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Relative abundance of breeding birds and habitat associations of select neotropical migrant songbirds on the Cherokee National Forest, Tennessee

John Gary Bartlett

To the Graduate Council:

I am submitting herewith a thesis written by John Gary Bartlett entitled "Relative abundance of breeding birds and habitat associations of select neotropical migrant songbirds on the Cherokee National Forest, Tennessee." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

David A. Buehler, Major Professor

We have read this thesis and recommend its acceptance:

Ralph Dimmick, Stuart Pimm

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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

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and Dean of the Graduate School

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Date May 23, 1995

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

A Thesis

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Degree

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John G. Bartlett

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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.

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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[1] in the Southern Appalachian portion of their range.

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[1] 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 at 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

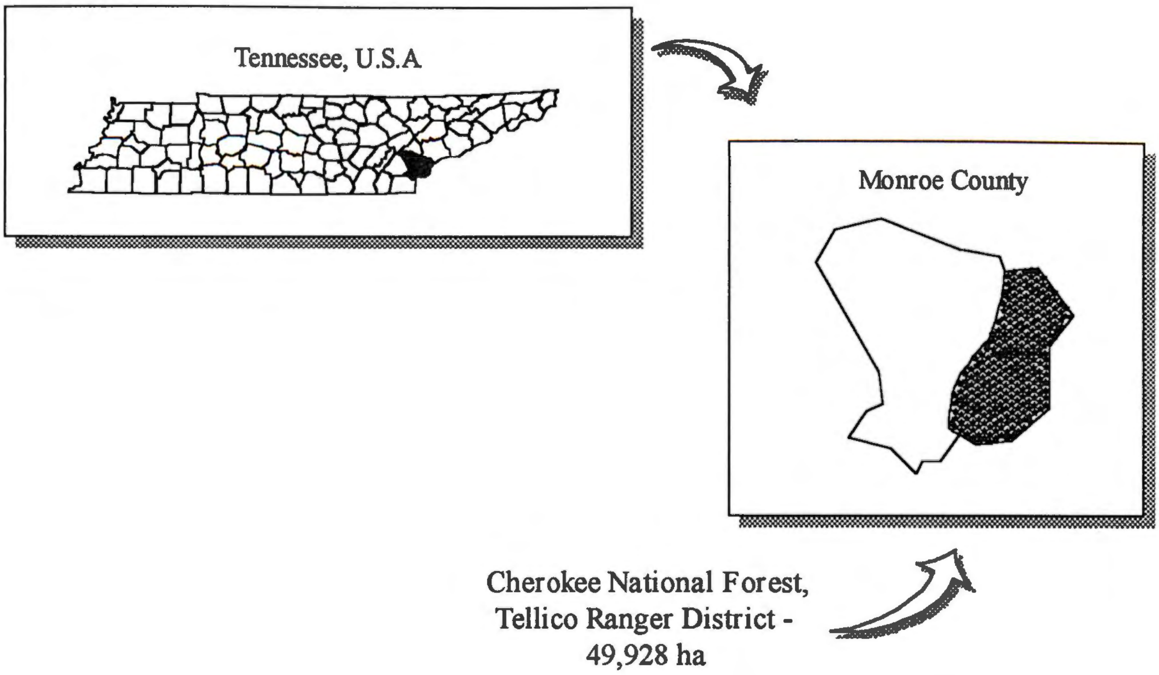

Figure 1. Study area location in the southern portion of the Cherokee National Forest, Tennessee.

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 ≥50% dominance of a single tree species or ≥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*[1])/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

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[1] 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	
White Pine	Eastern Hemlock / White Pine	HEMLCK
White Pine - Hemlock	Eastern Hemlock / White Pine	
Chestnut Oak - Scarlet Oak - Yellow Pine	Mixed Hardwood / Yellow Pine	
N. Red Oak - Hickory - Yellow Pine	Mixed Hardwood / Yellow Pine	
Pitch Pine - Oak	Mixed Hardwood / Yellow Pine	
Shortleaf Pine - Oak	Mixed Hardwood / Yellow Pine	MXEDHP
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	
Chestnut Oak - Scarlet Oak	Oak / Hickory	
N. Red Oak	Oak / Hickory	
Scarlet Oak	Oak / Hickory	OAKHIC
Scrub Oak	Oak / Hickory	
White Oak	Oak / Hickory	
White Oak - N. Red Oak - Hickory	Oak / Hickory	
Pitch Pine	Yellow Pine	
Shortleaf Pine	Yellow Pine	YEPINE
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 years	21 - 60 years	> 60 years	0 - 20 years	21 - 60 years	> 60 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
TOTALS	**4,215**	**3,763**	**17,310**	**743**	**2,706**	**19,566**

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) 13 (adequately stocked) 14 (inadequately stocked)	SEEDLG
poletimber	10-30 cm dbh	10-25 cm dbh	2 (damaged) 5 (sparse) 7 (low quality) 9 (mature) 11 (immature)	POLTMB
sawtimber	>30 cm dbh	>25 cm dbh	3 (damaged) 6 (sparse) 8 (low quality) 10 (mature) 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/ 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^2/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^2/ha)	(total basal area of standing snags) / (total basal area on plot) x 100% (ha)
SNGBSM	*	basal sum of snags (m^2/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) (m2/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 rees 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 (m^2/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
TOTALS =	*183*	*213*

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

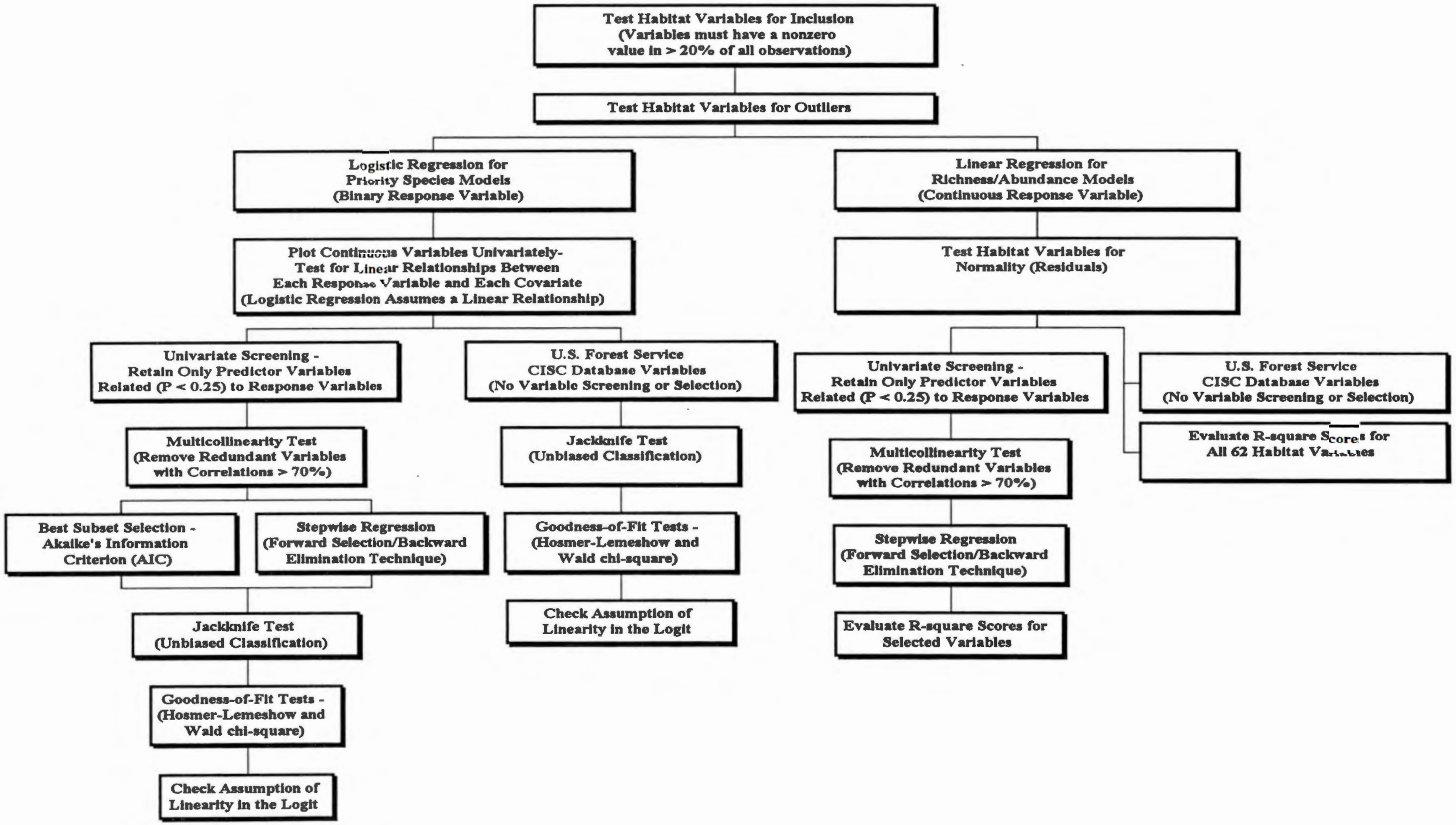

Figure 2. Procedures for developing predictive models of avian habitat relationships for high priority neotropical migrants and richness/abundance indices, Cherokee National Forest, Tennessee.

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 ≥ 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 ≥ 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 ≤ 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.

Redundant Variables	Eliminated Variable	Remaining Variable
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 ≤ 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
Correct classification rate = 2/4 = 50%			

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 ≥ 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 χ^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[1], 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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[1] 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

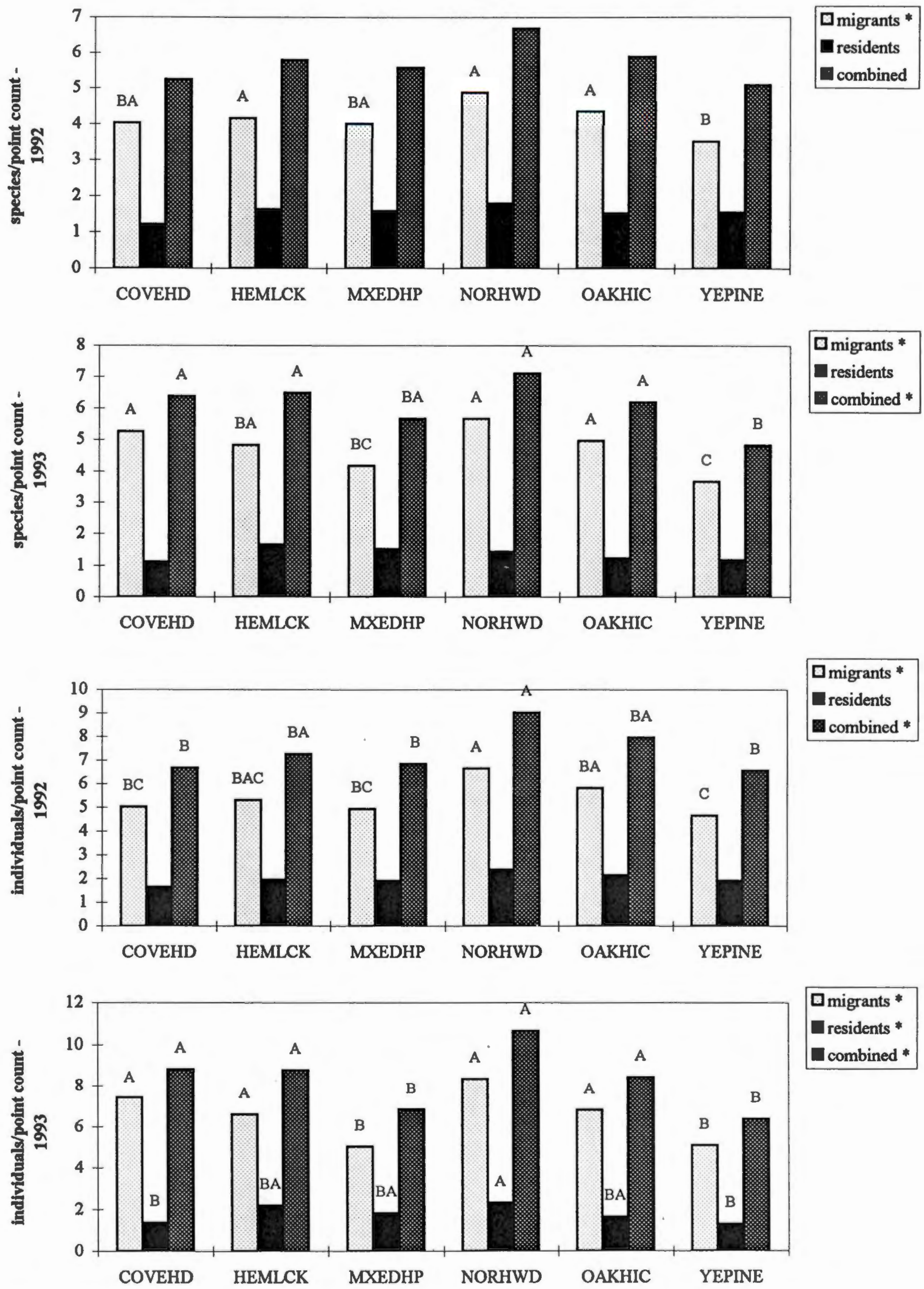

Figure 3. Mean species richness and abundance per point for neotropical migrants, residents, and combined across six forest types, Cherokee National Forest, Tennessee.* Indicates a difference across the forest types ($P \leq 0.05$), based on analysis of variance tests. Forest types within years and within 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.

Table 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.

		Species Grouping																	
Year	Comparison Across	Migrants						Residents						Combined					
		Richness			Abundance			Richness			Abundance			Richness			Abundance		
		df	F	P	df	F	P	df	F	P	df	F	P	df	F	P	df	F	P
1992	Forest type	5	3.12	0.010	5	3.07	0.011	5	1.27	0.278	5	1.07	0.378	5	1.90	0.097	5	2.40	0.039
1993		5	6.11	<0.001	5	8.25	<0.001	5	1.57	0.169	5	2.21	0.054	5	3.66	0.003	5	6.72	<0.001
1992	Cond. Class	2	1.16	0.317	2	1.65	0.195	2	1.28	0.281	2	1.12	0.329	2	0.84	0.432	2	1.36	0.259
1993		2	4.92	0.008	2	3.78	0.024	2	4.35	0.014	2	5.02	0.008	2	7.13	0.001	2	6.65	0.002
1992	Age Class	9	1.57	0.126	9	1.32	0.227	9	2.58	0.008	9	1.98	0.045	9	2.25	0.021	9	1.62	0.113
1993		9	3.18	0.001	9	2.89	0.003	9	3.07	0.002	9	3.80	<0.001	9	3.59	<0.001	9	4.37	<0.001

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 ($P \leq 0.05$).

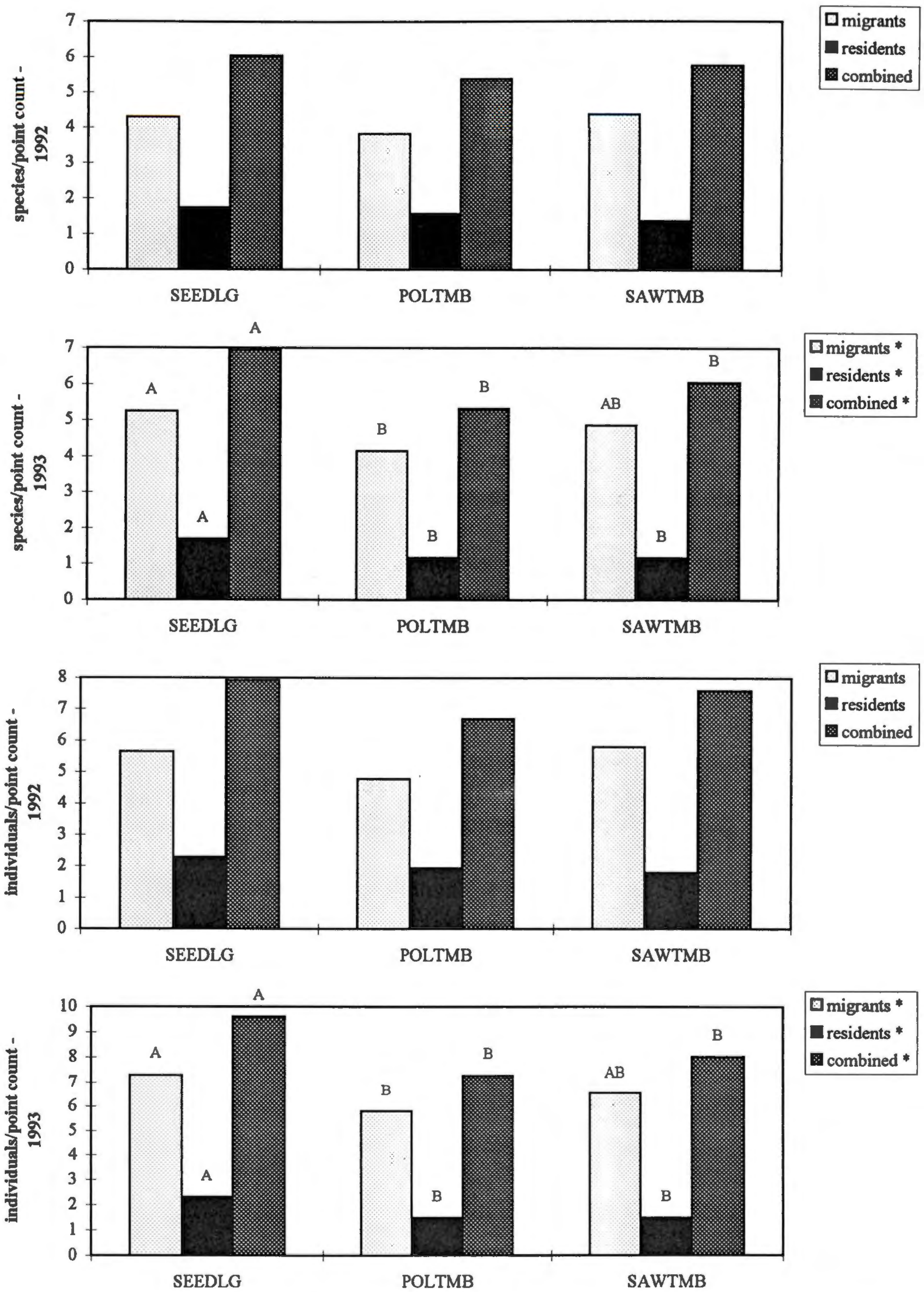

Figure 4. Mean species richness and abundance per point for neotropical migrants, residents, and combined across three condition classes, Cherokee National Forest, Tennessee. * Indicates a difference across the condition classes ($P \leq 0.05$), based on analysis of variance tests. Condition classes 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

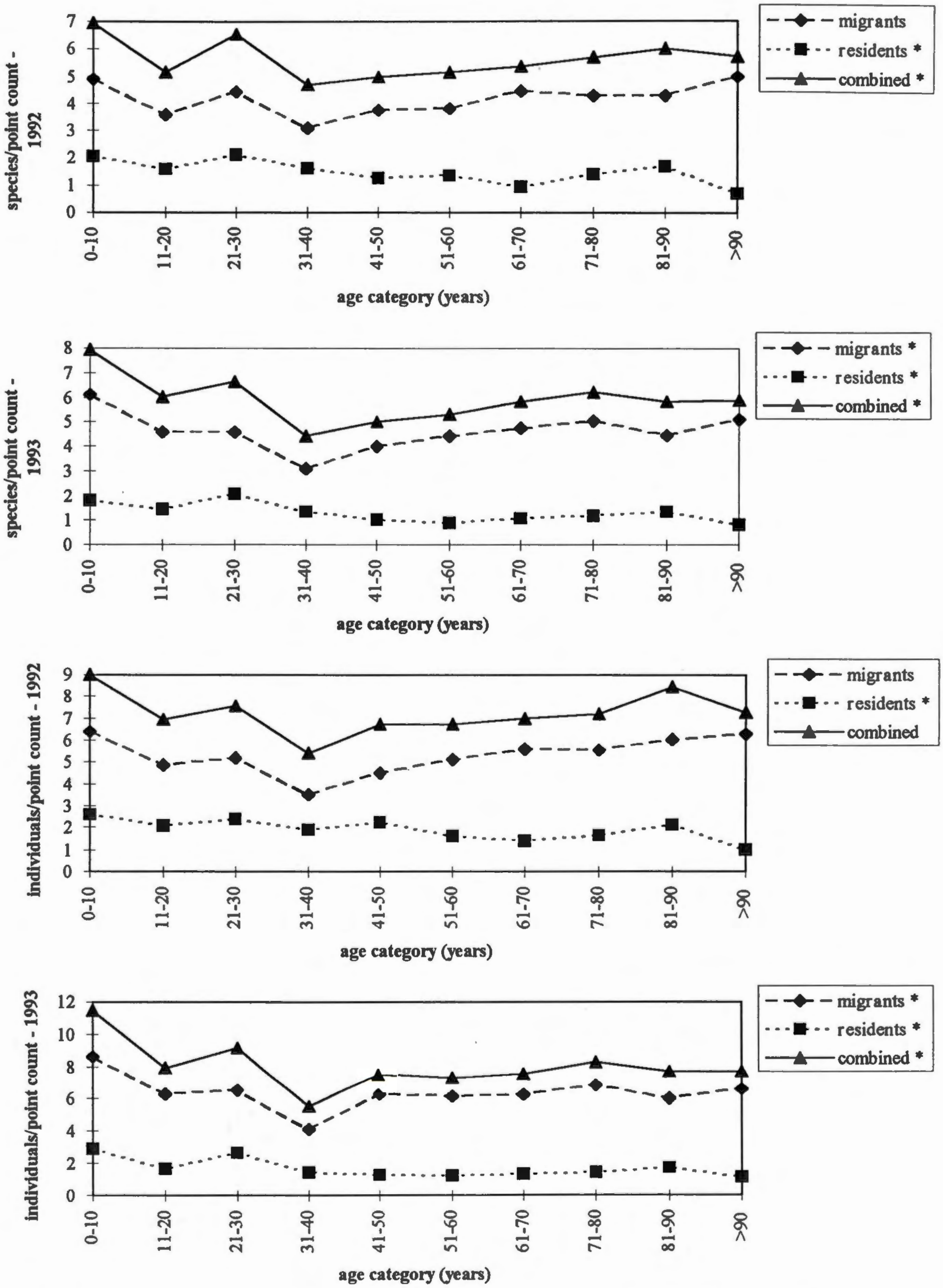

Figure 5. Mean species richness and abundance per point for neotropical migrants, residents, and combined across nine stand age categories, Cherokee National Forest, Tennessee.* Indicates a difference across the age categories ($P \leq 0.05$), based on analysis of variance tests. Sample sizes for each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

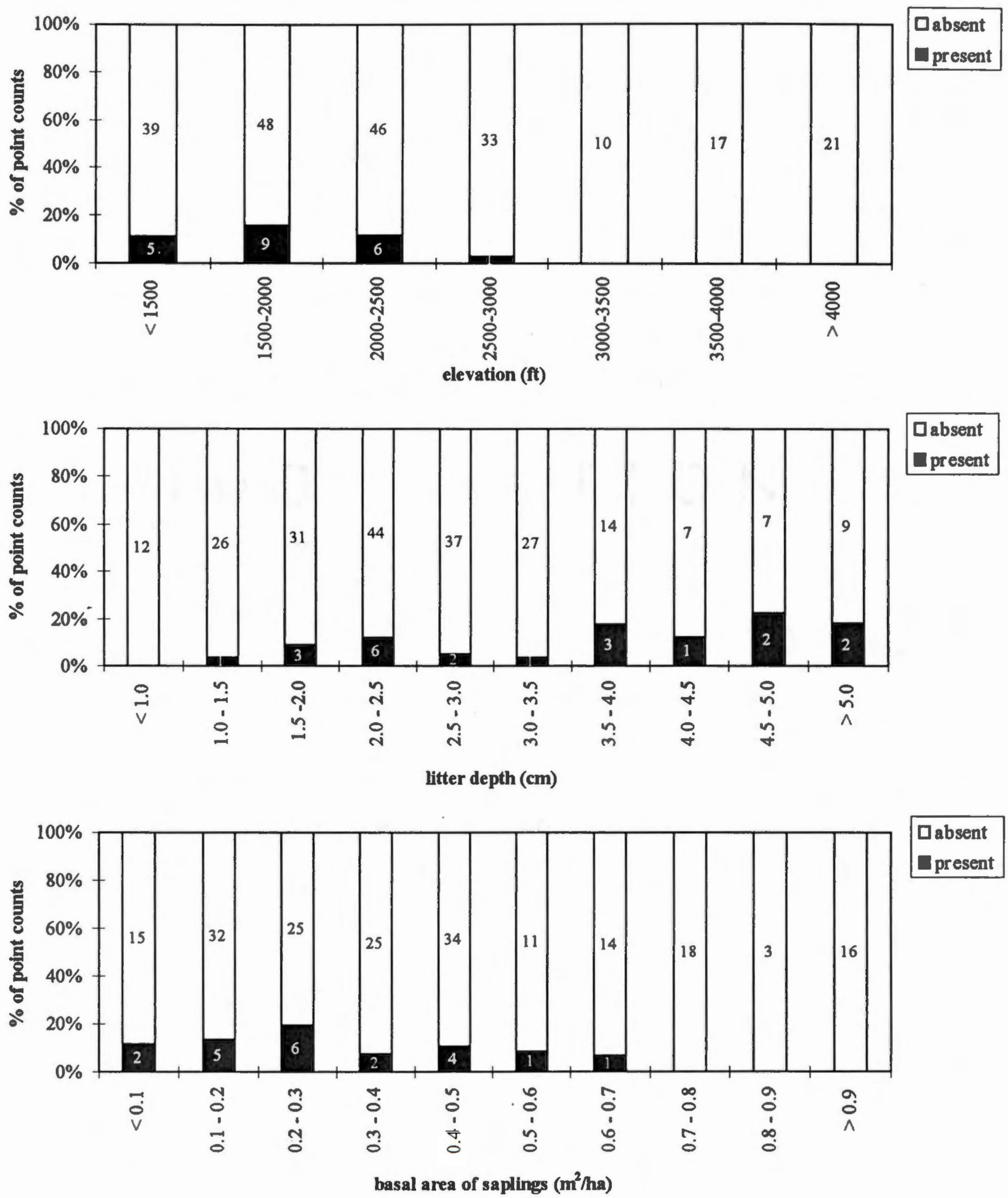

Figure 6. Percentage of points where acadian flycatcher was present and absent in 1992, 1993 or in both years, across five continuous habitat variables deemed best predictors of acadian flycatcher distribution, Cherokee National Forest, Tennessee.

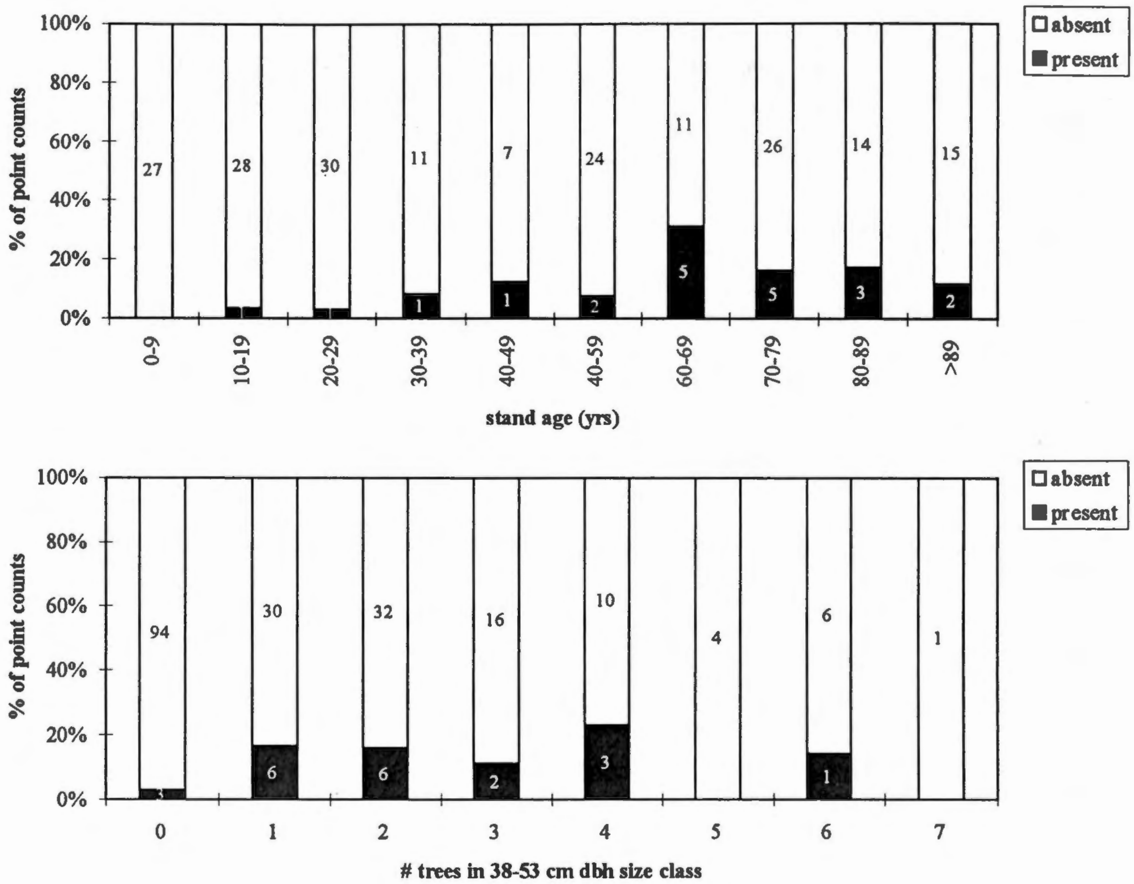

Figure 6. (continued)

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).

				Probability Tests of Correct Classification		Goodness-of-Fit Indicator
Model Type	Variables Selected	Parameter Estimate[1]	Pr. > χ^2	Concordance	Jack-knife	Hosmer / Lemeshow
	CONSTANT	-3.829	0.174			
	ELEVTN	-0.002	0.000*			
	LITDPH	0.387	0.057*			
	SLOPE%	0.007	0.796			
	NOSAPS	3.591	0.729			
FULL[2]	BSLSAP	-1831.5	0.728	87.3 %	86.9 %	C = 7.16
	CNDCLS[3]					P = 0.31
	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			
	CONSTANT	-0.341	0.890			
	COVEHD	0.752	0.526			
	HEMLCK	1.225	0.215			
	MXEDHP	0.175	0.807			
	NORHWD	-1.435	0.241			
	OAKHIC	-0.841	0.384			
CISC	YEPINE[4]	0.124	0.807	79.3 %	88.8 %	C = 11.71
	SEEDLG	0.631	0.713			P = 0.17
	POLTMB	0.641	0.506			
	SAWTMB[5]	-1.272	0.713			
	STNDAG	0.046	0.058*			
	STENDX	0.072	0.042*			
	STNDSZ	0.002	0.502			
	ELEVTN[6]	-0.002	0.001*	85.1 %	88.3 %	
	CONSTANT	-0.268	0.845			
AIC	ELEVTN	-0.001	0.000*			
&	LITDPH	0.292	0.132*	85.4 %	89.7 %	C = 4.78
STEP-	BSLSAP	-2.431	0.096*			P = 0.57
WISE	STNDAG	0.026	0.030*			
	38-53DBH	0.268	0.104*	0,104 > 0,05 not < 0,05		

[1] Unstandardized coefficients - these estimates do not indicate the relative weight of each variable.
[2] Variables are listed in decreasing order of the significance of their F-statistic.
[3] 'SEEDLG' subgroup (parameter est.= 3.206, P = 0.123) recorded a significant ($P \leq 0.05$) Wald score.
[4] Reference group for the forest type design (dummy) variable group.
[5] Reference group for the condition class design (dummy) variable group.
[6] Correct classification rate for the CISC variables with the ELEVTN 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

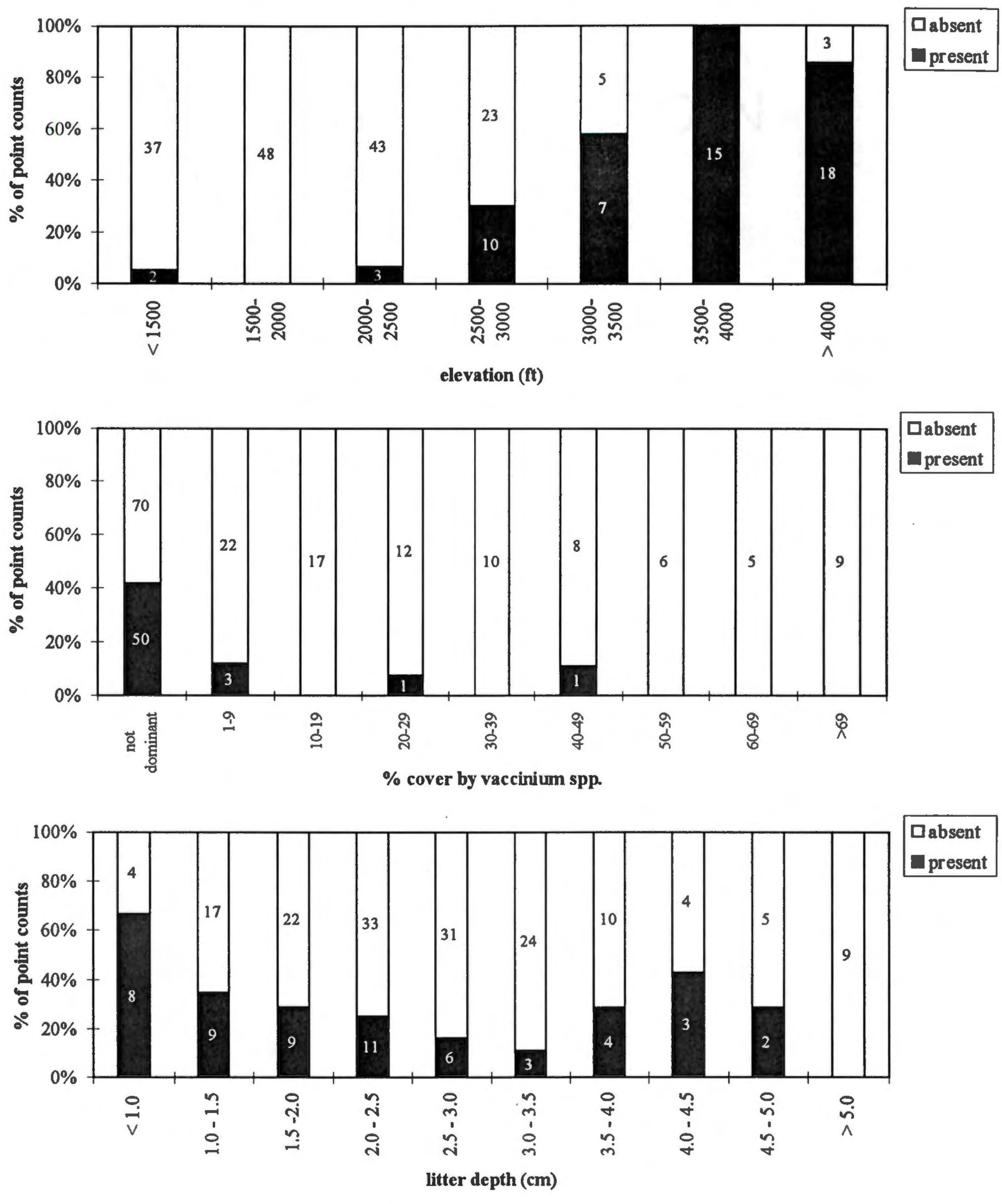

Figure 7. Percentage of points where black-throated blue warbler was present and absent in 1992, 1993 or in both years, across six continuous habitat variables deemed best predictors of black-throated blue warbler distribution, Cherokee National Forest, Tennessee.

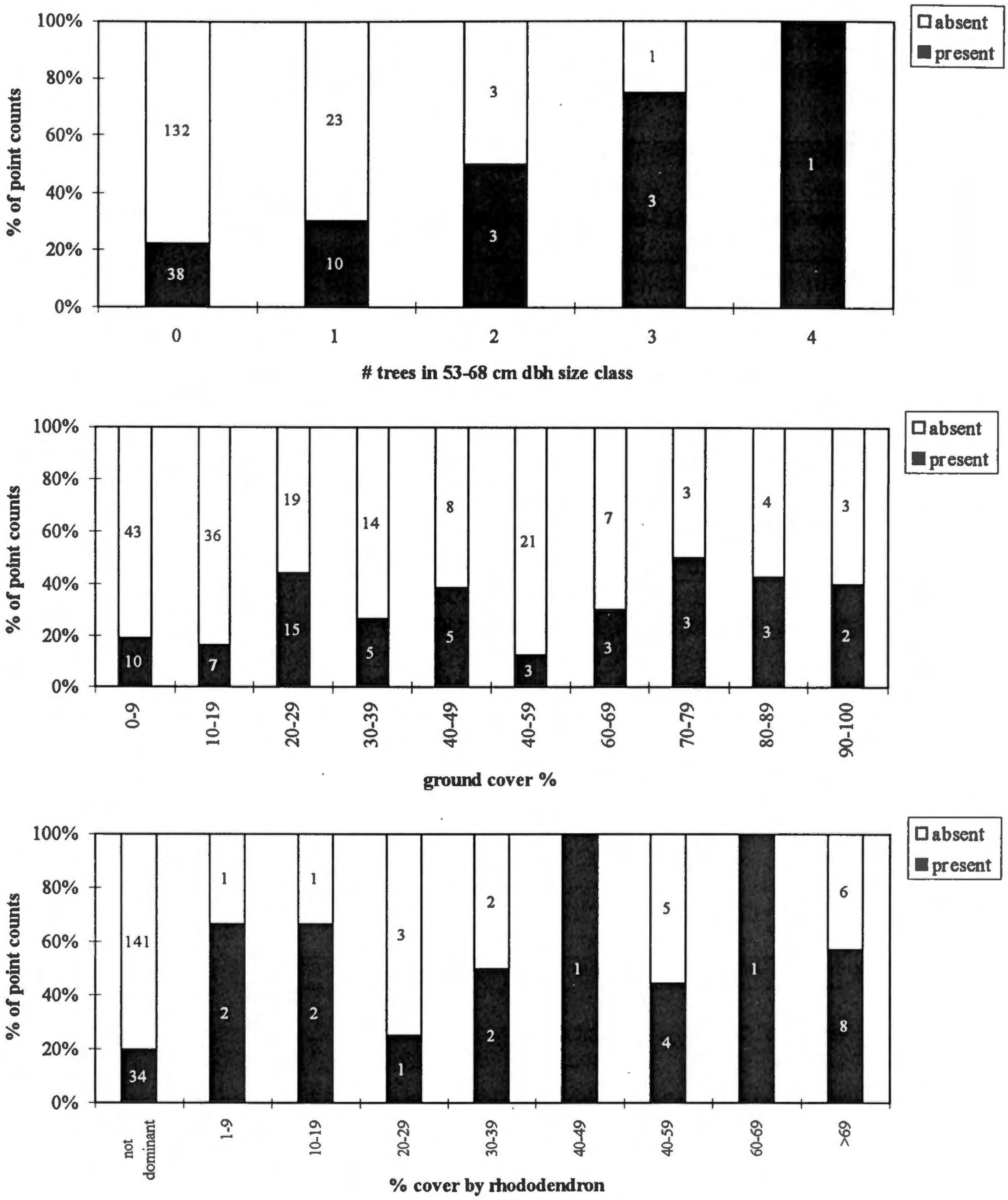

Figure 7. (continued)

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).

				Probability Tests of Correct Classification		Goodness-of-Fit Indicator
Model Type	Variables Selected	Parameter Estimate[1]	Pr. > χ^2	Concordance	Jack-knife	Hosmer / Lemeshow
	CONSTANT	-5.620	0.001			
	ELEVTN	0.002	0.000*			
	FORTYP[2]					
	CONFRQ	-0.037	0.607			
	RHODCR	0.021	0.058*			
FULL[3]	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			
	CONSTANT	-4.718	0.058			
	COVEHD	1.928	0.159*			
	HEMLCK	0.522	0.697			
	MXEDHP	0.568	0.651			
	NORHWD	5.841	0.000*			
	OAKHIC	2.731	0.015*	89.0 %	84.6 %	C = 8.16
CISC	YEPINE[4]	-11.590	0.652			P = 0.42
	SEEDLG	0.160	0.916			
	POLTMB	-0.134	0.873			
	SAWTMB[5]	-0.026	0.916			
	STNDAG	0.009	0.667			
	STENDX	0.017	0.521			
	STNDSZ	-0.006	0.072*			
	ELEVTN[6]	0.002	0.000*	93.9 %	88.8 %	
	CONSTANT	-5.864	0.000			
AIC	ELEVTN	0.008	0.000*			
&	VACCVR	-0.046	0.081*	95.0 %	92.1 %	C = 14.01
STEP-	LITDPH	-0.559	0.040*			P = 0.05
WISE	53-68DBH	0.572	0.103*			
	GRNDCV	-0.021	0.080*			
	RHODCR	0.015	0.130*			

[1] Unstandardized coefficients - these estimates do not indicate the relative weight of each variable.
[2] 'OAKHIC' subgroup (parameter est.= 1.869, P = 0.151) recorded a significant ($P \leq 0.05$) Wald score.
[3] Variables are listed in decreasing order of the significance of their F-statistic.
[4] Reference group for the forest type design (dummy) variable group.
[5] Reference group for the condition class design (dummy) variable group.
[6] Correct classification rate for the CISC variables with the ELEVTN component included.

%[1], 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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[1] Ground cover % was not a top ten predictor variable but passed the univariate test ($P \leq 0.25$).

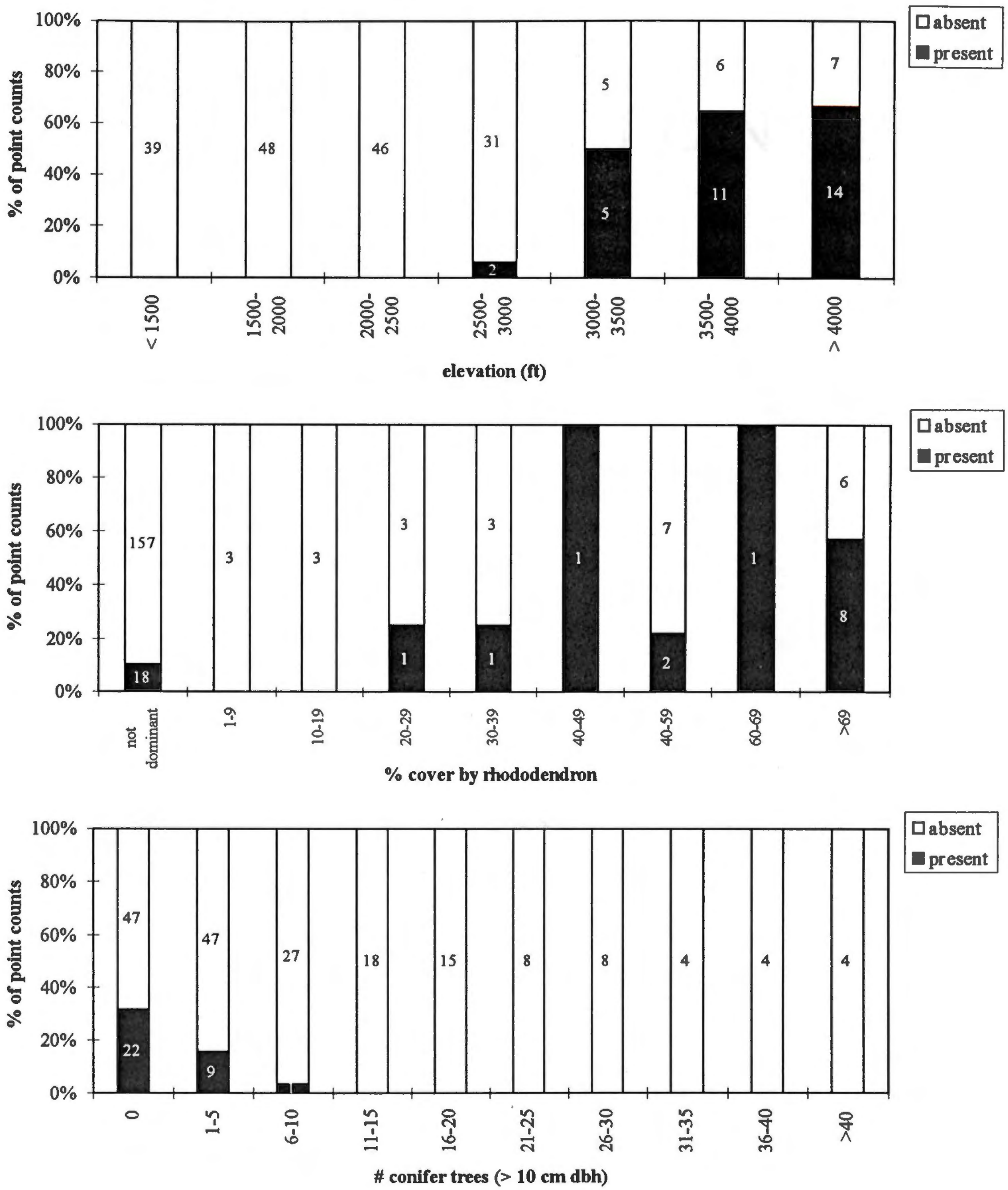

Figure 8. Percentage of points where Canada warbler was present and absent in 1992, 1993 or in both years, across six continuous habitat variables deemed best predictors of Canada warbler distribution, Cherokee National Forest, Tennessee.

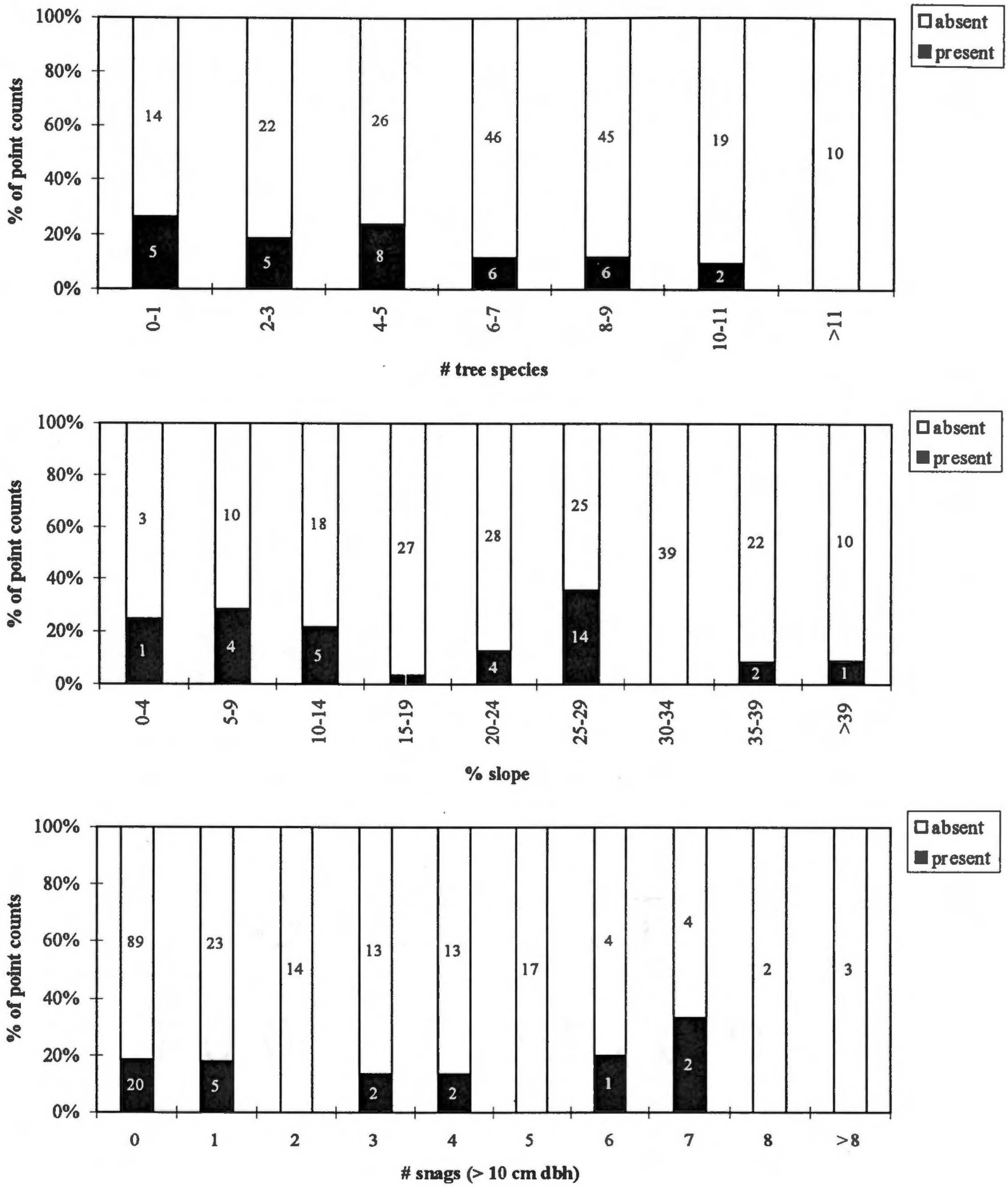

Figure 8. (continued)

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).

				Probability Tests for Correct Classification		Goodness-of-Fit Indicator
Model Type	Variables Selected	Parameter Estimate[1]	Pr. > χ^2	Concordance	Jack-knife	Hosmer / Lemeshow
	CONSTANT	-8.220	0.001			
	ELEVTN	0.003	0.000*			
	RHODCR	0.091	0.001*			
	CONFRQ	-0.504	0.072*			
	NOTRSP	-0.442	0.073*			
FULL[2]	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			
	CONSTANT	-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*			
CISC	<u>YEPINE</u>[3]	-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>[4]	-1.180	0.511			
	STNDAG	0.014	0.538			
	STENDX	0.001	0.984			
	STNDSZ	-0.004	0.207			
	ELEVTN[5]	0.000	0.001*	95.8 %	90.2 %	
	CONSTANT	-7.560	0.000			
AIC	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			
	CONSTANT	-9.529	0.000			
	ELEVTN	0.003	0.000*			
STEP-WISE	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*			

[1] Unstandardized coefficients - these estimates do not indicate the relative weight of each variable.
[2] Variables are listed in decreasing order of the significance of their F-statistic.
[3] Reference group for the forest type design (dummy) variable group.
[4] Reference group for the condition class design (dummy) variable group.
[5] 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

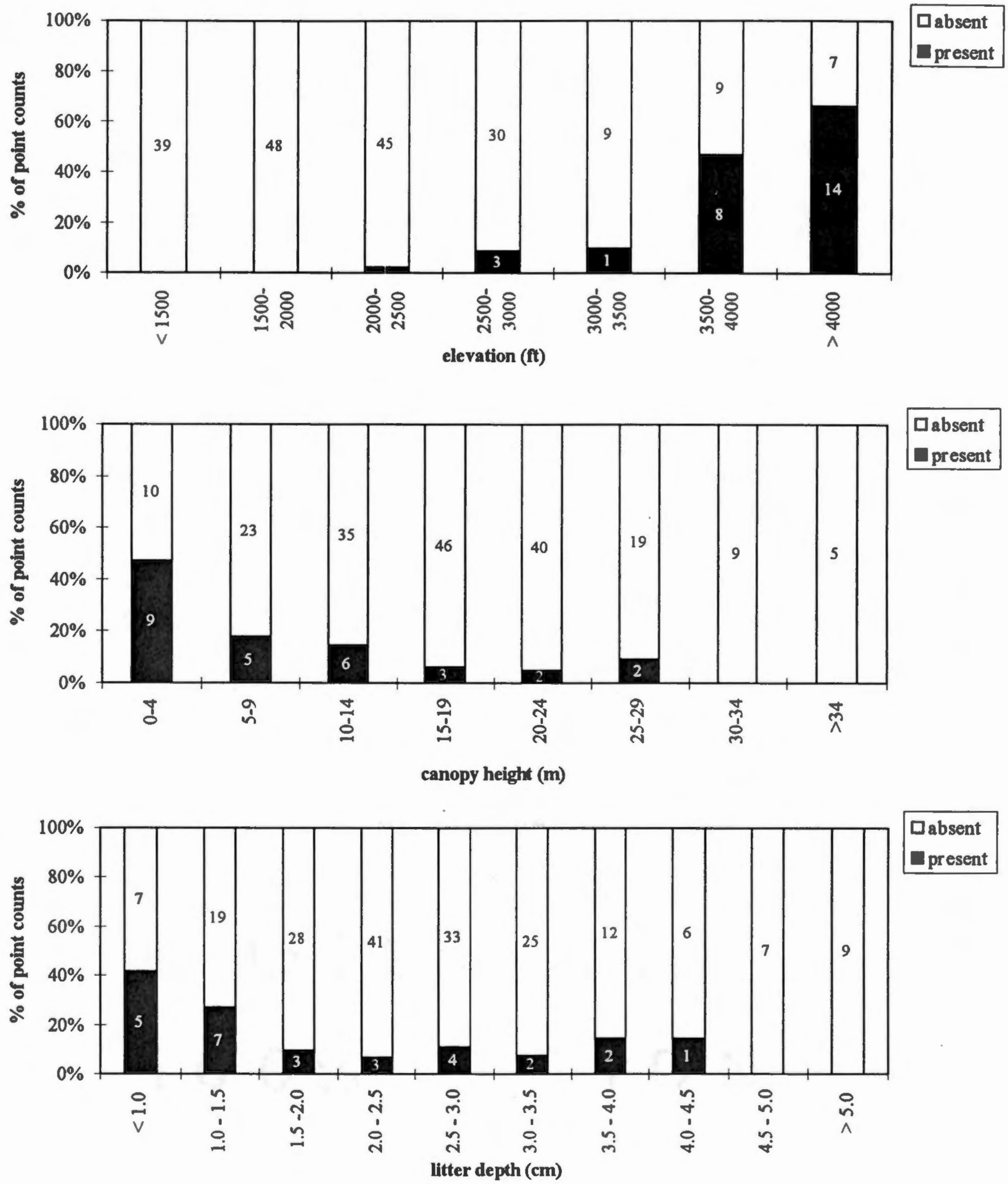

Figure 9. Percentage of points where chestnut-sided warbler was present and absent in 1992, 1993 or in both years, across three continuous habitat variables deemed best predictors of chestnut-sided warbler distribution, Cherokee National Forest, Tennessee.

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[1]	Pr. > χ^2	Probability Tests of Correct Classification: Concordance	Probability Tests of Correct Classification: Jack-knife	Goodness-of-Fit Indicator: Hosmer / Lemeshow
	CONSTANT	-6.048	0.198			
	ELEVTN	0.003	0.000*			
	NOTRSP	0.059	0.825			
	CNPYHT	-0.221	0.034*			
	TOTNTR	0.155	0.158*			
FULL[2]	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*			
	CONSTANT	-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*			
CISC	<u>YEPINE</u>[3]	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>[4]	-0.008	0.537			
	STNDAG	-0.024	0.448			
	STENDX	0.007	0.870			
	STNDSZ	-0.012	0.008*			
	ELEVTN[5]	0.000	0.001*	98.2 %	91.6 %	
AIC	*CONSTANT*	-5.731	0.000			
&	ELEVTN	0.003	0.000*	97.5 %	93.5 %	C = 1.20
STEP-	CNPYHT	-0.187	0.000*			P = 0.52
WISE	LITDPH	-0.629	0.063*			

[1] Unstandardized coefficients - these estimates do not indicate the relative weight of each variable.
[2] Variables are listed in decreasing order of the significance of their F-statistic.
[3] Reference group for the forest type design (dummy) variable group.
[4] Reference group for the condition class design (dummy) variable group.
[5] Correct classification rate for the CISC variables with the ELEVTN 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 ($P = 0.19$).

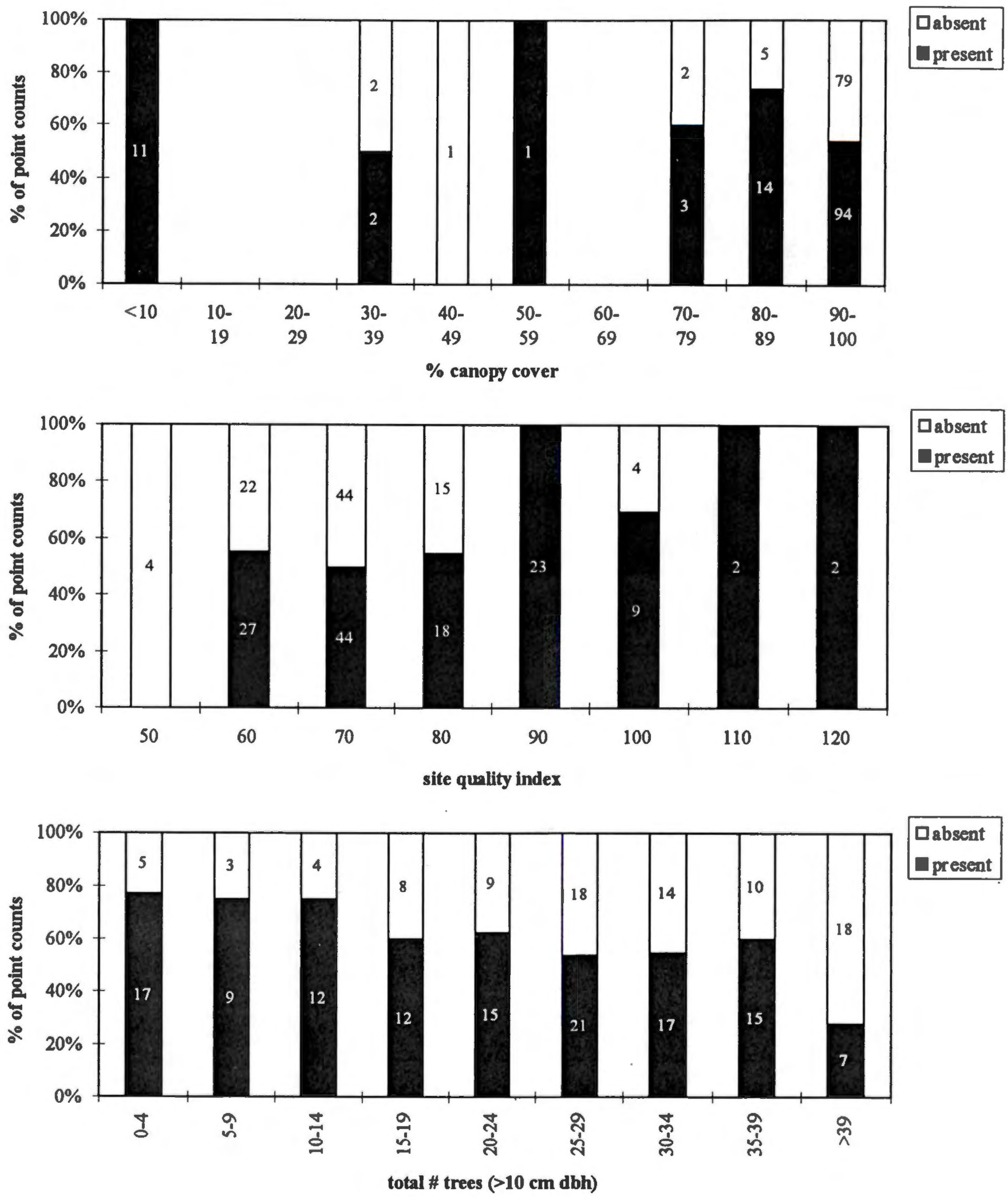

Figure 10. Percentage of points where hooded warbler was present and absent in 1992, 1993 or in both years, across seven continuous habitat variables deemed best predictors of hooded warbler distribution, Cherokee National Forest, Tennessee.

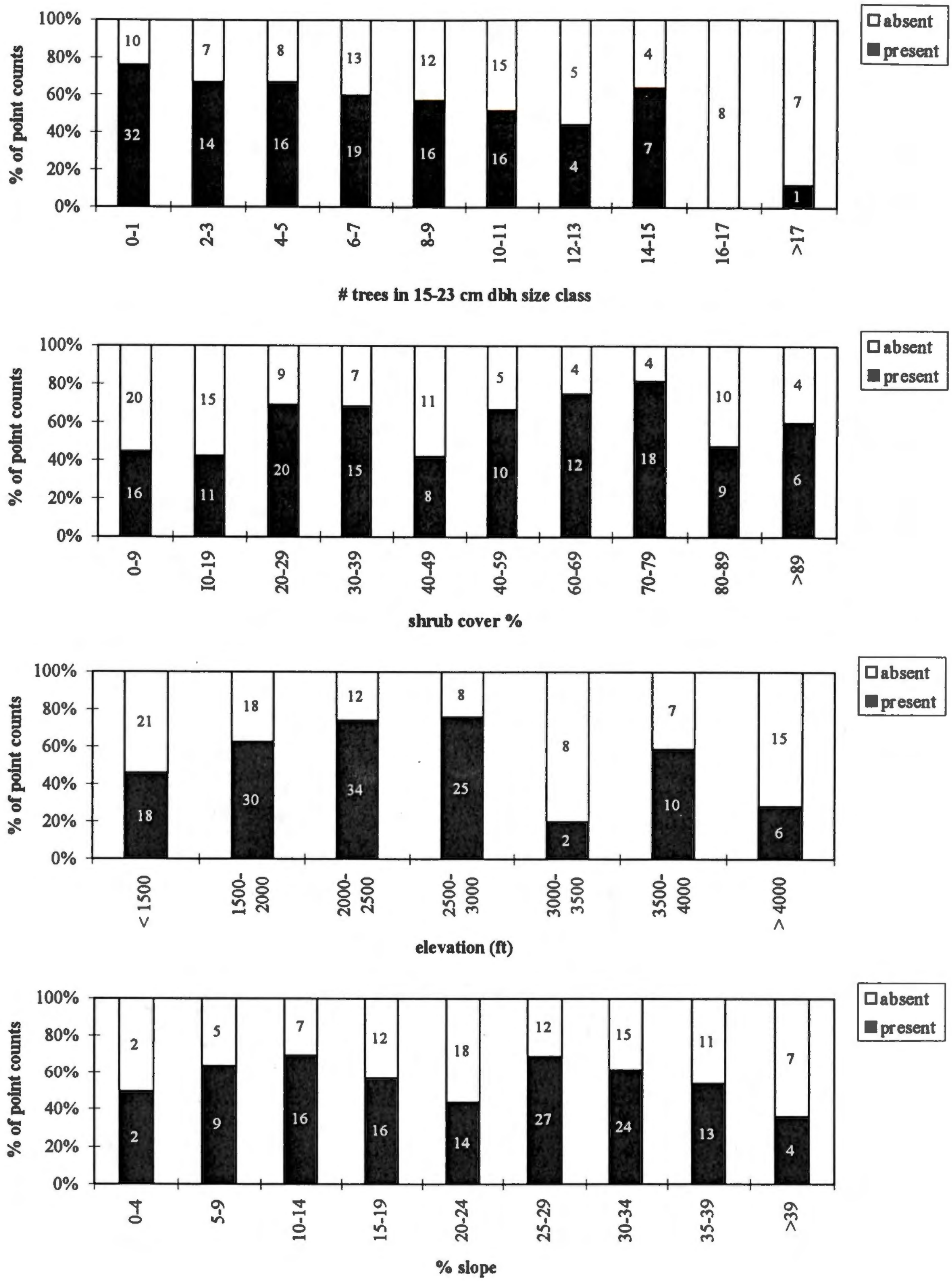

Figure 10. (continued)

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

[1] Unstandardized coefficients - these estimates do not indicate the relative weight of each variable.
[2] 'COVEHD' subgroup (parameter est.= 2.041, P = 0.034) recorded a significant ($P \leq 0.05$) Wald score.
[3] Variables are listed in decreasing order of the significance of their F-statistic.
[4] 'SEEDLG' subgroup (parameter est.= 0.773, P = 0.157) recorded a significant ($P \leq 0.05$) Wald score.
[5] Reference group for the forest type design (dummy) variable group.
[6] Reference group for the condition class design (dummy) variable group.
[7] Correct classification rate for the CISC variables with the ELEVTN component included.

Table 15. (continued)

Model Type	Variables Selected	Parameter Estimate	Pr. > χ^2	Probability Tests of Correct Classification: Concordance	Jack-knife	Goodness-of-Fit Indicator: Hosmer / Lemeshow
	CONSTANT	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*			
STEP-WISE	COVEHD	2.761	0.000*	77.6 %	66.8 %	C = 9.30 P = 0.37
	HEMLCK	0.870	0.101*			
	MXEDHP	0.711	0.162*			
	NORHWD	1.065	0.156*			
	OAKHIC	0.659	0.243			
	YEPINE	-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,

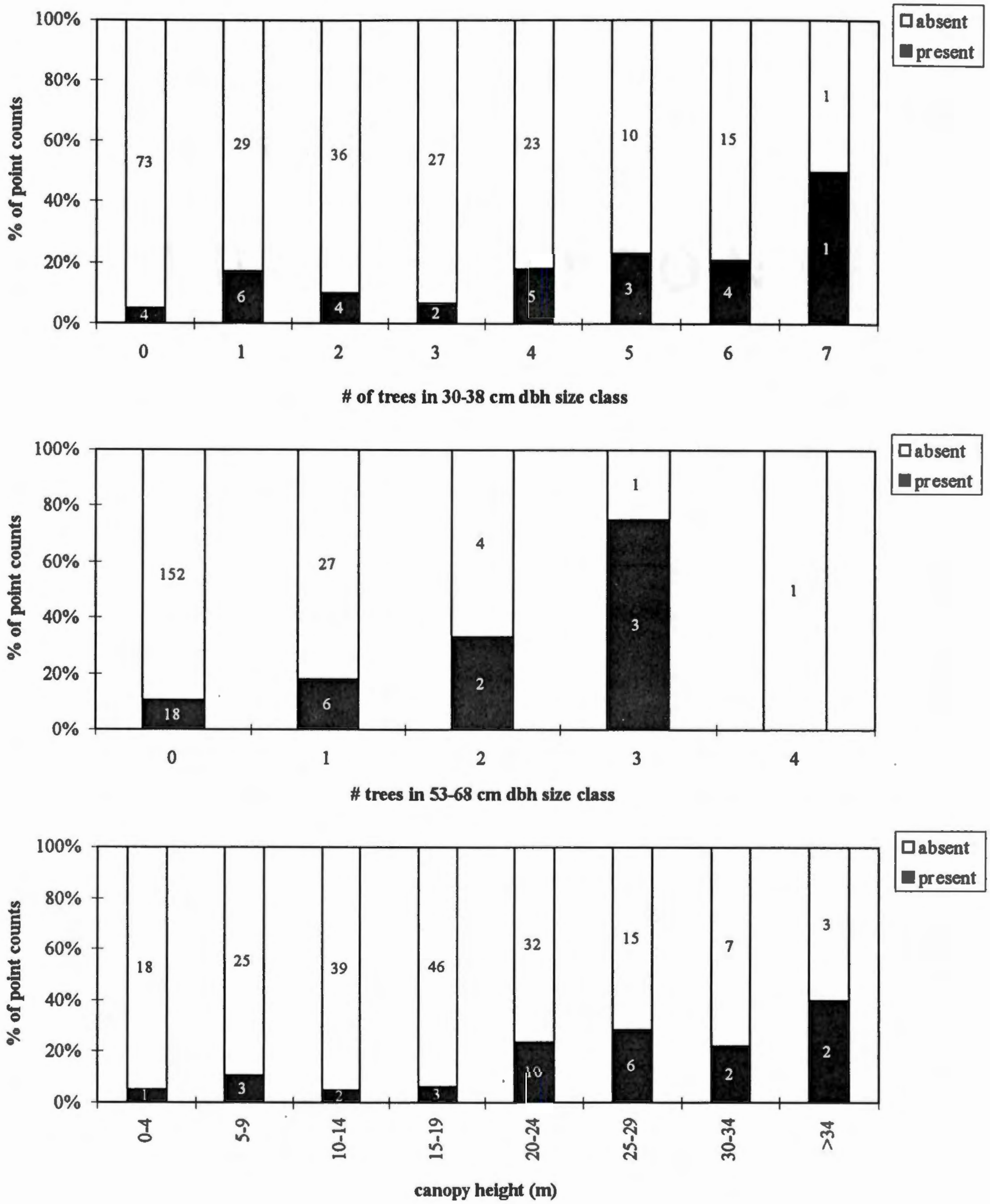

Figure 11. Percentage of points where wood thrush was present and absent in 1992, 1993 or in both years, across three continuous habitat variables deemed best predictors of woodthrush distribution, Cherokee National Forest, Tennessee.

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[1]	Pr. > χ^2	Probability Tests of Correct Classification: Concordance	Probability Tests of Correct Classification: Jack-knife	Goodness-of-Fit Indicator: Hosmer / Lemeshow
	CONSTANT	-2.401	0.199			
	CNPYHT	0.049	0.232			
	NOSAPS	4.022	0.694			
	BSLSAP	-2048.90	0.694			
	CNDCLS					
FULL[2]	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			
	TOTBSL	0.063	0.916			
	CONSTANT	-1.411	0.513			
	COVEHD	1.923	0.089*			
	HEMLCK	1.786	0.069*			
	MXEDHP	1.010	0.258			
	NORHWD	-0.467	0.719			
	OAKHIC	1.488	0.103*			
CISC	YEPINE[3]	-5.740	0.258	73.2 %	84.6 %	C = 2.05
	SEEDLG	-1.228	0.373			P = 0.98
	POLTMB	-0.326	0.679			
	SAWTMB[4]	1.554	0.373			
	STNDAG	0.006	0.762			
	STENDX	-0.017	0.498			
	STNDSZ	-0.004	0.352			
	ELEVTN[5]	0.000	0.130	74.0 %	86.4 %	
	CONSTANT	-2.842	0.000			
AIC	30-38DBH	0.293	0.005*	67.6 %	86.4 %	C = 18.91
	53-68DBH	0.700	0.004*			P = 0.00
	CONSTANT	-3.472	0.000			
STEP-WISE	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*			

[1] Unstandardized coefficients - these estimates do not indicate the relative weight of each variable.
[2] Variables are listed in decreasing order of the significance of their F-statistic.
[3] Reference group for the forest type design (dummy) variable group.
[4] Reference group for the condition class design (dummy) variable group.
[5] Correct classification rate for the CISC variables with the ELEVTN 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 ≤ 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 ≤ 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

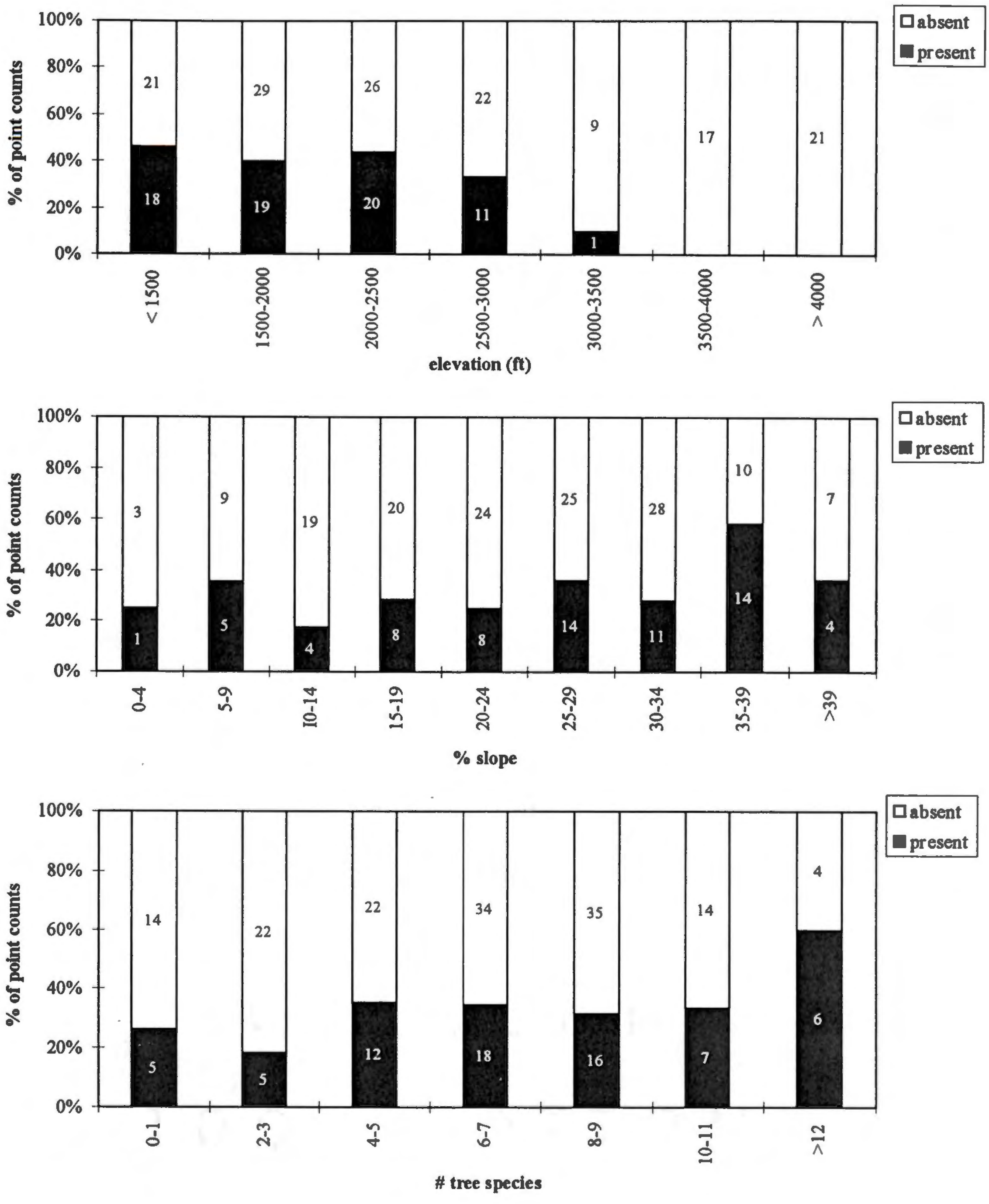

Figure 12. Percentage of points where worm-eating warbler was present and absent in 1992, 1993 or in both years, across five continuous habitat variables deemed best predictors of worm-eating warbler distribution, Cherokee National Forest, Tennessee.

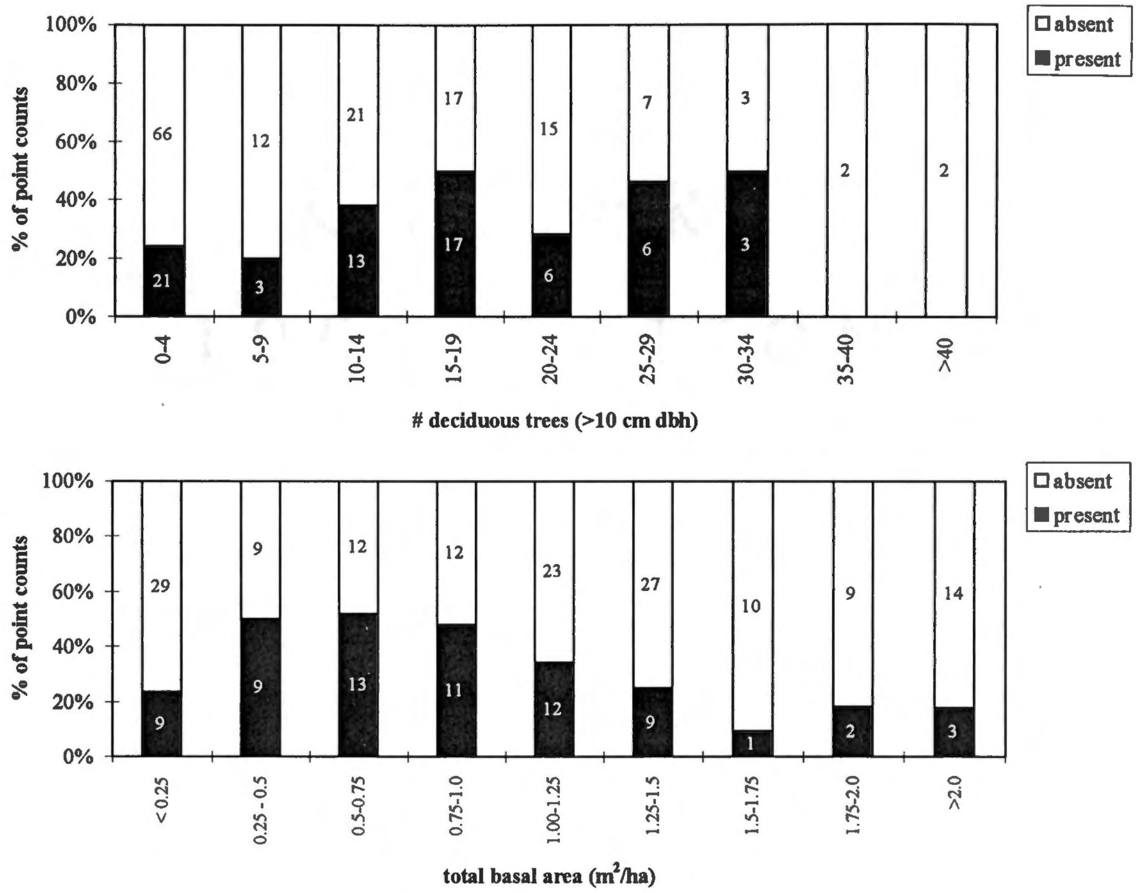

Figure 12. (continued)

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).

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

[1] Unstandardized coefficients - these estimates do not indicate the relative weight of each variable.
[2] Variables are listed in decreasing order of the significance of their F-statistic.
[3] 'OAKHIC' subgroup (parameter est.= 1.117, $P = 0.062$) recorded a significant ($P \leq 0.05$) Wald score.
[4] Reference group for the forest type design (dummy) variable group.
[5] Reference group for the condition class design (dummy) variable group.
[6] Correct classification rate for the CISC variables with the ELEVTN 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 ≤ 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.

Diversity Index	R^2
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^2**
Migrant Richness	*CONSTANT*	2.517	10.57	0.001	**Model R^2 = 0.261**
	ELEVTN	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	**Model R^2 = 0.149**
	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	**Model R^2 = 0.129**
	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
	ELEVTN	0.000	8.46	0.004	0.021
Migrant Abundance	*CONSTANT*	2.632	5.68	0.018	**Model R^2 = 0.262**
	ELEVTN	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	**Model R^2 = 0.132**
	ELEVTN	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	**Model R^2 = 0.292**
	ELEVTN	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
	CONSTANT	2.129	3.57	0.060	**Model R^2 = 0.394**
	OAKHIC	1.281	11.26	0.001	0.022
	ELEVTN	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
Migrant	NORHWD	0.617	1.60	0.207	0.036
Richness	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
	CONSTANT	4.299	33.70	0.000	**Model R^2 = 0.209**
	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
Resident	ELEVTN	0.000	3.02	0.084	0.007
Richness	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
	CONSTANT	6.427	18.44	0.000	**Model R^2 = 0.311**
	ELEVTN	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
Combined	COVEHD	1.114	2.70	0.102	0.000
Richness	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^2
	CONSTANT	1.689	1.10	0.296	**Model R^2 = 0.476**
	ELEVTN	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
Migrant Abundance	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
	CONSTANT	5.299	25.33	0.000	**Model R^2 = 0.241**
	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
	ELEVTN	0.000	7.14	0.008	0.039
	SEEDLG	-1.556	6.25	0.013	0.043
Resident Abundance	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
	CONSTANT	6.988	11.70	0.001	**Model R^2 = 0.464**
	ELEVTN	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
Combined Abundance	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 occured 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:

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

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

where g(x) = the logit transformation of the conditional mean of y given x when the logistic distribution is used, β_0 = y-intercept (value of y when x = 0), β_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 (ψ) 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 + COVEHD (0.752) + HEMLCK (1.225) + MXEDHP (0.175) + NORHWD (-1.435) + OAKHIC (-0.841) + YEPINE (0.124) + SEEDLG (0.631) + POLTMB (0.641) + SAWTMB (-1.272) + STNDAG (0.046) + STENDX (-0.072) + STNDSZ (0.002) + ELEVTN (-0.002)
	AIC / Stepwise	g(x) = -0.268 + ELEVTN (-0.001) + LITDPH (0.292) + BSLSAP (-2.431) + STNDAG (0.026) + 38-53DBH (0.268)
BTBW	CISC	g(x) = -4.718 + COVEHD (1.928) + HEMLCK (0.522) + MXEDHP (0.568) + NORHWD (5.841) + OAKHIC (2.731) + YEPINE (-11.590) + SEEDLG (0.160) + POLTMB (-0.134) + SAWTMB (-0.026) + STNDAG (0.009) + STENDX (0.017) + STNDSZ (-0.006) + ELEVTN (0.002)
	AIC / Stepwise	g(x) = (-5.864) + ELEVTN (0.008) + VACCVR (-0.046) + LITDPH (-0.559) + 53-68DBH (0.572) + GRNDCV (-0.021) + RHODCR (0.015)
CAWA	CISC	g(x) = -31.90 + COVEHD (28.752) + HEMLCK (28.236) + MXEDHP (28.040) + NORHWD (31.643) +OAKHIC (28.820) + YEPINE (-145.50) + SEEDLG (1.128) + POLTMB (0.052) + SAWTMB (-1.180) + STNDAG (0.014) + STENDX (0.001) + STNDSZ (-0.004)
	AIC	g(x) = -7.56 + ELEVTN (0.002) + CONFRQ (-0.129) + LITDPH (-0.102)
	Stepwise	g(x) = -9.529 + ELEVTN (0.003) + RHODCR (0.107) + CONFRQ (-0.672) + NOTRSP (-0.315) + SLOPE% (-0.093) + SNGFRQ (-0.494)
CSWA	CISC	g(x) = -3.735 + COVEHD (0.843) + HEMLCK (0.046) + MXEDHP (-11.223) + NORHWD (6.174) + OAKHIC (2.132) + YEPINE (2.028) + SEEDLG (1.535) + POLTMB (-1.527) + SAWTMB (-0.008) + STNDAG (-0.024) + STENDX (0.007) + STNDSZ (-0.012)
	AIC / Stepwise	g(x) = -5.731 + ELEVTN (0.003) + CNPYHT (-0.187) + LITDPH (-0.629)
HOWA	CISC	g(x) = -1.789 + COVEHD (2.643) + HEMLCK (0.939) + MXEDHP (0.712) + NORHWD (0.149) + OAKHIC (0.552) + YEPINE (-4.994) + SEEDLG (1.618) + POLTMB (-0.121) + SAWTMB (-1.497) + STNDAG (0.014) + STENDX (0.004) + STNDSZ (-0.001)
	AIC	g(x) = 0.897 + CNPYCR (-0.012) + COVEHD (1.998) + HEMLCK (0.538) + MXEDHP (0.517) + NORHWD (-0.107) + OAKHIC (0.242) + YEPINE (-3.188) + STENDX (0.012) + TOTNTR (-0.031)
	Stepwise	g(x) = 1.30 + 15-23DBH (-0.118) + SHRBCV (0.014) + ELEVTN (-0.000) + SLOPE% (-0.025) + COVEHD (2.761) + HEMLCK (0.87) + MXEDHP (0.711) + NORHWD (1.065) + OAKHIC (0.659) + YEPINE (-6.066)

Table 21. (continued)

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

[1] Poor-fitting model - not recommended for use.

of 5 m, and an average litter depth of 2 cm, would have an estimated odds ratio (ψ): g(x) = [-5.731 + (4000 x 0.003) + (5 x -0.187) + (2 x -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 shere 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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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	*Castanea pumila*	red mulberry	*Morus rubra*
alternate-leaf dogwood	*Cornus alternifolia*	redbud	*Cercis canadensis*
American basswood	*Tilia americana*	rosebay rhododendron	*Rhododendron maximum*
American beech	*Fagus grandifolia*	sassafras	*Sassafras albidum*
American elm	*Ulmus americana*	scarlet oak	*Quercus coccinea*
American holly	*Ilex opaca*	shortleaf pine	*Pinus echinata*
ash spp.	*Fraxinus* spp.	slippery elm	*Ulmus rubra*
black cherry	*Prunus serotina*	smooth sumac	*Rhus glabra*
black locust	*Robinia pseudoacacia*	sourwood	*Oxydendrum arboreum*
black oak	*Quercus velutina*	southern red oak	*Quercus falcata*
black walnut	*Juglans nigra*	striped maple	*Acer pensylvanicum*
black willow	*Salix nigra*	sugar maple	*Acer saccharum*
blackberry spp.	*Rubus* spp.	sweet birch	*Betula lenta*
blackgum	*Nyssa sylvatica*	sweetgum	*Liquidambar styraciflua*
blackjack oak	*Quercus marilandica*	table mountain pine	*Pinus pungens*
box elder	*Acer negundo*	tuliptree	*Liriodendron tulipifera*
butternut	*Juglans cinerea*	umbrella magnolia	*Magnolia tripetala*
Carolina silverbell	*Halesia carolina*	Virginia pine	*Pinus virginiana*
chestnut	*Castenea dentata*	white oak	*Quercus alba*
chestnut oak	*Quercus prinus*	white pine	*Pinus strobus*
common elderberry	*Sambucus canadensis*	wild grape spp.	*Vitis* spp.
common pawpaw	*Asimina triloba*	winged sumac	*Rhus copallina*
common persimmon	*Diospyros virginiana*	witch-hazel	*Hamamelis virginiana*
cucumbertree	*Magnolia acuminata*	yellow birch	*Betula alleghaniensis*
downy serviceberry	*Amelanchier arborea*	yellow buckeye	*Aesculus octandra*
Eastern hemlock	*Tsuga canadensis*		
Eastern hophornbeam	*Ostrya virginiana*		
Eastern redcedar	*Juniperus virginiana*		
Eastern sycamore	*Platanus occidentalis*		
fire cherry	*Prunus pensylvanica*		
flowering dogwood	*Cornus florida*		
Fraser magnolia	*Magnolia fraseri*		
hawthorn spp.	*Crataegus* spp.		
honey locust	*Gleditsia triacanthos*		
ironwood	*Caprinus caroliniana*		
mockernut hickory	*Carya tomentosa*		
mountain laurel	*Kalmia latifolia*		
mountain maple	*Acer spicatum*		
mountain pepperbush	*Clethra acuminata*		
northern catalpa	*Catalpa speciosa*		
northern red oak	*Quercus rubra*		
pignut hickory	*Carya glabra*		
pitch pine	*Pinus rigida*		
post oak	*Quercus stellata*		
red maple	*Acer rubrum*		

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

Table B.1. (continued)

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

Cove Hardwood	seedling/sapling		poletimber		sawtimber	
physical / habitat variables	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error
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)

Cove Hardwood	seedling/sapling		poletimber		sawtimber	
physical / habitat variables	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error
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.

Eastern Hemlock/White Pine						
	seedling/sapling		**poletimber**		**sawtimber**	
physical / habitat variables	**Mean**	**Std. Error**	**Mean**	**Std. Error**	**Mean**	**Std. Error**
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)

Eastern Hemlock / White Pine						
	seedling/sapling		poletimber		sawtimber	
physical / habitat variables	**Mean**	**Std. Error**	**Mean**	**Std. Error**	**Mean**	**Std. Error**
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.

Mixed Hardwood/Pine						
	seedling/sapling		poletimber		sawtimber	
physical / habitat variables	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error
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)

Mixed Hardwood/Pine						
	seedling/sapling		poletimber		sawtimber	
physical / habitat variables	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error
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						
	seedling/sapling		poletimber		sawtimber	
physical / habitat variables	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						
	seedling/sapling		**poletimber**		**sawtimber**	
physical / habitat variables	**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.

Oak/Hickory						
	seedling/sapling		**poletimber**		**sawtimber**	
physical / habitat variables	**Mean**	**Std. Error**	**Mean**	**Std. Error**	**Mean**	**Std. Error**
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
SHRTLF					0.42	0.34

Table C.5. (continued)

Oak/Hickory	seedling/sapling		poletimber		sawtimber	
physical / habitat variables	**Mean**	**Std. Error**	**Mean**	**Std. Error**	**Mean**	**Std. Error**
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.

Yellow Pine						
	seedling/sapling		poletimber		sawtimber	
physical / habitat variables	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error
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)

Yellow Pine						
	seedling/sapling		**poletimber**		**sawtimber**	
physical / habitat variables	**Mean**	**Std. Error**	**Mean**	**Std. Error**	**Mean**	**Std. Error**
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 - seedling/sapling			Cove Hardwood - poletimber			Cove Hardwood - sawtimber		
species code	% occurrence	density/ 100 ha	species code	% occurrence	density/ 100 ha	species code	% occurrence	density/ 100 ha
howa	90	141	howa	75	127	howa	85	119
revi	80	184	btnw	42	85	revi	62	102
inbu	60	127	revi	42	74	btnw	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	btbw	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	btbw	8	11	acfl	8	8
wewa	20	42	carw	8	21	blbw	8	8
btbw	10	14	dowo	8	11	cach	8	17
btnw	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 - seedling/sapling			Cove Hardwood - poletimber			Cove Hardwood - sawtimber		
species code	% occurrence	density/ 100 ha	species code	% occurrence	density/ 100 ha	species code	% occurrence	density/ 100 ha
howa	85	147	btnw	85	166	revi	77	127
revi	85	166	howa	69	127	btnw	62	93
inbu	77	147	revi	69	147	baww	54	85
scta	69	137	baww	46	59	oven	54	102
rsto	62	88	cach	38	59	howa	46	110
amre	54	127	oven	31	39	scta	46	59
btnw	54	88	etti	31	39	btbw	38	51
oven	54	78	wewa	31	59	cawa	23	34
btbw	31	39	sovi	23	29	sovi	23	34
baww	31	49	inbu	15	29	cach	15	59
amgo	23	29	lowa	15	20	scju	15	17
cach	23	29	acfl	8	10	wewa	15	17
cswa	23	49	amgo	8	10	woth	15	17
rbgr	23	29	blja	8	10	acfl	8	8
blja	15	20	btbw	8	10	amcr	8	8
sovi	15	20	piwo	8	10	amgo	8	17
wewa	15	20	rbgr	8	10	amro	8	17
cawa	8	10	scta	8	10	blbw	8	8
cedw	8	10	woth	8	10	cedw	8	17
eawp	8	10				eawp	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
veer	8	10				wiwr	8	8
wbnu	8	10				ybsa	8	8
wevi	8	20				ytwa	8	8
ybch	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 - 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
revi	100	216	inbu	63	127	revi	90	140
inbu	70	114	revi	63	111	btnw	70	153
howa	50	89	cach	50	79	howa	60	76
rsto	50	89	carw	38	48	cach	50	102
wewa	50	64	amgo	25	32	etti	30	38
oven	40	64	amro	25	32	wewa	30	38
ybch	40	64	blja	25	32	acfl	20	51
btnw	30	51	btnw	25	32	baww	20	25
amgo	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
amre	10	13	howa	13	16	grca	10	13
amro	10	13	piwa	13	16	scju	10	51
brth	10	13	rbgr	13	16	rbgr	10	13
bwha	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		
species code	% occurrence	density/ 100 ha
inbu	92	148
revi	83	223
howa	67	127
rsto	67	159
oven	50	95
wewa	42	53
baww	33	42
scta	33	64
ytwa	33	53
cach	25	42
ybcu	25	32
bggn	17	21
carw	17	32
etti	17	21
wevi	17	21
woth	17	21
ybch	17	21
amgo	8	21
blja	8	11
brth	8	11
btnw	8	11
cawa	8	11
cswa	8	11
gcfl	8	11
kewa	8	11
modo	8	11
noca	8	11
nopa	8	11
piwa	8	11
piwo	8	11
rbwo	8	11
rthu	8	11

E. Hemlock/White Pine - poletimber		
species code	% occurrence	density/ 100 ha
revi	91	223
inbu	64	74
btnw	45	95
cach	36	42
ybcu	36	42
carw	27	32
howa	27	74
wewa	27	42
woth	27	32
bggn	18	21
baww	18	21
gcfl	18	21
nopa	18	21
rsto	18	21
etti	18	21
amgo	9	21
blja	9	32
cogr	9	11
coha	9	11
noca	9	11
oven	9	11
piwo	9	11
wevi	9	11
ybch	9	11
ytwa	9	11

E. Hemlock/White Pine - sawtimber		
species code	% occurrence	density/ 100 ha
revi	91	208
btnw	55	104
baww	55	69
howa	55	104
oven	45	69
acfl	36	46
cach	36	81
scta	27	35
inbu	18	23
nopa	18	35
rsto	18	23
wbnu	18	23
wewa	18	23
ytvi	18	35
amcr	9	23
blja	9	12
btbw	9	12
cawa	9	12
hawo	9	12
modo	9	12
piwa	9	12
rbgr	9	12
rthu	9	12
suta	9	12
etti	9	12
woth	9	12
ytwa	9	12

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 - seedling/sapling		
species code	% occurrence	density/ 100 ha
revi	70	165
btnw	40	51
baww	40	51
cach	30	64
howa	30	38
inbu	30	51
wewa	30	38
noca	20	25
oven	20	38
piwa	20	25
rsto	20	25
scta	20	25
wevi	20	25
piwo	10	13
etti	10	13
woth	10	13
ybch	10	25
ybcu	10	13

Mixed Hardwood/Pine - poletimber		
species code	% occurrence	density/ 100 ha
revi	67	127
wewa	44	57
baww	33	42
cach	33	85
howa	33	42
oven	33	57
ytwa	33	42
acfl	22	28
blja	22	28
btnw	22	28
inbu	22	28
piwa	22	28
scta	22	28
ybcu	22	28
amcr	11	14
carw	11	14
dowo	11	28
hawo	11	14
noca	11	14
sovi	11	14
etti	11	14
wbnu	11	14

Mixed Hardwood/Pine - sawtimber		
species code	% occurrence	density/ 100 ha
howa	64	98
oven	64	117
revi	57	137
etti	43	59
btnw	36	59
cach	36	68
inbu	36	49
wewa	29	39
baww	21	29
carw	21	29
nopa	21	29
scta	21	29
ytwa	21	29
acfl	14	20
blbw	14	29
btbw	14	49
cawa	14	39
piwa	14	20
piwo	14	29
sovi	14	29
woth	14	20
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 - seedling/sapling		
species code	% occurrence	density/ 100 ha
inbu	86	145
revi	86	127
baww	57	73
howa	57	73
cach	50	91
rsto	50	73
wevi	29	45
wewa	29	45
etti	21	36
btnw	14	18
piwo	14	18
acfl	7	9
amgo	7	18
bggn	7	9
blja	7	9
dowo	7	9
oven	7	9
scta	7	9
ybch	7	9
ybcu	7	9
ytvi	7	9

Mixed Hardwood/Pine - poletimber		
species code	% occurrence	density/ 100 ha
revi	82	162
oven	73	127
cach	45	104
btnw	36	58
baww	36	46
scta	36	46
etti	36	46
howa	27	35
blja	18	23
inbu	18	35
wewa	18	23
acfl	9	12
amcr	9	12
amgo	9	12
bwha	9	12
carw	9	12
dowo	9	12
piwo	9	12
rsto	9	12
sovi	9	12
suta	9	12
wbnu	9	12
woth	9	12
ytwa	9	23

Mixed Hardwood/Pine - sawtimber		
species code	% occurrence	density/ 100 ha
howa	62	138
oven	62	106
revi	62	106
btnw	54	74
scta	46	74
cach	31	42
etti	31	53
ytwa	31	42
wewa	23	32
woth	23	64
btbw	15	53
baww	15	21
cawa	15	32
dowo	15	21
hawo	15	21
inbu	15	32
nopa	15	21
piwo	15	21
sovi	15	21
acfl	8	11
amgo	8	21
blbw	8	11
scju	8	11
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 - seedling/sapling			Northern Hardwood - poletimber			Northern Hardwood - sawtimber		
species code	% occurrence	density/ 100 ha	species code	% occurrence	density/ 100 ha	species code	% occurrence	density/ 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	btnw	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	bwha	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
rugr	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 - seedling/sapling			Northern Hardwood - poletimber			Northern Hardwood - sawtimber		
species code	% occurrence	density/ 100 ha	species code	% occurrence	density/ 100 ha	species code	% occurrence	density/ 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	blja	18	25	btnw	25	32
oven	42	85	btnw	18	25	oven	25	32
revi	33	64	howa	18	25	rsto	25	32
wiwr	33	42	amcr	9	25	rbgr	17	21
amgo	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
etti	17	21	rsto	9	13	cedw	8	21
amre	8	11	woth	9	13	piwo	8	11
btnw	8	11				rbnu	8	21
cach	8	11				wiwr	8	11
cedw	8	11						
ysfl	8	11						
rthu	8	11						
ybch	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		
species code	% occurrence	density/ 100 ha
baww	67	102
howa	67	127
btbw	50	102
revi	50	76
etti	50	76
bggn	33	102
cach	33	127
rsto	33	76
scta	33	51
wewa	33	76
blja	17	25
btnw	17	25
cawa	17	51
cswa	17	51
gcfl	17	25
grca	17	25
inbu	17	76
noca	17	25
scju	17	25
nopa	17	25
piwa	17	25
sosp	17	25
sovi	17	25
veer	17	25
ybch	17	25
ybcu	17	25

Oak/Hickory - poletimber		
species code	% occurrence	density/ 100 ha
oven	71	145
revi	71	109
howa	43	73
scta	43	55
btbw	29	55
btnw	29	55
cach	29	91
rbgr	29	36
wewa	29	36
acfl	14	18
amcr	14	36
amre	14	36
bggn	14	18
baww	14	18
dowo	14	18
inbu	14	18
scju	14	36
piwo	14	18
rsto	14	18
sovi	14	18
etti	14	18
wbnu	14	18
woth	14	36

Oak/Hickory - sawtimber		
species code	% occurrence	density/ 100 ha
revi	83	162
scta	75	127
btnw	58	104
baww	50	81
howa	42	92
oven	42	116
btbw	25	35
cach	25	58
carw	25	35
inbu	25	46
wewa	25	35
etti	17	23
woth	17	35
ybcu	17	23
amre	8	12
hawo	8	12
noca	8	23
ysfl	8	23
nopa	8	12
piwo	8	12
rbgr	8	12
rsto	8	12
sovi	8	12
veer	8	23
ytwa	8	12

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			Oak/Hickory - poletimber			Oak/Hickory - sawtimber		
species code	% occurrence	density/ 100 ha	species code	% occurrence	density/ 100 ha	species code	% occurrence	density/ 100 ha
revi	86	276	btnw	67	127	oven	62	127
howa	71	148	oven	50	92	scta	62	117
baww	57	85	revi	50	116	inbu	46	74
inbu	57	127	baww	42	58	revi	46	138
rsto	43	64	howa	42	58	howa	38	85
scta	43	64	sovi	42	116	sovi	38	85
amgo	29	85	wewa	42	69	woth	38	53
btbw	29	42	cach	33	69	btnw	31	64
cswa	29	127	inbu	33	46	baww	31	64
gwwa	29	42	scta	33	46	cach	31	53
oven	29	64	btbw	25	58	wewa	31	42
rbgr	29	64	cawa	8	12	btbw	23	53
etti	29	85	dowo	8	12	dowo	23	42
veer	29	42	eape	8	12	blja	15	32
bhco	14	21	hawo	8	12	lowa	15	32
blja	14	21	scju	8	23	rsto	15	21
btnw	14	42	etti	8	12	ytwa	15	21
cach	14	21	veer	8	23	acfl	8	11
cawa	14	42	ybcu	8	12	amgo	8	11
cedw	14	85				amre	8	21
cogr	14	42				bbcu	8	11
nopa	14	21				cedw	8	11
suta	14	21				cswa	8	11
wewa	14	21				gcfl	8	11
ybch	14	64				hawo	8	11
ybcu	14	21				scju	8	21
						piwo	8	11
						rbgr	8	11
						suta	8	11
						etti	8	11
						veer	8	11
						wbnu	8	11
						ytvi	8	11

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 code	% occurrence	density/ 100 ha	species code	% occurrence	density/ 100 ha	species code	% occurrence	density/ 100 ha
revi	58	191	revi	82	197	revi	75	68
inbu	50	143	btnw	73	127	wewa	50	39
baww	33	64	oven	55	92	btnw	25	20
howa	33	95	baww	36	46	cach	25	29
oven	33	79	inbu	36	58	dowo	25	20
amgo	25	79	etti	36	46	howa	25	29
btnw	25	48	cach	27	46	inbu	25	20
cach	25	48	howa	27	46	oven	25	39
piwa	25	48	piwa	27	35	piwa	25	29
rsto	25	79	ytwa	27	46	etti	25	29
blja	17	64	amcr	18	23	acfl	13	10
etti	17	32	blja	18	23	amcr	13	20
wewa	17	32	scta	18	35	blja	13	10
acfl	8	16	wewa	18	23	carw	13	10
btbw	8	64	ybcu	18	23	gcfl	13	10
carw	8	16	acfl	9	12	nopa	13	10
cswa	8	16	amgo	9	12	piwo	13	10
dowo	8	16	carw	9	12	rsto	13	10
noca	8	16	hawo	9	12	sovi	13	10
ysfl	8	16	ysfl	9	12	woth	13	10
praw	8	16	rsto	9	12			
rbgr	8	16						
rbwo	8	16						
scta	8	32						
wpwi	8	16						
ybch	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/ 100 ha	species code	% occurrence	density/ 100 ha	species code	% occurrence	density/ 100 ha
revi	79	153	revi	100	215	revi	67	127
inbu	71	136	btnw	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	btnw	33	42
ybch	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
btnw	14	17	bggn	8	10	etti	22	28
howa	14	17	piwa	8	10	bggn	11	14
piwo	14	17	rsto	8	10	blja	11	14
rsto	14	25	rthu	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	woth	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

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