. 1989a).

***Final Model.*** Because of the highly specialized habitat requirements for this species, obtaining strong predictive models was no surprise, nor were the variables comprising the final model - positive correlation with elevation, negative correlation with canopy height, and negative correlation with litter depth. Thus, the distribution of chestnut-sided warblers on the Tellico Ranger District was consistent with Hamel's (1992) description of primary breeding habitat. This model was the best single-species model with a 93.5% correct classification rate and very good fit to the data.

***CISC Model.*** From the CISC model, chestnut-sided warbler distribution was positively correlated with northern hardwood and oak/hickory forest types and elevation and negatively correlated to stand size. This model performed better at predicting species distribution than any other CISC model in the study with an excellent fit to the data. I recorded peak % occurrence and peak densities of chestnut-sided warblers in the northern hardwood - seedling/sapling habitat combination. Kendeigh and Fawver (1981) reported peak breeding densities of chestnut-sided warblers in early-seral spruce-fir forests and high densities in mid-seral spruce-fir forests in GSMNP. Spruce-fir forests do not occur on the Tellico Ranger District. Conner and Adkisson (1975) reported maximum relative abundance for chestnut-sided warblers in 3 year-old oak/hickory clearcuts in southwestern Virginia. Webb et al. (1977) reported that chestnut-sided warbler populations in an Adirondack northern hardwood forest increased progressively with increased logging intensity.



## **Hooded Warbler**

***Habitat Requirements.*** Hooded warblers breed in the Southern Appalachians at elevations up to 3,900 ft MSL (Stupka 1963). Hooded warblers nest in shrubs, glean insects from shrubs and trees, and inhabit mature forest hillsides and ravines (deciduous and sometimes coniferous) with a dense understory (Robinson 1990, Hamel 1992). Smith's (1977) model for predicting hooded warbler distribution in the Ozarks was very similar to her acadian flycatcher model: a positive correlation with large sized trees (> 38 cm dbh) and moisture gradients and negative correlations with intermediate and small sized trees (< 38 cm dbh). In the mid-Atlantic region, % ground cover, canopy height, and shrub/seedling-layer foliage density were positively correlated to hooded warbler relative abundance (Robbins et al. 1989a). In Oak Ridge, Tennessee, Anderson and Shugart (1974) identified three variables as important predictors of hooded warbler abundance in univariate tests- biomass of foliage, biomass of branches and biomass of boles in the lower vegetative layers.

***Final Model.*** Several variables were correlated to hooded warbler distribution on the Tellico District. Significant variables in the stepwise model include: 15-23 dbh, shrub cover, elevation, slope, cove hardwood, hemlock/white pine, mixed hardwood/pine, and northern hardwood forest types. From this model, hooded warblers were positively correlated with shrub cover and all four forest types, while 15-23 dbh, elevation, and slope were negatively correlated with hooded warbler distribution. Hooded warblers in the Ozarks (Smith 1977) and on the Tellico District were negatively correlated to stands with many small-sized trees. Hooded warblers in the mid-Atlantic region (Robbins et al.

1989a) and on the Tellico District were positively correlated with percent of ground-story cover. The moderate predictive power of the final habitat model is noteworthy and likely reflected the 'generalist' nature of this species.

**CISC Model.** From the CISC model, hooded warblers showed a positive correlation with cove hardwood, hemlock/white pine, and mixed hardwood/pine forest types and for the seedling/sapling condition class. Hooded warbler was negatively correlated with the yellow pine forest type, sawtimber condition class, and elevation. The model performance was the poorest among all CISC species models for the same reasons that the final models were limited. I recorded peak % occurrence and peak densities of hooded warbler in the cove hardwood - seedling/sapling habitat combination. Kendeigh and Fawver (1981) reported peak breeding densities of hooded warblers in chestnut oak forests in GSMNP. Conner and Adkisson (1975) recorded hooded warbler in 3, 7, and 12 year-old clearcuts, but not in poletimber or sawtimber habitat in oak/hickory stands in southwestern Virginia.

## **Wood Thrush**

**Habitat Requirements.** Hamel (1992) described wood thrush habitat in the Southeast as "deciduous or mixed forests with a fairly well-developed deciduous understory, especially where moist..." Rich hardwood forests are considered prime habitat, but the species occurs in coniferous forests with a deciduous understory (Hamel 1992). The wood thrush nests in understory trees and "gleans insects and other invertebrates on the forest floor, often among dead leaves on the ground...in shrubs and in low trees" (Hamel 1992). Stupka (1963) recorded wood thrushes up to 4,900 ft MSL in



GSMNP. Crawford et al. (1981) reported that wood thrushes were restricted to stands with a closed overstory canopy and their relative density was positively correlated to stands with many trees in the > 36 cm dbh size class and to stands with many trees in the < 22 cm dbh size class in southwest Virginia. For the mid-Atlantic region, wood thrush relative abundance was best predicted by (1) canopy height, (2) area of surrounding forest, (3) total number of trees > 3 cm dbh/ha (negatively correlated), (4) % canopy cover by conifers (negatively correlated), and (5) number of trees > 38 cm dbh (negatively correlated) (Robbins et al. 1989a).

***Final Model.*** Wood thrushes on the Tellico District occurred across a variety of forest types, such that wood thrush distribution was best predicted by structural components as opposed to specific vegetation types. All three variables in the final stepwise model (number of trees in the 30-38 cm dbh size class, number of trees in the 53-68 cm dbh size class, and canopy height) were components of older, sawtimber class stands. The final stepwise model performed well at predicting wood thrush distribution with the existing dataset (jackknife test), with an adequate fit to the data. The relatively small number of wood thrush-present points ( $n = 29$ ) likely led to the higher correct classification rates in all models for the unbiased (jackknife) test as opposed to the biased (concordance) test.

***CISC Model.*** From the CISC model, wood thrushes occupied cove hardwood, hemlock/white pine, and oak/hickory forest types. No other variables were significantly correlated to wood thrush distribution in the CISC model. The model performance was good, however, and the fit to the data was excellent. I recorded peak % occurrence for wood thrushes in the oak/hickory - sawtimber combination and peak densities in the mixed

hardwood/pine - sawtimber combination. Kendeigh and Fawver (1981) reported peak breeding densities of wood thrushes in cove forests and high densities in hemlock-deciduous and red oak forests in GSMNP. Conner and Adkisson (1975) reported maximum relative abundance for wood thrushes in mature oak/hickory stands and high densities in poletimber stands in southwestern Virginia. Webb et al. (1977) reported that wood thrushes showed no response to light logging activity and responded negatively to heavy logging activity in a northern hardwood forest.

### **Worm-eating warbler**

*Habitat Requirements.* Hamel (1992) describes inland worm-eating warbler breeding habitat as "...ravines and mountainsides...in deciduous or mixed forests with a rich understory (especially of rhododendron or mountain laurel)..." This ground-nester gleans insects from shrubs or leaf litter and occurs up to 3,900 ft MSL in eastern Tennessee (Robinson 1990). In the middle Atlantic region, Robbins et al. (1989a) reported the following variables as significant predictors of worm-eating warbler relative abundance: positive correlations with canopy height, area of surrounding forest, total number of trees > 3 cm dbh/ha, and stands with high shrub/sapling layer foliage density. Moisture gradient and % slope were negatively correlated with worm-eating warbler relative abundance.

*Final Model.* On the Tellico District, worm-eating warblers were found in low to mid-elevation deciduous forests across a wide range of habitat conditions. Consistent with Hamel's (1992) description of preferred worm-eating warbler habitat, a shrub component occurred in my full model (% cover by rhododendron) but not in the final model. Overall,

the model performance was fair at predicting worm-eating warbler distribution with the existing dataset (jackknife test). The model fit to the data was adequate. Like the hooded warbler, the 'generalist' nature of this species likely accounted for the observed model performance.

**CISC Model.** From the CISC model, three variables were significantly correlated to worm-eating warbler distribution - stand size (positive correlation), northern hardwood forest type (negative correlation), and elevation (negative correlation). The biological significance of the stand size variable relative to forest fragmentation and/or habitat heterogeneity is unclear because forest stands on the Tellico District often did not have distinct edges (habitat was usually contiguous). Robbins et al. (1989a) observed a positive correlation between worm-eating warbler relative abundance and area of forest. In contrast to my study, Robbins et al. (1989a) surveyed the highly fragmented landscapes of the mid-Atlantic states and worm-eating warblers in that region likely encountered different rates of brood parasitism, competition, and/or predation. The model performance was fair and the goodness-of-fit was acceptable. I recorded peak % occurrence of worm-eating warblers in hemlock/white pine - seedling/sapling stands, whereas peak densities occurred in oak/hickory - seedling/sapling stands. In southwest Virginia, worm-eating warblers occurred in 7 and 12 year-old clearcuts, but not in poletimber or mature oak/hickory stands (Conner and Adkisson 1975). Kendeigh and Fawver (1981) reported peak breeding densities of worm-eating warblers in chestnut oak forests in GSMNP. Thompson et al. (1992) reported higher densities of worm-eating warblers in forests with clearcutting than in forests without clearcutting in the Ozarks. In the same study, worm-eating warblers reached peak densities in regeneration or sapling

stands and their territories extended over into the adjacent, poorer-quality poletimber stands.

### Model Interpretation

The results of the high priority species' model selections were used to quantify habitat-use patterns for each species. Predictive equations or estimated logits were used to map or "predict" habitat use patterns on a stand-by-stand basis across the district by creating a linear regression line for each species (Table 21). The slope and origin of this line for a particular species and model (full, CISC, and AIC/stepwise) is determined by the logit,  $g(x)$  value, and the corresponding habitat use probability. The logit of the multiple logistic regression model is given by the equation:

$$\left\{ g(x) = \beta_0 + \beta_1 x_1 + \dots + \sum_{u=1}^{k_j - 1} \beta_{ju} D_{ju} + \beta_p x_p \right\}$$

( $\beta_{ju} D_{ju}$  for design or 'dummy' variables) (Hosmer and Lemeshow 1989)

where  $g(x)$  = the logit transformation of the conditional mean of  $y$  given  $x$  when the logistic distribution is used,  $\beta_0$  = y-intercept (value of  $y$  when  $x = 0$ ),  $\beta_1$  = slope of the straight line (change in  $y$  for a unit change in  $x$ ), and  $D = k_j - 1$  design or dummy variables ( $k = \Sigma$  possible values for a nominal scaled variable) (Ott 1988).

**Final Species Models.** The habitat use probability estimate can be used in these models to assess the nature of the relationship between species' distribution and the best set of sampled predictor variables. For example, for chestnut-sided warblers, a hypothetical forest stand "A" located at 4000 ft elevation, with an average canopy height



Table 21. Estimated logits or predictive equations for calculating odds ratios ( $\psi$ ) and habitat use probabilities based on final predictive habitat models and USFS CISC database variables for seven species of neotropical songbirds, Cherokee National Forest, Tennessee. See Table 5 for variable descriptions.

| Species | Model Type     | Logit Equation                                                                                                                                                                                                                                                                                                                                |
|---------|----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ACFL    | CISC           | $g(x) = -0.341 + \text{COVEHD} (0.752) + \text{HEMLCK} (1.225) + \text{MXEDHP} (0.175) + \text{NORHWD} (-1.435) + \text{OAKHIC} (-0.841) + \text{YEPINE} (0.124) + \text{SEEDLG} (0.631) + \text{POLTMB} (0.641) + \text{SAWTMB} (-1.272) + \text{STNDAG} (0.046) + \text{STENDX} (-0.072) + \text{STNDSZ} (0.002) + \text{ELEVTVN} (-0.002)$ |
|         | AIC / Stepwise | $g(x) = -0.268 + \text{ELEVTVN} (-0.001) + \text{LITDPH} (0.292) + \text{BSLSAP} (-2.431) + \text{STNDAG} (0.026) + 38\text{-}53\text{DBH} (0.268)$                                                                                                                                                                                           |
| BTBW    | CISC           | $g(x) = -4.718 + \text{COVEHD} (1.928) + \text{HEMLCK} (0.522) + \text{MXEDHP} (0.568) + \text{NORHWD} (5.841) + \text{OAKHIC} (2.731) + \text{YEPINE} (-11.590) + \text{SEEDLG} (0.160) + \text{POLTMB} (-0.134) + \text{SAWTMB} (-0.026) + \text{STNDAG} (0.009) + \text{STENDX} (0.017) + \text{STNDSZ} (-0.006) + \text{ELEVTVN} (0.002)$ |
|         | AIC / Stepwise | $g(x) = (-5.864) + \text{ELEVTVN} (0.008) + \text{VACCVR} (-0.046) + \text{LITDPH} (-0.559) + 53\text{-}68\text{DBH} (0.572) + \text{GRNDCV} (-0.021) + \text{RHODCR} (0.015)$                                                                                                                                                                |
| CAWA    | CISC           | $g(x) = -31.90 + \text{COVEHD} (28.752) + \text{HEMLCK} (28.236) + \text{MXEDHP} (28.040) + \text{NORHWD} (31.643) + \text{OAKHIC} (28.820) + \text{YEPINE} (-145.50) + \text{SEEDLG} (1.128) + \text{POLTMB} (0.052) + \text{SAWTMB} (-1.180) + \text{STNDAG} (0.014) + \text{STENDX} (0.001) + \text{STNDSZ} (-0.004)$                      |
|         | AIC            | $g(x) = -7.56 + \text{ELEVTVN} (0.002) + \text{CONFRQ} (-0.129) + \text{LITDPH} (-0.102)$                                                                                                                                                                                                                                                     |
|         | Stepwise       | $g(x) = -9.529 + \text{ELEVTVN} (0.003) + \text{RHODCR} (0.107) + \text{CONFRQ} (-0.672) + \text{NOTRSP} (-0.315) + \text{SLOPE\%} (-0.093) + \text{SNGFRQ} (-0.494)$                                                                                                                                                                         |
| CSWA    | CISC           | $g(x) = -3.735 + \text{COVEHD} (0.843) + \text{HEMLCK} (0.046) + \text{MXEDHP} (-11.223) + \text{NORHWD} (6.174) + \text{OAKHIC} (2.132) + \text{YEPINE} (2.028) + \text{SEEDLG} (1.535) + \text{POLTMB} (-1.527) + \text{SAWTMB} (-0.008) + \text{STNDAG} (-0.024) + \text{STENDX} (0.007) + \text{STNDSZ} (-0.012)$                         |
|         | AIC / Stepwise | $g(x) = -5.731 + \text{ELEVTVN} (0.003) + \text{CNPYHT} (-0.187) + \text{LITDPH} (-0.629)$                                                                                                                                                                                                                                                    |
| HOWA    | CISC           | $g(x) = -1.789 + \text{COVEHD} (2.643) + \text{HEMLCK} (0.939) + \text{MXEDHP} (0.712) + \text{NORHWD} (0.149) + \text{OAKHIC} (0.552) + \text{YEPINE} (-4.994) + \text{SEEDLG} (1.618) + \text{POLTMB} (-0.121) + \text{SAWTMB} (-1.497) + \text{STNDAG} (0.014) + \text{STENDX} (0.004) + \text{STNDSZ} (-0.001)$                           |
|         | AIC            | $g(x) = 0.897 + \text{CNPYCR} (-0.012) + \text{COVEHD} (1.998) + \text{HEMLCK} (0.538) + \text{MXEDHP} (0.517) + \text{NORHWD} (-0.107) + \text{OAKHIC} (0.242) + \text{YEPINE} (-3.188) + \text{STENDX} (0.012) + \text{TOTNTR} (-0.031)$                                                                                                    |
|         | Stepwise       | $g(x) = 1.30 + 15\text{-}23\text{DBH} (-0.118) + \text{SHRBCV} (0.014) + \text{ELEVTVN} (-0.000) + \text{SLOPE\%} (-0.025) + \text{COVEHD} (2.761) + \text{HEMLCK} (0.87) + \text{MXEDHP} (0.711) + \text{NORHWD} (1.065) + \text{OAKHIC} (0.659) + \text{YEPINE} (-6.066)$                                                                   |

Table 21. (continued)

| Species | Model Type       | Logit Equation                                                                                                                                                                                                                                                                                                        |
|---------|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| WOTH    | CISC             | $g(x) = -1.411 + \text{COVEHD} (1.923) + \text{HEMLCK} (1.786) + \text{MXEDHP} (1.010) + \text{NORHWD} (-0.467) + \text{OAKHIC} (1.488) + \text{YEPINE} (-5.740) + \text{SEEDLG} (-1.227) + \text{POLTMB} (-0.326) + \text{SAWTMB} (1.554) + \text{STNDAG} (0.006) + \text{STENDX} (-0.017) + \text{STNDSZ} (-0.004)$ |
|         | AIC <sup>1</sup> | $g(x) = -2.842 + 30\text{-}38\text{DBH} (0.293) + 53\text{-}68\text{DBH} (0.700)$                                                                                                                                                                                                                                     |
|         | Stepwise         | $g(x) = -3.4724 + 30\text{-}38\text{DBH} (0.229) + 53\text{-}68\text{DBH} (0.547) + \text{CNPYHT} (0.044)$                                                                                                                                                                                                            |
| WEWA    | CISC             | $g(x) = -2.314 + \text{COVEHD} (-0.056) + \text{HEMLCK} (0.607) + \text{MXEDHP} (0.165) + \text{NORHWD} (-2.356) + \text{OAKHIC} (0.522) + \text{YEPINE} (1.118) + \text{SEEDLG} (1.319) + \text{POLTMB} (0.697) + \text{SAWTMB} (-2.016) + \text{STNDAG} (0.015) + \text{STENDX} (-0.000) + \text{STNDSZ} (0.004)$   |
|         | AIC / Stepwise   | $g(x) = -0.013 + \text{ELEVTVN} (-0.001) + \text{SLOPE\%} (0.028) + \text{NOTRSP} (0.13) + \text{COVEHD} (0.378) + \text{HEMLCK} (0.435) + \text{MXEDHP} (0.049) + \text{NORHWD} (-0.159) + \text{OAKHIC} (1.131) + \text{YEPINE} (-1.834) + \text{DECFRQ} (0.029) + \text{TOTBSL} (-1.035)$                          |

<sup>1</sup> Poor-fitting model - not recommended for use.



of 5 m, and an average litter depth of 2 cm, would have an estimated odds ratio ( $\psi$ ):  $g(x) = [-5.731 + (4000 \times 0.003) + (5 \times -0.187) + (2 \times -0.629)] = 4.076$ . This translates into a probability of occurrence for chestnut-sided warblers:  $e^{g(x)} / (1 + e^{g(x)}) = e^{4.076} / (1 + e^{4.076}) = 58.909 / 59.909 = 0.983$  (98% probability of occurrence in this stand). In contrast, a hypothetical forest stand “B” at 2000 ft elevation, with a litter depth of 2 cm and a canopy height of 20 m would yield a  $g(x) = -4.729$ , and a probability of occurrence = 0.00876 (< 1% probability of occurrence in this stand). Thus, chestnut-sided warblers would be much more likely to occur in stand “A” (98.3%), as opposed to stand “B” (< 1 %). These probabilities thus can be generated for any species with any combination of habitat variables in the full, CISC, or final model.

For acadian flycatchers, with every 1 foot increase in elevation, the predicted probability that acadian flycatchers would use that area decreased by 1% ( $e^{-0.001}$ ). In contrast, a 2 cm increase in litter depth resulted in a 1.8% increase in the predicted probability of use by acadian flycatchers ( $e^{2 \times 0.292}$ ). For wood thrush, each additional tree in the 53-68 cm dbh size class increased the probability of observing this species by 1.7% ( $e^{0.547}$ ). A 10% increase in shrub cover increased the probability of observing hooded warblers by 1.2% ( $e^{10 \times 0.014}$ ).

For the categorical variables, the sign of the parameter estimate indicated whether a sublevel or design variable was used more (+) or less (-) than expected, whereas the value of the parameter estimate indicated the magnitude of the relationship (Hosmer and Lemeshow 1989). The P-value for the chi-square test corresponding to each parameter estimate, along with the Wald score, indicated the statistical significance of this relationship and whether a parameter estimate was different from zero. For example, for

the hooded warbler-stepwise model (Table 17), use of cove hardwood, hemlock, mixed, northern hardwood, and oak/hickory stands was more than expected whereas yellow pine use was less than expected. Additionally, the cove hardwood type was the most important forest type used because the magnitude of the parameter estimate was greater than all other types with positive correlations.

It is important to notice the P-values and Wald scores for both continuous and categorical variables to determine if these associations were significant ( $P \leq 0.05$  -Wald score). For example, for hooded warblers, the AIC model contains only 2 significant continuous variables and one significant categorical variable ( $P \leq 0.05$  - Wald score); whereas the stepwise model contains 4 significant continuous variables, 4 significant categorical variables ( $P \leq 0.05$  - Wald score), and had higher correct classification rates. Therefore, the stepwise model would be a better choice, overall, for predicting hooded warbler distribution on the Tellico District. Models that failed to pass the Hosmer-Lemeshow goodness-of-fit test ( $P < 0.05$ ) indicate large differences between within-group observed and expected frequencies (i.e...poor predictive power) and are not recommended for future use. These models include: wood thrush - full model and wood thrush - AIC model.

**CISC Models.** The probability of occurrence estimates for all seven priority species across the Tellico District using the six habitat variables contained in the CISC database can be used to generate district-wide geographic information system coverages of predicted species occurrence. Trends in habitat use across forest types and tree size classes (condition class) were not as apparent in these models, however, because the continuous CISC variables - stand age, site index, stand size and elevation, were

significant ( $P \leq 0.05$ ) much more often across the species models than were the categorical variables - forest type and condition class. Forest type occurred in the final, selected models of only two species - hooded warbler and worm-eating warbler, and condition class did not occur in the final model for any species.

## **MODELS OF AVIAN DIVERSITY**

At first glance, it appeared that my attempts to model avian diversity across the Tellico District were of limited value because relatively little variation could be explained by my explanatory variables at this spatial scale. Avian diversity across forest stands on the Tellico District was relatively uniform as a result of the existing array of forest management practices, site quality, and elevational effects. Therefore, modeling the relative occurrence and abundance of > 65 avian species at each point across the landscape may be difficult if the proper scale necessary to sufficiently assess these relationships is not identified. Ricklefs and Schluter (1993) suggested that ecological insights regarding species richness gained from simple habitat models do not transfer well to natural systems in which "...spatial heterogeneity over a variety of distances, historical development of species assemblages, and evolution enter the overall equation for coexistence." They suggested that ecologists must reject the tradition of approaching species richness on the local diversity scale with standard insights of population biology. They recommended that ecologists recognize that ecology, evolution, geography, and history are different facets of a single set of processes and researchers "cannot isolate any one system of a particular dimension from processes and structures at a smaller scale embedded within it or from those at a larger scale containing it." For all of these reasons and given my model

performance, it may be difficult to predict avian species richness on the local, district-wide scale with a high degree of confidence. It was interesting to note that the limited CISC variables appeared to explain more of the variation in diversity than the full set of habitat variables (n=62). The predictive strength of the full model may have been masked, however, by the sheer complexity of the statistical test which simultaneously evaluated all 62 variables.

## **CURRENT FOREST MANAGEMENT PRACTICES**

During this study on the Tellico District, clearcutting was the predominant timber-harvesting technique. Thus, the patterns of avian diversity observed, to a certain extent, reflect the effects of those practices along with the original (turn-of-the-century) timber harvest, and other site-specific effects. Because timber management practices such as clearcutting and shelterwood cutting create additional edge, researchers are concerned that these forest management alternatives may be contributing to regional declines of forest-interior birds (Wilcove 1988). At least one potentially detrimental aspect of forest fragmentation - brood parasitism by the brown-headed cowbird (*Molothrus ater*), was not a factor on the Tellico District due to very low brown-headed cowbird densities recorded in this study. This is consistent with the results presented by Thompson et al. (1992) for the Ozark Mountains.

There is a wide range of results in the literature relative to the effects of forest management on avian populations. Thompson et al. (1992) suggested that in extensively forested areas such as those in the Ozark Mountains, densities of three forest-interior species (pine warbler (*Dendroica pinus*), red-eyed vireo (*Vireo olivaceus*), and scarlet



tanager (*Piranga olivacea*)) were higher in areas without timber harvesting as compared to areas with timber harvesting (clearcuts). They suggested, however, that densities of three forest-interior species (black-and-white warbler (*Mniotilta varia*), Kentucky warbler (*Oporornis formosus*), and worm-eating warbler) remained unchanged or increased in areas that were clearcut because the species made substantial use of young, even-aged stands. They further suggested that forest-interior bird populations were not reduced by the edge-effects of forest fragmentation in the Ozarks. Hooper (1967) studied the effects of clearcutting on bird populations in southwestern Virginia and showed that both the number of species and the number of individuals was larger on logged areas than on unlogged areas. He associated these differences to increased levels of understory development in the logged areas. In a study conducted in that same region, Conner and Adkisson (1975) recorded the highest breeding bird species diversity (MacArthur and MacArthur 1961) in their 7 year-old clearcuts. Webb et al. (1977) reported their lowest breeding species richness and diversity (Shannon Index) on areas undisturbed by logging. On their Adirondack Mountain study area, species richness increased progressively with increased intensity of logging activity. They suggested that foliage height diversity was increased by logging and bird species diversity increased as a result. This is consistent with the conclusions derived by MacArthur et al. (1962) regarding foliage height diversity.

At this time, it appears that forest management effects on avian species individually and patterns of diversity overall are still being sorted out. Studies such as mine shed little light on actual causal mechanisms. The best way to determine if avian species diversity is truly enhanced in forests that are actively managed for timber as opposed to those for which no harvesting occurs, is to conduct extensive surveys of nesting productivity and



demographics in managed and unmanaged forests of similar latitude with comparable vegetative cover types. This type of study would address the following question: *Are managed forests population sinks where reproduction is insufficient to compensate for adult mortality* (Pulliam 1988)? Such studies are critically needed to definitively resolve the debate.

## CHAPTER V

### SUMMARY

- 1) The yellow pine forest type supports fewer avian species and individuals than other forest types on the Tellico District.
- 2) Neotropical migrant richness and abundance is essentially similar across cove hardwood, eastern hemlock/white pine, mixed hardwood/pine, and oak/hickory forest types.
- 3) Seedling/sapling and sawtimber stands support similar avian richness and abundance for neotropical migrants.
- 4) Seedling/sapling stands support higher avian richness and abundance for residents and combined migrants and residents than poletimber and sawtimber stands.
- 5) High elevation, early successional cove hardwood and northern hardwood forest types provide critical habitat for several high priority neotropical migrants such as chestnut-sided warbler and golden-winged warbler (*Vermivora chrysoptera*).
- 6) Species' distributions of seven neotropical migrants may be accurately predicted on the district-wide scale using standard vegetation parameters including those supported by the U.S.F.S. CISC database.

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## LITERATURE CITED

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## **APPENDICES**

**Appendix A.** Common and scientific names of woody plant species recorded on vegetation plots.

Table A.1. Common and scientific names of woody plant species recorded on vegetation plots using a standard 11.3-m radius circular plot technique, Cherokee National Forest, Tennessee.

| Common Name            | Scientific Name              | Common Name          | Scientific Name                |
|------------------------|------------------------------|----------------------|--------------------------------|
| Allegheny chinkapin    | <i>Castanea pumila</i>       | red mulberry         | <i>Morus rubra</i>             |
| alternate-leaf dogwood | <i>Cornus alternifolia</i>   | redbud               | <i>Cercis canadensis</i>       |
| American basswood      | <i>Tilia americana</i>       | rosebay rhododendron | <i>Rhododendron maximum</i>    |
| American beech         | <i>Fagus grandifolia</i>     | sassafras            | <i>Sassafras albidum</i>       |
| American elm           | <i>Ulmus americana</i>       | scarlet oak          | <i>Quercus coccinea</i>        |
| American holly         | <i>Ilex opaca</i>            | shortleaf pine       | <i>Pinus echinata</i>          |
| ash spp.               | <i>Fraxinus</i> spp.         | slippery elm         | <i>Ulmus rubra</i>             |
| black cherry           | <i>Prunus serotina</i>       | smooth sumac         | <i>Rhus glabra</i>             |
| black locust           | <i>Robinia pseudoacacia</i>  | sourwood             | <i>Oxydendrum arboreum</i>     |
| black oak              | <i>Quercus velutina</i>      | southern red oak     | <i>Quercus falcata</i>         |
| black walnut           | <i>Juglans nigra</i>         | striped maple        | <i>Acer pensylvanicum</i>      |
| black willow           | <i>Salix nigra</i>           | sugar maple          | <i>Acer saccharum</i>          |
| blackberry spp.        | <i>Rubus</i> spp.            | sweet birch          | <i>Betula lenta</i>            |
| blackgum               | <i>Nyssa sylvatica</i>       | sweetgum             | <i>Liquidambar styraciflua</i> |
| blackjack oak          | <i>Quercus marilandica</i>   | table mountain pine  | <i>Pinus pungens</i>           |
| box elder              | <i>Acer negundo</i>          | tuliptree            | <i>Liriodendron tulipifera</i> |
| butternut              | <i>Juglans cinerea</i>       | umbrella magnolia    | <i>Magnolia tripetala</i>      |
| Carolina silverbell    | <i>Halesia carolina</i>      | Virginia pine        | <i>Pinus virginiana</i>        |
| chestnut               | <i>Castanea dentata</i>      | white oak            | <i>Quercus alba</i>            |
| chestnut oak           | <i>Quercus prinus</i>        | white pine           | <i>Pinus strobus</i>           |
| common elderberry      | <i>Sambucus canadensis</i>   | wild grape spp.      | <i>Vitis</i> spp.              |
| common pawpaw          | <i>Asimina triloba</i>       | winged sumac         | <i>Rhus copallina</i>          |
| common persimmon       | <i>Diospyros virginiana</i>  | witch-hazel          | <i>Hamamelis virginiana</i>    |
| cucumbertree           | <i>Magnolia acuminata</i>    | yellow birch         | <i>Betula alleghaniensis</i>   |
| downy serviceberry     | <i>Amelanchier arborea</i>   | yellow buckeye       | <i>Aesculus octandra</i>       |
| Eastern hemlock        | <i>Tsuga canadensis</i>      |                      |                                |
| Eastern hophornbeam    | <i>Ostrya virginiana</i>     |                      |                                |
| Eastern redcedar       | <i>Juniperus virginiana</i>  |                      |                                |
| Eastern sycamore       | <i>Platanus occidentalis</i> |                      |                                |
| fire cherry            | <i>Prunus pensylvanica</i>   |                      |                                |
| flowering dogwood      | <i>Cornus florida</i>        |                      |                                |
| Fraser magnolia        | <i>Magnolia fraseri</i>      |                      |                                |
| hawthorn spp.          | <i>Crataegus</i> spp.        |                      |                                |
| honey locust           | <i>Gleditsia triacanthos</i> |                      |                                |
| ironwood               | <i>Caprinus caroliniana</i>  |                      |                                |
| mockernut hickory      | <i>Carya tomentosa</i>       |                      |                                |
| mountain laurel        | <i>Kalmia latifolia</i>      |                      |                                |
| mountain maple         | <i>Acer spicatum</i>         |                      |                                |
| mountain pepperbush    | <i>Clethra acuminata</i>     |                      |                                |
| northern catalpa       | <i>Catalpa speciosa</i>      |                      |                                |
| northern red oak       | <i>Quercus rubra</i>         |                      |                                |
| pignut hickory         | <i>Carya glabra</i>          |                      |                                |
| pitch pine             | <i>Pinus rigida</i>          |                      |                                |
| post oak               | <i>Quercus stellata</i>      |                      |                                |
| red maple              | <i>Acer rubrum</i>           |                      |                                |



**Appendix B.** Common and scientific names of avian species recorded on point count surveys, 1992 and 1993.

Table B.1. Common name, scientific name, U.S. Fish and Wildlife Service Bird Banding Laboratory code (Bird Banding Laboratory 1988), and migration status of avian species recorded during the 1992 and 1993 breeding seasons, Cherokee National Forest, Tennessee.

| Common Name                  | Scientific Name                  | USFWS<br>Species Code | Migrant or<br>Resident |
|------------------------------|----------------------------------|-----------------------|------------------------|
| Acadian Flycatcher           | <i>Empidonax virescens</i>       | acfl                  | m                      |
| American Crow                | <i>Corvus brachyrhynchos</i>     | amcr                  | r                      |
| American Goldfinch           | <i>Carduelis tristis</i>         | amgo                  | r                      |
| American Redstart            | <i>Setophaga ruticilla</i>       | amre                  | m                      |
| American Robin               | <i>Turdus migratorius</i>        | amro                  | r                      |
| Barred Owl                   | <i>Strix varia</i>               | baow                  | r                      |
| Black-and-white Warbler      | <i>Mniotilta varia</i>           | baww                  | m                      |
| Black-billed Cuckoo          | <i>Coccyzus erythrophthalmus</i> | bbcu                  | m                      |
| Black-capped Chickadee       | <i>Parus atricapillus</i>        | bcch                  | r                      |
| Black-throated Blue Warbler  | <i>Dendroica caerulescens</i>    | btbw                  | m                      |
| Black-throated Green Warbler | <i>Dendroica virens</i>          | btnw                  | m                      |
| Blackburnian Warbler         | <i>Dendroica fusca</i>           | blbw                  | m                      |
| Blue Grosbeak                | <i>Guiraca caerulea</i>          | blgr                  | m                      |
| Blue Jay                     | <i>Cyanocitta cristata</i>       | blja                  | r                      |
| Blue-Gray Gnatcatcher        | <i>Poliophtila caerulea</i>      | bggn                  | m                      |
| Blue-winged Warbler          | <i>Vermivora pinus</i>           | bwwa                  | m                      |
| Brown Thrasher               | <i>Toxostoma rufum</i>           | brth                  | r                      |
| Brown-headed Cowbird         | <i>Molothrus ater</i>            | bhco                  | r                      |
| Canada Warbler               | <i>Wilsonia canadensis</i>       | cawa                  | m                      |
| Carolina Chickadee           | <i>Parus carolinensis</i>        | cach                  | r                      |
| Carolina Wren                | <i>Thryothorus ludovicianus</i>  | carw                  | r                      |
| Cedar Waxwing                | <i>Bombycilla cedrorum</i>       | cedw                  | r                      |
| Chestnut-sided Warbler       | <i>Dendroica pensylvanica</i>    | cswa                  | m                      |
| Common Grackle               | <i>Quiscalus quiscula</i>        | cogr                  | r                      |
| Common Yellowthroat          | <i>Geothlypis trichas</i>        | coye                  | m                      |
| Cooper's Hawk                | <i>Accipiter cooperii</i>        | coha                  | r                      |
| Downy Woodpecker             | <i>Picoides pubescens</i>        | dowo                  | r                      |
| Eastern Phoebe               | <i>Sayornis phoebe</i>           | eaph                  | r                      |
| Eastern Wood-Pewee           | <i>Contopus virens</i>           | eawp                  | m                      |
| Field Sparrow                | <i>Spizella pusilla</i>          | fisp                  | r                      |
| Golden-winged Warbler        | <i>Vermivora chrysoptera</i>     | gwwa                  | m                      |
| Gray Catbird                 | <i>Dumetella carolinensis</i>    | grca                  | m                      |
| Great Crested Flycatcher     | <i>Myiarchus crinitus</i>        | gcfl                  | m                      |
| Hairy Woodpecker             | <i>Picoides villosus</i>         | hawo                  | r                      |
| Hooded Warbler               | <i>Wilsonia citrina</i>          | howa                  | m                      |
| Indigo Bunting               | <i>Passerina cyanea</i>          | inbu                  | m                      |
| Kentucky Warbler             | <i>Oporornis formosus</i>        | kewa                  | m                      |
| Louisiana Waterthrush        | <i>Seiurus motacilla</i>         | lowa                  | m                      |
| Mourning Dove                | <i>Zenaida macroura</i>          | modo                  | r                      |
| Northern Bobwhite            | <i>Colinus virginianus</i>       | nobo                  | r                      |
| Northern Cardinal            | <i>Cardinalis cardinalis</i>     | noca                  | r                      |
| Northern Flicker             | <i>Colaptes auratus</i>          | ysfl                  | r                      |
| Northern Junco               | <i>Junco hyemalis</i>            | scju                  | r                      |
| Northern Parula              | <i>Parula americana</i>          | nopa                  | m                      |
| Ovenbird                     | <i>Seiurus aurocapillus</i>      | oven                  | m                      |

Table B.1. (continued)

| Common Name               | Scientific Name                | AOU Species Code | Migrant or Resident |
|---------------------------|--------------------------------|------------------|---------------------|
| Pileated Woodpecker       | <i>Dryocopus pileatus</i>      | piwo             | r                   |
| Pine Warbler              | <i>Dendroica pinus</i>         | piwa             | m                   |
| Prairie Warbler           | <i>Dendroica discolor</i>      | praw             | m                   |
| Red-bellied Woodpecker    | <i>Melanerpes carolinus</i>    | rbwo             | r                   |
| Red-breasted Nuthatch     | <i>Sitta canadensis</i>        | rbnu             | r                   |
| Red-eyed Vireo            | <i>Vireo olivaceus</i>         | revi             | m                   |
| Rose-breasted Grosbeak    | <i>Pheucticus ludovicianus</i> | rbgr             | m                   |
| Ruby-throated Hummingbird | <i>Archilochus colubris</i>    | rthu             | m                   |
| Ruffed Grouse             | <i>Bonasa umbellus</i>         | rugr             | r                   |
| Rufous-sided Towhee       | <i>Pipilo erythrophthalmus</i> | rsto             | r                   |
| Scarlet Tanager           | <i>Piranga olivacea</i>        | scta             | m                   |
| Sharp-shinned Hawk        | <i>Accipiter striatus</i>      | ssha             | r                   |
| Solitary Vireo            | <i>Vireo solitarius</i>        | sovi             | m                   |
| Song Sparrow              | <i>Melospiza melodia</i>       | sosp             | r                   |
| Summer Tanager            | <i>Piranga rubra</i>           | suta             | m                   |
| Swainson's Warbler        | <i>Limnithlypis swainsonii</i> | swwa             | m                   |
| Tufted Titmouse           | <i>Parus bicolor</i>           | etti             | r                   |
| Veery                     | <i>Catharus fuscescens</i>     | veer             | m                   |
| Whip-poor-will            | <i>Caprimulgus vociferus</i>   | wpwi             | m                   |
| White-breasted Nuthatch   | <i>Sitta carolinensis</i>      | wbnu             | r                   |
| White-eyed Vireo          | <i>Vireo griseus</i>           | wevi             | m                   |
| Winter Wren               | <i>Troglodytes troglodytes</i> | wiwr             | r                   |
| Wood Thrush               | <i>Hylocichla mustelina</i>    | woth             | m                   |
| Worm-eating Warbler       | <i>Helmitheros vermivorus</i>  | wewa             | m                   |
| Yellow Warbler            | <i>Dendroica petechia</i>      | ywar             | m                   |
| Yellow-bellied Sapsucker  | <i>Sphyrapicus varius</i>      | ybsa             | r                   |
| Yellow-billed Cuckoo      | <i>Coccyzus americanus</i>     | ybcu             | m                   |
| Yellow-breasted Chat      | <i>Icteria virens</i>          | ybch             | m                   |
| Yellow-throated Vireo     | <i>Vireo flavifrons</i>        | ythi             | m                   |
| Yellow-throated Warbler   | <i>Dendroica dominica</i>      | ytda             | m                   |

**Appendix C.** Mean and standard error for physical and vegetative parameters  
across six forest types and three condition classes.

Table C.1. Mean and S.E. for physical and habitat variables across three condition classes in the cove hardwood forest type, Cherokee National Forest, Tennessee. Variable descriptions are in Table 5.

| <b>Cove Hardwood</b>                    |                         |                   |                   |                   |                  |                   |
|-----------------------------------------|-------------------------|-------------------|-------------------|-------------------|------------------|-------------------|
| <b>physical / habitat<br/>variables</b> | <b>seedling/sapling</b> |                   | <b>poletimber</b> |                   | <b>sawtimber</b> |                   |
|                                         | <b>Mean</b>             | <b>Std. Error</b> | <b>Mean</b>       | <b>Std. Error</b> | <b>Mean</b>      | <b>Std. Error</b> |
| 10-15DBH                                | 7.46                    | 2.06              | 9.69              | 0.99              | 8.73             | 1.45              |
| 15-23DBH                                | 3.23                    | 1.12              | 7.31              | 0.77              | 5.40             | 0.58              |
| 23-30DBH                                | 1.00                    | 0.63              | 4.08              | 0.65              | 3.60             | 0.74              |
| 30-38DBH                                | 0.15                    | 0.15              | 3.54              | 0.43              | 2.13             | 0.38              |
| 38-53DBH                                | 0.15                    | 0.10              | 1.62              | 0.21              | 2.47             | 0.42              |
| 53-68DBH                                |                         |                   | 0.23              | 0.12              | 0.87             | 0.31              |
| AMBECH                                  |                         |                   |                   |                   | 0.27             | 0.27              |
| BKBRCH                                  |                         |                   | 0.85              | 0.64              | 1.33             | 0.88              |
| BKLCST                                  | 1.15                    | 0.59              | 0.15              | 0.10              | 0.40             | 0.27              |
| BLAGUM                                  |                         |                   | 0.23              | 0.17              | 0.07             | 0.07              |
| BLAOAK                                  |                         |                   |                   |                   | 0.40             | 0.19              |
| BSLSAP                                  | 0.62                    | 0.13              | 0.27              | 0.07              | 0.23             | 0.03              |
| CHTOAK                                  |                         |                   | 2.54              | 1.43              | 1.40             | 0.68              |
| CNPYCR                                  | 68.36                   | 10.76             | 95.68             | 1.69              | 83.67            | 8.78              |
| CNPYHT                                  | 7.97                    | 1.43              | 23.23             | 1.93              | 23.45            | 0.97              |
| CONFRQ                                  | 0.15                    | 0.15              | 2.77              | 0.28              | 1.93             | 0.28              |
| CSLVRB                                  | 3.00                    | 1.44              | 0.77              | 0.62              | 0.93             | 0.59              |
| DECFRQ                                  | 1.54                    | 0.72              | 15.69             | 1.78              | 14.87            | 2.30              |
| ELEVTN                                  | 2764.72                 | 175.05            | 2023.15           | 162.98            | 2419.57          | 156.23            |
| FDGWOD                                  | 0.38                    | 0.21              | 0.38              | 0.24              | 0.13             | 0.09              |
| GRNDCV                                  | 55.02                   | 7.73              | 20.5              | 6.13              | 22.29            | 4.93              |
| HEMTRE                                  | 0.23                    | 0.23              | 2.23              | 0.67              | 3.53             | 0.94              |
| LITDPH                                  | 1.82                    | 0.20              | 2.34              | 0.29              | 2.60             | 0.21              |
| MHCKRY                                  |                         |                   | 0.38              | 0.14              | 0.67             | 0.33              |
| NOTRSP                                  | 3.08                    | 0.65              | 8.23              | 0.53              | 7.60             | 0.62              |
| NRDOAK                                  |                         |                   | 0.15              | 0.10              | 0.73             | 0.38              |
| PTCHPN                                  |                         |                   | 0.85              | 0.77              | 0.73             | 0.73              |
| RDMAPL                                  | 0.46                    | 0.31              | 3.38              | 0.59              | 2.87             | 0.88              |
| RHODCR                                  |                         |                   | 19.92             | 7.65              | 15.00            | 8.09              |
| RHODDN                                  | 0.15                    | 0.15              | 1.31              | 0.83              | 0.80             | 0.66              |
| SAPNUM                                  | 315.31                  | 63.82             | 135               | 33.71             | 117              | 17.4              |
| SCTOAK                                  | 0.08                    | 0.08              | 1.23              | 0.79              | 0.33             | 0.23              |
| SGRMPL                                  | 0.23                    | 0.17              | 0.08              | 0.08              | 1.93             | 0.57              |
| SHRBCV                                  | 36.38                   | 5.77              | 49.69             | 7.71              | 37.93            | 8.10              |
| SHRTLF                                  |                         |                   | 0.38              | 0.21              |                  |                   |



Table C.1. (continued)

| <b>Cove Hardwood</b>                    |                         |                   |                   |                   |                  |                   |
|-----------------------------------------|-------------------------|-------------------|-------------------|-------------------|------------------|-------------------|
| <b>physical / habitat<br/>variables</b> | <b>seedling/sapling</b> |                   | <b>poletimber</b> |                   | <b>sawtimber</b> |                   |
|                                         | <b>Mean</b>             | <b>Std. Error</b> | <b>Mean</b>       | <b>Std. Error</b> | <b>Mean</b>      | <b>Std. Error</b> |
| SLOPE%                                  | 24.00                   | 2.69              | 27.69             | 2.43              | 24.87            | 2.24              |
| SNGBDM                                  | 0.06                    | 0.06              | 0.04              | 0.01              | 0.03             | 0.02              |
| SNGBSM                                  | 0.01                    | 0.01              | 0.06              | 0.02              | 0.03             | 0.02              |
| SNGFRQ                                  | 0.15                    | 0.1               | 2.15              | 0.54              | 0.93             | 0.52              |
| STENDX                                  | 97.69                   | 3.61              | 90.00             | 2.26              | 90.00            | 2.76              |
| STNDGE                                  | 9.69                    | 1.73              | 56.77             | 3.07              | 78.67            | 2.37              |
| STNDSZ                                  | 28.46                   | 2.47              | 84.46             | 24.15             | 93.6             | 23.15             |
| TOTBSL                                  | 0.26                    | 0.08              | 1.23              | 0.11              | 1.55             | 0.13              |
| TOTNTR                                  | 12.00                   | 3.30              | 26.69             | 1.77              | 23.73            | 1.99              |
| VACCVR                                  |                         |                   | 11.00             | 6.44              | 6.93             | 3.66              |
| VAPINE                                  |                         |                   | 1.62              | 0.57              | 0.27             | 0.27              |
| WHTOAK                                  | 0.46                    | 0.46              | 1.38              | 0.57              | 0.07             | 0.07              |
| WHTPNE                                  | 0.46                    | 0.46              | 0.85              | 0.37              | 0.20             | 0.14              |
| YBIRCH                                  | 0.08                    | 0.08              | 0.31              | 0.17              | 0.80             | 0.38              |
| YPOPLR                                  | 4.69                    | 1.90              | 2.15              | 0.99              | 2.07             | 0.49              |

Table C.2. Mean and S.E. for physical and habitat variables across three condition classes in the eastern hemlock/white pine forest type, Cherokee National Forest, Tennessee. Variable descriptions are in Table 5.

| <b>Eastern Hemlock/White Pine</b>       |                         |                   |                   |                   |                  |                   |
|-----------------------------------------|-------------------------|-------------------|-------------------|-------------------|------------------|-------------------|
| <b>physical / habitat<br/>variables</b> | <b>seedling/sapling</b> |                   | <b>poletimber</b> |                   | <b>sawtimber</b> |                   |
|                                         | <b>Mean</b>             | <b>Std. Error</b> | <b>Mean</b>       | <b>Std. Error</b> | <b>Mean</b>      | <b>Std. Error</b> |
| 10-15DBH                                | 8.17                    | 3.27              | 17.42             | 1.94              | 9.91             | 1.51              |
| 15-23DBH                                | 5.00                    | 2.04              | 11.17             | 1.48              | 7.45             | 1.09              |
| 23-30DBH                                | 1.75                    | 0.89              | 3.58              | 1.19              | 4.00             | 0.60              |
| 30-38DBH                                | 0.67                    | 0.28              | 2.25              | 0.64              | 3.36             | 0.51              |
| 38-53DBH                                | 0.17                    | 0.17              | 1.58              | 0.48              | 1.91             | 0.34              |
| 53-68DBH                                |                         |                   | 0.17              | 0.11              | 0.91             | 0.31              |
| AMBECH                                  |                         |                   |                   |                   |                  |                   |
| BKBRCH                                  |                         |                   |                   |                   | 1.91             | 1.38              |
| BKLCST                                  |                         |                   | 0.08              | 0.08              |                  |                   |
| BLAGUM                                  |                         |                   |                   |                   | 0.36             | 0.28              |
| BLAOAK                                  |                         |                   | 0.67              | 0.43              | 0.55             | 0.37              |
| BSLSAP                                  | 0.55                    | 0.08              | 0.49              | 0.08              | 0.14             | 0.04              |
| CHTOAK                                  | 0.08                    | 0.08              | 1.25              | 0.52              | 2.00             | 0.84              |
| CNPYCR                                  | 70.71                   | 10.68             | 98.73             | 0.22              | 97.46            | 0.90              |
| CNPYHT                                  | 7.67                    | 1.06              | 14.84             | 1.76              | 23.25            | 1.57              |
| CONFRQ                                  | 1.75                    | 0.74              | 2.42              | 0.19              | 3.27             | 0.27              |
| CSLVRB                                  |                         |                   | 0.08              | 0.08              |                  |                   |
| DECFRQ                                  | 3.08                    | 1.23              | 9.92              | 2.05              | 17.73            | 1.92              |
| ELEVTN                                  | 1740.79                 | 180.28            | 1437.31           | 84.49             | 2078.27          | 209.03            |
| FDGWOD                                  | 0.42                    | 0.26              | 0.42              | 0.34              | 0.18             | 0.12              |
| GRNDCV                                  | 35.39                   | 8.16              | 8.44              | 2.37              | 13.18            | 3.65              |
| HEMTRE                                  | 1.42                    | 1.42              | 1.42              | 1.16              | 3.82             | 0.74              |
| LITDPH                                  | 2.00                    | 0.20              | 2.88              | 0.22              | 2.72             | 0.35              |
| MHCKRY                                  | 0.42                    | 0.42              | 0.17              | 0.11              | 0.36             | 0.28              |
| NOTRSP                                  | 2.5                     | 0.82              | 7.67              | 0.95              | 9.00             | 0.85              |
| NRDOAK                                  |                         |                   | 0.25              | 0.13              | 0.45             | 0.21              |
| PTCHPN                                  |                         |                   | 1.17              | 0.53              |                  |                   |
| RDMAPL                                  | 1.17                    | 0.61              | 3.17              | 0.91              | 3.82             | 0.81              |
| RHODCR                                  |                         |                   |                   |                   | 30.36            | 9.40              |
| RHODDN                                  |                         |                   |                   |                   | 1.64             | 0.49              |
| SAPNUM                                  | 280.67                  | 42.36             | 249.08            | 40.95             | 72.36            | 19.87             |
| SCTOAK                                  |                         |                   | 0.92              | 0.31              | 0.09             | 0.09              |
| SGRMPL                                  |                         |                   | 0.08              | 0.08              | 0.82             | 0.50              |
| SHRBCV                                  | 42.67                   | 7.34              | 16.75             | 5.53              | 47.73            | 6.48              |
| SHRTLF                                  |                         |                   | 0.33              | 0.26              | 0.09             | 0.09              |

Table C.2. (continued)

| <b>Eastern Hemlock / White Pine</b>     |                         |                   |                   |                   |                  |                   |
|-----------------------------------------|-------------------------|-------------------|-------------------|-------------------|------------------|-------------------|
| <b>physical / habitat<br/>variables</b> | <b>seedling/sapling</b> |                   | <b>poletimber</b> |                   | <b>sawtimber</b> |                   |
|                                         | <b>Mean</b>             | <b>Std. Error</b> | <b>Mean</b>       | <b>Std. Error</b> | <b>Mean</b>      | <b>Std. Error</b> |
| SLOPE%                                  | 15.25                   | 3.00              | 20.5              | 2.52              | 28.00            | 4.54              |
| SNGBDM                                  | 0.03                    | 0.02              | 0.06              | 0.03              | 0.04             | 0.01              |
| SNGBSM                                  | 0.02                    | 0.01              | 0.06              | 0.03              | 0.06             | 0.02              |
| SNGFRQ                                  | 0.25                    | 0.13              | 1.58              | 0.54              | 2.00             | 0.74              |
| STENDX                                  | 70.00                   | 1.23              | 75.83             | 1.49              | 84.55            | 3.66              |
| STNDGE                                  | 13.33                   | 1.65              | 28.58             | 2.85              | 75.82            | 3.23              |
| STNDSZ                                  | 43.08                   | 6.29              | 60.33             | 11.96             | 62.09            | 10.87             |
| TOTBSL                                  | 0.42                    | 0.13              | 1.15              | 0.21              | 1.44             | 0.14              |
| TOTNTR                                  | 15.75                   | 5.41              | 36.17             | 3.95              | 27.64            | 2.29              |
| VACCVR                                  | 20.17                   | 6.93              | 5.25              | 2.22              | 8.09             | 6.85              |
| VAPINE                                  | 4.83                    | 2.55              | 6.08              | 1.90              | 0.64             | 0.31              |
| WHTOAK                                  | 0.33                    | 0.26              | 0.83              | 0.58              | 1.00             | 0.62              |
| WHTPNE                                  | 6.83                    | 3.50              | 14.33             | 2.97              | 1.73             | 0.81              |
| YBIRCH                                  |                         |                   |                   |                   | 0.45             | 0.25              |
| YPOPLR                                  | 0.17                    | 0.11              | 0.25              | 0.13              | 1.82             | 0.77              |

Table C.3. Mean and S.E. for physical and habitat variables across three condition classes in the mixed hardwood/pine forest type, Cherokee National Forest, Tennessee. Variable descriptions are in Table 5.

| <b>Mixed Hardwood/Pine</b>              |                         |                   |                   |                   |                  |                   |
|-----------------------------------------|-------------------------|-------------------|-------------------|-------------------|------------------|-------------------|
| <b>physical / habitat<br/>variables</b> | <b>seedling/sapling</b> |                   | <b>poletimber</b> |                   | <b>sawtimber</b> |                   |
|                                         | <b>Mean</b>             | <b>Std. Error</b> | <b>Mean</b>       | <b>Std. Error</b> | <b>Mean</b>      | <b>Std. Error</b> |
| 10-15DBH                                | 13.57                   | 2.70              | 12.73             | 1.58              | 10.85            | 1.61              |
| 15-23DBH                                | 4.57                    | 1.04              | 9.82              | 1.17              | 8.08             | 1.78              |
| 23-30DBH                                | 0.36                    | 0.20              | 3.36              | 0.68              | 3.23             | 0.58              |
| 30-38DBH                                | 0.07                    | 0.07              | 3.18              | 0.48              | 1.92             | 0.54              |
| 38-53DBH                                | 0.07                    | 0.07              | 0.91              | 0.39              | 1.08             | 0.29              |
| 53-68DBH                                |                         |                   | 0.27              | 0.19              | 0.23             | 0.12              |
| AMBECH                                  |                         |                   |                   |                   | 0.08             | 0.08              |
| BKBRCH                                  |                         |                   |                   |                   | 0.85             | 0.45              |
| BKLCST                                  | 1.29                    | 0.68              |                   |                   |                  |                   |
| BLAGUM                                  | 0.36                    | 0.17              | 0.27              | 0.19              | 0.15             | 0.15              |
| BLAOAK                                  | 0.07                    | 0.07              | 1.09              | 0.90              | 0.08             | 0.08              |
| BSLSAP                                  | 0.56                    | 0.04              | 0.58              | 0.16              | 0.33             | 0.06              |
| CHTOAK                                  | 1.57                    | 0.71              | 5.73              | 2.46              | 3.69             | 1.09              |
| CNPYCR                                  | 89.79                   | 5.62              | 97.40             | 0.53              | 78.31            | 9.26              |
| CNPYHT                                  | 9.41                    | 0.81              | 18.89             | 1.40              | 23.07            | 2.16              |
| CONFRQ                                  | 1.43                    | 0.25              | 2.36              | 0.28              | 2.00             | 0.28              |
| CSLVRB                                  |                         |                   |                   |                   | 0.15             | 0.10              |
| DECFRQ                                  | 8.93                    | 3.11              | 16.73             | 3.24              | 14.46            | 1.79              |
| ELEVTN                                  | 1848.71                 | 79.47             | 2017.36           | 178.1             | 2141.77          | 222.47            |
| FDGWOD                                  |                         |                   |                   |                   | 0.08             | 0.08              |
| GRNDCV                                  | 20.57                   | 4.12              | 22.38             | 5.20              | 28.63            | 7.10              |
| HEMTRE                                  | 0.07                    | 0.07              | 0.36              | 0.36              | 0.46             | 0.31              |
| LITDPH                                  | 2.50                    | 0.18              | 2.55              | 0.19              | 3.32             | 0.54              |
| MHCKRY                                  | 0.14                    | 0.14              | 0.18              | 0.18              | 0.08             | 0.08              |
| NOTRSP                                  | 4.57                    | 0.81              | 7.73              | 0.47              | 6.92             | 0.56              |
| NRDOAK                                  |                         |                   | 0.27              | 0.19              | 0.77             | 0.41              |
| PTCHPN                                  | 0.43                    | 0.31              | 1.45              | 0.51              | 1.69             | 0.87              |
| RDMAPL                                  | 2.57                    | 0.88              | 4.73              | 1.18              | 3.85             | 0.73              |
| RHODCR                                  |                         |                   |                   |                   | 12.69            | 8.60              |
| RHODDN                                  |                         |                   |                   |                   |                  |                   |
| SAPNUM                                  | 286.36                  | 19.64             | 294.36            | 79.12             | 168.62           | 29.67             |
| SCTOAK                                  | 0.29                    | 0.19              | 1.55              | 0.58              | 2.08             | 0.50              |
| SGRMPL                                  |                         |                   |                   |                   | 0.15             | 0.10              |
| SHRBCV                                  | 28.00                   | 8.76              | 40.18             | 7.81              | 59.31            | 7.45              |
| SHRTLF                                  | 0.21                    | 0.21              | 0.18              | 0.12              | 0.31             | 0.31              |

Table C.3. (continued)

| <b>Mixed Hardwood/Pine</b>              |                         |                   |                   |                   |                  |                   |
|-----------------------------------------|-------------------------|-------------------|-------------------|-------------------|------------------|-------------------|
| <b>physical / habitat<br/>variables</b> | <b>seedling/sapling</b> |                   | <b>poletimber</b> |                   | <b>sawtimber</b> |                   |
|                                         | <b>Mean</b>             | <b>Std. Error</b> | <b>Mean</b>       | <b>Std. Error</b> | <b>Mean</b>      | <b>Std. Error</b> |
| SLOPE%                                  | 19.79                   | 1.93              | 25.91             | 3.17              | 22.85            | 3.52              |
| SNGBDM                                  |                         |                   | 0.10              | 0.03              | 0.09             | 0.05              |
| SNGBSM                                  |                         |                   | 0.13              | 0.05              | 0.10             | 0.06              |
| SNGFRQ                                  |                         |                   | 2.64              | 0.68              | 1.77             | 0.80              |
| STENDX                                  | 64.29                   | 1.37              | 62.73             | 2.37              | 68.46            | 2.22              |
| STNDGE                                  | 15.43                   | 1.21              | 47.64             | 4.04              | 82.62            | 4.14              |
| STNDSZ                                  | 43.79                   | 8.21              | 97.09             | 29.53             | 59.62            | 14.23             |
| TOTBSL                                  | 0.30                    | 0.06              | 1.17              | 0.12              | 1.01             | 0.13              |
| TOTNTR                                  | 18.64                   | 3.71              | 30.45             | 2.27              | 25.69            | 2.97              |
| VACCVR                                  | 8.14                    | 2.52              | 14.82             | 4.82              | 23.08            | 6.79              |
| VAPINE                                  | 6.43                    | 2.45              | 6.18              | 1.93              | 3.23             | 1.14              |
| WHTOAK                                  | 0.21                    | 0.15              | 2.45              | 0.80              | 0.92             | 0.43              |
| WHTPNE                                  | 1.36                    | 0.80              | 1.73              | 0.75              | 3.15             | 1.29              |
| YBIRCH                                  | 0.21                    | 0.11              |                   |                   | 0.38             | 0.21              |
| YPOPLR                                  | 2.50                    | 1.23              | 0.09              | 0.09              | 0.08             | 0.08              |



Table C.4. Mean and S.E. for physical and habitat variables across three condition classes in the northern hardwood forest type, Cherokee National Forest, Tennessee. Variable descriptions are in Table 5.

| Northern Hardwood               |                  |            |            |            |           |            |
|---------------------------------|------------------|------------|------------|------------|-----------|------------|
| physical / habitat<br>variables | seedling/sapling |            | poletimber |            | sawtimber |            |
|                                 | Mean             | Std. Error | Mean       | Std. Error | Mean      | Std. Error |
| 10-15DBH                        | 8.67             | 2.15       | 12.4       | 2.21       | 6.75      | 1.18       |
| 15-23DBH                        | 2.58             | 1.07       | 13.4       | 2.14       | 6.42      | 1.14       |
| 23-30DBH                        | 1.50             | 0.76       | 3.30       | 0.70       | 4.42      | 0.69       |
| 30-38DBH                        | 0.50             | 0.26       | 3.40       | 0.79       | 2.58      | 0.31       |
| 38-53DBH                        | 0.75             | 0.37       | 2.50       | 0.76       | 2.50      | 0.65       |
| 53-68DBH                        |                  |            | 0.40       | 0.22       | 0.92      | 0.34       |
| AMBECH                          | 0.25             | 0.18       | 4.90       | 2.03       | 3.92      | 1.36       |
| BKBRCH                          | 2.92             | 1.45       | 7.10       | 2.44       | 0.42      | 0.19       |
| BKLCST                          | 0.50             | 0.34       |            |            | 0.33      | 0.26       |
| BLAGUM                          |                  |            |            |            |           |            |
| BLAOAK                          |                  |            |            |            | 0.33      | 0.22       |
| BSLSAP                          | 0.50             | 0.09       | 0.31       | 0.06       | 0.30      | 0.07       |
| CHTOAK                          |                  |            |            |            |           |            |
| CNPYCR                          | 93.88            | 2.30       | 98.15      | 1.05       | 97.43     | 0.91       |
| CNPYHT                          | 8.47             | 1.76       | 21.60      | 1.85       | 19.49     | 2.07       |
| CONFRQ                          | 0.42             | 0.23       | 1.30       | 0.45       | 0.58      | 0.31       |
| CSLVRB                          | 3.50             | 2.57       | 5.50       | 2.88       | 1.17      | 0.82       |
| DECFRQ                          | 8.00             | 3.18       | 18.5       | 5.87       | 5.58      | 2.31       |
| ELEVTN                          | 3964.13          | 98.86      | 4010.6     | 144.74     | 4063.08   | 275.68     |
| FDGWOD                          |                  |            |            |            | 0.33      | 0.26       |
| GRNDCV                          | 45.27            | 7.30       | 54.61      | 8.67       | 46.73     | 6.77       |
| HEMTRE                          | 0.58             | 0.40       | 2.50       | 1.28       | 0.67      | 0.45       |
| LITDPH                          | 1.26             | 0.23       | 2.71       | 0.45       | 2.73      | 0.3        |
| MHCKRY                          |                  |            |            |            | 0.17      | 0.17       |
| NOTRSP                          | 3.17             | 0.67       | 6.00       | 0.49       | 6.67      | 0.76       |
| NRDOAK                          |                  |            |            |            | 1.42      | 0.86       |
| PTCHPN                          |                  |            |            |            | 0.08      | 0.08       |
| RDMAPL                          |                  |            | 1.20       | 0.68       | 2.17      | 1.19       |
| RHODCR                          |                  |            | 39.20      | 13.73      | 11.41     | 5.30       |
| RHODDN                          |                  |            |            |            | 0.33      | 0.26       |
| SAPNUM                          | 254.58           | 43.37      | 157.50     | 30.84      | 152.17    | 33.88      |
| SCTOAK                          |                  |            |            |            | 0.67      | 0.47       |
| SGRMPL                          | 0.42             | 0.26       | 2.50       | 1.02       | 2.33      | 0.72       |
| SHRBCV                          | 25.00            | 4.44       | 32.90      | 12.52      | 30.67     | 8.90       |
| SHRTLF                          |                  |            |            |            |           |            |

Table C.4. (continued)

| Northern Hardwood               |                  |            |            |            |           |            |
|---------------------------------|------------------|------------|------------|------------|-----------|------------|
| physical / habitat<br>variables | seedling/sapling |            | poletimber |            | sawtimber |            |
|                                 | Mean             | Std. Error | Mean       | Std. Error | Mean      | Std. Error |
| SLOPE%                          | 23.67            | 1.88       | 15.8       | 2.71       | 28.25     | 3.16       |
| SNGBDM                          |                  |            | 0.04       | 0.01       | 0.09      | 0.04       |
| SNGBSM                          |                  |            | 0.07       | 0.03       | 0.13      | 0.04       |
| SNGFRQ                          |                  |            | 2.00       | 0.58       | 2.92      | 0.84       |
| STENDX                          | 74.17            | 1.49       | 71.00      | 1.00       | 75.00     | 1.95       |
| STNDGE                          | 12.33            | 2.32       | 46.00      | 4.90       | 86.33     | 2.77       |
| STNDSZ                          | 136.42           | 44.52      | 84.1       | 33.06      | 87.25     | 20.73      |
| TOTBSL                          | 0.41             | 0.15       | 1.61       | 0.23       | 1.60      | 0.27       |
| TOTNTR                          | 14.00            | 3.97       | 35.5       | 3.84       | 24.00     | 2.23       |
| VACCVR                          |                  |            |            |            |           |            |
| VAPINE                          |                  |            |            |            |           |            |
| WHTOAK                          |                  |            |            |            | 0.17      | 0.11       |
| WHTPNE                          |                  |            |            |            | 0.17      | 0.11       |
| YBIRCH                          | 0.67             | 0.40       | 5.00       | 1.59       | 2.00      | 0.79       |
| YPOPLR                          | 0.17             | 0.17       | 2.30       | 1.54       | 1.33      | 0.93       |

Table C.5. Mean and S.E. for physical and habitat variables across three condition classes in the oak/hickory forest type, Cherokee National Forest, Tennessee. Variable descriptions are in Table 5.

| <b>Oak/Hickory</b>                      |                         |                   |                   |                   |                  |                   |
|-----------------------------------------|-------------------------|-------------------|-------------------|-------------------|------------------|-------------------|
| <b>physical / habitat<br/>variables</b> | <b>seedling/sapling</b> |                   | <b>poletimber</b> |                   | <b>sawtimber</b> |                   |
|                                         | <b>Mean</b>             | <b>Std. Error</b> | <b>Mean</b>       | <b>Std. Error</b> | <b>Mean</b>      | <b>Std. Error</b> |
| 10-15DBH                                | 10.00                   | 4.35              | 14.73             | 1.96              | 8.67             | 2.27              |
| 15-23DBH                                | 2.00                    | 1.29              | 7.91              | 0.79              | 6.83             | 1.27              |
| 23-30DBH                                | 0.83                    | 0.54              | 2.91              | 0.48              | 3.58             | 0.65              |
| 30-38DBH                                | 0.17                    | 0.17              | 3.64              | 0.58              | 3.58             | 0.65              |
| 38-53DBH                                | 0.17                    | 0.17              | 2.18              | 0.5               | 2.92             | 0.65              |
| 53-68DBH                                |                         |                   | 0.36              | 0.15              | 0.33             | 0.19              |
| AMBECH                                  |                         |                   |                   |                   |                  |                   |
| BKBRCH                                  | 0.33                    | 0.33              | 2.82              | 1.76              | 1.33             | 1.09              |
| BKLCST                                  |                         |                   | 0.45              | 0.28              | 0.17             | 0.11              |
| BLAGUM                                  | 0.17                    | 0.17              | 0.45              | 0.25              | 0.42             | 0.29              |
| BLAOAK                                  |                         |                   | 0.36              | 0.28              |                  |                   |
| BSLSAP                                  | 0.86                    | 0.12              | 0.34              | 0.07              | 0.26             | 0.04              |
| CHTOAK                                  | 0.50                    | 0.50              | 5.36              | 1.53              | 4.58             | 1.27              |
| CNPYCR                                  | 96.37                   | 2.85              | 80.83             | 11.67             | 96.6             | 2.05              |
| CNPYHT                                  | 7.17                    | 1.38              | 21.96             | 1.59              | 23.84            | 2.08              |
| CONFRQ                                  | 1.17                    | 0.54              | 1.82              | 0.55              | 2.00             | 0.54              |
| CSLVRB                                  |                         |                   | 0.64              | 0.54              | 0.42             | 0.19              |
| DECFRQ                                  | 7.83                    | 3.68              | 16.73             | 3.92              | 12.83            | 3.12              |
| ELEVTN                                  | 2647.95                 | 538.86            | 2539.73           | 241.8             | 2595.04          | 223.83            |
| FDGWOD                                  | 0.33                    | 0.33              | 0.36              | 0.36              | 0.08             | 0.08              |
| GRNDCV                                  | 24.43                   | 6.90              | 30.24             | 6.27              | 27.78            | 6.84              |
| HEMTRE                                  | 0.17                    | 0.17              | 1.64              | 0.78              | 1.08             | 0.56              |
| LITDPH                                  | 2.28                    | 0.92              | 2.65              | 0.29              | 2.57             | 0.31              |
| MHCKRY                                  |                         |                   | 0.27              | 0.19              | 0.58             | 0.36              |
| NOTRSP                                  | 4.00                    | 1.55              | 8.55              | 0.68              | 7.50             | 1.03              |
| NRDOAK                                  |                         |                   | 0.55              | 0.25              | 1.75             | 0.75              |
| PTCHPN                                  |                         |                   |                   |                   | 1.50             | 1.18              |
| RDMAPL                                  | 1.83                    | 1.17              | 5.91              | 1.47              | 3.50             | 0.93              |
| RHODCR                                  |                         |                   | 16.18             | 7.82              | 7.08             | 4.86              |
| RHODDN                                  |                         |                   | 1.73              | 0.73              | 2.17             | 0.99              |
| SAPNUM                                  | 440.33                  | 60.21             | 171.45            | 33.82             | 130.67           | 20.39             |
| SCTOAK                                  | 0.33                    | 0.33              | 1.18              | 0.54              | 1.17             | 0.74              |
| SGRMPL                                  |                         |                   | 0.09              | 0.09              | 0.17             | 0.17              |
| SHRBCV                                  | 35.17                   | 8.66              | 47.45             | 8.69              | 42.17            | 9.42              |
| SHRTLTF                                 |                         |                   |                   |                   | 0.42             | 0.34              |

Table C.5. (continued)

| <b>Oak/Hickory</b>                      |                         |                   |                   |                   |                  |                   |
|-----------------------------------------|-------------------------|-------------------|-------------------|-------------------|------------------|-------------------|
| <b>physical / habitat<br/>variables</b> | <b>seedling/sapling</b> |                   | <b>poletimber</b> |                   | <b>sawtimber</b> |                   |
|                                         | <b>Mean</b>             | <b>Std. Error</b> | <b>Mean</b>       | <b>Std. Error</b> | <b>Mean</b>      | <b>Std. Error</b> |
| SLOPE%                                  | 26.67                   | 4.42              | 28.18             | 2.95              | 27.50            | 2.30              |
| SNGBDM                                  | 0.13                    | 0.12              | 0.13              | 0.03              | 0.05             | 0.03              |
| SNGBSM                                  | 0.02                    | 0.02              | 0.18              | 0.04              | 0.08             | 0.04              |
| SNGFRQ                                  | 0.33                    | 0.21              | 4.36              | 0.97              | 2.00             | 0.55              |
| STENDX                                  | 70.00                   | 2.58              | 69.09             | 0.91              | 72.50            | 1.79              |
| STNDGE                                  | 12.17                   | 2.94              | 53.45             | 3.25              | 84.33            | 3.39              |
| STNDSZ                                  | 28.5                    | 3.38              | 66.00             | 10.66             | 77.33            | 20.31             |
| TOTBSL                                  | 0.24                    | 0.10              | 1.45              | 0.14              | 1.45             | 0.21              |
| TOTNTR                                  | 13.17                   | 5.66              | 32.00             | 2.57              | 26.17            | 3.86              |
| VACCVR                                  | 7.17                    | 5.71              | 16.09             | 8.69              | 22.17            | 8.50              |
| VAPINE                                  | 0.33                    | 0.33              |                   |                   | 0.08             | 0.08              |
| WHTOAK                                  | 0.33                    | 0.33              | 0.27              | 0.14              | 0.92             | 0.67              |
| WHTPNE                                  | 4.00                    | 4.00              | 0.36              | 0.28              | 0.50             | 0.42              |
| YBIRCH                                  |                         |                   | 0.36              | 0.28              | 0.08             | 0.08              |
| YPOPLR                                  | 2.83                    | 1.42              | 1.82              | 0.88              | 0.67             | 0.33              |

Table C.6. Mean and S.E. for physical and habitat variables across three condition classes in the yellow pine forest type, Cherokee National Forest, Tennessee. Variable descriptions are in Table 5.

| <b>Yellow Pine</b>                      |                         |                   |                   |                   |                  |                   |
|-----------------------------------------|-------------------------|-------------------|-------------------|-------------------|------------------|-------------------|
| <b>physical / habitat<br/>variables</b> | <b>seedling/sapling</b> |                   | <b>poletimber</b> |                   | <b>sawtimber</b> |                   |
|                                         | <b>Mean</b>             | <b>Std. Error</b> | <b>Mean</b>       | <b>Std. Error</b> | <b>Mean</b>      | <b>Std. Error</b> |
| 10-15DBH                                | 14.67                   | 3.11              | 16.69             | 1.67              | 9.44             | 1.65              |
| 15-23DBH                                | 4.47                    | 1.25              | 11.92             | 1.13              | 9.67             | 1.40              |
| 23-30DBH                                | 1.73                    | 0.73              | 4.85              | 0.62              | 4.00             | 1.12              |
| 30-38DBH                                | 0.40                    | 0.19              | 2.00              | 0.42              | 2.33             | 0.29              |
| 38-53DBH                                | 0.20                    | 0.14              | 1.15              | 0.46              | 2.00             | 0.44              |
| 53-68DBH                                |                         |                   | 0.15              | 0.10              | 0.22             | 0.15              |
| AMBECH                                  |                         |                   | 0.08              | 0.08              |                  |                   |
| BKBRCH                                  | 0.33                    | 0.33              | 0.46              | 0.31              |                  |                   |
| BKLCST                                  | 0.40                    | 0.29              | 0.15              | 0.15              | 0.11             | 0.11              |
| BLAGUM                                  | 0.93                    | 0.60              | 0.62              | 0.21              | 1.11             | 1.11              |
| BLAOAK                                  | 0.13                    | 0.09              | 0.08              | 0.08              | 0.33             | 0.24              |
| BSLSAP                                  | 0.61                    | 0.06              | 0.31              | 0.05              | 0.47             | 0.04              |
| CHTOAK                                  | 0.20                    | 0.14              | 3.15              | 1.18              | 2.11             | 0.84              |
| CNPYCR                                  | 86.41                   | 5.49              | 97.43             | 0.63              | 96.96            | 0.67              |
| CNPYHT                                  | 8.23                    | 0.78              | 18.16             | 1.96              | 20.89            | 1.32              |
| CONFRQ                                  | 1.73                    | 0.28              | 3.15              | 0.10              | 5.33             | 2.59              |
| CSLVRB                                  |                         |                   |                   |                   |                  |                   |
| DECFRQ                                  | 5.33                    | 1.43              | 10.46             | 1.83              | 12.67            | 2.23              |
| ELEVTN                                  | 1690.13                 | 99.27             | 2192.69           | 115.63            | 1878.89          | 234.65            |
| FDGWOD                                  | 0.07                    | 0.07              |                   |                   | 0.11             | 0.11              |
| GRNDCV                                  | 26.05                   | 5.14              | 23.69             | 6.26              | 27.2             | 6.23              |
| HEMTRE                                  | 0.07                    | 0.07              | 0.92              | 0.59              | 0.33             | 0.24              |
| LITDPH                                  | 2.43                    | 0.28              | 4.00              | 0.57              | 2.56             | 0.36              |
| MHCKRY                                  |                         |                   | 0.31              | 0.21              | 0.11             | 0.11              |
| NOTRSP                                  | 3.87                    | 0.62              | 8.15              | 0.76              | 7.67             | 0.85              |
| NRDOAK                                  |                         |                   | 0.08              | 0.08              |                  |                   |
| PTCHPN                                  | 1.27                    | 0.57              | 2.46              | 1.09              | 0.89             | 0.56              |
| RDMAPL                                  | 1.67                    | 0.83              | 2.08              | 0.61              | 3.67             | 1.19              |
| RHODCR                                  | 3.33                    | 3.33              | 12.69             | 8.63              |                  |                   |
| RHODDN                                  |                         |                   | 0.69              | 0.55              |                  |                   |
| SAPNUM                                  | 312.87                  | 28.12             | 159.46            | 24.69             | 239.44           | 21.69             |
| SCTOAK                                  | 0.67                    | 0.29              | 0.77              | 0.41              | 1.78             | 0.57              |
| SGRMPL                                  |                         |                   |                   |                   |                  |                   |
| SHRBCV                                  | 39.87                   | 7.12              | 59.08             | 6.24              | 41.33            | 8.96              |
| SHRTLf                                  | 0.07                    | 0.07              | 1.00              | 0.44              | 1.11             | 0.61              |



Table C.6. (continued)

| <b>Yellow Pine</b>                      |                         |                   |                   |                   |                  |                   |
|-----------------------------------------|-------------------------|-------------------|-------------------|-------------------|------------------|-------------------|
| <b>physical / habitat<br/>variables</b> | <b>seedling/sapling</b> |                   | <b>poletimber</b> |                   | <b>sawtimber</b> |                   |
|                                         | <b>Mean</b>             | <b>Std. Error</b> | <b>Mean</b>       | <b>Std. Error</b> | <b>Mean</b>      | <b>Std. Error</b> |
| SLOPE%                                  | 18.67                   | 1.69              | 31.54             | 2.62              | 26.33            | 2.65              |
| SNGBDM                                  | 0.02                    | 0.01              | 0.08              | 0.02              | 0.09             | 0.05              |
| SNGBSM                                  | 0.02                    | 0.01              | 0.10              | 0.03              | 0.10             | 0.05              |
| SNGFRQ                                  | 1.20                    | 0.50              | 3.69              | 0.76              | 1.89             | 0.68              |
| STENDX                                  | 62.67                   | 1.18              | 60.00             | 1.13              | 61.11            | 2.00              |
| STNDGE                                  | 15.60                   | 1.57              | 44.08             | 2.90              | 79.00            | 2.61              |
| STNDSZ                                  | 54.47                   | 11.23             | 71.08             | 15.53             | 43.56            | 8.36              |
| TOTBSL                                  | 0.44                    | 0.11              | 1.18              | 0.10              | 1.22             | 0.10              |
| TOTNTR                                  | 21.47                   | 4.28              | 36.77             | 2.22              | 27.78            | 3.29              |
| VACCVR                                  | 17.93                   | 6.12              | 36.46             | 7.68              | 15.00            | 5.05              |
| VAPINE                                  | 7.33                    | 2.05              | 7.15              | 2.90              | 6.44             | 2.68              |
| WHTOAK                                  | 0.60                    | 0.32              | 0.15              | 0.15              | 0.56             | 0.44              |
| WHTPNE                                  | 6.53                    | 2.80              | 2.85              | 1.28              | 2.56             | 1.46              |
| YBIRCH                                  |                         |                   |                   |                   | 0.11             | 0.11              |
| YPOPLR                                  | 0.73                    | 0.56              | 0.46              | 0.46              |                  |                   |

**Appendix D.** Avian species occurrence and density across condition class categories  
for six USFS forest types.

Table D.1. Avian species occurrence and density (pairs/100 ha) across three condition class categories in the cove hardwood forest type, 1992.

| Cove Hardwood -<br>seedling/sapling |                 |                    |  | Cove Hardwood -<br>poletimber |                 |                    |  | Cove Hardwood -<br>sawtimber |                 |                    |  |
|-------------------------------------|-----------------|--------------------|--|-------------------------------|-----------------|--------------------|--|------------------------------|-----------------|--------------------|--|
| species<br>code                     | %<br>occurrence | density/<br>100 ha |  | species<br>code               | %<br>occurrence | density/<br>100 ha |  | species<br>code              | %<br>occurrence | density/<br>100 ha |  |
| howa                                | 90              | 141                |  | howa                          | 75              | 127                |  | howa                         | 85              | 119                |  |
| revi                                | 80              | 184                |  | blnw                          | 42              | 85                 |  | revi                         | 62              | 102                |  |
| inbu                                | 60              | 127                |  | revi                          | 42              | 74                 |  | blnw                         | 38              | 59                 |  |
| rsto                                | 60              | 198                |  | cach                          | 33              | 53                 |  | baww                         | 38              | 42                 |  |
| cach                                | 40              | 57                 |  | wewa                          | 33              | 42                 |  | grca                         | 23              | 25                 |  |
| amre                                | 30              | 71                 |  | baww                          | 25              | 42                 |  | oven                         | 23              | 25                 |  |
| baww                                | 30              | 42                 |  | oven                          | 25              | 42                 |  | etti                         | 23              | 25                 |  |
| carw                                | 30              | 57                 |  | acfl                          | 17              | 21                 |  | blbw                         | 15              | 17                 |  |
| grca                                | 20              | 28                 |  | sovi                          | 17              | 21                 |  | noca                         | 15              | 17                 |  |
| kewa                                | 20              | 57                 |  | etti                          | 17              | 21                 |  | scju                         | 15              | 25                 |  |
| noca                                | 20              | 28                 |  | woth                          | 17              | 21                 |  | scta                         | 15              | 17                 |  |
| scta                                | 20              | 28                 |  | amcr                          | 8               | 11                 |  | wewa                         | 15              | 17                 |  |
| etti                                | 20              | 28                 |  | blbw                          | 8               | 11                 |  | acfl                         | 8               | 8                  |  |
| wewa                                | 20              | 42                 |  | carw                          | 8               | 21                 |  | blbw                         | 8               | 8                  |  |
| blbw                                | 10              | 14                 |  | dowo                          | 8               | 11                 |  | cach                         | 8               | 17                 |  |
| blnw                                | 10              | 14                 |  | grca                          | 8               | 11                 |  | cawa                         | 8               | 17                 |  |
| cswa                                | 10              | 14                 |  | lowa                          | 8               | 11                 |  | carw                         | 8               | 8                  |  |
| ysfl                                | 10              | 14                 |  | scju                          | 8               | 21                 |  | lowa                         | 8               | 8                  |  |
| oven                                | 10              | 28                 |  | nopa                          | 8               | 11                 |  | nopa                         | 8               | 8                  |  |
| praw                                | 10              | 14                 |  | scta                          | 8               | 21                 |  | piwo                         | 8               | 8                  |  |
| rthu                                | 10              | 14                 |  |                               |                 |                    |  |                              |                 |                    |  |
| sovi                                | 10              | 14                 |  |                               |                 |                    |  |                              |                 |                    |  |
| wevi                                | 10              | 14                 |  |                               |                 |                    |  |                              |                 |                    |  |
| woth                                | 10              | 14                 |  |                               |                 |                    |  |                              |                 |                    |  |
| ybch                                | 10              | 28                 |  |                               |                 |                    |  |                              |                 |                    |  |
| ywar                                | 10              | 14                 |  |                               |                 |                    |  |                              |                 |                    |  |

Table D.2. Avian species occurrence and density (pairs/100 ha) across three condition class categories in the cove hardwood forest type, 1993.

| Cove Hardwood -<br>seedling/sapling |                 |                    |  | Cove Hardwood -<br>poletimber |                 |                    |  | Cove Hardwood -<br>savannah |                 |                    |  |
|-------------------------------------|-----------------|--------------------|--|-------------------------------|-----------------|--------------------|--|-----------------------------|-----------------|--------------------|--|
| species<br>code                     | %<br>occurrence | density/<br>100 ha |  | species<br>code               | %<br>occurrence | density/<br>100 ha |  | species<br>code             | %<br>occurrence | density/<br>100 ha |  |
| howa                                | 85              | 147                |  | btw                           | 85              | 166                |  | revi                        | 77              | 127                |  |
| revi                                | 85              | 166                |  | howa                          | 69              | 127                |  | btw                         | 62              | 93                 |  |
| inbu                                | 77              | 147                |  | revi                          | 69              | 147                |  | baww                        | 54              | 85                 |  |
| scta                                | 69              | 137                |  | baww                          | 46              | 59                 |  | oven                        | 54              | 102                |  |
| rsfo                                | 62              | 88                 |  | cach                          | 38              | 59                 |  | howa                        | 46              | 110                |  |
| amre                                | 54              | 127                |  | oven                          | 31              | 39                 |  | scta                        | 46              | 59                 |  |
| btw                                 | 54              | 88                 |  | etti                          | 31              | 39                 |  | btw                         | 38              | 51                 |  |
| oven                                | 54              | 78                 |  | wewa                          | 31              | 59                 |  | cawa                        | 23              | 34                 |  |
| btw                                 | 31              | 39                 |  | sovi                          | 23              | 29                 |  | sovi                        | 23              | 34                 |  |
| baww                                | 31              | 49                 |  | inbu                          | 15              | 29                 |  | cach                        | 15              | 59                 |  |
| ango                                | 23              | 29                 |  | lowa                          | 15              | 20                 |  | scju                        | 15              | 17                 |  |
| cach                                | 23              | 29                 |  | acfl                          | 8               | 10                 |  | wewa                        | 15              | 17                 |  |
| cswa                                | 23              | 49                 |  | ango                          | 8               | 10                 |  | wth                         | 15              | 17                 |  |
| rbgr                                | 23              | 29                 |  | blja                          | 8               | 10                 |  | acfl                        | 8               | 8                  |  |
| blja                                | 15              | 20                 |  | btw                           | 8               | 10                 |  | amcr                        | 8               | 8                  |  |
| sovi                                | 15              | 20                 |  | piwo                          | 8               | 10                 |  | ango                        | 8               | 17                 |  |
| wewa                                | 15              | 20                 |  | rbgr                          | 8               | 10                 |  | amro                        | 8               | 17                 |  |
| cawa                                | 8               | 10                 |  | scta                          | 8               | 10                 |  | blbw                        | 8               | 8                  |  |
| cedw                                | 8               | 10                 |  | wth                           | 8               | 10                 |  | cedw                        | 8               | 17                 |  |
| eaup                                | 8               | 10                 |  |                               |                 |                    |  | eaup                        | 8               | 8                  |  |
| grca                                | 8               | 20                 |  |                               |                 |                    |  | inbu                        | 8               | 8                  |  |
| noca                                | 8               | 10                 |  |                               |                 |                    |  | piwo                        | 8               | 8                  |  |
| scju                                | 8               | 10                 |  |                               |                 |                    |  | rbgr                        | 8               | 17                 |  |
| piwo                                | 8               | 10                 |  |                               |                 |                    |  | swwa                        | 8               | 8                  |  |
| sosp                                | 8               | 10                 |  |                               |                 |                    |  | etti                        | 8               | 8                  |  |
| vear                                | 8               | 10                 |  |                               |                 |                    |  | wiwr                        | 8               | 8                  |  |
| wbnu                                | 8               | 10                 |  |                               |                 |                    |  | ybsa                        | 8               | 8                  |  |
| wevi                                | 8               | 20                 |  |                               |                 |                    |  | yawa                        | 8               | 8                  |  |
| ybcn                                | 8               | 10                 |  |                               |                 |                    |  |                             |                 |                    |  |

Table D.3. Avian species occurrence and density (pairs/100 ha) across three condition class categories in the eastern hemlock/white pine forest type, 1992.

| E. Hemlock/White Pine -<br>seedling/sapling |                 |                    |  | E. Hemlock/White Pine -<br>poletimber |                 |                    |  | E. Hemlock/White Pine -<br>sawtimber |                 |                    |  |
|---------------------------------------------|-----------------|--------------------|--|---------------------------------------|-----------------|--------------------|--|--------------------------------------|-----------------|--------------------|--|
| species<br>code                             | %<br>occurrence | density/<br>100 ha |  | species<br>code                       | %<br>occurrence | density/<br>100 ha |  | species<br>code                      | %<br>occurrence | density/<br>100 ha |  |
| revi                                        | 100             | 216                |  | inbu                                  | 63              | 127                |  | revi                                 | 90              | 140                |  |
| inbu                                        | 70              | 114                |  | revi                                  | 63              | 111                |  | btw                                  | 70              | 153                |  |
| hova                                        | 50              | 89                 |  | cach                                  | 50              | 79                 |  | hova                                 | 60              | 76                 |  |
| rsto                                        | 50              | 89                 |  | carw                                  | 38              | 48                 |  | cach                                 | 50              | 102                |  |
| wewa                                        | 50              | 64                 |  | ango                                  | 25              | 32                 |  | etti                                 | 30              | 38                 |  |
| oven                                        | 40              | 64                 |  | amro                                  | 25              | 32                 |  | wewa                                 | 30              | 38                 |  |
| ybch                                        | 40              | 64                 |  | blja                                  | 25              | 32                 |  | acfl                                 | 20              | 51                 |  |
| btw                                         | 30              | 51                 |  | btw                                   | 25              | 32                 |  | baww                                 | 20              | 25                 |  |
| ango                                        | 20              | 25                 |  | baww                                  | 25              | 32                 |  | nopa                                 | 20              | 25                 |  |
| bggn                                        | 20              | 25                 |  | wewa                                  | 25              | 32                 |  | oven                                 | 20              | 51                 |  |
| baww                                        | 20              | 25                 |  | cedw                                  | 13              | 32                 |  | piwo                                 | 20              | 25                 |  |
| cach                                        | 20              | 25                 |  | gcfl                                  | 13              | 16                 |  | scta                                 | 20              | 38                 |  |
| noca                                        | 20              | 38                 |  | grca                                  | 13              | 16                 |  | btbw                                 | 10              | 13                 |  |
| wevi                                        | 20              | 25                 |  | heth                                  | 13              | 16                 |  | dowo                                 | 10              | 13                 |  |
| anne                                        | 10              | 13                 |  | hova                                  | 13              | 16                 |  | grca                                 | 10              | 13                 |  |
| amro                                        | 10              | 13                 |  | piwa                                  | 13              | 16                 |  | scju                                 | 10              | 51                 |  |
| brth                                        | 10              | 13                 |  | rbgr                                  | 13              | 16                 |  | rbgr                                 | 10              | 13                 |  |
| bwlha                                       | 10              | 13                 |  | rsto                                  | 13              | 16                 |  | veer                                 | 10              | 13                 |  |
| carw                                        | 10              | 13                 |  | etti                                  | 13              | 16                 |  | wbnu                                 | 10              | 13                 |  |
| cswa                                        | 10              | 13                 |  | wevi                                  | 13              | 16                 |  | wevi                                 | 10              | 13                 |  |
| dowo                                        | 10              | 13                 |  | ybch                                  | 13              | 16                 |  | wiwr                                 | 10              | 13                 |  |
| grca                                        | 10              | 13                 |  | ybcu                                  | 13              | 16                 |  | woth                                 | 10              | 13                 |  |
| piwa                                        | 10              | 13                 |  |                                       |                 |                    |  |                                      |                 |                    |  |
| rbgr                                        | 10              | 13                 |  |                                       |                 |                    |  |                                      |                 |                    |  |
| rthu                                        | 10              | 13                 |  |                                       |                 |                    |  |                                      |                 |                    |  |
| scta                                        | 10              | 25                 |  |                                       |                 |                    |  |                                      |                 |                    |  |
| etti                                        | 10              | 13                 |  |                                       |                 |                    |  |                                      |                 |                    |  |
| ywar                                        | 10              | 13                 |  |                                       |                 |                    |  |                                      |                 |                    |  |



Table D.4. Avian species occurrence and density (pairs/100 ha) across three condition class categories in the eastern hemlock/white pine forest type, 1993.

| E. Hemlock/White Pine - seedling/sapling |              |                 |  | E. Hemlock/White Pine - poletimber |              |                 |  | E. Hemlock/White Pine - sawtimber |              |                 |  |
|------------------------------------------|--------------|-----------------|--|------------------------------------|--------------|-----------------|--|-----------------------------------|--------------|-----------------|--|
| species code                             | % occurrence | density/ 100 ha |  | species code                       | % occurrence | density/ 100 ha |  | species code                      | % occurrence | density/ 100 ha |  |
| inbu                                     | 92           | 148             |  | revi                               | 91           | 223             |  | revi                              | 91           | 208             |  |
| revi                                     | 83           | 223             |  | inbu                               | 64           | 74              |  | blnw                              | 55           | 104             |  |
| howa                                     | 67           | 127             |  | blnw                               | 45           | 95              |  | baww                              | 55           | 69              |  |
| rsto                                     | 67           | 159             |  | cach                               | 36           | 42              |  | howa                              | 55           | 104             |  |
| oven                                     | 50           | 95              |  | ybcu                               | 36           | 42              |  | oven                              | 45           | 69              |  |
| wewa                                     | 42           | 53              |  | carw                               | 27           | 32              |  | acfl                              | 36           | 46              |  |
| baww                                     | 33           | 42              |  | howa                               | 27           | 74              |  | cach                              | 36           | 81              |  |
| scta                                     | 33           | 64              |  | wewa                               | 27           | 42              |  | scta                              | 27           | 35              |  |
| ytwa                                     | 33           | 53              |  | woth                               | 27           | 32              |  | inbu                              | 18           | 23              |  |
| cach                                     | 25           | 42              |  | bggn                               | 18           | 21              |  | nopa                              | 18           | 35              |  |
| ybcu                                     | 25           | 32              |  | baww                               | 18           | 21              |  | rsto                              | 18           | 23              |  |
| bggn                                     | 17           | 21              |  | gcfl                               | 18           | 21              |  | wbnu                              | 18           | 23              |  |
| carw                                     | 17           | 32              |  | nopa                               | 18           | 21              |  | wewa                              | 18           | 23              |  |
| eti                                      | 17           | 21              |  | rsto                               | 18           | 21              |  | ytvi                              | 18           | 35              |  |
| wevi                                     | 17           | 21              |  | eti                                | 18           | 21              |  | amcr                              | 9            | 23              |  |
| woth                                     | 17           | 21              |  | ango                               | 9            | 21              |  | bjia                              | 9            | 12              |  |
| yoch                                     | 17           | 21              |  | bjia                               | 9            | 32              |  | btbw                              | 9            | 12              |  |
| ango                                     | 8            | 21              |  | cogr                               | 9            | 11              |  | cawa                              | 9            | 12              |  |
| bjia                                     | 8            | 11              |  | coha                               | 9            | 11              |  | hawo                              | 9            | 12              |  |
| brth                                     | 8            | 11              |  | noca                               | 9            | 11              |  | modo                              | 9            | 12              |  |
| blnw                                     | 8            | 11              |  | oven                               | 9            | 11              |  | piwa                              | 9            | 12              |  |
| cawa                                     | 8            | 11              |  | piwo                               | 9            | 11              |  | rbgr                              | 9            | 12              |  |
| cswa                                     | 8            | 11              |  | wevi                               | 9            | 11              |  | rtlu                              | 9            | 12              |  |
| gcfl                                     | 8            | 11              |  | ybcu                               | 9            | 11              |  | suta                              | 9            | 12              |  |
| kewa                                     | 8            | 11              |  | ytwa                               | 9            | 11              |  | eti                               | 9            | 12              |  |
| modo                                     | 8            | 11              |  |                                    |              |                 |  | woth                              | 9            | 12              |  |
| noca                                     | 8            | 11              |  |                                    |              |                 |  | ytwa                              | 9            | 12              |  |
| nopa                                     | 8            | 11              |  |                                    |              |                 |  |                                   |              |                 |  |
| piwa                                     | 8            | 11              |  |                                    |              |                 |  |                                   |              |                 |  |
| piwo                                     | 8            | 11              |  |                                    |              |                 |  |                                   |              |                 |  |
| rtwo                                     | 8            | 11              |  |                                    |              |                 |  |                                   |              |                 |  |
| rtlu                                     | 8            | 11              |  |                                    |              |                 |  |                                   |              |                 |  |

Table D.5. Avian species occurrence and density (pairs/100 ha) across three condition class categories in the mixed hardwood/pine forest type, 1992.

| Mixed Hardwood/Pine -<br>seedling/sapling |                 |                    | Mixed Hardwood/Pine -<br>poletimber |                 |                    | Mixed Hardwood/Pine -<br>sawtimber |                 |                    |
|-------------------------------------------|-----------------|--------------------|-------------------------------------|-----------------|--------------------|------------------------------------|-----------------|--------------------|
| species<br>code                           | %<br>occurrence | density/<br>100 ha | species<br>code                     | %<br>occurrence | density/<br>100 ha | species<br>code                    | %<br>occurrence | density/<br>100 ha |
| revi                                      | 70              | 165                | revi                                | 67              | 127                | howa                               | 64              | 98                 |
| btnw                                      | 40              | 51                 | wewa                                | 44              | 57                 | oven                               | 64              | 117                |
| baww                                      | 40              | 51                 | baww                                | 33              | 42                 | revi                               | 57              | 137                |
| cach                                      | 30              | 64                 | cach                                | 33              | 85                 | etti                               | 43              | 59                 |
| howa                                      | 30              | 38                 | howa                                | 33              | 42                 | btnw                               | 36              | 59                 |
| inbu                                      | 30              | 51                 | oven                                | 33              | 57                 | cach                               | 36              | 68                 |
| wewa                                      | 30              | 38                 | ytwa                                | 33              | 42                 | inbu                               | 36              | 49                 |
| noca                                      | 20              | 25                 | acfl                                | 22              | 28                 | wewa                               | 29              | 39                 |
| oven                                      | 20              | 38                 | blja                                | 22              | 28                 | baww                               | 21              | 29                 |
| piwa                                      | 20              | 25                 | btnw                                | 22              | 28                 | carw                               | 21              | 29                 |
| rsto                                      | 20              | 25                 | inbu                                | 22              | 28                 | nopa                               | 21              | 29                 |
| scta                                      | 20              | 25                 | piwa                                | 22              | 28                 | scta                               | 21              | 29                 |
| wevi                                      | 20              | 25                 | scta                                | 22              | 28                 | ytwa                               | 21              | 29                 |
| piwo                                      | 10              | 13                 | ybcu                                | 22              | 28                 | acfl                               | 14              | 20                 |
| etti                                      | 10              | 13                 | amcr                                | 11              | 14                 | blbw                               | 14              | 29                 |
| woth                                      | 10              | 13                 | carw                                | 11              | 14                 | btbw                               | 14              | 49                 |
| ybch                                      | 10              | 25                 | dowo                                | 11              | 28                 | cawa                               | 14              | 39                 |
| ybcu                                      | 10              | 13                 | hawo                                | 11              | 14                 | piwa                               | 14              | 20                 |
|                                           |                 |                    | noca                                | 11              | 14                 | piwo                               | 14              | 29                 |
|                                           |                 |                    | sovi                                | 11              | 14                 | sovi                               | 14              | 29                 |
|                                           |                 |                    | etti                                | 11              | 14                 | woth                               | 14              | 20                 |
|                                           |                 |                    | wbnu                                | 11              | 14                 | amre                               | 7               | 10                 |
|                                           |                 |                    |                                     |                 |                    | amro                               | 7               | 10                 |
|                                           |                 |                    |                                     |                 |                    | blja                               | 7               | 10                 |
|                                           |                 |                    |                                     |                 |                    | dowo                               | 7               | 10                 |
|                                           |                 |                    |                                     |                 |                    | hawo                               | 7               | 10                 |
|                                           |                 |                    |                                     |                 |                    | noca                               | 7               | 10                 |
|                                           |                 |                    |                                     |                 |                    | rbwo                               | 7               | 10                 |
|                                           |                 |                    |                                     |                 |                    | rsto                               | 7               | 20                 |
|                                           |                 |                    |                                     |                 |                    | wiwr                               | 7               | 10                 |
|                                           |                 |                    |                                     |                 |                    | ybcu                               | 7               | 10                 |

Table D.6. Avian species occurrence and density (pairs/100 ha) across three condition class categories in the mixed hardwood/pine forest type, 1993.

| Mixed Hardwood/Pine -<br>seedling/sapling |                 |                    | Mixed Hardwood/Pine -<br>poletimber |                 |                    | Mixed Hardwood/Pine -<br>sawtimber |                 |                    |
|-------------------------------------------|-----------------|--------------------|-------------------------------------|-----------------|--------------------|------------------------------------|-----------------|--------------------|
| species<br>code                           | %<br>occurrence | density/<br>100 ha | species<br>code                     | %<br>occurrence | density/<br>100 ha | species<br>code                    | %<br>occurrence | density/<br>100 ha |
| inbu                                      | 86              | 145                | revi                                | 82              | 162                | howa                               | 62              | 138                |
| revi                                      | 86              | 127                | oven                                | 73              | 127                | oven                               | 62              | 106                |
| baww                                      | 57              | 73                 | cach                                | 45              | 104                | revi                               | 62              | 106                |
| howa                                      | 57              | 73                 | btnw                                | 36              | 58                 | btnw                               | 54              | 74                 |
| cach                                      | 50              | 91                 | baww                                | 36              | 46                 | scta                               | 46              | 74                 |
| rsto                                      | 50              | 73                 | scta                                | 36              | 46                 | cach                               | 31              | 42                 |
| wevi                                      | 29              | 45                 | etti                                | 36              | 46                 | etti                               | 31              | 53                 |
| wewa                                      | 29              | 45                 | howa                                | 27              | 35                 | ytwa                               | 31              | 42                 |
| etti                                      | 21              | 36                 | blja                                | 18              | 23                 | wewa                               | 23              | 32                 |
| btnw                                      | 14              | 18                 | inbu                                | 18              | 35                 | woth                               | 23              | 64                 |
| piwo                                      | 14              | 18                 | wewa                                | 18              | 23                 | btbw                               | 15              | 53                 |
| acfl                                      | 7               | 9                  | acfl                                | 9               | 12                 | baww                               | 15              | 21                 |
| amgo                                      | 7               | 18                 | amcr                                | 9               | 12                 | cawa                               | 15              | 32                 |
| bggn                                      | 7               | 9                  | amgo                                | 9               | 12                 | dowo                               | 15              | 21                 |
| blja                                      | 7               | 9                  | bwha                                | 9               | 12                 | hawo                               | 15              | 21                 |
| dowo                                      | 7               | 9                  | carw                                | 9               | 12                 | inbu                               | 15              | 32                 |
| oven                                      | 7               | 9                  | dowo                                | 9               | 12                 | nopa                               | 15              | 21                 |
| scta                                      | 7               | 9                  | piwo                                | 9               | 12                 | piwo                               | 15              | 21                 |
| ybch                                      | 7               | 9                  | rsto                                | 9               | 12                 | sovi                               | 15              | 21                 |
| ybcu                                      | 7               | 9                  | sovi                                | 9               | 12                 | acfl                               | 8               | 11                 |
| ytvi                                      | 7               | 9                  | suta                                | 9               | 12                 | amgo                               | 8               | 21                 |
|                                           |                 |                    | wbnu                                | 9               | 12                 | blbw                               | 8               | 11                 |
|                                           |                 |                    | woth                                | 9               | 12                 | scju                               | 8               | 11                 |
|                                           |                 |                    | ytwa                                | 9               | 23                 | rbwo                               | 8               | 11                 |
|                                           |                 |                    |                                     |                 |                    | swwa                               | 8               | 11                 |

Table D.7. Avian species occurrence and density (pairs/100 ha) across three condition class categories in the northern hardwood forest type, 1992.

| Northern Hardwood -<br>seedling/sapling |                 |                    |  | Northern Hardwood -<br>poletimber |                 |                    |  | Northern Hardwood -<br>sawtimber |                 |                    |  |
|-----------------------------------------|-----------------|--------------------|--|-----------------------------------|-----------------|--------------------|--|----------------------------------|-----------------|--------------------|--|
| species<br>code                         | %<br>occurrence | density/<br>100 ha |  | species<br>code                   | %<br>occurrence | density/<br>100 ha |  | species<br>code                  | %<br>occurrence | density/<br>100 ha |  |
| scju                                    | 73              | 127                |  | btbw                              | 90              | 198                |  | btbw                             | 75              | 127                |  |
| veer                                    | 73              | 104                |  | scju                              | 80              | 170                |  | scju                             | 58              | 127                |  |
| cswa                                    | 64              | 139                |  | sovi                              | 70              | 99                 |  | veer                             | 58              | 148                |  |
| btbw                                    | 55              | 81                 |  | veer                              | 60              | 113                |  | sovi                             | 50              | 106                |  |
| howa                                    | 45              | 69                 |  | cawa                              | 50              | 71                 |  | btbw                             | 33              | 74                 |  |
| cawa                                    | 36              | 81                 |  | wiwr                              | 50              | 71                 |  | cswa                             | 33              | 74                 |  |
| revi                                    | 36              | 58                 |  | oven                              | 40              | 85                 |  | revi                             | 33              | 64                 |  |
| carw                                    | 27              | 35                 |  | rbgr                              | 40              | 85                 |  | blbw                             | 25              | 74                 |  |
| inbu                                    | 27              | 35                 |  | cswa                              | 30              | 42                 |  | baww                             | 25              | 42                 |  |
| oven                                    | 27              | 46                 |  | scta                              | 30              | 42                 |  | rsto                             | 25              | 32                 |  |
| rbgr                                    | 27              | 46                 |  | blbw                              | 20              | 42                 |  | scta                             | 25              | 32                 |  |
| rsto                                    | 27              | 58                 |  | cach                              | 20              | 28                 |  | wiwr                             | 25              | 32                 |  |
| wiwr                                    | 27              | 35                 |  | howa                              | 20              | 28                 |  | bwla                             | 17              | 21                 |  |
| amgo                                    | 18              | 35                 |  | revi                              | 20              | 28                 |  | cach                             | 17              | 42                 |  |
| grca                                    | 18              | 23                 |  | rsto                              | 20              | 28                 |  | cawa                             | 17              | 42                 |  |
| scta                                    | 18              | 23                 |  | amre                              | 10              | 14                 |  | rbgr                             | 17              | 21                 |  |
| sovi                                    | 18              | 23                 |  | bcch                              | 10              | 14                 |  | etti                             | 17              | 21                 |  |
| ybch                                    | 18              | 35                 |  | blja                              | 10              | 14                 |  | bcch                             | 8               | 32                 |  |
| bcch                                    | 9               | 12                 |  | inbu                              | 10              | 14                 |  | chsw                             | 8               | 11                 |  |
| baww                                    | 9               | 12                 |  | nopa                              | 10              | 14                 |  | howa                             | 8               | 11                 |  |
| gwwa                                    | 9               | 23                 |  | piwo                              | 10              | 14                 |  | nopa                             | 8               | 11                 |  |
| nopa                                    | 9               | 12                 |  | etti                              | 10              | 28                 |  | oven                             | 8               | 11                 |  |
| rbgr                                    | 9               | 12                 |  |                                   |                 |                    |  | wbnu                             | 8               | 11                 |  |
|                                         |                 |                    |  |                                   |                 |                    |  | wewa                             | 8               | 11                 |  |

Table D.8. Avian species occurrence and density (pairs/100 ha) across three condition class categories in the northern hardwood forest type, 1993.

| Northern Hardwood -<br>seedling/sapling |                 |                    |  | Northern Hardwood -<br>poletimber |                 |                    |  | Northern Hardwood -<br>sawtimber |                 |                    |  |
|-----------------------------------------|-----------------|--------------------|--|-----------------------------------|-----------------|--------------------|--|----------------------------------|-----------------|--------------------|--|
| species<br>code                         | %<br>occurrence | density/<br>100 ha |  | species<br>code                   | %<br>occurrence | density/<br>100 ha |  | species<br>code                  | %<br>occurrence | density/<br>100 ha |  |
| cswa                                    | 83              | 233                |  | btbw                              | 100             | 318                |  | btbw                             | 75              | 180                |  |
| veer                                    | 75              | 148                |  | sovi                              | 100             | 203                |  | scju                             | 58              | 127                |  |
| btbw                                    | 67              | 117                |  | veer                              | 73              | 127                |  | sovi                             | 58              | 117                |  |
| rbgr                                    | 58              | 74                 |  | cawa                              | 64              | 127                |  | veer                             | 50              | 85                 |  |
| sovi                                    | 58              | 127                |  | scju                              | 55              | 153                |  | howa                             | 42              | 53                 |  |
| cawa                                    | 50              | 117                |  | oven                              | 45              | 76                 |  | blbw                             | 33              | 53                 |  |
| howa                                    | 50              | 85                 |  | scta                              | 45              | 64                 |  | cawa                             | 33              | 42                 |  |
| scju                                    | 50              | 159                |  | blbw                              | 27              | 51                 |  | cswa                             | 33              | 42                 |  |
| rsto                                    | 50              | 95                 |  | wiwr                              | 27              | 51                 |  | scta                             | 33              | 42                 |  |
| inbu                                    | 42              | 64                 |  | bjla                              | 18              | 25                 |  | btbw                             | 25              | 32                 |  |
| oven                                    | 42              | 85                 |  | btbw                              | 18              | 25                 |  | oven                             | 25              | 32                 |  |
| revi                                    | 33              | 64                 |  | howa                              | 18              | 25                 |  | rsto                             | 25              | 32                 |  |
| wiwr                                    | 33              | 42                 |  | amcr                              | 9               | 25                 |  | rbgr                             | 17              | 21                 |  |
| ango                                    | 17              | 53                 |  | cedw                              | 9               | 25                 |  | revi                             | 17              | 32                 |  |
| baww                                    | 17              | 21                 |  | cswa                              | 9               | 13                 |  | wewa                             | 17              | 32                 |  |
| dowo                                    | 17              | 32                 |  | nopa                              | 9               | 13                 |  | acfl                             | 8               | 11                 |  |
| grca                                    | 17              | 21                 |  | rbgr                              | 9               | 13                 |  | baww                             | 8               | 11                 |  |
| hawo                                    | 17              | 21                 |  | revi                              | 9               | 13                 |  | cach                             | 8               | 11                 |  |
| eti                                     | 17              | 21                 |  | rsto                              | 9               | 13                 |  | cedw                             | 8               | 21                 |  |
| amre                                    | 8               | 11                 |  | woth                              | 9               | 13                 |  | piwo                             | 8               | 11                 |  |
| btbw                                    | 8               | 11                 |  |                                   |                 |                    |  | rbnu                             | 8               | 21                 |  |
| cach                                    | 8               | 11                 |  |                                   |                 |                    |  | wiwr                             | 8               | 11                 |  |
| cedw                                    | 8               | 11                 |  |                                   |                 |                    |  |                                  |                 |                    |  |
| ysfl                                    | 8               | 11                 |  |                                   |                 |                    |  |                                  |                 |                    |  |
| rthu                                    | 8               | 11                 |  |                                   |                 |                    |  |                                  |                 |                    |  |
| ybcn                                    | 8               | 21                 |  |                                   |                 |                    |  |                                  |                 |                    |  |



Table D.9. Avian species occurrence and density (pairs/100 ha) across three condition class categories in the oak/hickory forest type, 1992.

| Oak/Hickory - seedling/sapling |              |                 |  | Oak/Hickory - poletimber |              |                 |  | Oak/Hickory - sawtimber |              |                 |  |
|--------------------------------|--------------|-----------------|--|--------------------------|--------------|-----------------|--|-------------------------|--------------|-----------------|--|
| species code                   | % occurrence | density/ 100 ha |  | species code             | % occurrence | density/ 100 ha |  | species code            | % occurrence | density/ 100 ha |  |
| baww                           | 67           | 102             |  | oven                     | 71           | 145             |  | revi                    | 83           | 162             |  |
| howa                           | 67           | 127             |  | revi                     | 71           | 109             |  | scta                    | 75           | 127             |  |
| btbw                           | 50           | 102             |  | howa                     | 43           | 73              |  | btbw                    | 58           | 104             |  |
| revi                           | 50           | 76              |  | scta                     | 43           | 55              |  | baww                    | 50           | 81              |  |
| etti                           | 50           | 76              |  | btbw                     | 29           | 55              |  | howa                    | 42           | 92              |  |
| bggn                           | 33           | 102             |  | blnw                     | 29           | 55              |  | oven                    | 42           | 116             |  |
| cach                           | 33           | 127             |  | cach                     | 29           | 91              |  | btbw                    | 25           | 35              |  |
| rsto                           | 33           | 76              |  | rbgr                     | 29           | 36              |  | cach                    | 25           | 58              |  |
| scta                           | 33           | 51              |  | wewa                     | 29           | 36              |  | carw                    | 25           | 35              |  |
| wewa                           | 33           | 76              |  | acfl                     | 14           | 18              |  | inbu                    | 25           | 46              |  |
| bija                           | 17           | 25              |  | amcr                     | 14           | 36              |  | wewa                    | 25           | 35              |  |
| blnw                           | 17           | 25              |  | amre                     | 14           | 36              |  | etti                    | 17           | 23              |  |
| cawa                           | 17           | 51              |  | bggn                     | 14           | 18              |  | woth                    | 17           | 35              |  |
| cswa                           | 17           | 51              |  | baww                     | 14           | 18              |  | ybcu                    | 17           | 23              |  |
| gcfl                           | 17           | 25              |  | dowo                     | 14           | 18              |  | amre                    | 8            | 12              |  |
| grca                           | 17           | 25              |  | inbu                     | 14           | 18              |  | hawo                    | 8            | 12              |  |
| inbu                           | 17           | 76              |  | scju                     | 14           | 36              |  | noca                    | 8            | 23              |  |
| noca                           | 17           | 25              |  | piwo                     | 14           | 18              |  | ysfl                    | 8            | 23              |  |
| scju                           | 17           | 25              |  | rsto                     | 14           | 18              |  | nopa                    | 8            | 12              |  |
| nopa                           | 17           | 25              |  | sovi                     | 14           | 18              |  | piwo                    | 8            | 12              |  |
| piwa                           | 17           | 25              |  | etti                     | 14           | 18              |  | rbgr                    | 8            | 12              |  |
| sosp                           | 17           | 25              |  | wbnu                     | 14           | 18              |  | rsto                    | 8            | 12              |  |
| sovi                           | 17           | 25              |  | woth                     | 14           | 36              |  | sovi                    | 8            | 12              |  |
| veer                           | 17           | 25              |  |                          |              |                 |  | veer                    | 8            | 23              |  |
| ybeh                           | 17           | 25              |  |                          |              |                 |  | ytw                     | 8            | 12              |  |
| ybcu                           | 17           | 25              |  |                          |              |                 |  |                         |              |                 |  |

Table D.10. Avian species occurrence and density (pairs/100 ha) across three condition class categories in the oak/hickory forest type, 1993.

| Oak/Hickory - seedling/sapling |    |            |       |
|--------------------------------|----|------------|-------|
| species                        | %  | occurrence | code  |
| density/                       |    | 100 ha     |       |
| revis                          | 86 | 276        | blnw  |
| howa                           | 71 | 148        | oven  |
| baww                           | 57 | 85         | revis |
| inbu                           | 57 | 127        | baww  |
| rsio                           | 43 | 64         | howa  |
| scta                           | 43 | 64         | sovi  |
| amgo                           | 29 | 85         | wewa  |
| blbw                           | 29 | 42         | cach  |
| cswa                           | 29 | 127        | inbu  |
| gswa                           | 29 | 42         | scta  |
| oven                           | 29 | 64         | blbw  |
| rbgr                           | 29 | 64         | cawa  |
| etti                           | 29 | 85         | dowo  |
| veer                           | 29 | 42         | cape  |
| bhco                           | 14 | 21         | hawo  |
| blja                           | 14 | 21         | scju  |
| blnw                           | 14 | 42         | etti  |
| cach                           | 14 | 21         | veer  |
| cawa                           | 14 | 42         | ybcu  |
| cedw                           | 14 | 85         | amre  |
| cogr                           | 14 | 42         | bbcw  |
| nopa                           | 14 | 21         | cedw  |
| suta                           | 14 | 21         | cswa  |
| wewa                           | 14 | 21         | gcll  |
| ybcw                           | 14 | 64         | hawo  |
| ybcu                           | 14 | 21         | scju  |
| Oak/Hickory - poletimber       |    |            |       |
| species                        | %  | occurrence | code  |
| density/                       |    | 100 ha     |       |
| blnw                           | 67 | 127        | oven  |
| inbu                           | 50 | 116        | inbu  |
| revis                          | 50 | 116        | inbu  |
| baww                           | 42 | 58         | revis |
| howa                           | 42 | 58         | howa  |
| sovi                           | 42 | 116        | sovi  |
| wolh                           | 69 | 69         | wolh  |
| blnw                           | 69 | 69         | blnw  |
| baww                           | 46 | 46         | baww  |
| cach                           | 46 | 58         | wewa  |
| blbw                           | 12 | 12         | dowo  |
| etti                           | 8  | 8          | cape  |
| cawa                           | 8  | 8          | hawo  |
| scju                           | 8  | 8          | scju  |
| etti                           | 8  | 8          | etti  |
| veer                           | 8  | 23         | veer  |
| ybcu                           | 8  | 12         | ybcu  |
| Oak/Hickory - sawtimber        |    |            |       |
| species                        | %  | occurrence | code  |
| density/                       |    | 100 ha     |       |
| oven                           | 62 | 62         | oven  |
| scta                           | 62 | 62         | scta  |
| inbu                           | 46 | 46         | inbu  |
| revis                          | 46 | 46         | revis |
| howa                           | 38 | 38         | howa  |
| sovi                           | 38 | 38         | sovi  |
| wolh                           | 38 | 38         | wolh  |
| blnw                           | 31 | 31         | blnw  |
| baww                           | 31 | 31         | baww  |
| cach                           | 31 | 31         | cach  |
| wewa                           | 31 | 58         | wewa  |
| blbw                           | 23 | 12         | dowo  |
| etti                           | 23 | 12         | etti  |
| cape                           | 8  | 8          | cape  |
| hawo                           | 8  | 8          | hawo  |
| scju                           | 8  | 8          | scju  |
| etti                           | 8  | 8          | etti  |
| ybcu                           | 8  | 8          | ybcu  |
| amre                           | 8  | 8          | amre  |
| bbcw                           | 8  | 8          | bbcw  |
| cedw                           | 8  | 8          | cedw  |
| cswa                           | 8  | 8          | cswa  |
| gcll                           | 8  | 8          | gcll  |
| hawo                           | 8  | 8          | hawo  |
| scju                           | 8  | 8          | scju  |
| piwo                           | 8  | 8          | piwo  |
| rbgr                           | 8  | 8          | rbgr  |
| suta                           | 8  | 8          | suta  |
| etti                           | 8  | 8          | etti  |
| veer                           | 8  | 8          | veer  |
| wbnu                           | 8  | 8          | wbnu  |
| ytwi                           | 8  | 8          | ytwi  |

Table D.11. Avian species occurrence and density (pairs/100 ha) across three condition class categories in the yellow pine forest type, 1992.

| Yellow Pine - seedling/sapling |    |                    |      | Yellow Pine - poletimber |     |                    |      | Yellow Pine - sawtimber |    |                    |      |
|--------------------------------|----|--------------------|------|--------------------------|-----|--------------------|------|-------------------------|----|--------------------|------|
| species                        | %  | density/<br>100 ha | code | species                  | %   | density/<br>100 ha | code | species                 | %  | density/<br>100 ha | code |
| revi                           | 58 | 191                | revi | 82                       | 197 | revi               | 75   | 68                      | 75 | 68                 | revi |
| inbu                           | 50 | 143                | btnw | 73                       | 127 | wewa               | 50   | 39                      | 50 | 20                 | btnw |
| baww                           | 33 | 64                 | oven | 55                       | 92  | cach               | 25   | 20                      | 25 | 29                 | cach |
| howa                           | 33 | 95                 | baww | 36                       | 46  | dowo               | 25   | 20                      | 25 | 29                 | howa |
| oven                           | 33 | 79                 | inbu | 36                       | 58  | howa               | 25   | 29                      | 25 | 20                 | inbu |
| amgo                           | 25 | 79                 | etti | 36                       | 46  | howa               | 25   | 29                      | 25 | 20                 | howa |
| btnw                           | 25 | 48                 | cach | 27                       | 46  | inbu               | 25   | 20                      | 25 | 29                 | inbu |
| cach                           | 25 | 48                 | howa | 27                       | 46  | oven               | 25   | 39                      | 25 | 29                 | oven |
| piwa                           | 25 | 48                 | piwa | 27                       | 35  | piwa               | 25   | 29                      | 25 | 29                 | piwa |
| rsto                           | 25 | 79                 | ytwa | 27                       | 46  | etti               | 25   | 29                      | 25 | 29                 | etti |
| blja                           | 17 | 64                 | amcr | 18                       | 23  | acfl               | 13   | 10                      | 13 | 20                 | amcr |
| etti                           | 17 | 32                 | blja | 18                       | 23  | amcr               | 13   | 20                      | 13 | 20                 | amcr |
| wewa                           | 17 | 32                 | scta | 18                       | 35  | blja               | 13   | 10                      | 13 | 10                 | blja |
| acfl                           | 8  | 16                 | wewa | 18                       | 23  | carw               | 13   | 10                      | 13 | 10                 | carw |
| btbw                           | 8  | 64                 | ybcu | 18                       | 23  | gcfl               | 13   | 10                      | 13 | 10                 | gcfl |
| carw                           | 8  | 16                 | acfl | 9                        | 12  | nopa               | 13   | 10                      | 13 | 10                 | nopa |
| cswa                           | 8  | 16                 | amgo | 9                        | 12  | piwo               | 13   | 10                      | 13 | 10                 | piwo |
| dowo                           | 8  | 16                 | carw | 9                        | 12  | rsto               | 13   | 10                      | 13 | 10                 | rsto |
| noca                           | 8  | 16                 | hawa | 9                        | 12  | sovi               | 13   | 10                      | 13 | 10                 | sovi |
| ysfl                           | 8  | 16                 | ysfl | 9                        | 12  | wolh               | 13   | 10                      | 13 | 10                 | wolh |
| praw                           | 8  | 16                 | rsto | 9                        | 12  |                    |      |                         |    |                    |      |
| rbgr                           | 8  | 16                 |      |                          |     |                    |      |                         |    |                    |      |
| rbwo                           | 8  | 16                 |      |                          |     |                    |      |                         |    |                    |      |
| scta                           | 8  | 32                 |      |                          |     |                    |      |                         |    |                    |      |
| wpwi                           | 8  | 16                 |      |                          |     |                    |      |                         |    |                    |      |
| ybcu                           | 8  | 32                 |      |                          |     |                    |      |                         |    |                    |      |

Table D.12. Avian species occurrence and density (pairs/100 ha) across three condition class categories in the yellow pine forest type, 1993.

| Yellow Pine - seedling/sapling |      |            |                    | Yellow Pine - poletimber |      |            |                    | Yellow Pine - sawtimber |      |            |                    |
|--------------------------------|------|------------|--------------------|--------------------------|------|------------|--------------------|-------------------------|------|------------|--------------------|
| species                        | code | occurrence | density/<br>100 ha | species                  | code | occurrence | density/<br>100 ha | species                 | code | occurrence | density/<br>100 ha |
|                                |      |            |                    |                          |      |            |                    |                         |      |            |                    |
| revi                           |      | 79         | 153                | revi                     |      | 100        | 215                | revi                    |      | 67         | 127                |
| inbu                           |      | 71         | 136                | btmw                     |      | 69         | 127                | inbu                    |      | 44         | 57                 |
| cach                           |      | 43         | 59                 | oven                     |      | 54         | 108                | oven                    |      | 44         | 99                 |
| oven                           |      | 43         | 59                 | cach                     |      | 38         | 59                 | scta                    |      | 44         | 57                 |
| baww                           |      | 29         | 42                 | baww                     |      | 31         | 39                 | acfl                    |      | 33         | 42                 |
| scta                           |      | 29         | 42                 | howa                     |      | 23         | 49                 | btmw                    |      | 33         | 42                 |
| ybcn                           |      | 29         | 42                 | blja                     |      | 15         | 20                 | baww                    |      | 33         | 42                 |
| blja                           |      | 21         | 34                 | inbu                     |      | 15         | 20                 | cach                    |      | 33         | 57                 |
| etti                           |      | 21         | 25                 | wewa                     |      | 15         | 20                 | amcr                    |      | 22         | 28                 |
| wewa                           |      | 21         | 25                 | ytwa                     |      | 15         | 20                 | howa                    |      | 22         | 28                 |
| btmw                           |      | 14         | 17                 | bgen                     |      | 8          | 10                 | etti                    |      | 22         | 28                 |
| howa                           |      | 14         | 17                 | piwa                     |      | 8          | 10                 | bgen                    |      | 11         | 14                 |
| piwo                           |      | 14         | 17                 | rsto                     |      | 8          | 10                 | blja                    |      | 11         | 14                 |
| rsto                           |      | 14         | 25                 | rtlu                     |      | 8          | 10                 | gcfl                    |      | 11         | 14                 |
| ybcu                           |      | 14         | 17                 | scta                     |      | 8          | 10                 | hawo                    |      | 11         | 14                 |
| amgo                           |      | 7          | 8                  | etti                     |      | 8          | 10                 | noca                    |      | 11         | 14                 |
| cedw                           |      | 7          | 17                 | wbnu                     |      | 8          | 10                 | ysfl                    |      | 11         | 14                 |
| cswa                           |      | 7          | 8                  | wolh                     |      | 8          | 10                 | piwa                    |      | 11         | 14                 |
| noca                           |      | 7          | 8                  | ybcu                     |      | 8          | 10                 | piwo                    |      | 11         | 14                 |
| ysfl                           |      | 7          | 8                  |                          |      |            |                    | ytwa                    |      | 11         | 14                 |
| wbnu                           |      | 7          | 8                  |                          |      |            |                    | wewa                    |      | 11         | 14                 |

## **VITA**

John Gary Bartlett was born in Richmond, Virginia on March 14, 1968. He attended grade school in the Prince George County, Virginia School District and graduated from Prince George High School in June, 1986. The following September he entered Virginia Commonwealth University. He transferred to Virginia Polytechnic Institute and State University in 1989 and in May, 1992 received a Bachelor of Science degree in Wildlife Science. He entered the University of Tennessee in May, 1992 and in August, 1995 received a Master of Science degree in Wildlife and Fisheries Science.

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