To the Graduate Council:

I am submitting herewith a thesis written by Robert P. Ford entitled "Habitat Relationships of Breeding Birds and Winter Birds in Forested Wetlands of West Tennessee." I have examined the final 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.

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HABITAT RELATIONSHIPS OF BREEDING BIRDS AND WINTER BIRDS IN FORESTED WETLANDS OF WEST TENNESSEE

A Thesis

presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Robert P. Ford

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ABSTRACT

Rapid and substantial losses of wetlands in the lower Mississippi River Valley during the last 200 years have made wise environmental planning increasingly important. Documentation of bird-habitat relationships provides one assessment of human impacts in wetlands. The objectives of this study were to 1) characterize breeding and winter bird communities occurring in west Tennessee forested wetlands, 2) assess bird density, composition, and species richness among watersheds with highly variable degrees of disturbance, and 3) provide habitat models for abundant breeding and winter season birds.

Bird density and species richness in west Tennessee is limited by cumulative impacts of minor projects which reduce forest tract size and alter natural flood regimes. Highest breeding density and species richness occurred in watersheds with the least amount of disturbance. Birds often show a higher mobility during winter than during breeding season. As a result, winter densities and species richness varied among watersheds. Land management that encourages agriculture and water impoundments provided for high densities of blackbirds and waterfowl, which exaggerated density in disturbed

watersheds. High winter density and species richness in relatively undisturbed watersheds were attributed to large tract size and relatively normal flood regimes.

Habitat structure is a more consistent predictor of bird density than habitat (tree species) composition. A low percentage of shrub cover was an important structural component of forests with high densities of abundant birds. During winter, small patchy cover appeared to be more beneficial than a continuous shrub layer.

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CHAPTER I

INTRODUCTION

Bird density, abundance, and richness are relatively high in the Mississippi Alluvial Plain, Upper Gulf Coastal Plain, and Western Valley physiographic provinces of the southeastern United States (Dickson 1978, Conner et al. 1983, Pitts 1985, Robbins et al. 1986, Smith 1987). Forested wetlands within these provinces generally have higher bird densities than adjacent upland habitats. Bird density and species richness in forested wetlands of west Tennessee are higher than, or comparable to, other physiographic regions of the state, such as the Central Basin (Ford and Hamel 1988).

Rapid and substantial losses of forested wetlands (see Office of Technological Assessment 1984, Tiner 1984) have made ornithological research in these habitats increasingly important. Federal legislation, such as the National Environmental Policy Act of 1978 and Clean Waters Act as updated in 1987, requires consideration of environmental impacts during development planning. Baseline ecological data enhance development planning by providing a natural resource inventory for the habitats involved.

Relatively little is known of the avifauna in west Tennessee's forested wetlands. Research in west Tennessee,

as well as other parts of the Mississippi Alluvial Plain, Gulf Coastal Plain and Western Valley, has been either site-specific, emphasizing managed public lands (e.g. Pitts 1985, Smith 1987), or species-specific, emphasizing threatened or endangered species (e.g. Kalla and Alsop 1983). Most research has been conducted solely during breeding seasons, although Dickson (1978) and Smith (1987) provided exceptions.

Federal and state governments are receiving pressure from society to manage for nongame species and for biodiversity (Norse et al. 1986, Norton 1987), and provide incentives for nonconsumptive use of public areas (Kellert 1985). Species other than those threatened, endangered, or nearing minimum viable populations are also in need of management (Hutto et al. 1987, Conner 1988). Cumulative impacts of relatively minor development projects result in a deterioration of bird habitats within watersheds (Gosselink et al. 1989).

Site-specific environmental impacts of development are assessed by various habitat evaluation models. Habitat relationships for individual species are summarized by some models, such as the Habitat Suitability Index (Schamberger et al. 1982). Important community variables in forests are summarized by other models, such as the Habitat Evaluation System (USACOE 1980). These models require quantifiable habitat data which are beneficial to individual species. Habitat requirements for birds, as presented in habitat

System (USACOE 1980). These models require quantifiable habitat data which are beneficial to individual species. Habitat requirements for birds, as presented in habitat models, often change over a species' geographic range (O'Neil et al. 1988). Appropriate development and application of models necessitate learning a species' habitat requirements in all parts of its range.

This study was initiated to document bird density, richness, and habitat relationships in swamp and bottomland hardwood forests of west Tennessee. This thesis represents the first systematic and comprehensive study of birds across the geographic and seral breadth of west Tennessee's forested wetland habitats. The objectives were to:

1) characterize breeding and winter bird communities in west Tennessee's wetland forests, which are part of the Mississippi Alluvial Plain, Upper Gulf Coastal Plain, and Western Valley physiographic provinces,

2) assess bird density, composition, and species richness among watersheds with highly variable degrees of disturbance,

3) provide habitat models in the form of species accounts for abundant breeding and winter season birds in forested wetland habitats of west Tennessee.

CHAPTER II

DESCRIPTION OF STUDY AREA

I. Landscape and climate of west Tennessee

The Mississippi Alluvial Plain, Upper Gulf Coastal Plain, and the Western Valley physiographic provinces occur in west Tennessee (Figure 1). The Mississippi Alluvial Plain extends in a narrow band along the western most edge of the region, ranging in width from less than 1 km (where the river meets the bluff) to 22 km; the plain is typified by flat topography and fertile soils deposited by the Mississippi River.

The Upper Gulf Coastal Plain is adjacent to, and east of, the Alluvial Plain in west Tennessee. Two distinct units embody the Upper Gulf Coastal Plain; the west Tennessee uplands and the west Tennessee plains. The uplands unit is characterized by rolling topography. Swamp rivers, with broad and flat floodplains, characterize the plains unit. Swamp rivers, with their characteristic floodplain forests, are a dominant natural landscape feature of west Tennessee.

The Western Valley province extends in a narrow north-south oriented band across the eastern edge of west

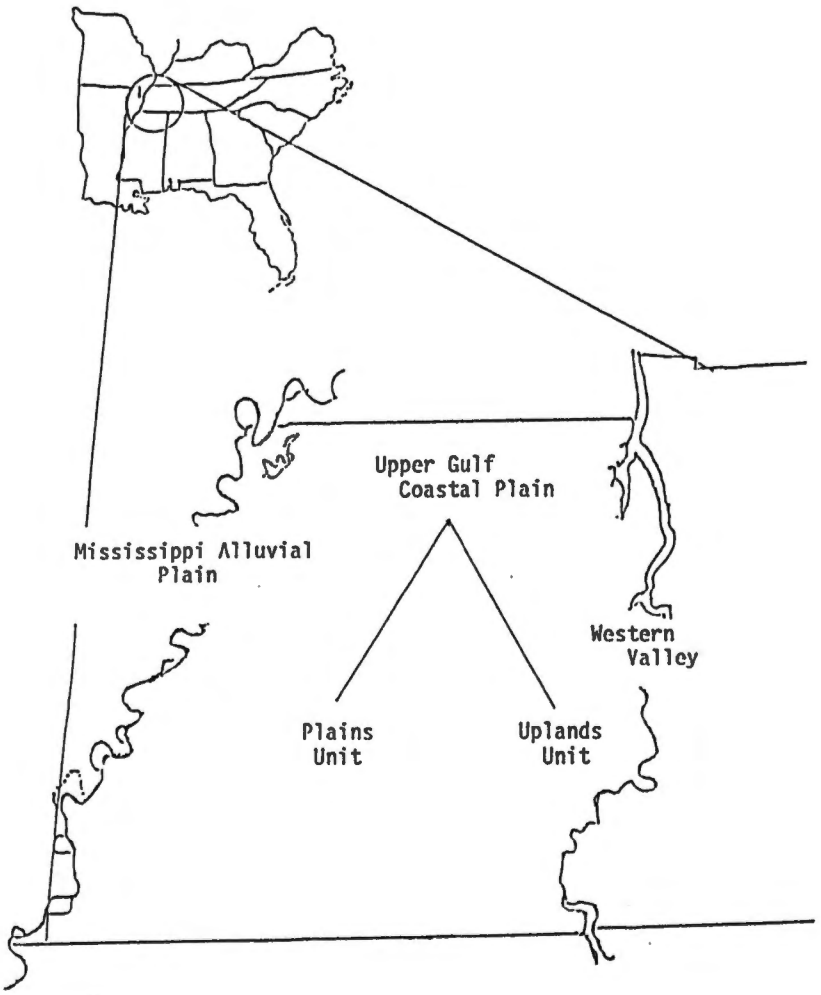


Figure 1. Physiographic regions occurring in west Tennessee (adapted from Wilkerson 1973).

Tennessee. This province is highly dissected by ridges and narrow floodplains. Only a small portion of this study was conducted in the Western Valley. For analysis, study sites in the Western Valley were combined with those in the Mississippi Alluvial and Upper Gulf Coastal Plains. Dominant landscape features in all provinces were formed by rivers and erosion of loess soils (Wilkerson 1973).

West Tennessee has a warm, humid climate, with mild winters and long summers. Average annual temperature is 17° C. July is the hottest month, with average temperatures of 27° C. Temperatures exceed 56° C an average of 69 days each year. Maximum temperatures of 42° C may be expected during July and August. The coldest month is January, with an average temperature of 6° C. On the average, sixty days each year have minimum temperatures of less than 0° C. Minimum temperatures of -24° to -26° C may be expected during January and February (Fribourg et al. 1973).

Average annual rainfall in west Tennessee is 122 cm. October is the driest month, averaging 7.6 cm of rain. The wettest month is January, with an average rainfall of 15.2 cm. Winter rains are steady and saturating, lasting 2 to 4 days. Spring and summer rains are characterized by short duration thunderstorms, which may be severe at times and cause flash flooding (Fribourg et al. 1973).

II. Forested wetlands in west Tennessee

West Tennessee's wetland habitats were classified using the United States Fish and Wildlife Service (USFWS) method, e.g., "lands transitional between terrestrial and aquatic systems where the water table is at or near the surface or the land is covered by shallow water" (Cowardin et al. 1977). Habitats were generally riverine or palustrine systems. Riverine systems are defined as "wetlands that are contained within an artificial or natural channel that periodically or continuously holds moving water" (Cowardin et al. 1977). West Tennessee streams fall into the lower perennial subsystem. Streams are characterized by a low gradient and low water velocity. The substrate is mainly sand and/or mud. Palustrine systems are defined as "all nontidal wetlands dominated by trees, shrubs, persistent emergents or emergent mosses or lichens" (Cowardin et al. 1977). Palustrine systems are typically found in the floodplain reaches of Riverine systems. There are no recognized subsystems in the classification. Classes of this system found in west Tennessee include emergent wetlands (characterized by erect, rooted herbaceous hydrophytes), scrub-scrub wetlands (characterized by a dominance of woody vegetation less than 6 m), and forested wetlands (characterized by a dominance of woody vegetation greater than 6 m in height). The most common sub-classes

were deciduous scrub-scrub, deciduous forest, dead scrub-scrub, and dead forest wetlands.

Sixteen forest communities were identified in west Tennessee bottomlands by Patterson and DeSelm (1989). The most hydric forests were dominated by cypress. Driest forests found in floodplains of west Tennessee rivers were dominated by boxelder. Hydrology in driest forests was typically manipulated by channelization and man-made levees. Sweetgum-mixed bottomland hardwoods was the most common community type in west Tennessee.

Steed (1979) described forest characteristics of the Hatchie River National Wildlife Refuge, Haywood County, Tennessee. Hydroseric types included swamps, sloughs, and low flats; these were dominated by bald cypress, tupelo, or overcup oak. Mesic communities broadly concurred with those described by Patterson and DeSelm (1989). The most common community type was sweetgum-cherrybark oak-swamp chestnut oak. The driest community type in forests with a relatively undisturbed hydrology was dominated by American beech and yellow-poplar.

III. Rivers of West Tennessee

Major river systems in west Tennessee are the Wolf, Loosahatchie, Hatchie, Forked Deer, Obion, Mississippi, and Tennessee rivers (Figure 2). About 228,575 ha of wetlands remained in west Tennessee at the time of this census,

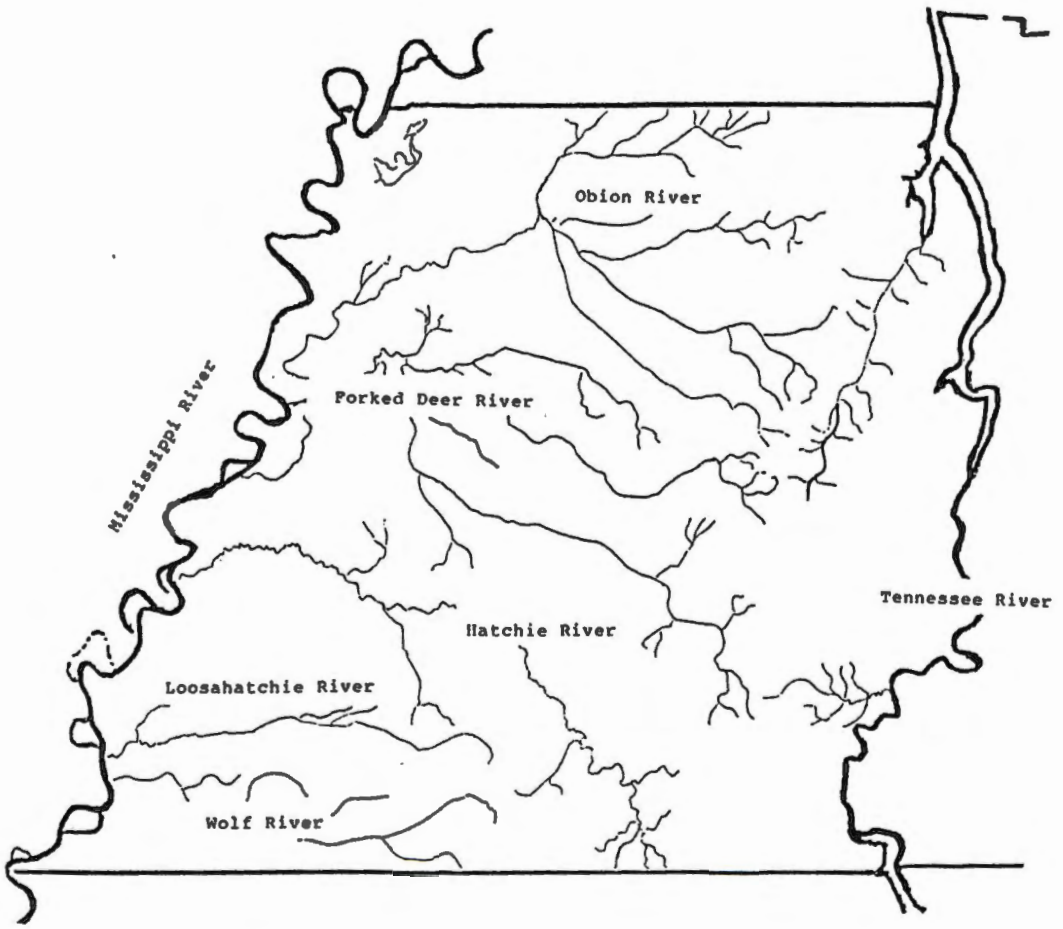


Figure 2. Location of the major river systems of west Tennessee.

constituting about 75% of the state's wetlands resource (Durham et al. 1988). Study sites were located in these floodplain forests.

Human impacts to forested wetlands in west Tennessee include channelization, high grade logging, sedimentation, point and non-point source pollution, agriculture, and urbanization.

Beaver (Castor canadensis) populations in west Tennessee have increased in the recent past as well. Beaver dams pond water, resulting in a change in both structure and composition of bottomland hardwood forest stands. Structural changes in forests include the addition of permanent water, an increase in the number of dead trees, and a resultant decrease in percent canopy closure. Compositional changes result in a dominance of trees which require standing water, such as cypress and water tupelo. Over 80% of the black willow and black willow-cypress communities sampled in west Tennessee had been impacted by beavers (Patterson and DeSelm 1989).

The amount of disturbance varied widely among watersheds. The Hatchie has been the least disturbed relative to other west Tennessee rivers. Seral stages ranged from early successional forests to forests approximately 80 years old. Ten of 60 (16%) study sites were disturbed during the 2 year period of the survey.

Wolf River

The Wolf River flows 106 km through northern Mississippi and southern west Tennessee, draining a watershed of 208,000 ha. Approximately 14,577 ha of bottomland hardwood forest remain in the Tennessee portion of the basin, mostly in tracts of 2,000 to 4,000 ha (Durham et al. 1988). Forest tract size where study sites were located averaged 1,525 ha (se=722 ha, range=721-2234 ha, n=6 sites). Water tupelo, bald cypress, and green ash were dominant tree species on study sites. The driest forested wetland community type, boxelder, occurred commonly in the Shelby County portion of this floodplain; the wettest type, water tupelo, occurred commonly in the Fayette County portion (Patterson and DeSelm 1989). Agriculture and forestry are dominant land uses in the Fayette County portion of the river. In Shelby County, industry occupies land space in the floodplain.

Loosahatchie River

The Loosahatchie River is 105 km long, and drains an area of 189,840 ha. Approximately 10,752 ha of bottomland hardwood forest remain in the basin, mostly in tracts of 40 to 200 ha (Durham et al. 1988). No tracts were larger than 2,000 ha. Forest tract size where sites were located averaged 211 ha (se=58 ha, range=146-296 ha, n=5 sites). Sweetgum-mixed bottomland hardwoods was the most common

community type on study sites (Patterson and DeSelm 1989). Dominant tree species included sweetgum, cherrybark oak, and water oak. Severe channelization has occurred on upper portions of the river. Land use in the basin is predominantly agriculture and forestry.

Hatchie River

The Hatchie River flows 354 km through north Mississippi and west Tennessee, draining a watershed of 665,600 ha. Approximately 51,961 ha of bottomland hardwood forest remain in the Tennessee portion of the basin, the largest remaining acreage among west Tennessee rivers. Most tracts were 400 to 2,000 ha, although many other tracts ranged in size from 2,000 to more than 4,000 or ha (Durham et al. 1988). Forest tract size where sites were located averaged 4,871 ha (se=3,750 ha, range=951-9,812 ha, n=12 sites). Sweetgum-mixed bottomland hardwood was the most common community type on study sites (Patterson and DeSelm 1989). A range in forest cover types represent hydroseric to mesic soil conditions (Steed 1979). Dominant tree species included sweetgum, water tupelo, green ash, and bald cypress. That portion of the river occurring in Tennessee has been designated a state scenic river, allowing protection from excessive channelization, pollution, and poor forestry practices. No channelization has occurred on the main stem of this river. However, most tributaries have

been channelized. Forestry and agriculture are dominant land uses.

Forked Deer River

The Forked Deer River is a large, fan-shaped system that drains 537,600 ha of central west Tennessee. Approximately 40,986 ha of bottomland hardwood forest remain in the basin, mostly in tracts of 400 to 2,000 ha (Durham et al. 1988). Forest tract size where study sites were located averaged 2,807 ha (se=3,342 ha, range=496-8,158 ha, n=9 sites). Red maple-mixed bottomland hardwoods was the most common community type on study areas (Patterson and DeSelm 1989). Dominant tree species included black willow, green ash, and red maple. Natural processes joined the major flow of this river with the Obion River near Hales Point, Dyer County, Tennessee. As a result, these rivers are often referred to collectively as the Obion-Forked Deer River Basin. The floodplain forests above the confluence of these rivers treated separately. Channelization of the main stem and tributaries has occurred over most of the watershed. Predominant land use is agriculture.

Obion River

The Obion River drains 614,400 ha of north west Tennessee. Approximately 47,277 ha of bottomland hardwood forest remain in the basin, mostly in tracts of 400 to 2,000 ha (Durham et al. 1988). No tracts were larger than 4,000

ha. Forest tract size where study sites were located averaged 1,326 ha (se=903 ha, range=190-2,246 ha, n=8 sites). Sweetgum-mixed bottomland hardwoods was the most common community type on study areas (Patterson and DeSelm 1989). Dominant tree species included bald cypress, red maple, and sweetgum. Severe channelization has occurred on the river. Agriculture is the dominant land use.

Tennessee River

The Tennessee River in west Tennessee flows northward for approximately 176 km. Bottomland hardwood forest acreage on the west side of the river totaled approximately 28,457 ha (Durham et al. 1988). All study sites were located in the White Oak Creek State Wildlife Management Area, a 2,079 ha forest tract (n=5 sites). White Oak Creek was the only area representing the Western Valley physiographic region. Forest characteristics were similar to those forests sampled in the Upper Gulf Coastal Plain. Red maple-mixed bottomland hardwoods and sweetgum-mixed bottomland hardwoods were the most common community types of the study sites (Patterson and DeSelm 1989). Dominant tree species included red maple, green ash, and sweetgum. Dominant land uses are agriculture, forestry, and wildlife management. The Tennessee Valley Authority (TVA) regulates the flow of the Tennessee River for hydro-electric power. Two dams affect river flow and water levels.

Mississippi River

The Mississippi River borders west Tennessee for nearly 254 km. Approximately 36,696 ha of bottomland hardwood forest remain in the floodplain, mostly in tracts of 4,000 or more ha (Durham et al. 1988). MacDonald et al. (1979) estimated less than 22% of the original acreage of wetlands remained in this floodplain. Forest tracts in the Mississippi River floodplain were mostly large isolated blocks, whereas forests in other floodplains were linear tracts. The Anderson-Tully Wildlife Management Area and Chickasaw National Wildlife Refuge comprise 35% of the bottomland hardwood forest in the Mississippi River floodplain. Forest tract size where study sites were located averaged 2,954 ha (se=2,807, range=41-8158 ha, n=14 sites). Study sites represented the Mississippi Alluvial Plain. Forest characteristics were similar to forests in the Gulf Coastal Plain. Sugarberry-mixed bottomland hardwoods was the most common community type found on study sites; bald cypress was more common here than in other watersheds (Patterson and DeSelm 1989). Sugarberry, bald cypress, and green ash were dominant tree species. Agriculture is the dominant land use.

CHAPTER III

METHODS

Study sites were selected in the floodplain of each major river system found in west Tennessee. Study sites were: 1) located on forested wetlands, 2) situated on Quaternary, alluvial deposited soil, 3) represented by early, middle, or late seral stages, 4) a minimum of 40 ha, 5) represented by relatively homogeneous vegetation, and 6) accessible to field workers.

I. Site selection

River miles for each of the major river systems in west Tennessee were delineated on U. S. Geologic Survey (USGS) topographic maps. Three hundred river miles were selected by computer generated random numbers or hand drawn from the universe of total river miles. Lands upstream from, and adjacent to, that particular river mile represented potential study sites. Random coin toss established the side of the river and the placement of study sites in the floodplain (i.e. proximity to river or bluff). The number of study sites selected per river system was based on total watershed acreage, the most reliable figure available at the time of site selection.

Current land use, forest cover type (where possible), access locations, and tract size of potential study sites were determined from analysis of aerial photographs. This analysis eliminated 163 of 300 sites that did not fit minimum criteria. Field visits to the remaining 137 sites verified forest cover type, and determined percent canopy closure and relative homogeneity of vegetation. Potential study sites were then categorized by river system, percent canopy closure, canopy tree size class, and tree species composition.

Of the remaining 137 sites, 60 (20% of the original 300) were selected by random coin toss. Vegetation measurements were lost during field work for 1 site on Big Sandy Creek of the Tennessee River. The number of sites per watershed was determined by watershed acreage. Bird and vegetation sampling was conducted on 59 forested wetland sites (Figure 3). Latitude and longitude coordinates of the center of each site are listed in Appendix I.

II. Sampling Design

Sampling design was consistent for all study sites. A 1 km transect was delineated, originating from the point of

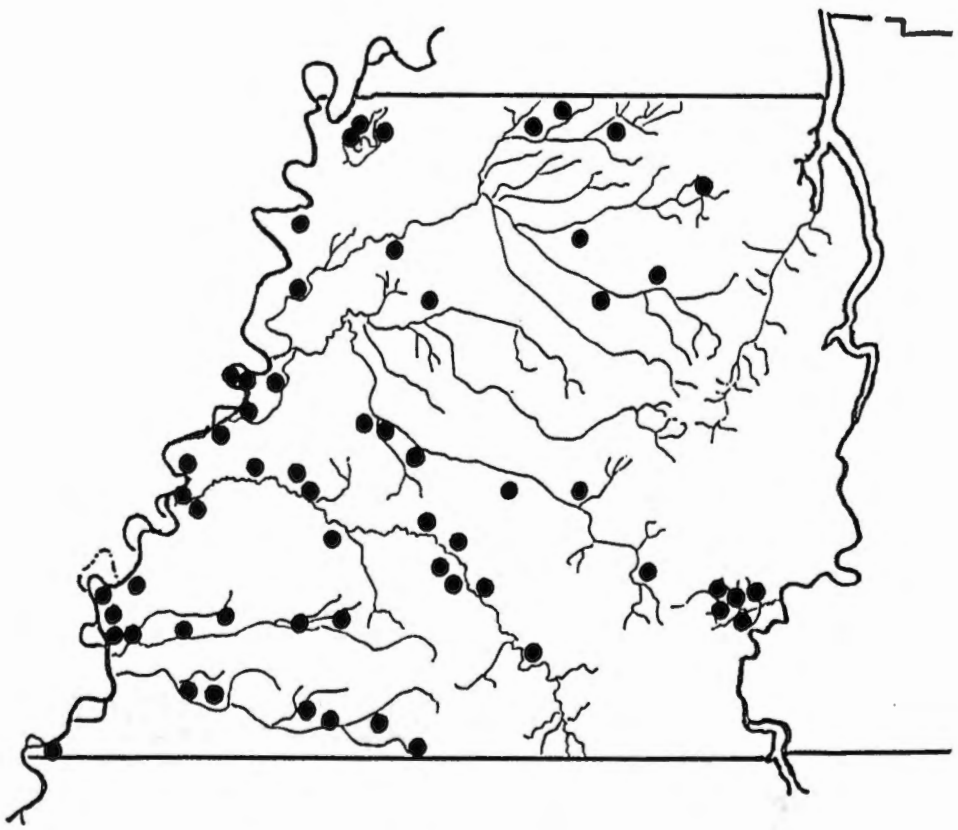


Figure 3. Location of 59 forested wetland sites in west Tennessee where birds and vegetation were sampled. Latitude and longitude for sites are listed in Appendix I.

easiest access at each study site for convenience to field workers. Transect azimuth was determined by computer generated random numbers. Bird surveys were executed along transects. Vegetation was sampled at 6 plots established along transects. One vegetation sampling plot was established non-randomly at the mid-point of each transect. For other plots, distances from the transect to plot centers were determined by computer generated random numbers. Scientific names of plant species used in this thesis are listed in Appendix II.

III. Bird sampling

Field Sampling

Birds were censused during breeding and winter seasons from May 1985 to February 1987. The fixed-width line transect method (Jarvinen and Vaisanen 1975) was used to sample bird populations. A 1 km transect was walked in 1 hour, a pace of 50 m every 3 minutes. Birds were detected by any cue (i.e. sight, song, or chip note) and identified. Individuals were determined to be in 1 of 2 belts parallel to the transect. The main belt was 0 to 25 m either side of the transect. The supplementary belt was all area beyond 25 m either side of the transect mid-line.

A total of 342 transect counts were conducted during the survey, 180 during breeding seasons. Breeding season surveys were conducted during May, June, and early July of

1985 and 1986. Time of day affects bird census results (Shields 1977). Sampling usually was completed during the first 4 hours after sunrise. Rarely, counts continued to 6 hours after sunrise because of weather conditions or travel delays.

Winter season surveys (162 transects) were conducted in December, January, and February of 1985-86 and 1986-87. Birds were censused daily during morning and evening hours. Morning surveys were completed the first 6 hours after sunrise. Evening surveys were timed so the observer could return to the main road or car by nightfall.

Transect counts were repeated twice on sites during breeding and winter seasons of both years. Bird surveys on sites were 25 to 30 days apart to account for migrant bird fluctuations and varying breeding schedules. Four observers sampled bird populations over the course of the study. Two observers sampled at 40 sites the first year. Four observers sampled at 55 sites the second year. During all seasons, 1 site was sampled simultaneously by 2 observers as a control for observer bias. During the second year 2 sites were sampled simultaneously by 2 observers.

Analysis of bird data

In the analysis and discussion of these data, 3 assumptions were made. First, I assumed that forest characteristics and bird abundance on study sites typified the entire floodplain forest within that watershed. Random

site selection processes used in this study and broad geographic coverage within watersheds made this a valid assumption. Cumulative impacts of minor development projects are detected at watershed scales (Gosselink et al. 1989). The assumption is necessary to examine fully differences in bird parameters among watersheds.

Second, I assumed that given proper habitat characteristics within the geographic range of a species, viable populations of that species may occur. Measured physical properties of the habitat were used to describe habitat relationships for a given species. Competition, predation, weather, and food abundance were not measured directly in this study. This procedure is typical for developing habitat models (U.S. Army Corps of Engineers 1980, Schamberger and O'Neil 1986).

Third, I assumed that high densities of a particular species equated to high quality habitat for that species. Transect methods that acquire density estimates and infer habitat utilization are presently common and accepted, despite drawbacks. Van Horn (1983) described situations, however, where high densities may not result from high quality habitat. For example, an unusually high overwinter survival may force many individuals to accept sub-optimal habitats within forests. This may temporarily "misplace" high densities of a species until population levels stabilize. Other factors confounding bird-habitat relationships include species at the edge of their

geographic range, species detectability, and the study design itself (Best and Stauffer 1986). Bell and Ferrier (1985) contended that the impact of confounding factors may be reduced by keeping variability consistent under all settings.

Habitat models should be developed only for birds that are strongly associated with the habitat and for which large amounts of information are available in the data base (Fry et al. 1986). The most abundant breeding and winter birds were selected for habitat models in this study. Strong relationships to forested wetland habitats for selected species were quantitative, rather than qualitative. Dickson (1978) listed the selected species in classes ranging from "present" to "abundant" in most forests of the southeastern United States.

IV. Vegetation sampling

The vegetation on 351 plots was sampled by botanist Vernon Bates, on contract with the Ecological Services Division, Tennessee Department of Conservation. Vegetation samples were taken on 6 square, 0.1 ha plots per study site. The structure and species composition of the canopy, subcanopy, shrub, and herbaceous layers were measured. Diameter at breast height (dbh) was determined for trees greater than 12.5 cm. A count by species was made for all stems between 2.5 and 12.5 cm dbh. Percent bare ground,

leaf litter, and brushpile coverage was estimated on a .025 ha subplot.

Height and dbh of all snags over 1 m tall were measured. Snags were categorized by 4 stages of decay. Category 1 was the youngest, with branches and bark still intact. Snags in category 2 had branches gone and loose bark. Category 3 had no branches or bark remaining, but had the trunk still mostly intact. Category 4 was the latest stage of decay, with no branches or bark, but the main trunk broken. Fallen logs were recorded by length, width, and number per plot. Intensity, type of, and time since disturbance was estimated.

Tract sizes for forests were delineated on USGS topographic maps with a planimeter (Durham et al. 1988). Borders used for delineation of forest tracts included roads, power lines, agricultural fields, bluffs, and the river.

A summary of techniques and data were presented by Durham et al. (1988). Patterson and DeSelm (1989) later analyzed these data to classify forest community types in west Tennessee forested wetlands.

V. Terminology

Breeding bird density is expressed as pairs per 100 ha. Observations during breeding season were mostly of singing males, which were assumed to be defending a territory and

mate. Winter bird density is expressed as birds per 100 ha, since individuals are not assumed to be defending territory at this time of year. Abundant birds were those species which comprised greater than 80% of total bird density. Importance values for trees were generated using number of individuals and basal area of a given species, and comparing them to total number of individuals and basal area of a plot.

CHAPTER IV

STATISTICAL ANALYSIS

I. Density estimation

Density estimates for birds were generated using techniques developed for the Finnish Line transect method (Jarvinen and Vaisanen 1975). This method provides a technique that computes a coefficient of detection for species and observers; the coefficient standardizes bird detectability and reduces observer bias. Density estimates are derived from the proportions of main and supplementary belt observations. The method assumes a random distribution of the distances to the birds from the transect and that observers detect all birds found on the transect line itself.

The linear model of the method was used to derive density estimates (Jarvinen and Vaisanen 1975). The model assumes that the probability a bird is observed decreases linearly with the right-angle distance from the transect. Lateral detectability is symbolized as

$$L_1(D) = -kD + 1$$

where k is a positive, species- or observer-specific constant and D is the distance in meters to the bird (Jarvinen and Vaisanen 1975). Since there is an assumption

of perfect efficiency by the observer at D = 0, the constant 1 is added to the equation.

The species- or observer-specific constant (k) is symbolized as

$$k = (1 - \sqrt{1-p}\ )/W$$

where p is the proportion of main to supplementary belt observations and W is the width of the main belt from the observer (Jarvinen and Vaisanen 1975). The proportion of main belt observations (p) is symbolized as

$$p = 2kW - k^2W^2$$

(Jarvinen and Vaisanen 1975).

To achieve a standard among species density estimates, densities were converted to number of individuals per 100 ha by

$$C_1 = 10^3\ Nk/T$$

where N is the total number of individuals, k is defined as above, and T is the total transect length in meters.

Standard error was included for most estimates of density. Standard error describes the amount of variation found among samples. For example, a small standard error of a large sample would signify a more uniform population than would a large standard error of a similar sample. Standard error is symbolized as

$$se = \sqrt{s^2_{yx}/\ S_{xx}}$$

where s^2_{yx} is the variance around the regression line in the sample, and S_{xx} is mean error estimate (Younger 1985).

II. Normalization of variables

Statistical analysis, as performed for this thesis, requires a normal distribution of variables. Procedures to normalize some bird densities and vegetation variables were natural log transformation, deletion of outliers, ARC SIN transformation, and square root transformation (Appendix III). Of densities for abundant breeding and winter birds, 12 were normally distributed without transformation procedures. Seven densities required a log transformation, whereas 6 densities required the elimination of outliers. Models for 3 winter birds (White-throated Sparrow, Common Grackle, Mallard) were not statistically significant. Densities for Northern Cardinal and Downy Woodpecker were normal for breeding season, but required log normal transformation for winter. One species, Yellow-rumped Warbler, required both log transformation and elimination of outliers.

Six structural variables of the vegetation were normally distributed without transformation procedures. Other vegetation variables needed log normal, ARC SIN, and square root transformations. Of structural variables, 5 required a log transformation, 2 required an ARC SIN transformation, and 2 required square root transformation.

Importance values of tree species used in this thesis were normally distributed without transformation.

III. Development of bird abundance and watershed comparisons

Each study site was visited at least twice during 1 breeding and 1 winter season. Bird density, number of individuals, and number of species were averaged from the totals of each transect count for sites. This number was used instead of absolute totals for each site and species. Absolute totals were biased by migrant bird influx, breeding schedules, and unevenly distributed visits to sites. A standardized total allows a more accurate comparison of individual and community bird parameters in physiographic provinces and watersheds.

IV. Development of species accounts

The Statistical Analysis System (SAS 1985) was used to execute regression tests on bird data. No appreciable differences were found in average number of species or total density per study site between years. Results from sites visited 2 years were combined with results from sites visited 1 year. No appreciable differences existed among observers for number of species per transect count. Fewer than 20 species made up greater than 80% of the total density during both seasons (Figure 4); habitat models were developed for these species.

Univariate analysis was used as a preliminary step to determine habitat relationships for birds during both

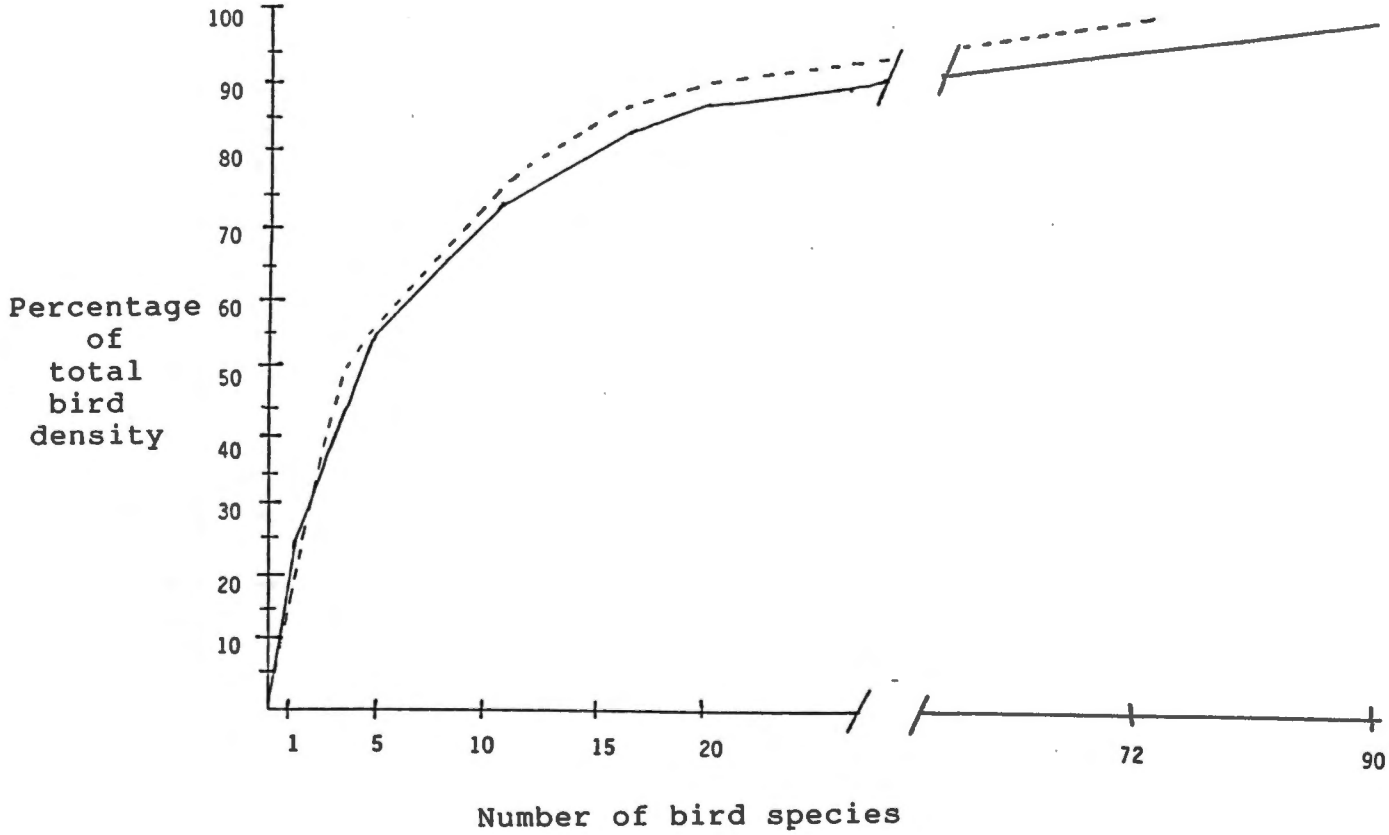


Figure 4. Numbers of bird species comprising percentiles of total bird density. The solid line represents breeding season, the dashed line winter.

seasons (e.g. Anderson and Shugart 1974). This step compared bird densities to single variables of vegetation structure and composition. Correlation analysis of bird densities and vegetation variables revealed more significant relationships than would be expected by chance alone. Of 558 tests, there were 104 significant correlations ($p \leq .05$). Significant relationships occurred more often during breeding than winter season. Furthermore, significant relationships occurred more often with structural variables (e.g. canopy closure, shrub cover) rather than tree species composition (Appendix IV). Variables important to birds were then used to develop multiple regression models.

Multiple regression was used to finalize habitat models for abundant species in breeding and winter seasons. The model used for regression analysis was

$$Y = a + b_1x_1 + b_2x_2 + b_3x_3 + \ldots\ldots + b_kx_k + u$$

where Y is the linear function of predictor variables, a is the Y-intercept, $b_1x_1 \ldots\ldots\ldots b_kx_k$ are predictor variables, and u is the amount of error (Younger 1985).

Multicollinearity problems arise in multiple regression analysis when predictor variables are highly correlated. This results in unreliable measures because the effects of some variables are confounded with the effects of other variables in the model (Younger 1985). In this study, for example, total basal area could be used to predict percent canopy closure, average tree height, or the number of trees per plot. Highly correlated predictor variables were

determined and were not used together in multiple regression analysis.

Each habitat model significant at the .05 level consisits of 3 or 4 vegetation variables. Regression lines of significant vegetation variables were plotted independently with bird density for illustrative purposes. Around each regression line, 95% confidence limits were plotted as well. Confidence limits provide an estimate of the range of values under which the sample is considered true. The model for confidence limits was represented by

$$P\ (u - 1.96\sigma/\sqrt{n} < Y < u + 1.96\sigma/\sqrt{n}\ )$$

where P equals the summation of population estimates, u equals the sample mean, and n the number of samples in the population.

CHAPTER V

RESULTS

One hundred thirty species of birds, encompassing 68,211 individuals, were observed. Forty-eight species were permanent residents, 42 were summer residents, 24 were winter residents, and 16 were transients. Wide ranges of bird abundance and distribution were represented (Appendix V).

I. Breeding season birds

Ninety species were observed during breeding seasons. An average of 113 individuals and 28 species occurred on individual sites. The number of individuals ranged from 45 to 146, and numbers of species from 15 to 40. Total density averaged 693 pairs per 100 ha.

Bird abundance in west Tennessee

Sixteen species (18%) were abundant breeding season residents in west Tennessee forested wetlands, comprising greater than 80% of the total density of birds (Table 1). Summer resident birds were more common than permanent residents among species considered abundant on study

Table 1. Abundant breeding birds of forested wetlands in west Tennessee. This table lists density per species (pairs per 100 ha), cumulative percentage of density per site, and bird residency status (Waldron 1987) in west Tennessee.

Abundant breeding birds	Density (pairs per 100 ha)	Cumulative percentage of density	Residency status
Blue-gray Gnatcatcher	147	21%	summer
Northern Cardinal	69	30%	permanent
Acadian Flycatcher	57	38%	summer
Carolina Chickadee	51	45%	permanent
Prothonotary Warbler	51	53%	summer
Indigo Bunting	36	58%	summer
Tufted Titmouse	27	62%	permanent
Downy Woodpecker	24	65%	permanent
Ruby-throated Hummingbird	20	68%	summer
Common Grackle	19	70%	permanent
Great-crested Flycatcher	18	73%	summer
Red-eyed Vireo	16	75%	summer
Red-bellied Woodpecker	15	77%	permanent
Northern Parula Warbler	13	79%	summer
White-eyed Vireo	11	81%	summer
Red-winged Blackbird	10	82%	permanent

sites. Eleven species (12%) were present across the geographic breadth of west Tennessee's wetland forests, but occurred in relatively low densities. These species were found on 45 or more of 59 sites sampled (Table 2). Of these, 6 were summer residents and 5 were permanent residents in west Tennessee. Twenty species (22%) occurred on fewer than 4 sites. Three, however, were either rare in west Tennessee or were difficult to census: Mississippi Kite, Hooded Merganser, and Black-crowned Night Heron.

Comparisons among watersheds

Density - Highest densities of breeding birds occurred in the Mississippi and Hatchie River floodplain forests (Table 3). The lowest average density of birds occurred in the Obion River floodplain. Transient species added less than 1% to total breeding bird density. High average density of the breeding wood warbler complex in west Tennesse (11 species) coincided with the percentage of forest tracts greater than 2000 ha in watersheds (Table 4).

Species richness - Surveys during intense migration periods (1 May through 19 May) were, on average, 1.6 species richer than surveys conducted from 20 May through 20 June. Highest species richness, with and without transients, occurred in floodplain forests of the Mississippi

Table 2. Widespread breeding birds in west Tennessee wetland forests, occurring on 45 or more of 59 sites. Density per 100 ha is relatively low. Residency status in west Tennessee (Waldron 1987) is included.

Widespread breeding birds	Number of sites	Density (pairs per 100 ha)	Residency status
Yellow-billed Cuckoo	57	9	summer
Carolina Wren	57	9	permanent
Brown-headeds Cowbird	57	8	permanent
Eastern-wood Pewee	54	5	summer
American Crow	53	2	permanent
Blue Jay	48	2	permanent
Pileated Woodpecker	47	2	permanent
Summer Tanager	47	5	summer
Kentucky Warbler	46	7	summer
White-breasted Nuthatch	45	4	permanent
Wood Thrush	45	5	summer

Table 3. Breeding bird density and number of species among west Tennessee watersheds. Species richness in watersheds are compared with and without transient species. Standard error (± SE) is included for density estimates and species richness. Number of sites sampled (n) without transients were less than the total number of sites in most cases.

River system	Mean density per site (± SE) (pairs per 100 ha)	Mean number of species (± SE) per site		Range in number of species per site	
		with transients	without transients	with transients	without transients
		n=number of sites sampled			
Mississippi	830 ± 114	28.5 ± 4 n= 14	27.6 ± 3 n= 12	20 - 39	20 - 32
Hatchie	734 ± 137	28.0 ± 5 n= 12	26.2 ± 4 n= 9	19 - 40	20 - 32
Tennessee	698 ± 112	31.1 ± 3 n= 5	30.9 ± 3 n= 5	25 - 35	25 - 34
Wolf	692 ± 124	28.9 ± 4 n= 6	26.3 ± 1 n= 3	24 - 36	25 - 28
Forked Deer	679 ± 99	27.5 ± 5 n= 9	26.0 ± 6 n= 8	15 - 37	18 - 36
Loosahatchie	677 ± 257	28.2 ± 6 n= 5	26.0 ± 7 n= 5	18 - 37	18 - 37
Obion	662 ± 176	28.0 ± 5 n= 8	26.6 ± 5 n= 7	19 - 39	19 - 34

Table 4. Percentage of forested tracts greater than 2000 ha compared to warbler density and richness among watersheds. Warbler density is expressed as pairs per 100 ha, warbler richness includes 11 breeding residents occurring on sites.

Watershed	Percentage of forest acreage in tracts greater than 2000 ha	Warbler density (pairs per 100 ha)	Warbler richness (11 species)
Hatchie	46%	150	11
Mississippi	45%	144	11
Wolf	44%	131	11
Forked Deer	22%	117	10
Obion	17%	117	11
Tennessee	15%	116	11
Loosahatchie	0%	105	10

River and forests of White Oak Creek, Tennessee River. Lowest species richness per site occurred in the Forked Deer and Loosahatchie floodplain forests. The number of species found per site ranged from 15 to 37 in the Forked Deer watershed, the broadest range of any west Tennessee river. The narrowest range in number of species occurred in White Oak Creek of the Tennessee River floodplain, probably because of the limited geographic distribution of sites.

Species accounts

Blue-gray Gnatcatcher - Density estimates ranged from 56 to 265 pairs per 100 ha. This summer resident was most abundant in forests with a high total basal area, low percentage of total shrub cover, and American elm as a dominant canopy tree (Figure 5). These elements accounted for 20% of the total variation in this species' density. A low percentage of total shrub cover was the strongest predictor of high density for this species. Forests with 150 or more pairs per 100 ha averaged less than 40% total shrub cover. Forests with less than 150 pairs per 100 ha averaged 60 to 80% total shrub cover.

Northern Cardinal - Density estimates ranged from 26 to 142 pairs per 100 ha. High breeding season densities of this permanent resident were in forested tracts with complex vertical structure. This species was most

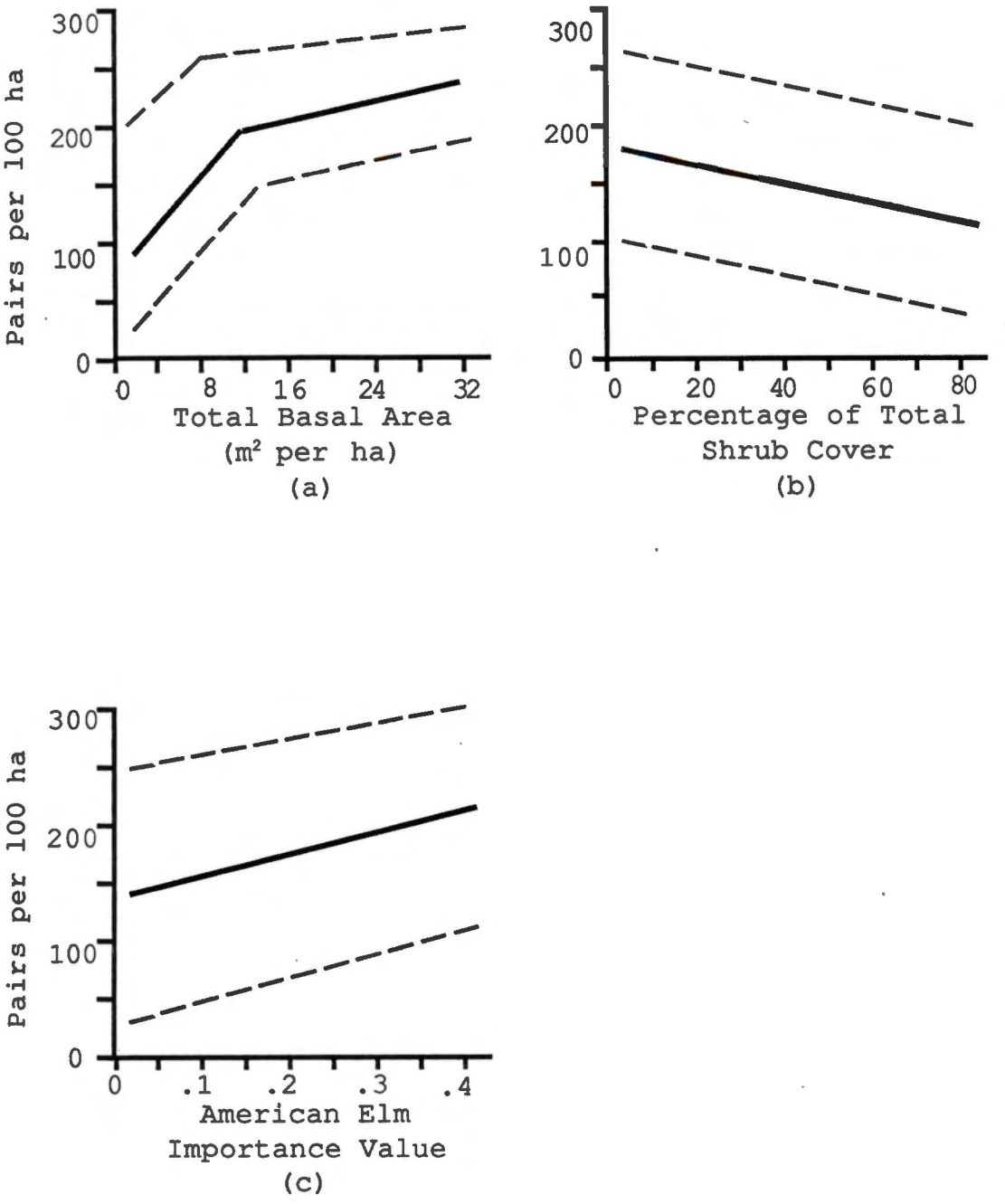


Figure 5. Regression of Blue-gray Gnatcatcher density with significant habitat variables of forested wetlands.

abundant in forests with dense canopy closure, and a high percentage of shrub and brushpile coverage; sugarberry was the dominant canopy tree (Figure 6). These elements accounted for 29% of the total variation in this species' density. Total shrub cover was the strongest predictor of density. Forests with 40 or more pairs per 100 ha averaged at least 50% total shrub cover, whereas forests averaging less than 50% held fewer cardinals.

Acadian Flycatcher - Density estimates ranged from 2.6 to 118 pairs per 100 ha. This summer resident was most abundant in forests of oak and slippery elm that had a tall dense canopy and low percentage of total shrub cover (Figure 7). These elements accounted for 42% of the variation in species density. Low total shrub coverage was the strongest predictor of high density for this species. On average, less than 3 pairs per 100 ha occurred in forests with greater than 45% total shrub cover.

Carolina Chickadee - Density estimates ranged from 5 to 132 pairs per 100 ha. During the breeding season, this permanent resident was most abundant in forests with high total basal area and low importance values for water tupelo and slippery elm (Figure 8). These elements accounted for 14.7% of the variation in this species' density. Rarity of slippery elm in forests was the strongest predictor of high densities. Forests with 20 or more pairs per 100 ha

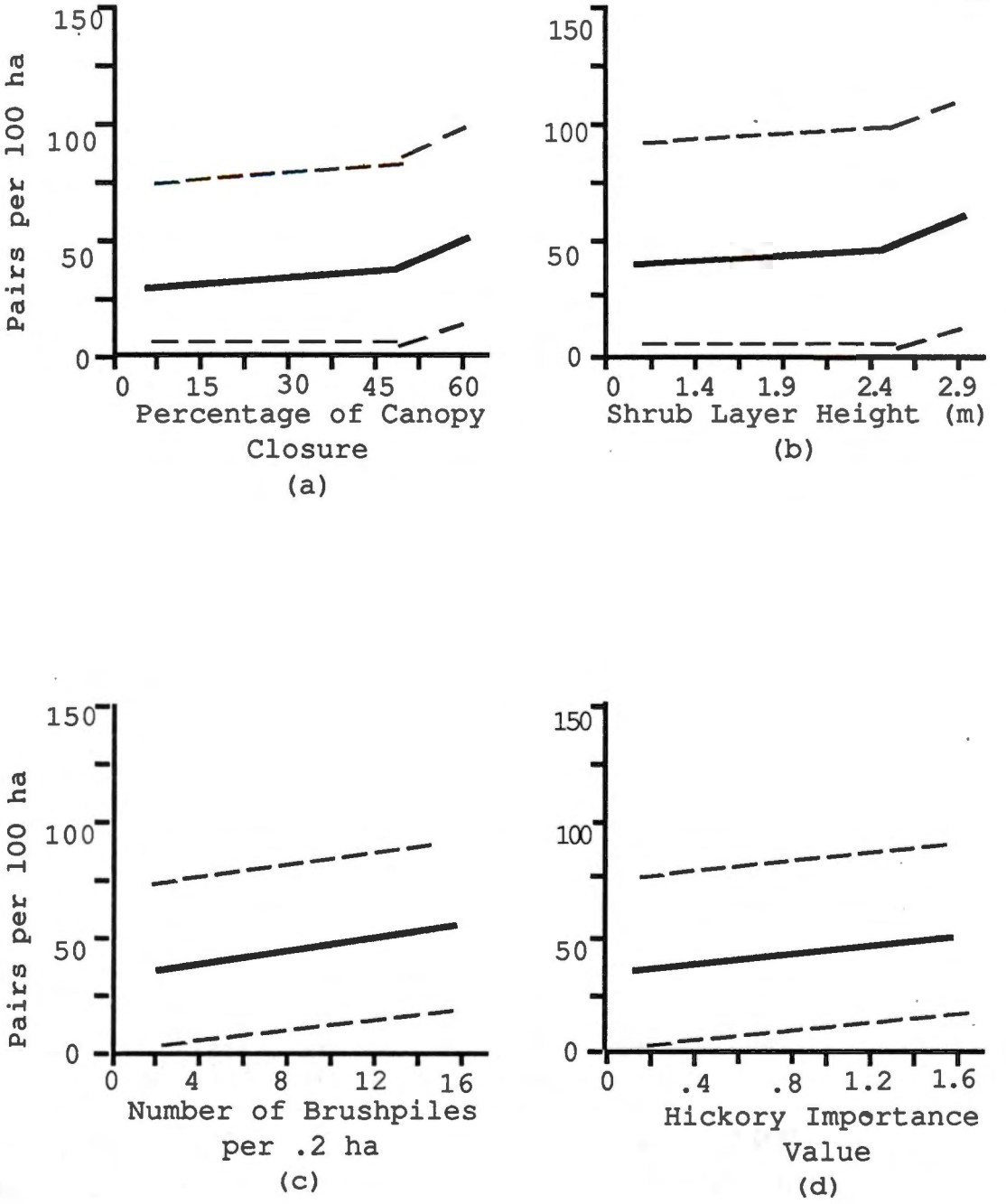


Figure 6. Regression of Northern Cardinal density with significant habitat variables of forested wetlands.

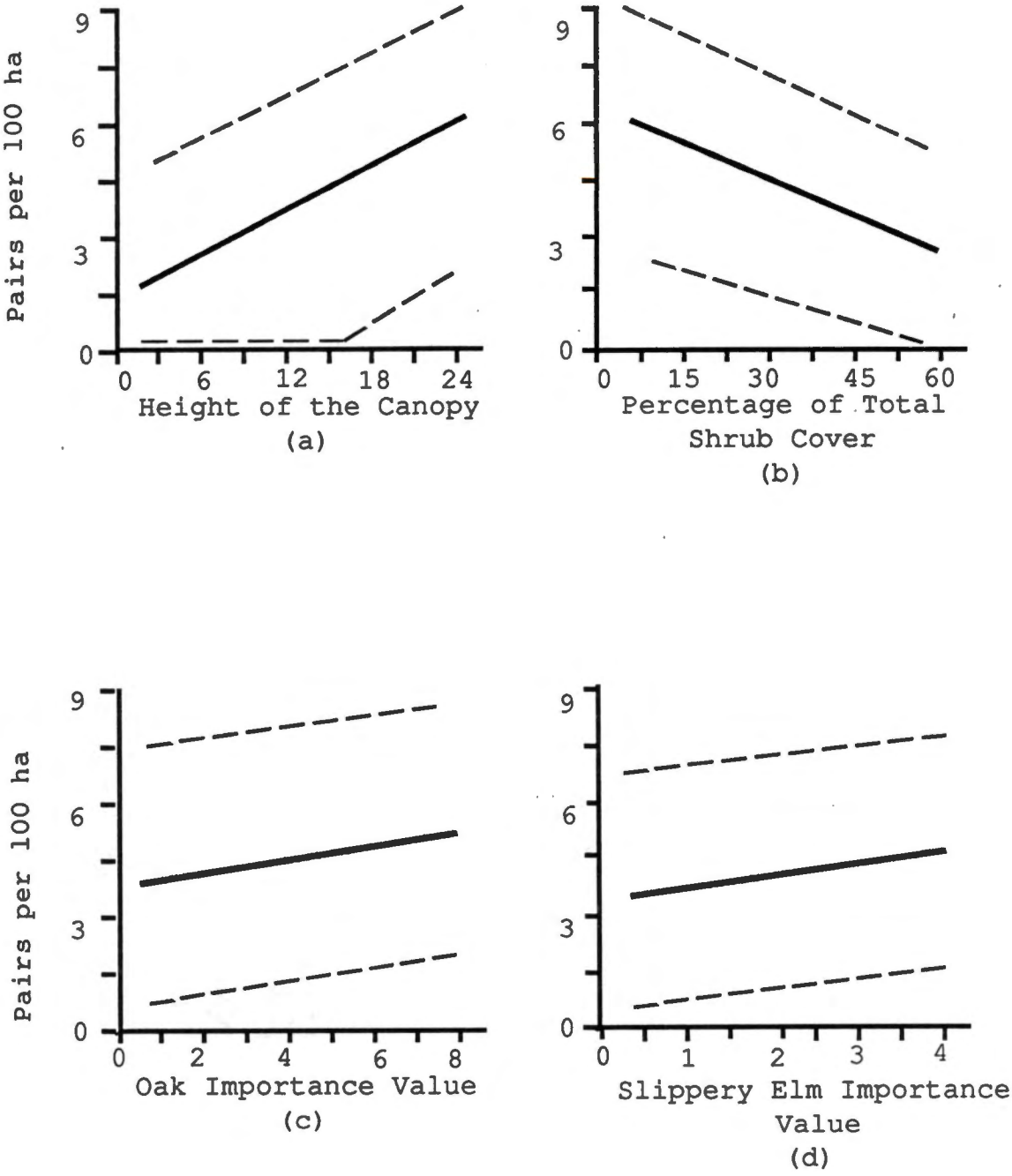


Figure 7. Regression of Acadian Flycatcher density with significant habitat variables of forested wetlands.

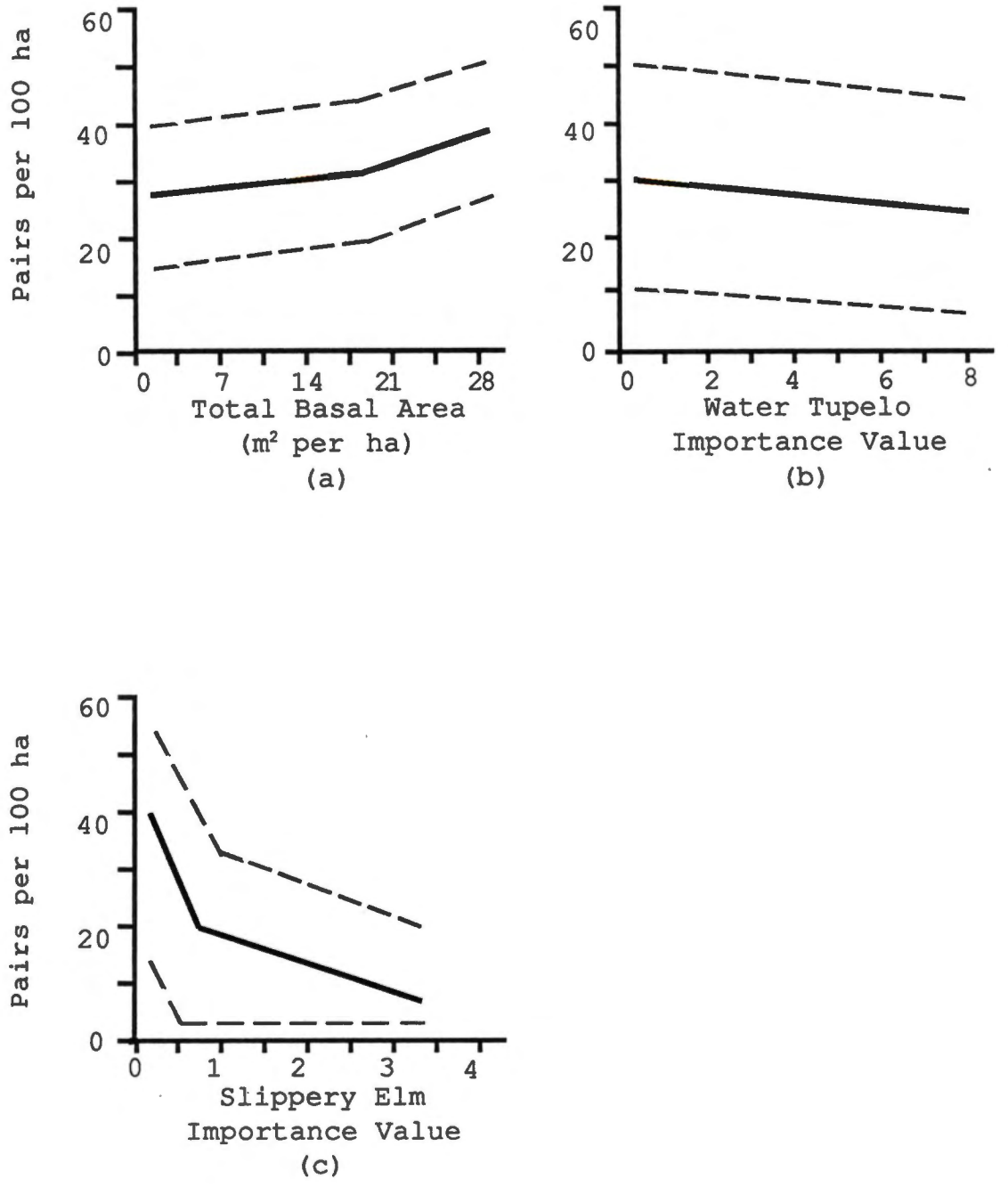


Figure 8. Regression of Carolina Chickadee density with significant habitat variables of forested wetlands.

averaged less than 1 importance value for slippery elm. Chickadee numbers declined to less than 10 pairs per 100 ha in forests where slippery elm was dominant.

Prothonotary Warbler - Density estimates ranged from 0 to 114 pairs per 100 ha. Highest densities of this summer resident occurred in forests with a high snag basal area and low herbaceous layer height. These forests were dominated by water tupelo (Figure 9). These elements accounted for 23% of the total variation found in this species' density. Low herbaceous layer height was the strongest predictor of density, and reflects the importance of habitats with standing water. Swamp forests with 40 or more pairs per 100 ha had herbaceous layers less than .6 m tall. Numbers of Prothonotary Warblers declined when the herbaceous layer was taller than 1.0 m.

Indigo Bunting - Density estimates ranged from 0 to 124 pairs per 100 ha. This summer resident was most abundant in isolated forest tracts with complex vertical structure. Density of the herbaceous layer, brushpile coverage, and the presence of sugarberry accounted for 58% of the variation in this species' density (Figure 10). Dense herbaceous layer coverage was the strongest predictor of high densities. Numbers of Indigo Buntings ranged from 26 to 52 pairs per 100 ha in forests with greater than 24% herbaceous layer cover.

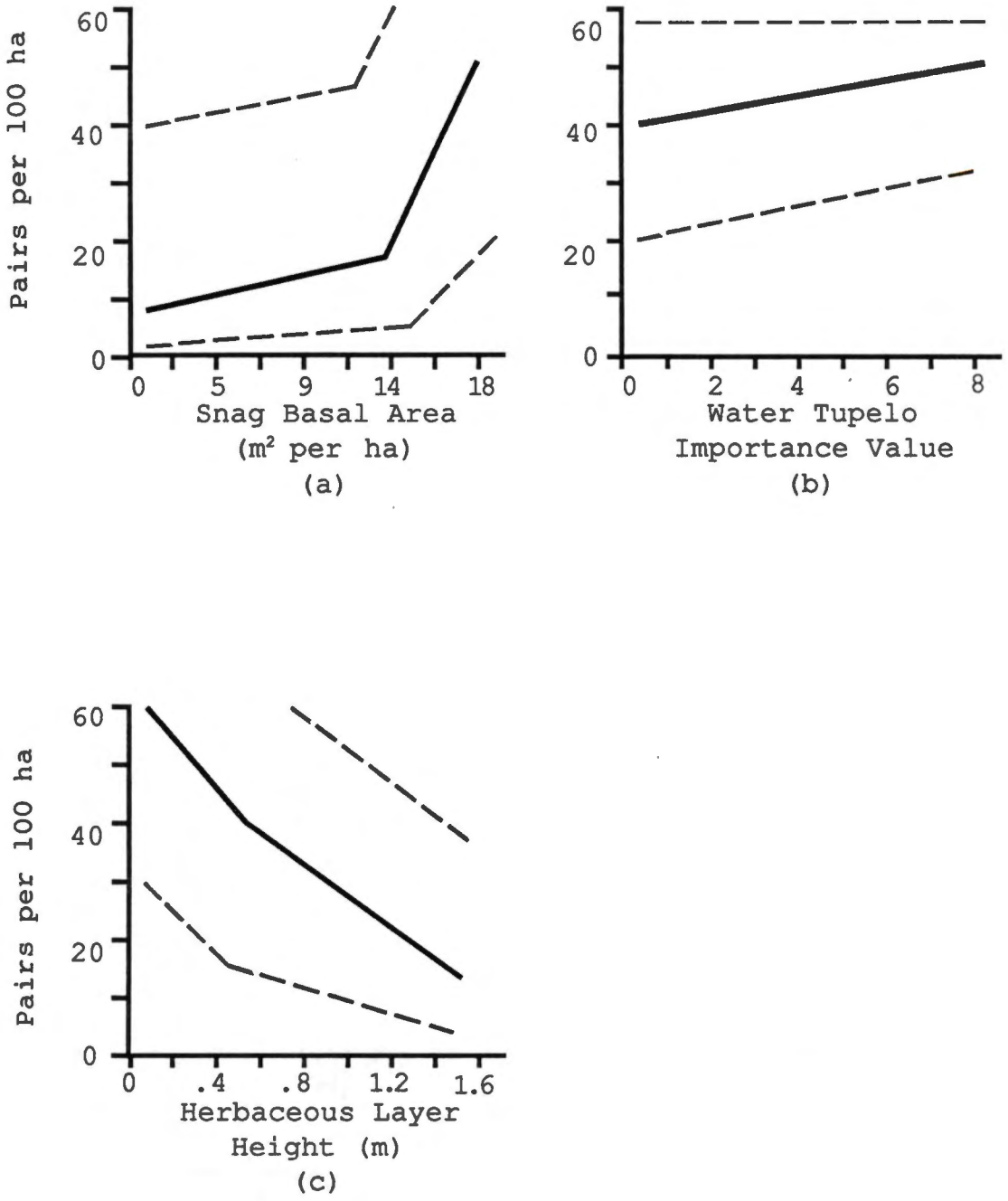


Figure 9. Regression of Prothonotary Warbler density with significant habitat variables of forested wetlands.

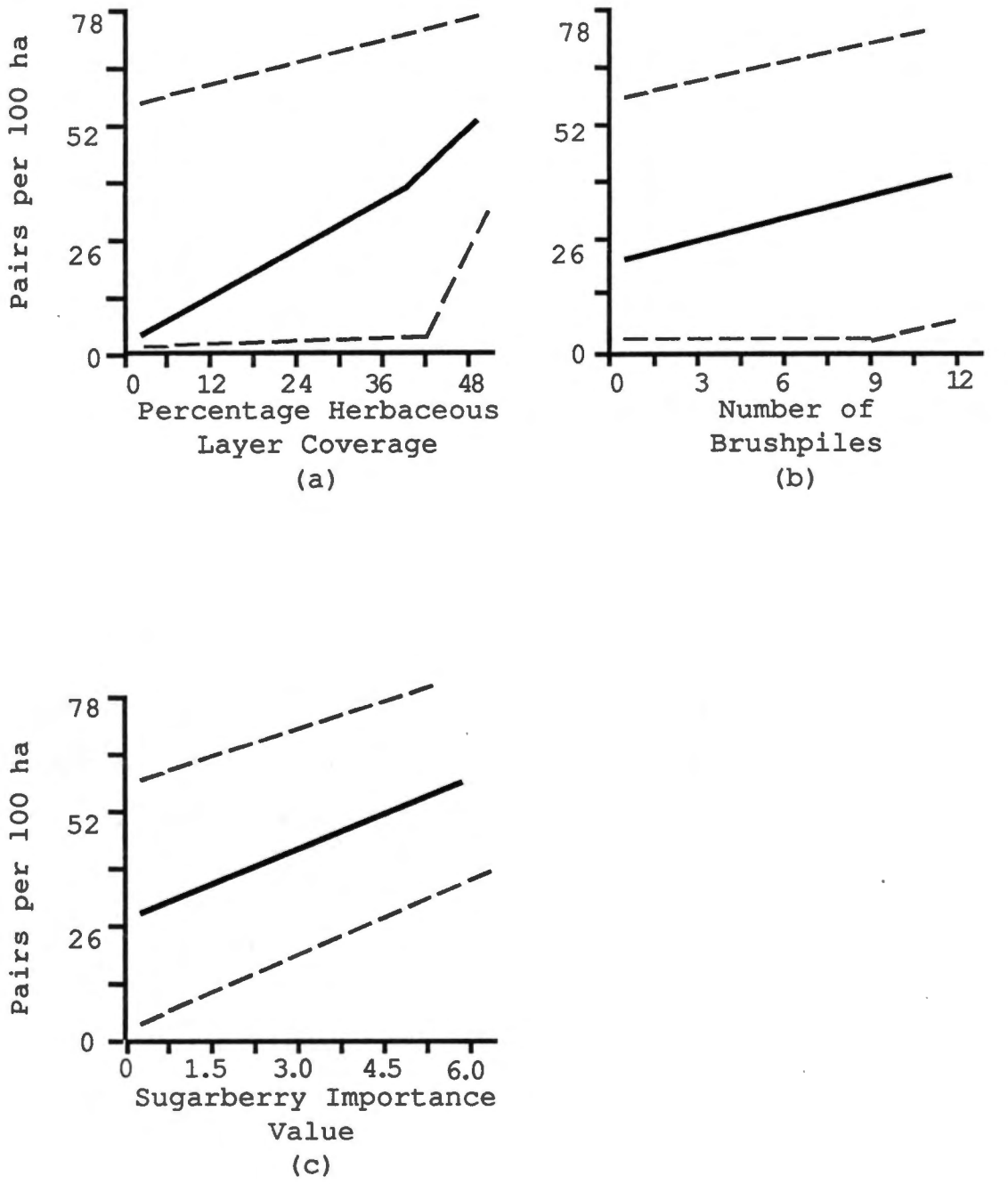


Figure 10. Regression of Indigo Bunting density with significant habitat variables of forested wetlands.

Tufted Titmouse - Density estimates ranged from 8.6 to 72 pairs per 100 ha. This permanent resident was most abundant during breeding seasons in forests with a high number of snags and trees in the subcanopy. Oak and sugarberry were dominant canopy trees in forests (Figure 11). These elements accounted for 21% of the total variation in this species' density. The number of snags was the strongest predictor of density. Forests with 20 or more pairs per 100 ha had 12 or more snags per .1 ha plot. Typically, snags were in the earliest stages of decay, with branches still intact.

Downy Woodpecker - Density estimates ranged from 0 to 69 pairs per 100 ha. Highest breeding densities of this permanent resident occurred in forests with scattered large canopy trees, low total shrub coverage, and sugarberry as a dominant canopy species (Figure 12). These elements accounted for 15% of the total variation in this species' density. A low percentage of total shrub cover was the strongest predictor of density. Forests with 40 to 50 pairs per 100 ha averaged 15% or less total shrub cover, whereas forests with 20 or fewer pairs per 100 ha averaged greater than 45% total shrub cover.

Ruby-throated Hummingbird - Density estimates ranged from 0 to 73 pairs per 100 ha. This summer resident was

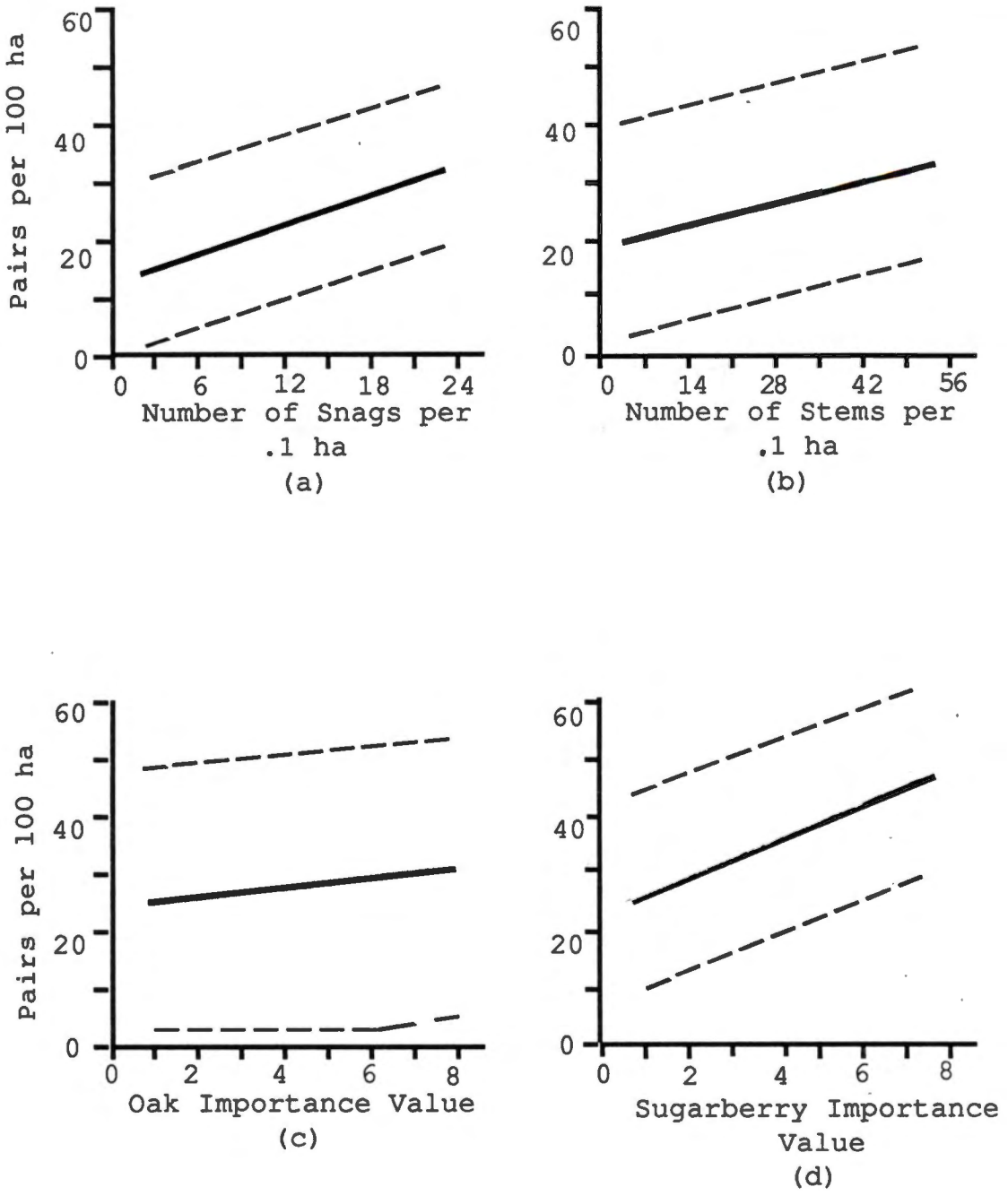


Figure 11. Regression of Tufted Titmouse density with significant habitat variables of forested wetlands.

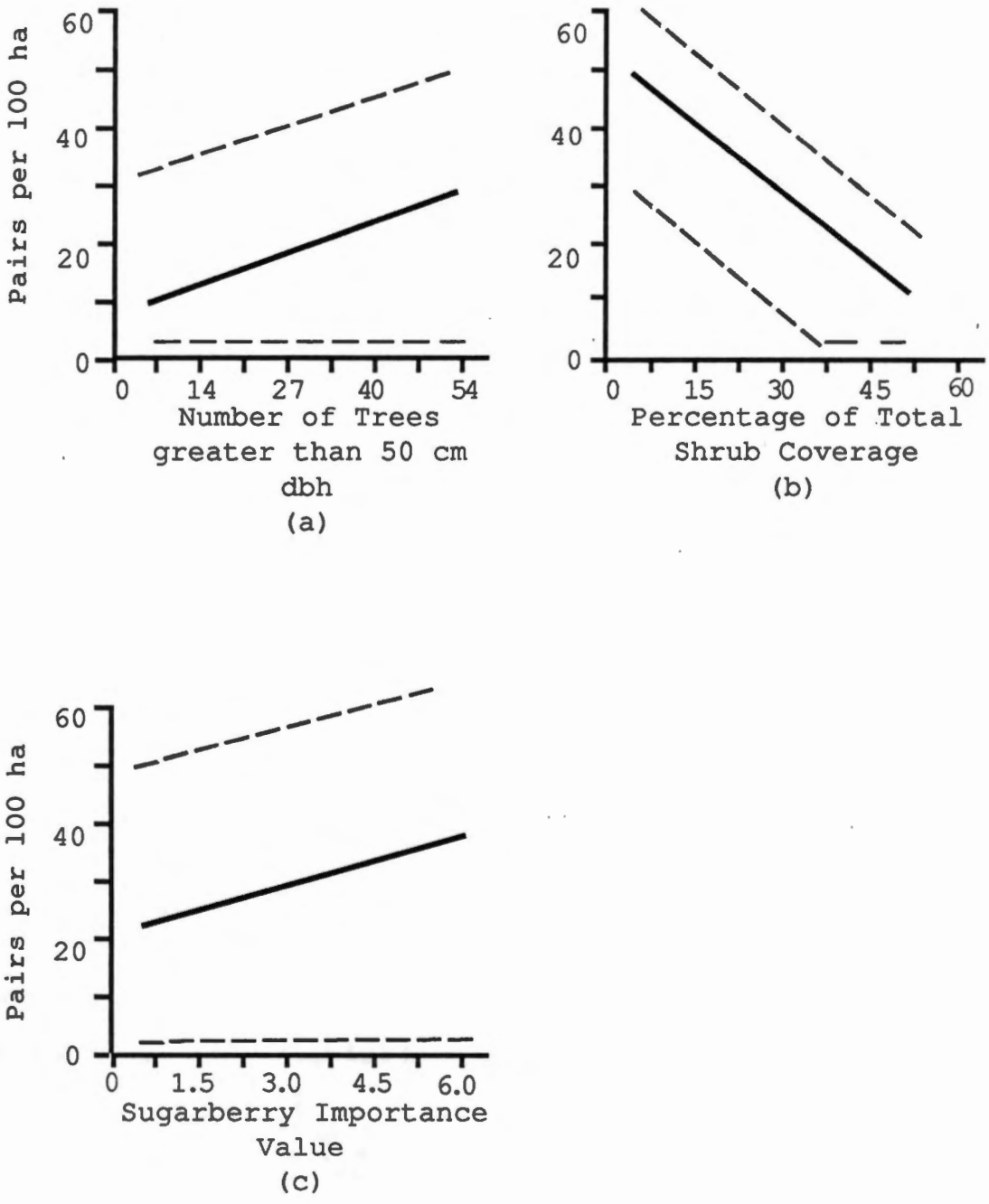


Figure 12. Regression of Downy Woodpecker density with significant habitat variables of forested wetlands.

most abundant in forests with a dense canopy closure, tall average snag height, tall herbaceous layer height, and a dominance of oak (Figure 13). These elements accounted for 21% of the total variation in this species' density. Average snag height was the strongest predictor of density for this species. Forests with 10 to 20 pairs per 100 ha had snags 4 to 8 m in height. Less than 10 hummingbirds per 100 ha occurred where snag height averaged 2 m.

Common Grackle - Density estimates for this species ranged from 0 to 59 pairs per 100 ha. Highest breeding season densities of this permanent resident occurred near riparian zones or backwater swamps in bottomland hardwood forests. A high total basal area and few trees in the subcanopy, combined with canopy dominance of cypress or silver maple, accounted for 22% of the variation in this species' density (Figure 14). The presence of silver maple was the strongest predictor of density. Grackles did not occur in forests without silver maple. Densities averaged more than 20 pairs per 100 ha in forests where silver maple importance value was at least 0.03.

Great-crested Flycatcher - Density estimates ranged from 0 to 75 pairs per 100 ha. This summer resident was most abundant in forests with a low number of subcanopy trees, high number of brushpiles, and low importance values for slippery elm and sycamore (Figure 15). These

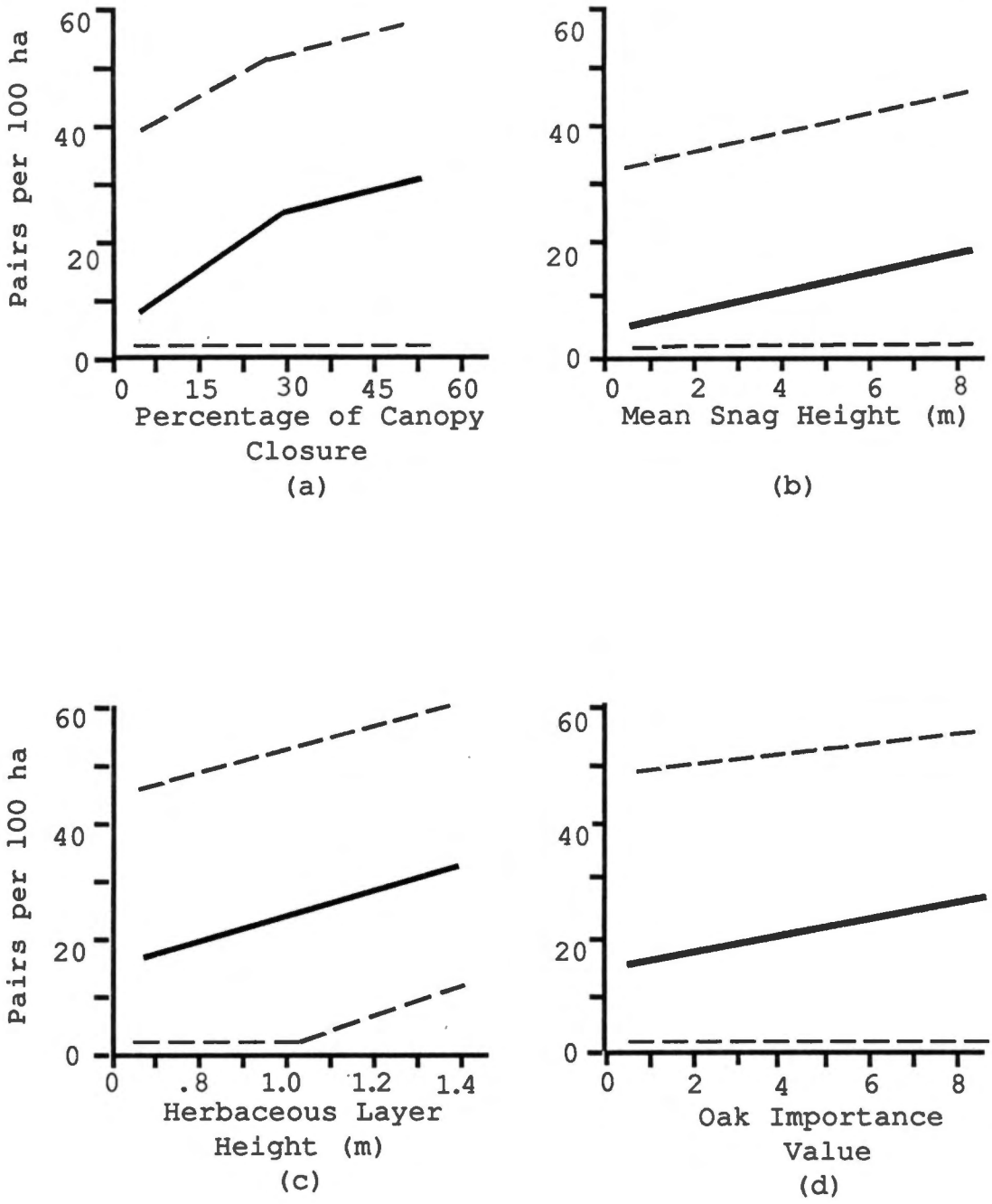


Figure 13. Regression of Ruby-throated Hummingbird density with significant habitat variables of forested wetlands.

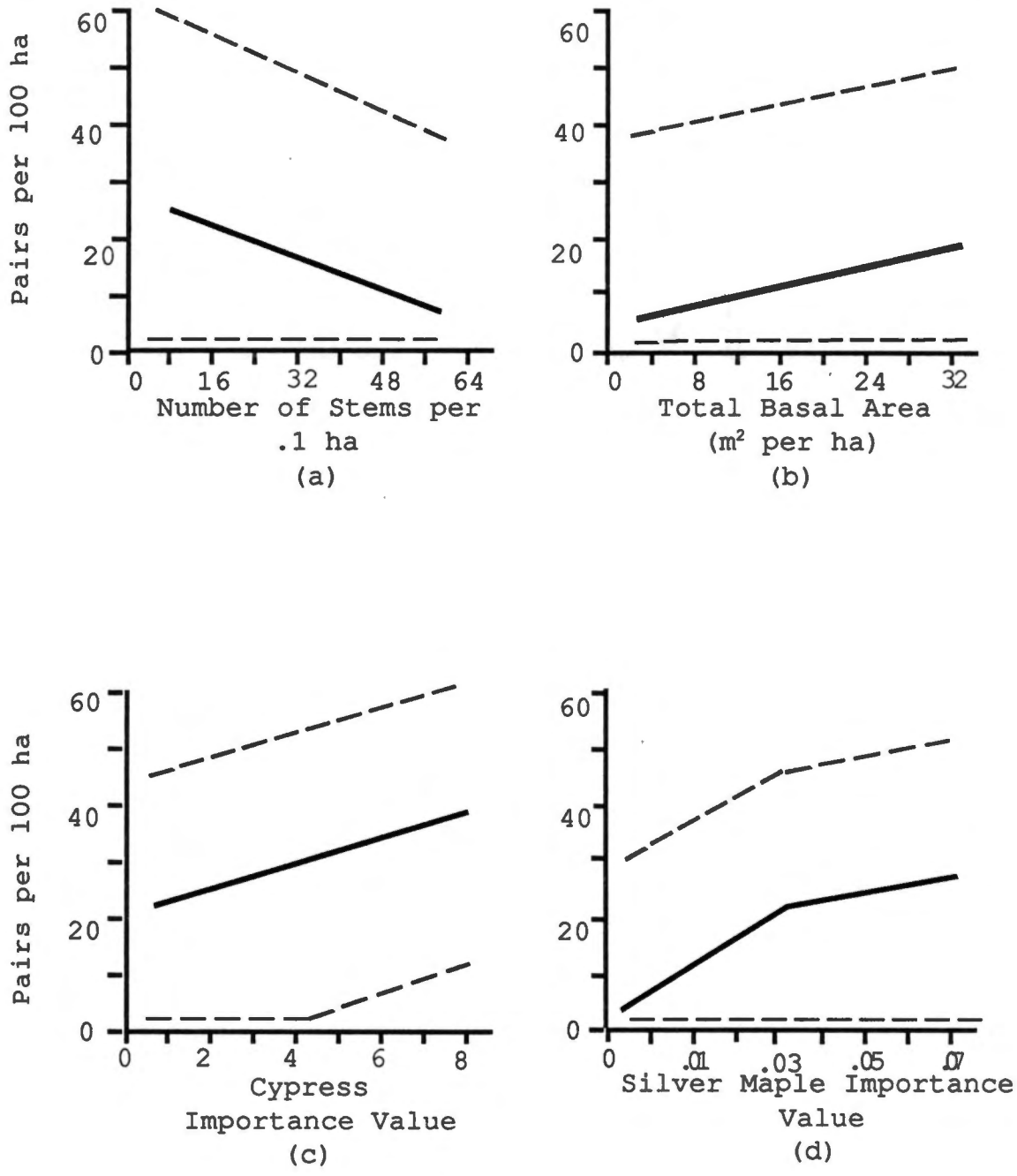


Figure 14. Regression of Common Grackle density with significant habitat variables of forested wetlands.

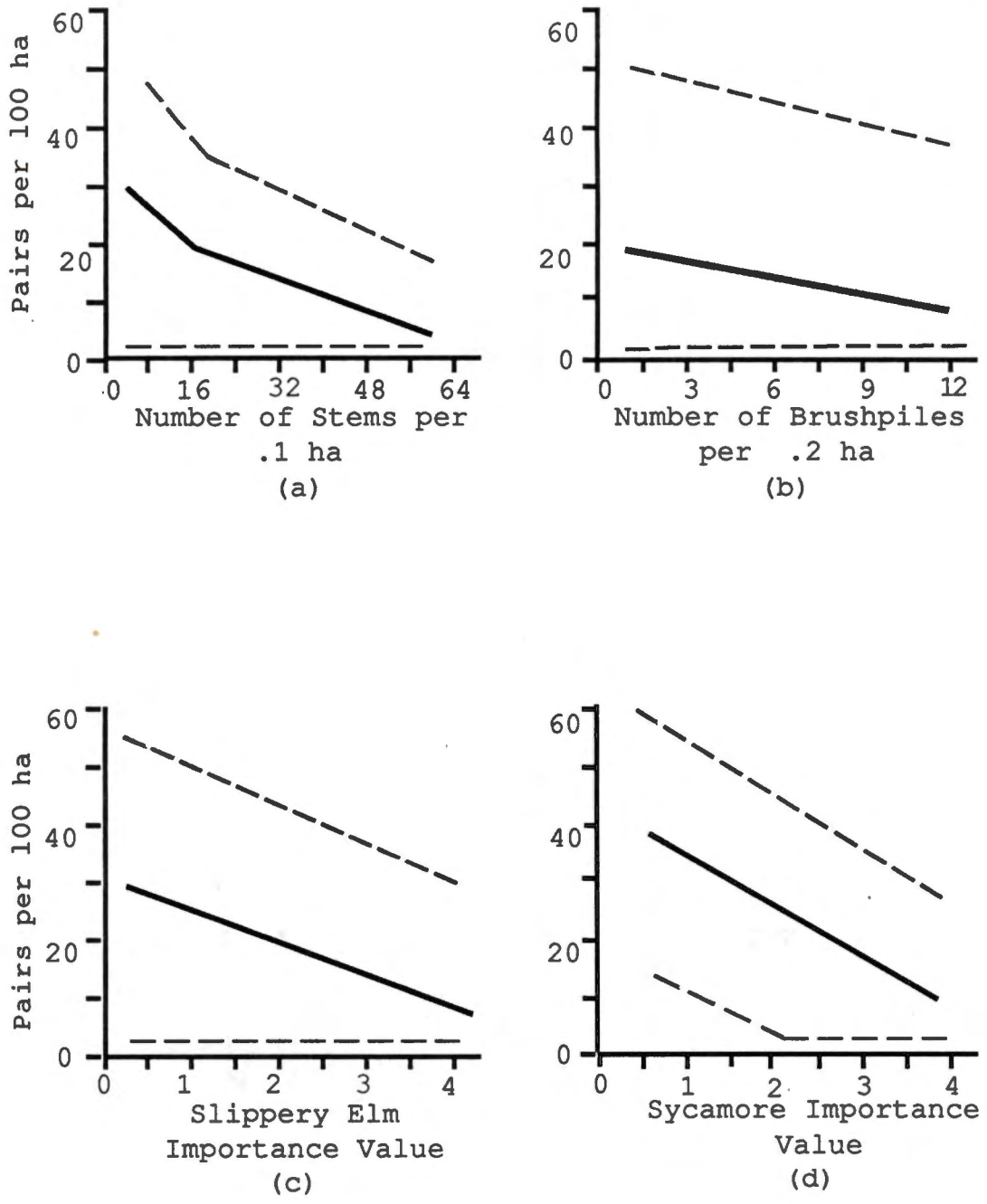


Figure 15. Regression of Great-crested Flycatcher density with significant habitat variables of forested wetlands.

elements accounted for 23% of the total variation in this species' density. A low importance value for sycamore was the strongest predictor of density. Forests with 30 or more pairs per 100 ha averaged a sycamore importance value of less than 1.2, whereas forests with less than 30 pairs per 100 ha averaged a sycamore importance value of greater than 1.2.

Red-eyed Vireo - Density estimates ranged from 0 to 58 pairs per 100 ha. High densities of this summer resident occurred in forests with a high total basal area, low percentage of total shrub cover, and a dominance of oaks (Figure 16). These elements accounted for 23% of the total variation in species density. A low percentage of total shrub coverage was the strongest predictor of density. Forests with fewer than 10 pairs per 100 ha averaged a total shrub cover of 60 to 80%.

Red-bellied Woodpecker - Density estimates ranged from 1 to 26 pairs per 100 ha. Highest breeding season densities of this permanent resident were in forests with a high total basal area, high number of large snags (>50 cm dbh), and a low percentage of total shrub cover; the dominant canopy tree was green ash (Figure 17). These elements accounted for 26% of the total variation in this species' density. Low percentage of total shrub cover was the strongest predictor of density for this species. Highest numbers of Red-bellied Woodpeckers occurred in forests with less than

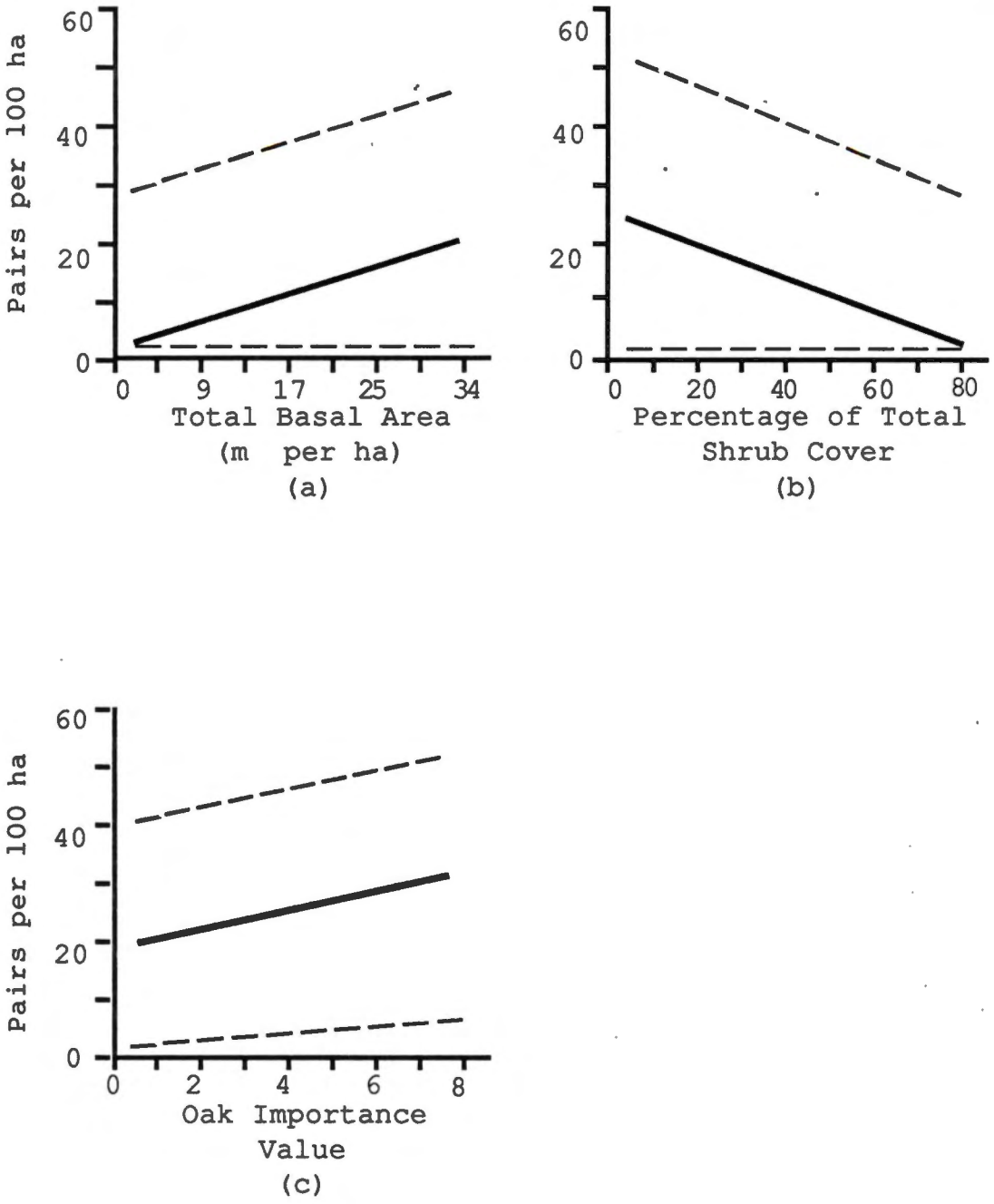


Figure 16. Regression of Red-eyed Vireo density with significant habitat variables of forested wetlands.

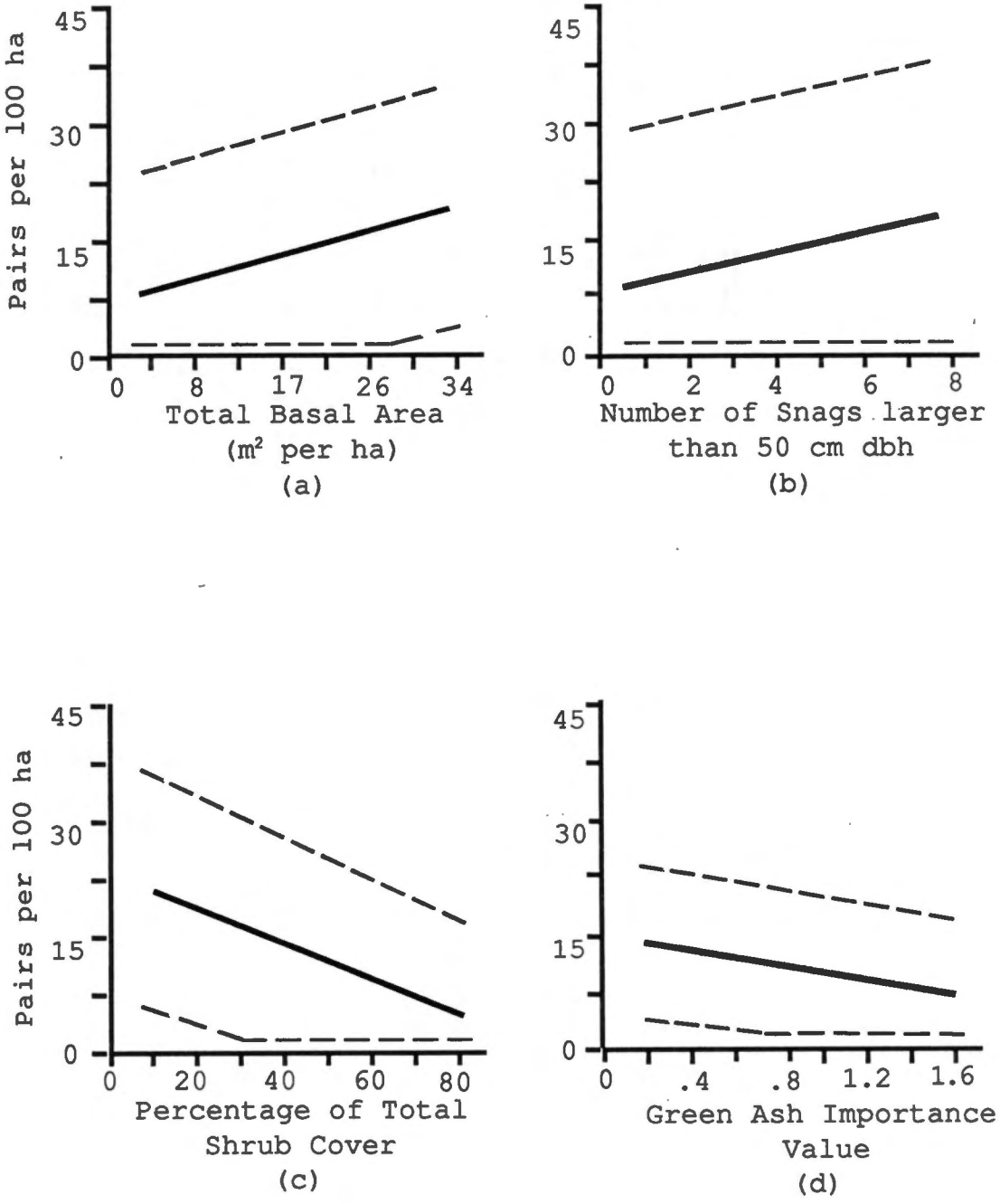


Figure 17. Regression of Red-bellied Woodpecker density with significant habitat variables of forested wetlands.

20% total shrub cover, whereas fewer than 10 pairs per 100 ha occurred in forests with 60 to 80% total shrub cover.

Northern Parula - Density estimates ranged from 0 to 43 pairs per 100 ha. This summer resident was most abundant in forests with a high total basal area, low percentage of total shrub cover, and low importance values for cypress (Figure 18). These elements accounted for 26% of the total variation in this species' density. A low percentage of total shrub cover was the strongest predictor of density. Eighteen or more pairs per 100 ha occurred in forests with less than 20% total shrub cover, whereas forests with greater than 50% total shrub cover had fewer than 8 pairs per 100 ha.

White-eyed Vireo - Density estimates ranged from 0 to 34 pairs per 100 ha. This summer resident was most abundant in boxelder forests with a high number of trees in the subcanopy and a tall herbaceous layer (Figure 19). These elements accounted for 24% of the total variation in this species' density. Height of the herbaceous layer was the strongest predictor of density. Forests with a herbaceous layer height of 1.0 to 1.6 m averaged 13 pairs per 100 ha, whereas forests with herbaceous layer height of less than .6 m averaged less than 10 pairs per 100 ha.

Red-winged Blackbird - Density estimates ranged from 0 to 62 pairs per 100 ha. Highest breeding season densities

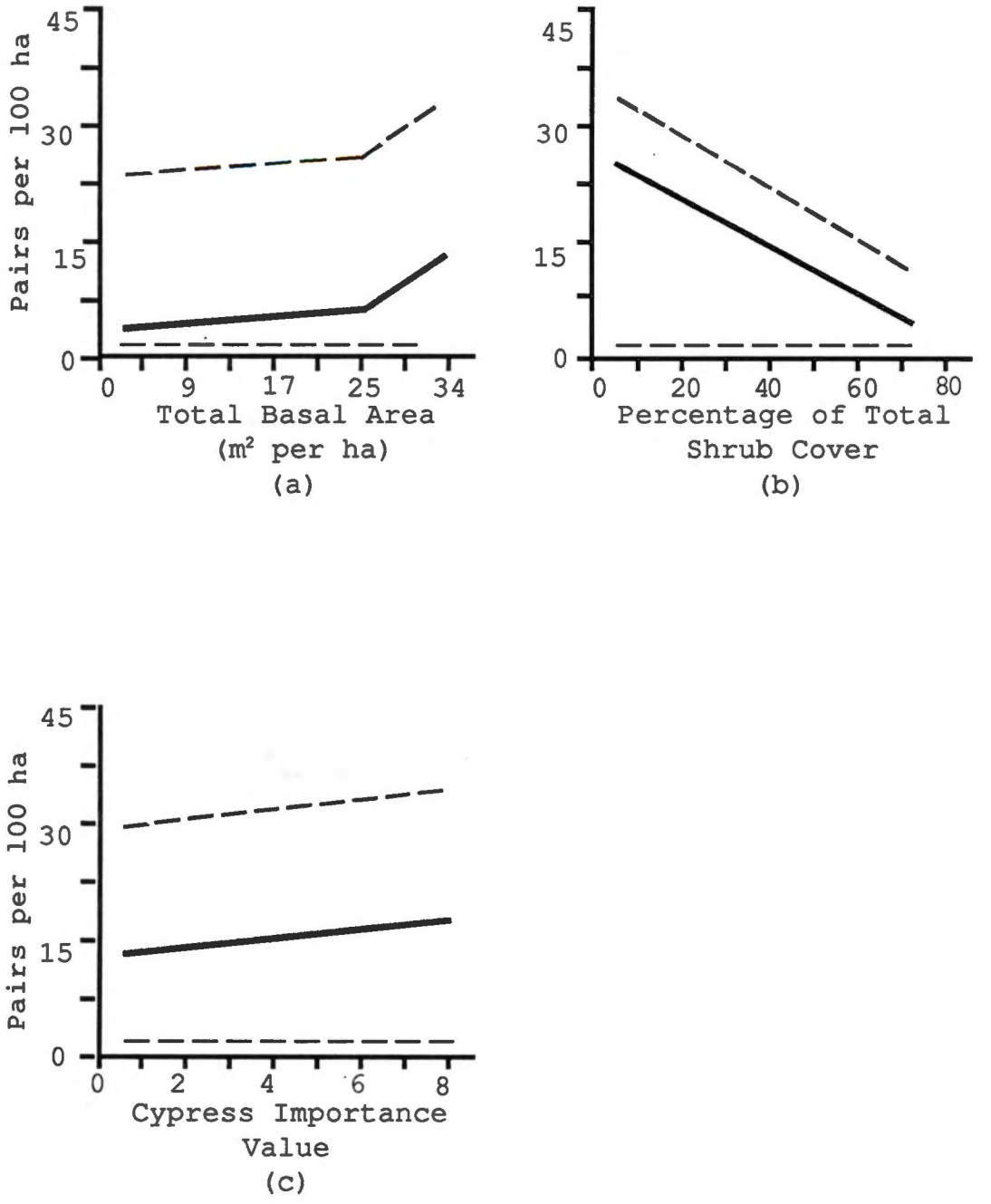


Figure 18. Regression of Northern Parula density with significant habitat variables of forested wetlands.

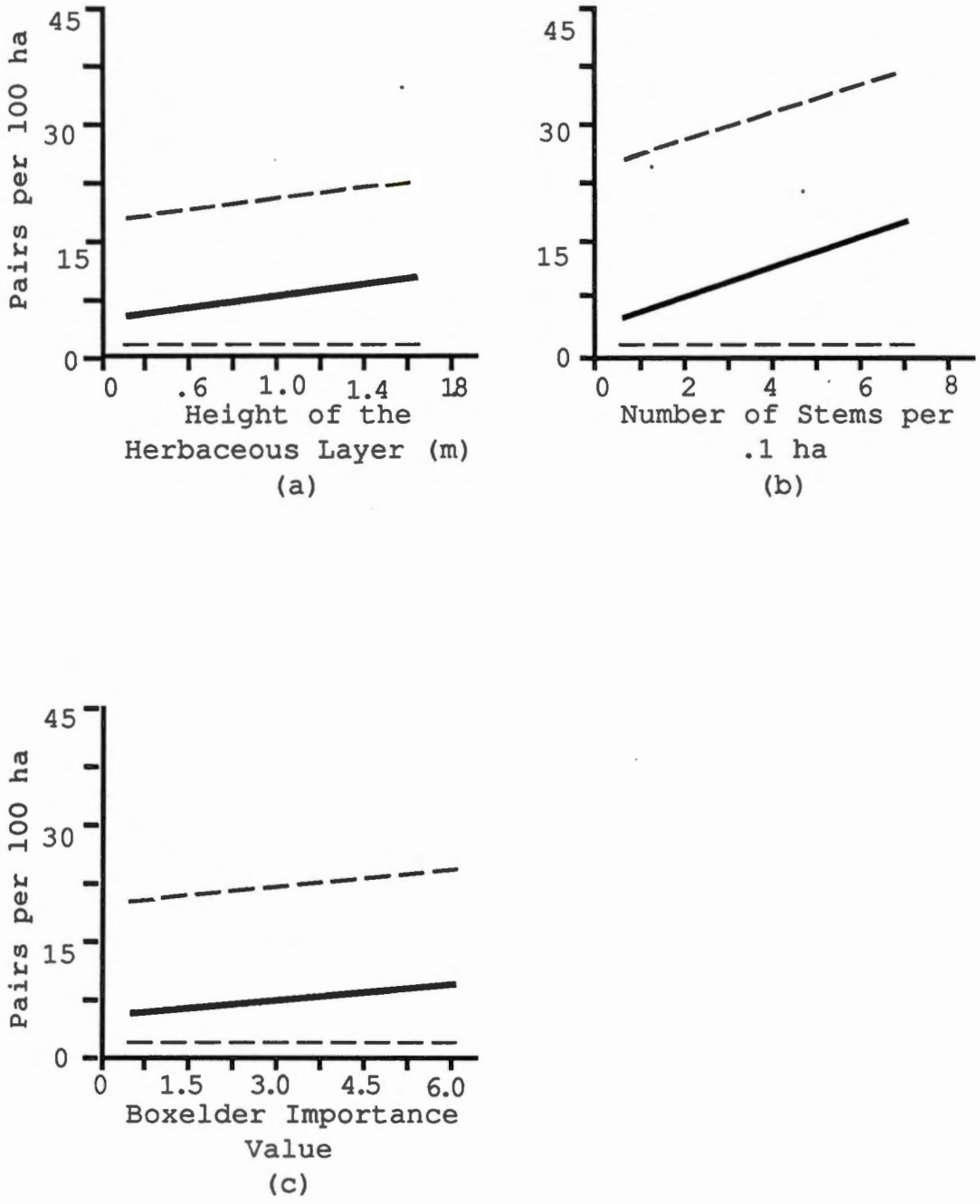


Figure 19. Regression of White-eyed Vireo density with significant habitat variables of forested wetlands.

of this permanent resident occurred in forests with an open canopy, low number of trees in the subcanopy, and low importance values for oaks (Figure 20). These elements accounted for 18% of the total variation in this species' density. A low percentage of canopy closure was the strongest predictor of high density. Highest numbers of Red-winged Blackbirds occurred in forests which averaged less than 33% canopy closure.

II. Winter season birds

Seventy-two species were observed during winter. An average of 296 individuals and 23 species occurred on individual sites. The number of species per site ranged from 12 to 29. Total density averaged 830 birds per 100 ha. Flocks of Common Grackles and Mallards comprised 33% of the total density. Excluding these flocks, bird density on sites was reduced to 689 birds per 100 ha.

Bird abundance in west Tennessee

Fifteen species (21%) were abundant winter residents in west Tennessee forested wetlands, comprising greater than 80% of the total density (Table 5). Ten of the group of abundant species were permanent residents in west Tennessee, 5 were winter migrants. Nine species (13%) present

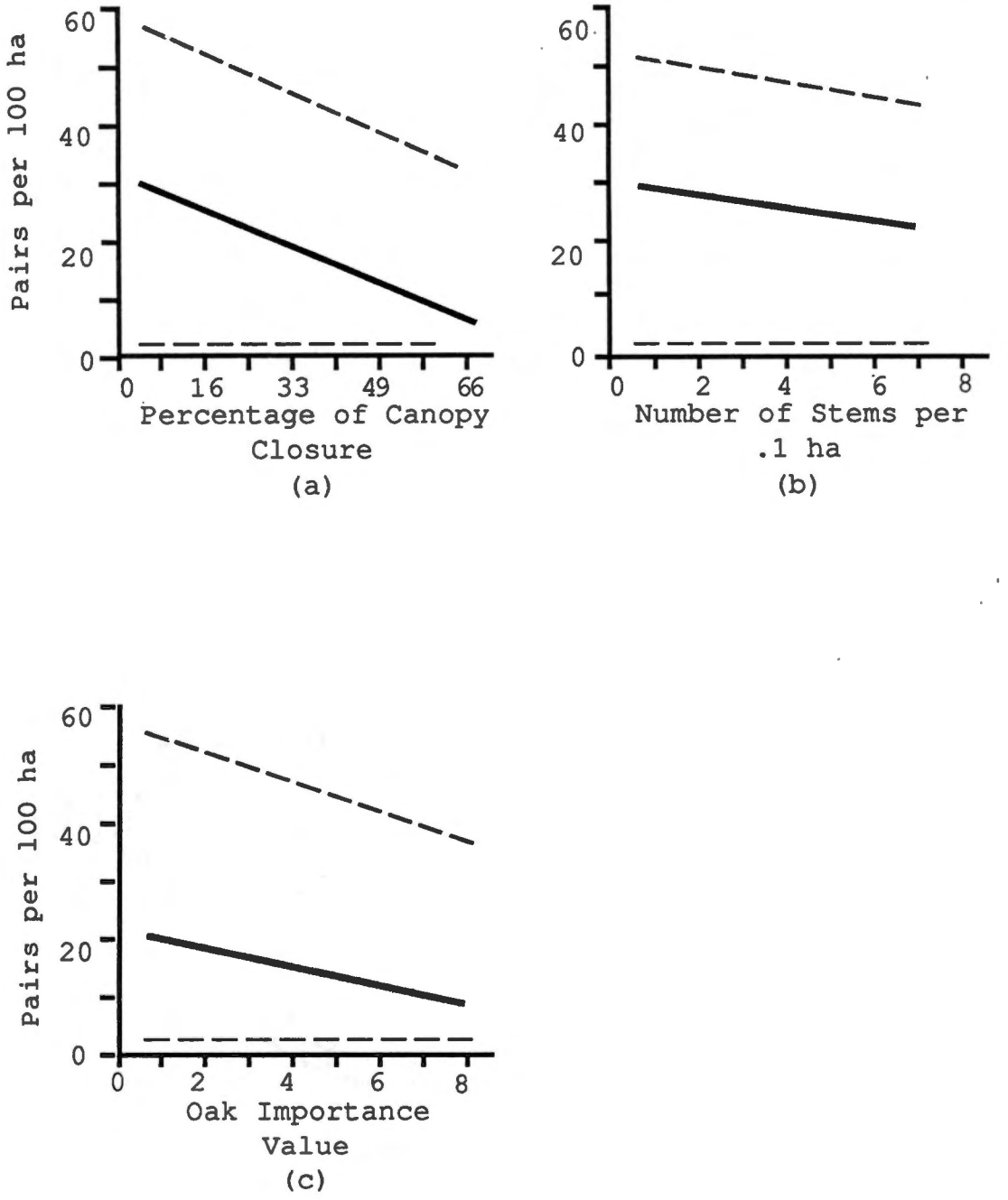


Figure 20. Regression of Red-winged Blackbird density with significant habitat variables of forested wetlands.

Table 5. Abundant winter birds in forested wetlands of west Tennessee. This table lists density per species (birds per 100 ha), cumulative percentage of density per site, and bird residency status (Waldron 1987) in west Tennessee.

Species	Density (birds per 100 ha)	Cumulative percentage of density	Residency status
White-throated Sparrow	136	17%	winter
Common Grackle	104	30%	permanent
Carolina Chickadee	98	42%	permanent
Northern Cardinal	46	48%	permanent
Red-headed Woodpecker	41	53%	permanent
Red-bellied Woodpecker	40	58%	permanent
Yellow-rumped Warbler	35	62%	winter
Downy Woodpecker	30	66%	permanent
Golden-crowned Kinglet	28	69%	winter
Tufted Titmouse	25	72%	permanent
Rusty Blackbird	21	75%	winter
Mallard	18	79%	permanent
American Robin	18	79%	permanent
American Goldfinch	17	81%	permanent
Winter Wren	16	83%	winter

throughout west Tennessee's forested wetlands during winter were recorded in relatively low densities. These species were found on 45 or more of 58 sites sampled, and density estimates ranged from .48 to 14 pairs per 100 ha (Table 6). All except Hermit Thrush were permanent residents in west Tennessee. Brown Creeper has traditionally been regarded as a winter resident in west Tennessee, but has recently been considered a permanent resident (Ford 1987). Fifteen species (21%) occurred on fewer than 4 sites. Three species were either rare in west Tennessee forested wetlands or were difficult to census: Sharp-shinned Hawk, Pine Warbler, and Sedge Wren.

Comparisons among watersheds

Density - Bird density among watersheds varied considerably with and without flocks of Common Grackles or Mallards (Table 7). Highest overall densities were found in forests near White Oak Creek of the Tennessee River, although 53% of density was accounted for by large flocks of Common Grackles and Mallards. One large grackle flock of over 10,000 birds, the largest observed during the survey, caused density estimates to nearly double.

Excluding flocks of Common Grackles and Mallards, highest densities of birds occurred in the Loosahatchie floodplain forests. The least variation among density estimates (with or without flocks) also occurred in the Loosahatchie floodplain. The least disturbed watersheds,

Table 6. Widespread winter birds in west Tennessee wetland forests, occurring on 45 or more of 59 sites. Density per 100 ha is relatively low. Residency status in west Tennessee (Waldron 1987) is included.

Widespread winter birds	Number of sites	Density (birds per 100 ha)	Residency status
Yellow-shafted Flicker	58	12	permanent
Blue Jay	58	5	permanent
Carolina Wren	58	13	permanent
White-breasted Nuthatch	50	4	permanent
Brown Creeper	50	14	permanent
American Crow	49	.5	permanent
Pileated Woodpecker	49	1.5	permanent
Hermit Thrush	48	10	winter
Hairy Woodpecker	45	4	permanent

Table 7. Winter bird densities and number of species among west Tennessee watersheds. Densities among sites are compared with and without flocking Common Grackles and Mallards. Standard error (±) is included for density estimates and species richness.

River system	Mean density of species (± SE) per site (birds per 100 ha) with flocks	Mean density of species (± SE) per site (birds per 100 ha) without flocks	Mean number of species (± SE) per site	Range in number of species
Tennessee	1267 ±1395	591 ±280	23.5 ±4.3	12 - 29
Mississippi	837 ±290	782 ±273	23.3 ±4.1	16 - 27
Hatchie	834 ±342	709 ±284	21.5 ±3.5	16 - 28
Loosahatchie	827 ±404	801 ±401	22.4 ±4.2	16 - 29
Forked Deer	742 ±353	661 ±367	22.3 ±4.2	14 - 29
Obion	608 ±230	532 ±218	21.1 ±3.1	16 - 27
Wolf	583 ±189	488 ±115	22.7 ±3.6	14 - 27

the Mississippi and Hatchie, ranked second and third in density, both with and without flocks.

Lowest densities of winter birds, both with and without flocks, were found in forests of the Wolf River floodplain.

Species richness - Species richness was highest in the White Oak Creek floodplain of the Tennessee River. The broadest range in number of species per site occurred in forests of this floodplain as well. Lowest species richness was in forests of the Obion River floodplain. Forests in this floodplain, along with those in the Mississippi River, had the narrowest range in number of species per site.

Species accounts

White-throated Sparrow - Density estimates ranged from 0 to 625 birds per 100 ha. This winter resident was most abundant in forests with a high percentage of total shrub cover, high number of snags, and high percentage of brushpile cover. Oak was the dominant canopy tree. However, the model was not statistically significant and these elements accounted for only 11% of the variation in this species' density. Forests with densities of 303 or more birds per 100 ha (n=6 sites) averaged 10% total shrub cover, whereas forests with 15 or less birds per 100 ha (n=5 sites) averaged 5% total shrub cover.

Common Grackle - Density estimates ranged from 0 to 2562 birds per 100 ha. Winter season densities of this

permanent resident were highest in forests with a high number of stems, low number of snags, and low importance value for oak. However, this model was not statistically significant and accounted for only 1% of the variation in this species' density. Flocks of Common Grackles ranged from approximately 500 to 10,600 individuals.

Carolina Chickadee - Density estimates ranged from 5 to 369 birds per 100 ha. During the winter, Carolina Chickadees were most abundant in forests with a high interspersion of wet and dry habitats. Forests typically had a high percentage canopy closure, low percentage of total shrub cover, and were dominated by cypress and hickory (Figure 21). These elements accounted for 23% of the total variation in this species' density. Percentage of total shrub cover was the strongest predictor of density. Forests with 80 to 148 birds per 100 ha averaged less than 30% total shrub cover, whereas forests with less than 75 birds per 100 ha averaged 40 to 80% total shrub cover.

Northern Cardinal - Density estimates ranged from 5 to 160 birds per 100 ha. Highest winter densities of this permanent resident occurred in forests with a dense canopy closure, tall average shrub height, high number of brushpiles, and a dominance of hickory (Figure 22). These elements accounted for 19.5% of the total variation in this species' density. Average shrub height was the strongest

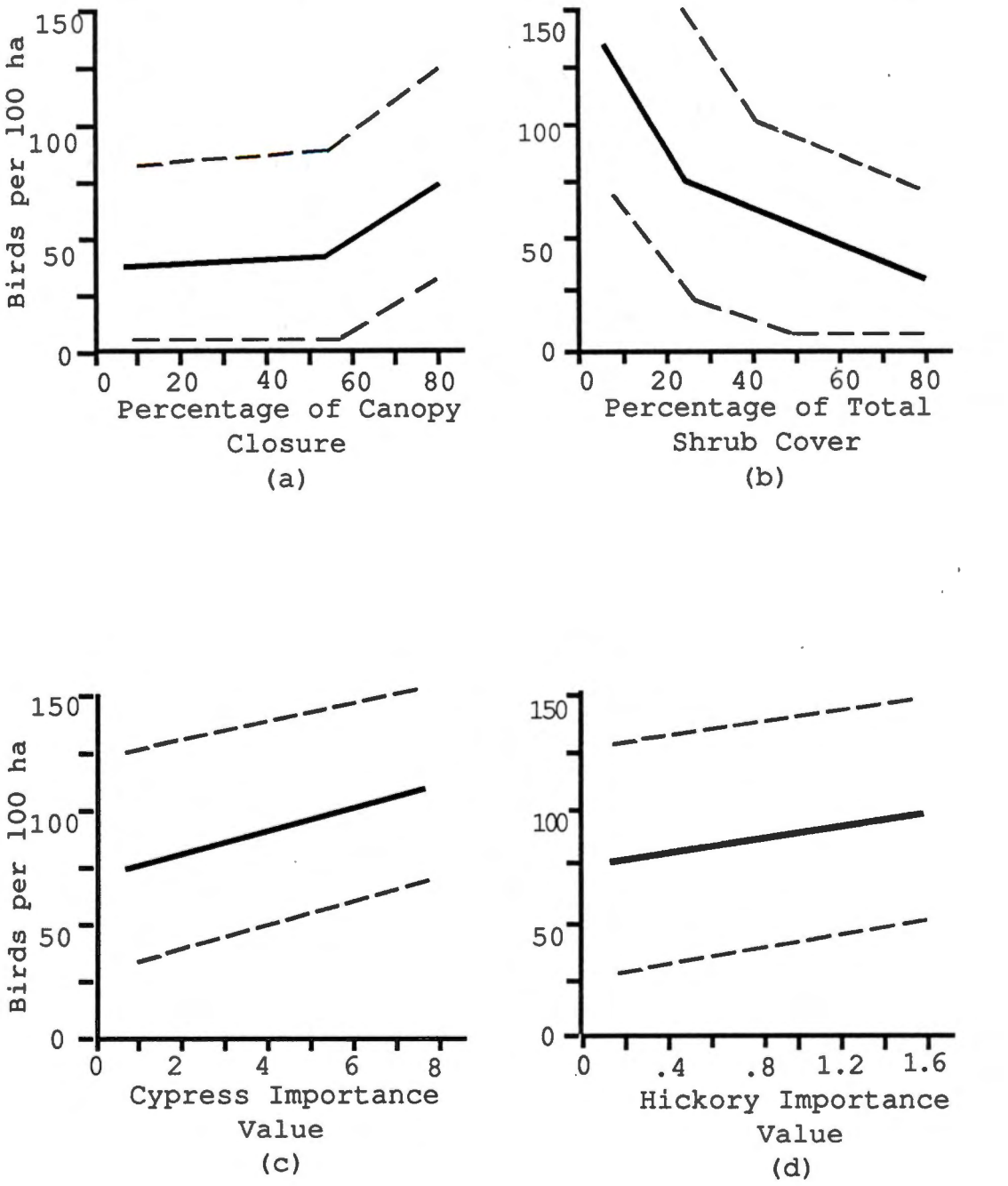


Figure 21. Regression of Carolina Chickadee density with significant habitat variables of forested wetlands.

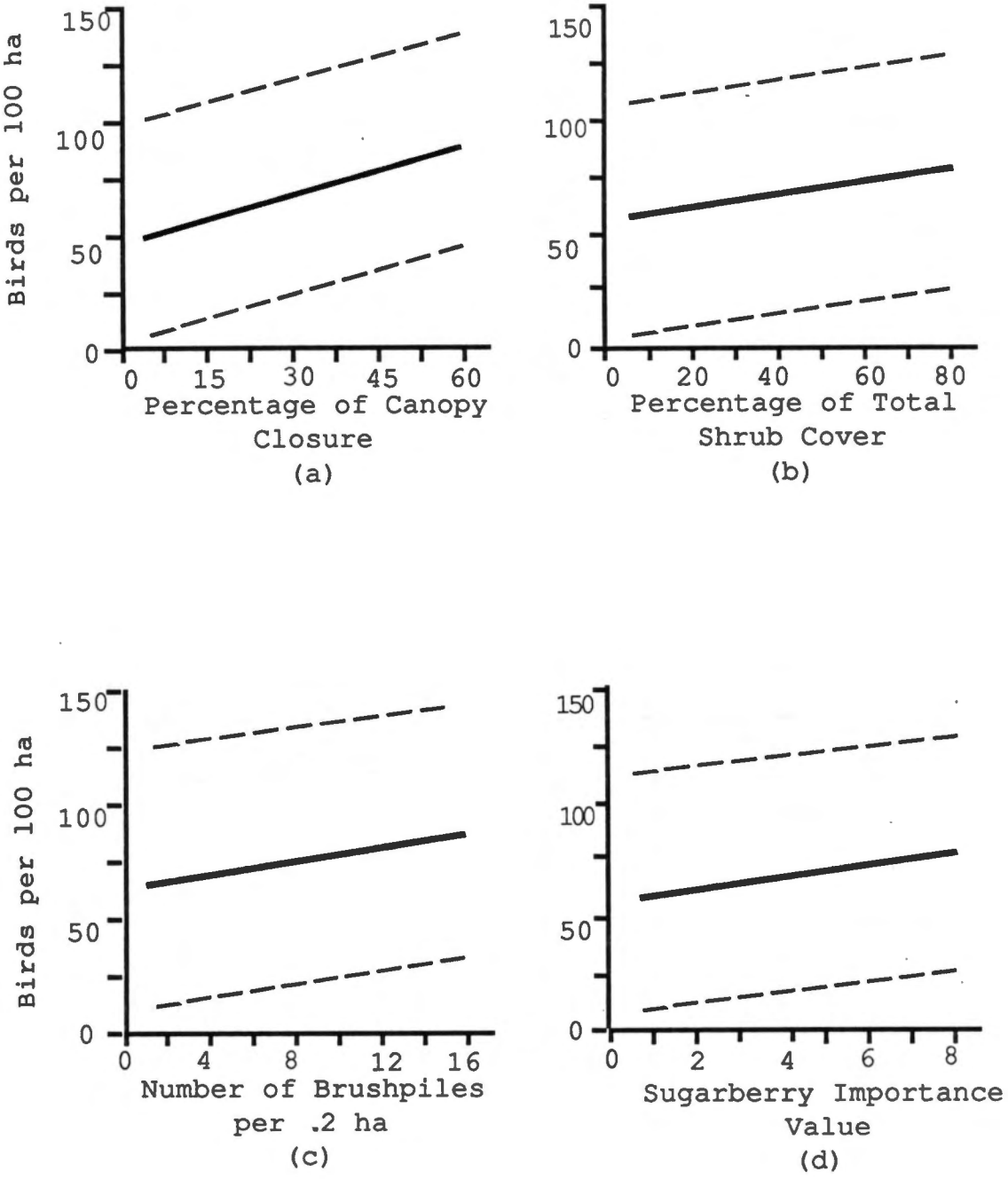


Figure 22. Regression of Northern Cardinal density with significant habitat variables of forested wetlands.

predictor of density. Lowest numbers of cardinals occurred in forests where shrub height was less than 2.4 m. Cardinal numbers increased to greater than 50 pairs per 100 ha in forests where shrub height averaged more than 2.4 m.

Red-headed Woodpecker - Density estimates ranged from 0 to 178 birds per 100 ha. Highest winter densities of this permanent resident occurred in hickory forests with a high total basal area and low percentage of total shrub cover (Figure 23). These elements accounted for 26% of the variation in this species' density. Percentage of total shrub cover was the strongest predictor of density. Forests with 75 to 100 birds per 100 ha averaged less than 40% total shrub cover, whereas forests with less than 50 birds per 100 ha averaged 60 to 70% total shrub cover.

Red-bellied Woodpecker - Density estimates ranged from 5 to 121 birds per 100 ha. High winter densities of this permanent resident occurred in sugarberry and cypress forests with scattered, large snags, and a low percentage of shrub cover (Figure 24). These elements accounted for 39% of the variability in this species' density. Percentage of total shrub cover was the strongest predictor of density. Forests with 45 to 60 birds per 100 ha averaged less than 40% total shrub cover, whereas forests with 30 birds per 100 ha greater than 70% total shrub cover.

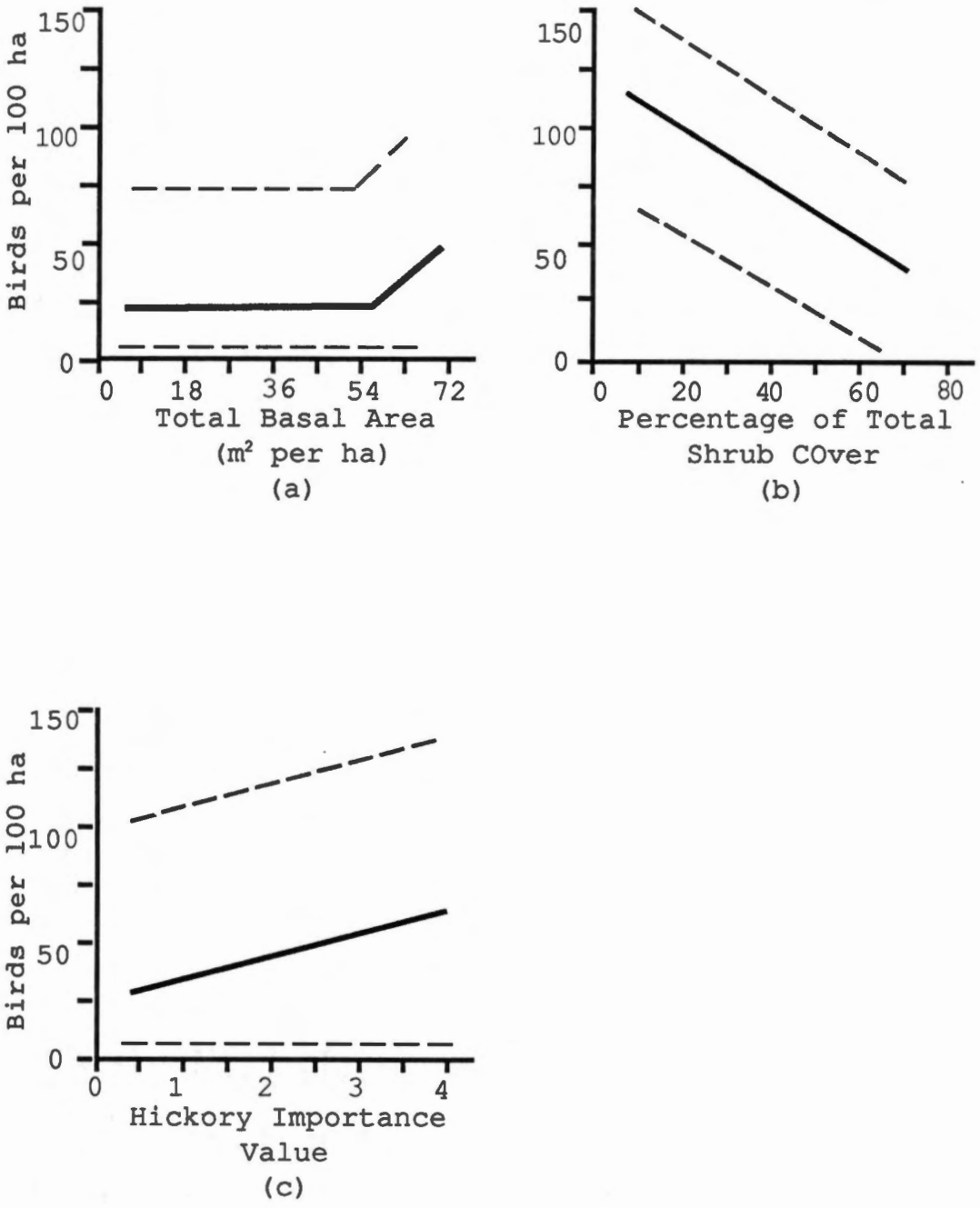


Figure 23. Regression of Red-headed Woodpecker density with significant habitat variables of forested wetlands.

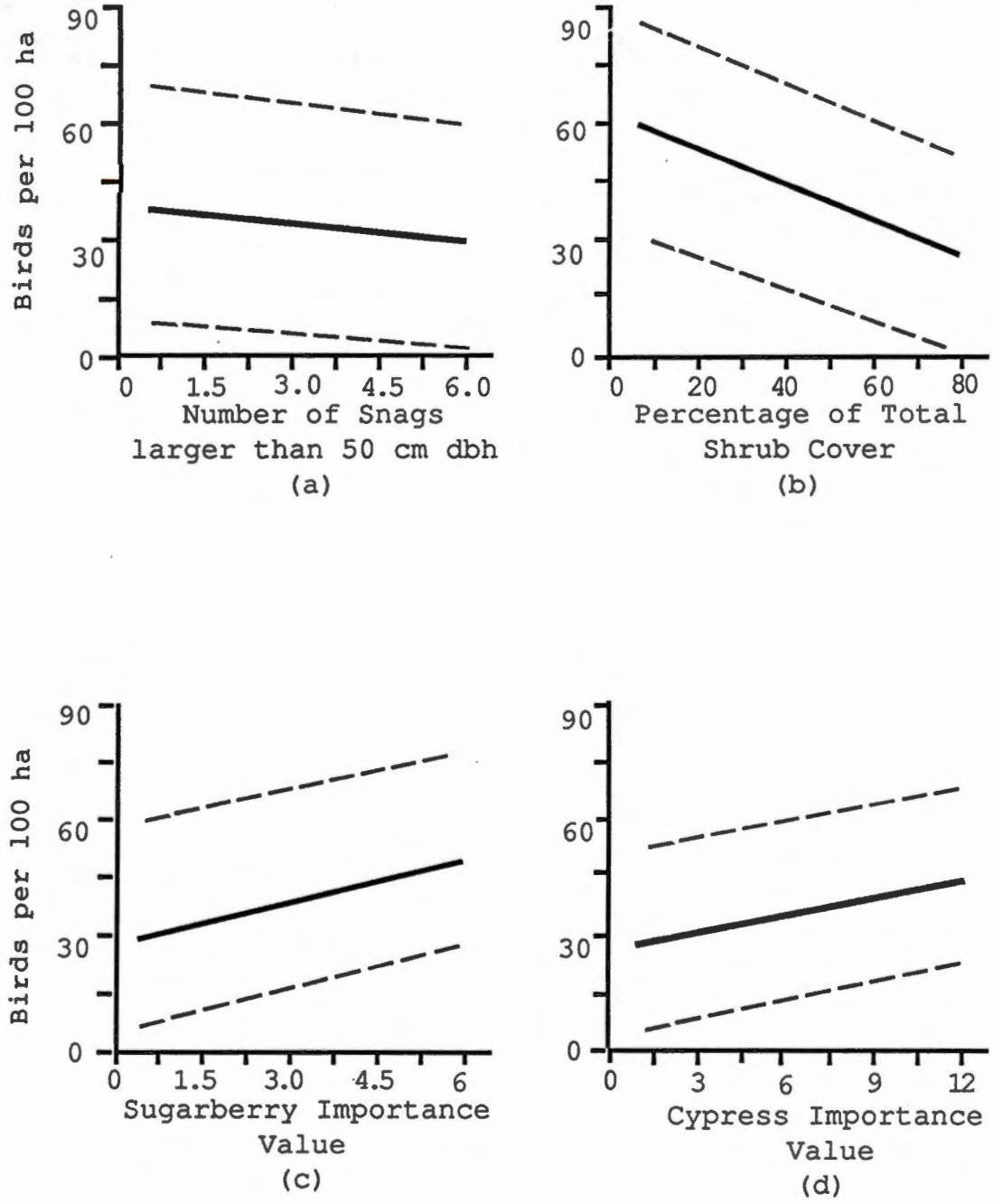


Figure 24. Regression of Red-bellied Woodpecker density with significant habitat variables of forested wetlands.

Yellow-rumped Warbler - Density estimates ranged from 0 to 322 birds per 100 ha. Highest densities of this winter resident occurred in large forested tracts in the Mississippi River floodplain. Canopy height, a low percentage of total shrub cover, and dominance of sugarberry and slippery elm accounted for 33% of the total variation in this species' density (Figure 25). Percentage of total shrub cover was the strongest predictor of density. Forests with less than 30% total shrub cover held 80 to 100 birds per 100 ha, whereas forests with 60 to 80% total shrub cover contained fewer than 75 pairs per 100 ha.

Downy Woodpecker - Density estimates ranged from 6 to 119 birds per 100 ha. During winter, this permanent resident was most abundant in sugarberry forests with a high total basal area and a low percentage of total shrub cover (Figure 26). These elements accounted for 24% of the total variation of this species' density. Percentage of total shrub cover was the strongest predictor of density. more than 30 birds per 100 ha occurred in forests where total shrub cover averaged less than 30%. Twenty or less birds per 100 ha occurred in forests where total shrub cover averaged 60% to 80%.

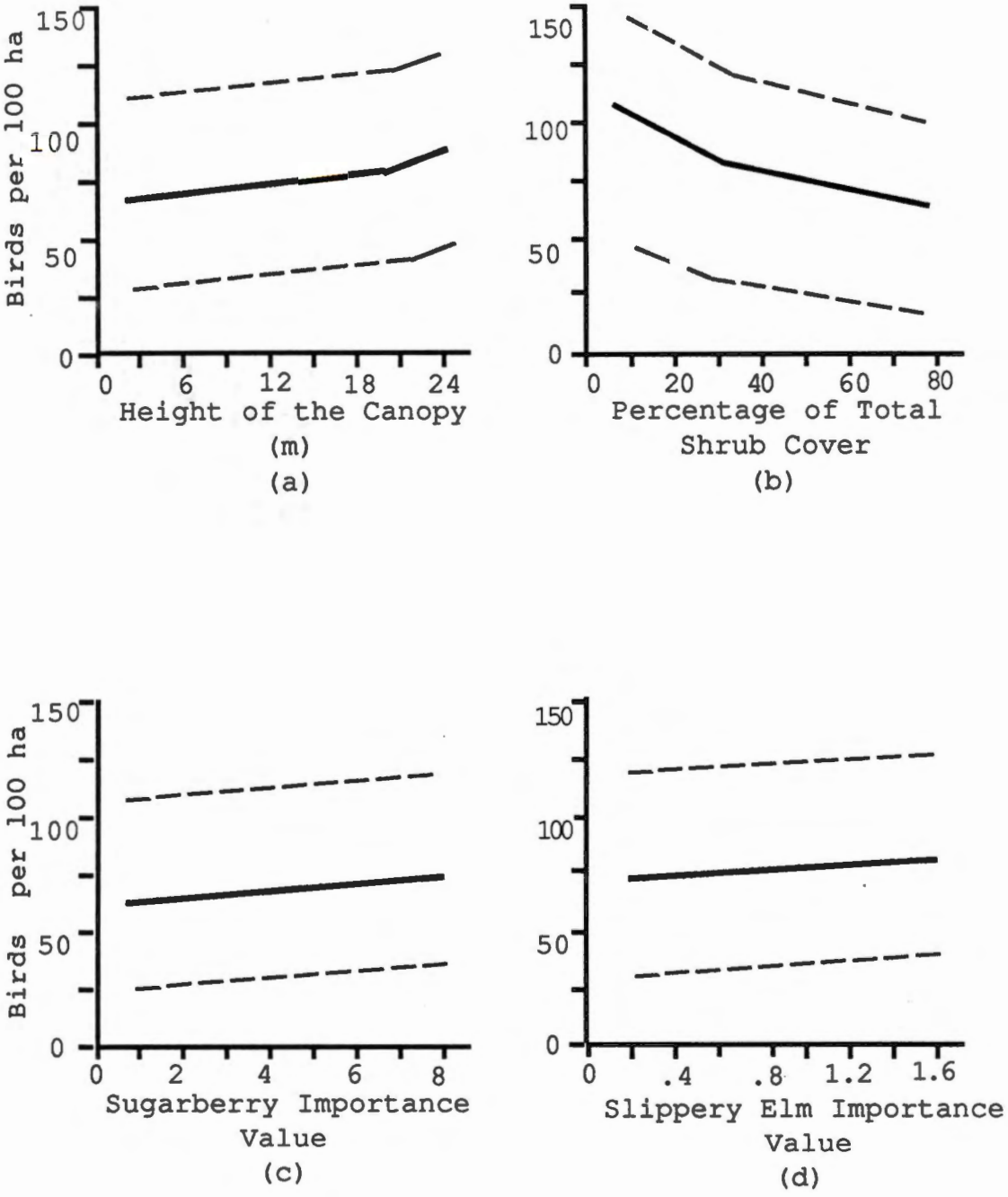


Figure 25. Regression of Yellow-rumped Warbler density with significant habitat variables of forested wetlands.

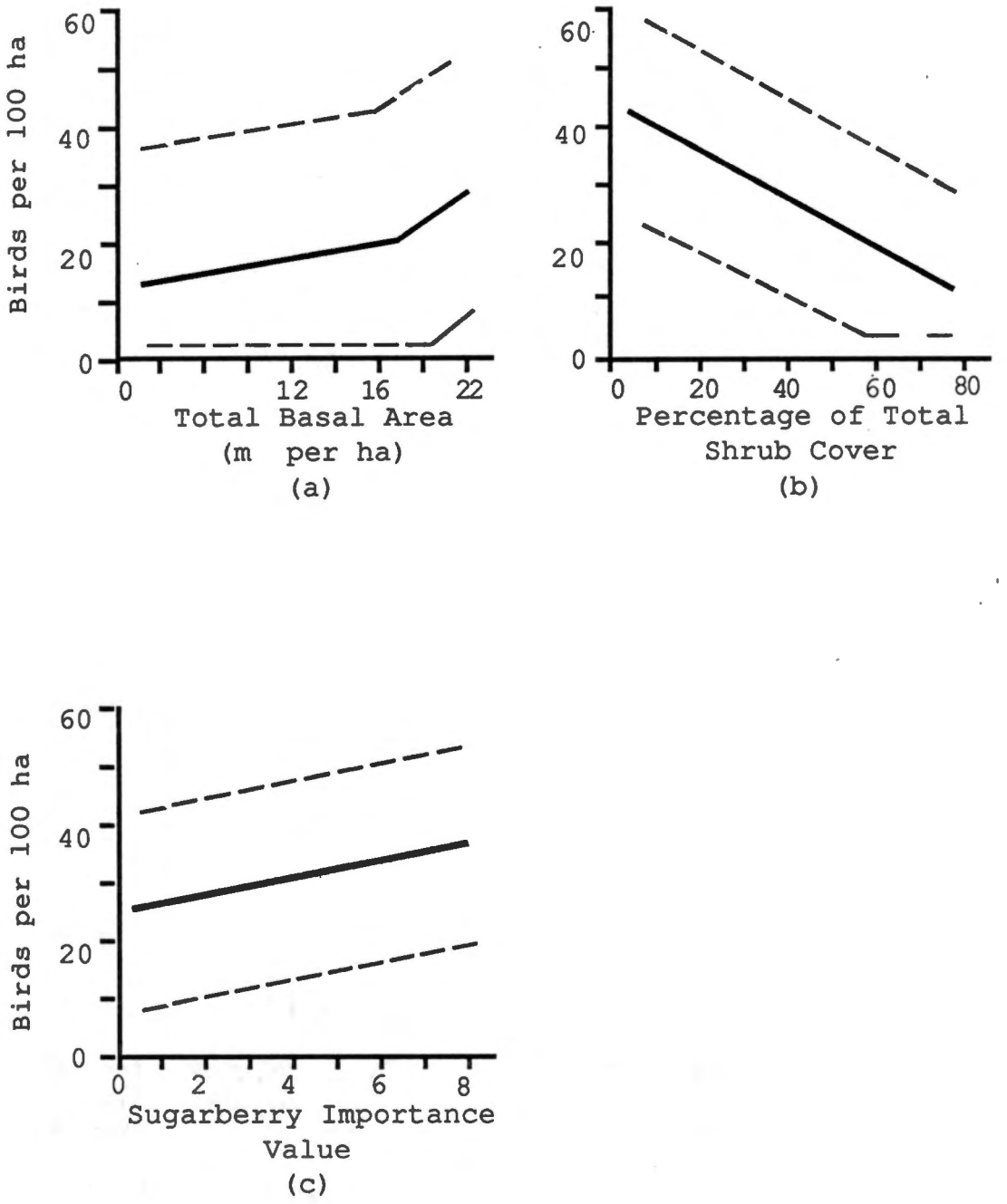


Figure 26. Regression of Downy Woodpecker density with significant habitat variables of forested wetlands.

Golden-crowned Kinglet - Density estimates ranged from 0 to 88 birds per 100 ha. This winter resident was most abundant in forests with a high total basal area, but a low number of stems in the subcanopy, and a dominance of sugarberry and silver maple (Figure 27). The presence of silver maple was the strongest predictor of density. In forests where silver maple reached an importance value of 4.5 or more, high densities of kinglets occurred. Kinglets occurred rarely in forests with few silver maples.

Tufted Titmouse - Density estimates ranged from 4 to 120 birds per 100 ha. Highest winter densities of this permanent resident occurred in forests with a high total basal area, a high importance value for slippery elm, and low importance values for green ash and boxelder (Figure 28). These elements accounted for 20% of the total variation in this species' density. The relative importance of green ash was the strongest predictor of density. Forests with 30 or more birds per 100 ha averaged .6 importance value green ash. Forests with less than 30 birds per 100 ha averaged an importance value for green ash of .9 to 1.2.

Rusty Blackbird - Density estimates ranged from 0 to 240 birds per 100 ha. Densities of this species were highest in forests with a low total basal area, low number of stems, and tall average tree height (Figure 29).

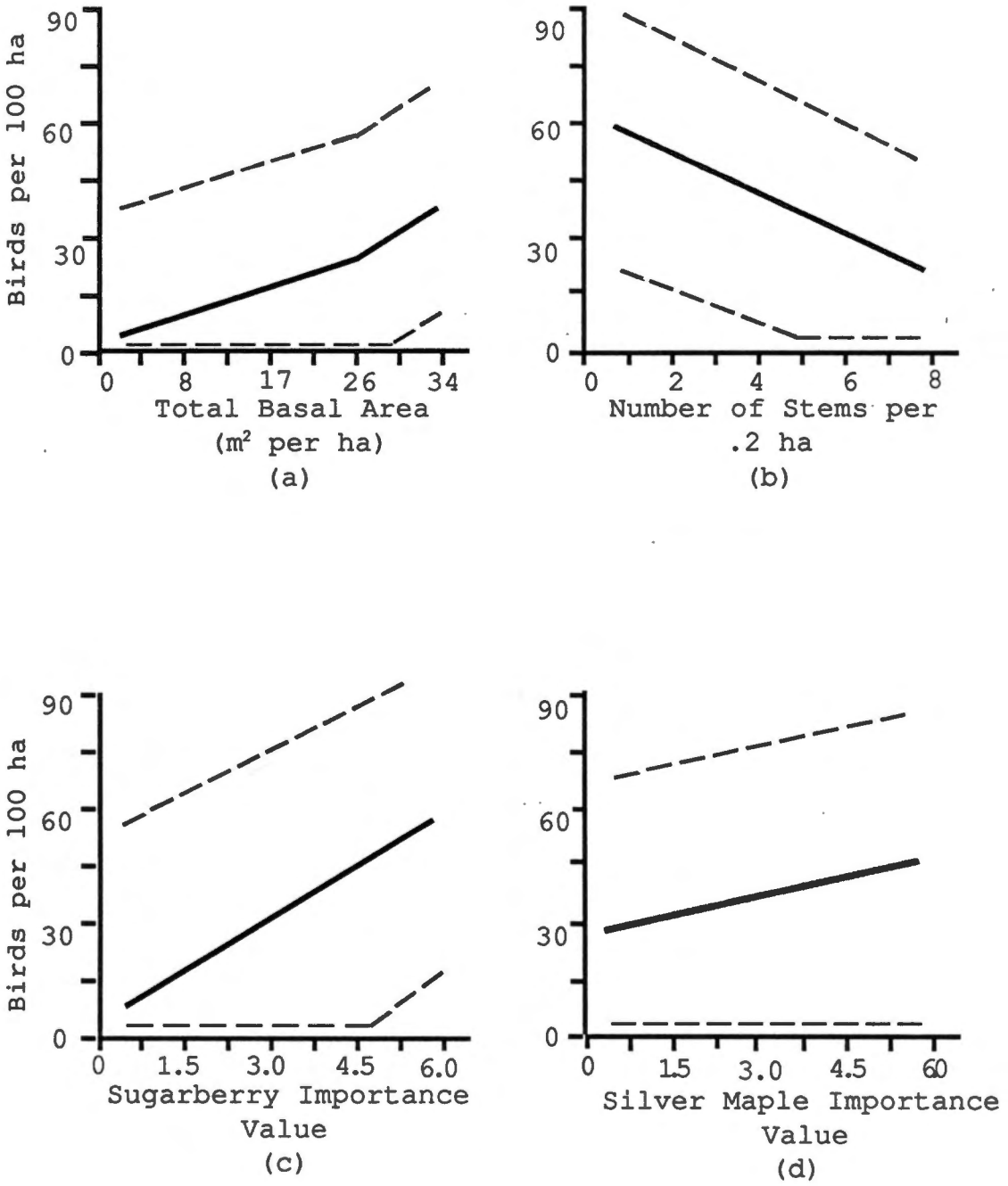


Figure 27. Regression of Golden-crowned Kinglet density with significant habitat variables of forested wetlands.

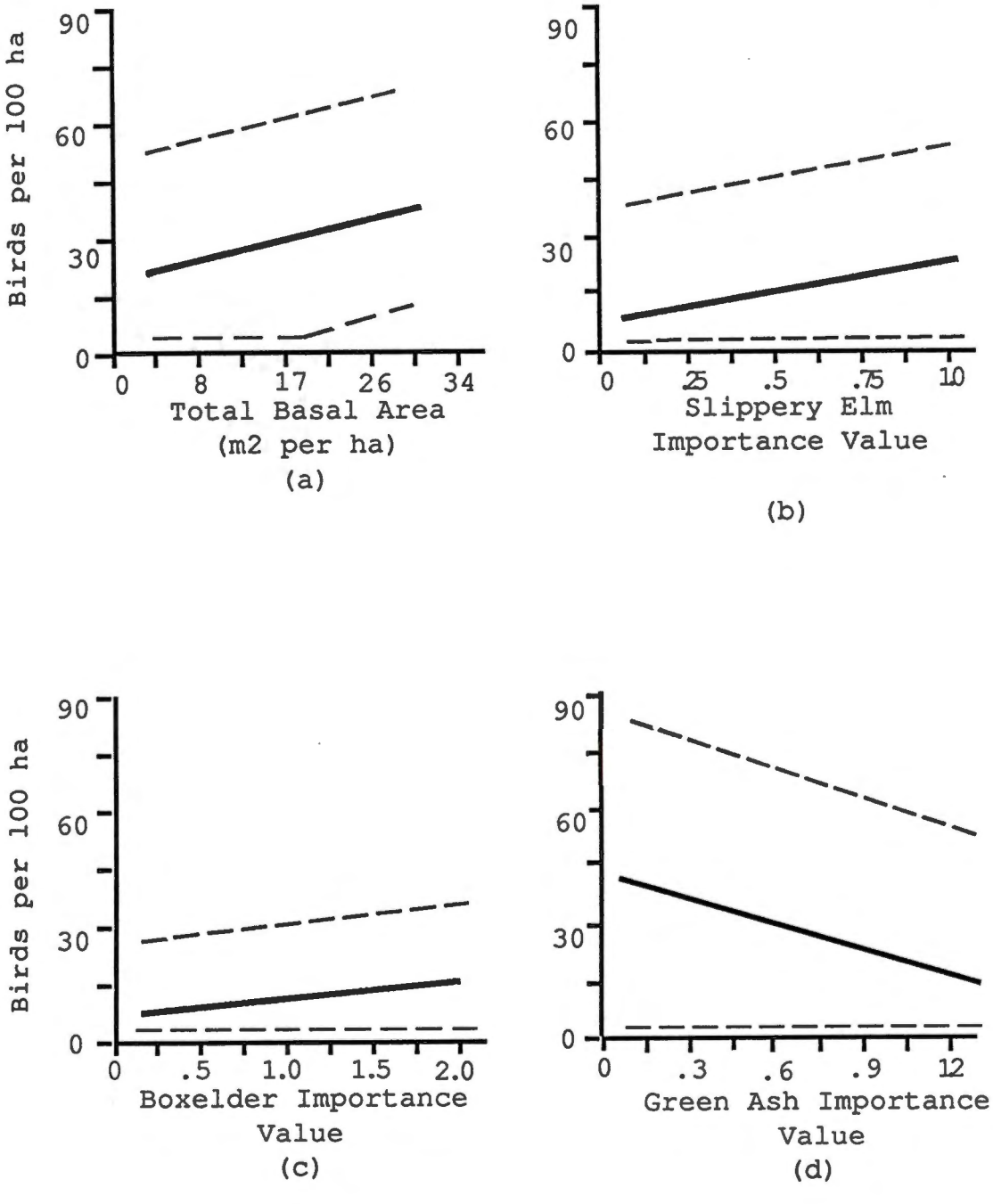


Figure 28. Regression of Tufted Titmouse density with significant habitat variables of forested wetlands.

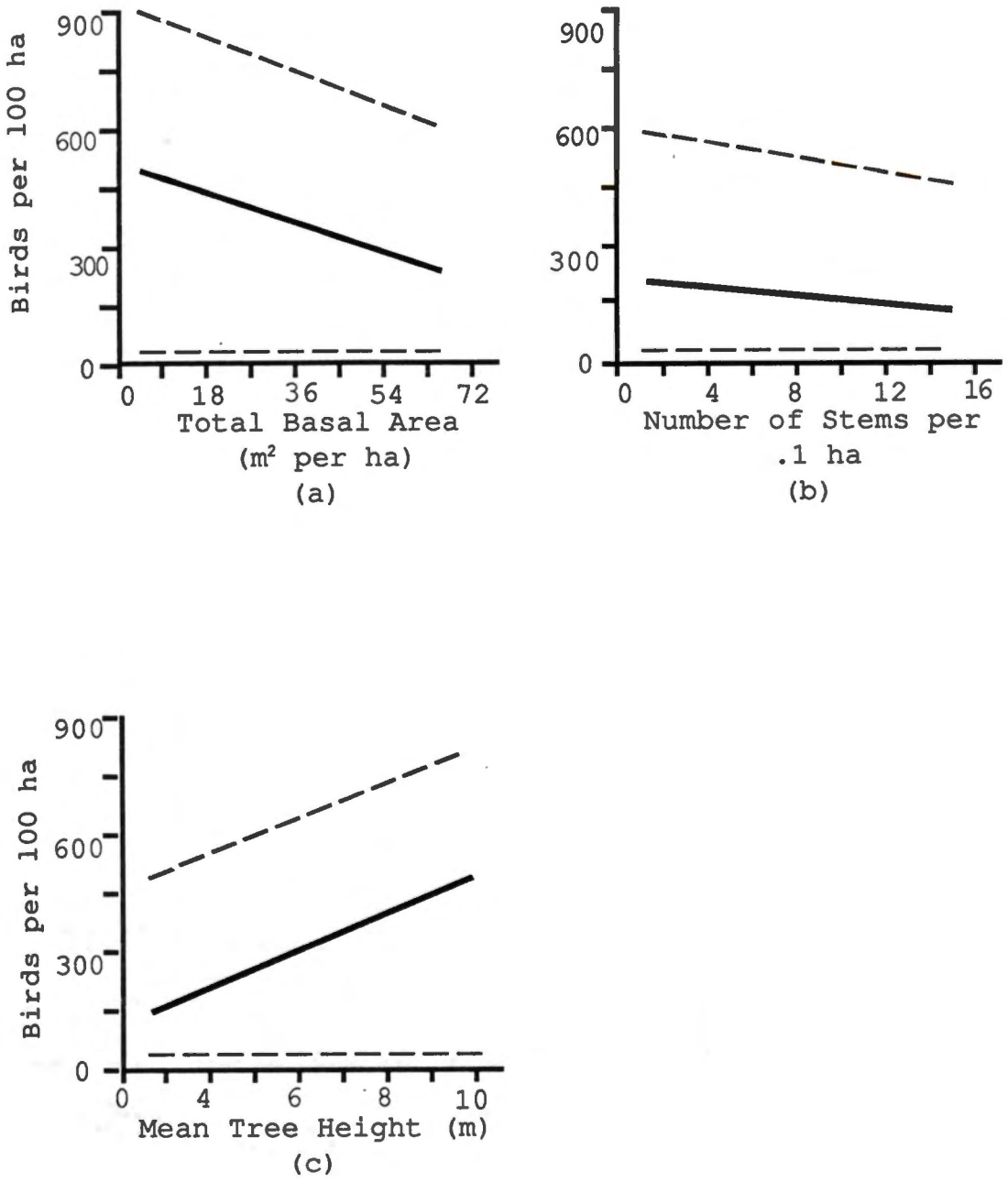


Figure 29. Regression of Rusty Blackbird density with significant habitat variables of forested wetlands.

These elements accounted for 16% of the total variation in this species' density. Total basal area was the strongest predictor of density. Forests with a total basal area of less than 18 m^2 per ha averaged 500 birds per 100 ha, whereas forests with a total basal area of more than 54 m^2 per ha averaged 300 birds per 100 ha.

Mallard - Density estimates ranged from 0 to 351 birds per 100 ha. This species concentrates in large flocks during the winter, and was abundant on some sites but scarce on others. The presence of water tupelo and oaks, combined with a high snag basal area, accounted for only 1% of the variation in this species' density, and the model was not statistically significant. Highest densities were found on 2 publicly owned wildlife management areas; the Chickasaw National Wildlife Refuge (density=351 birds per 100 ha) and White Oak Swamp (density=173 birds per 100 ha). Forests with 0 birds per 100 ha (n=34 sites) were mostly dry bottomland hardwoods, rarely flooded because of stream channelization and/or isolation of the forest tract from the river.

American Robin - Density estimates ranged from 0 to 80 birds per 100 ha. High winter densities of this permanent resident occurred in forests dominated by sugarberry, and having an open canopy and few brushpiles (Figure 30). These elements accounted for 42% of the total variation in this species' density. A relatively open canopy was the

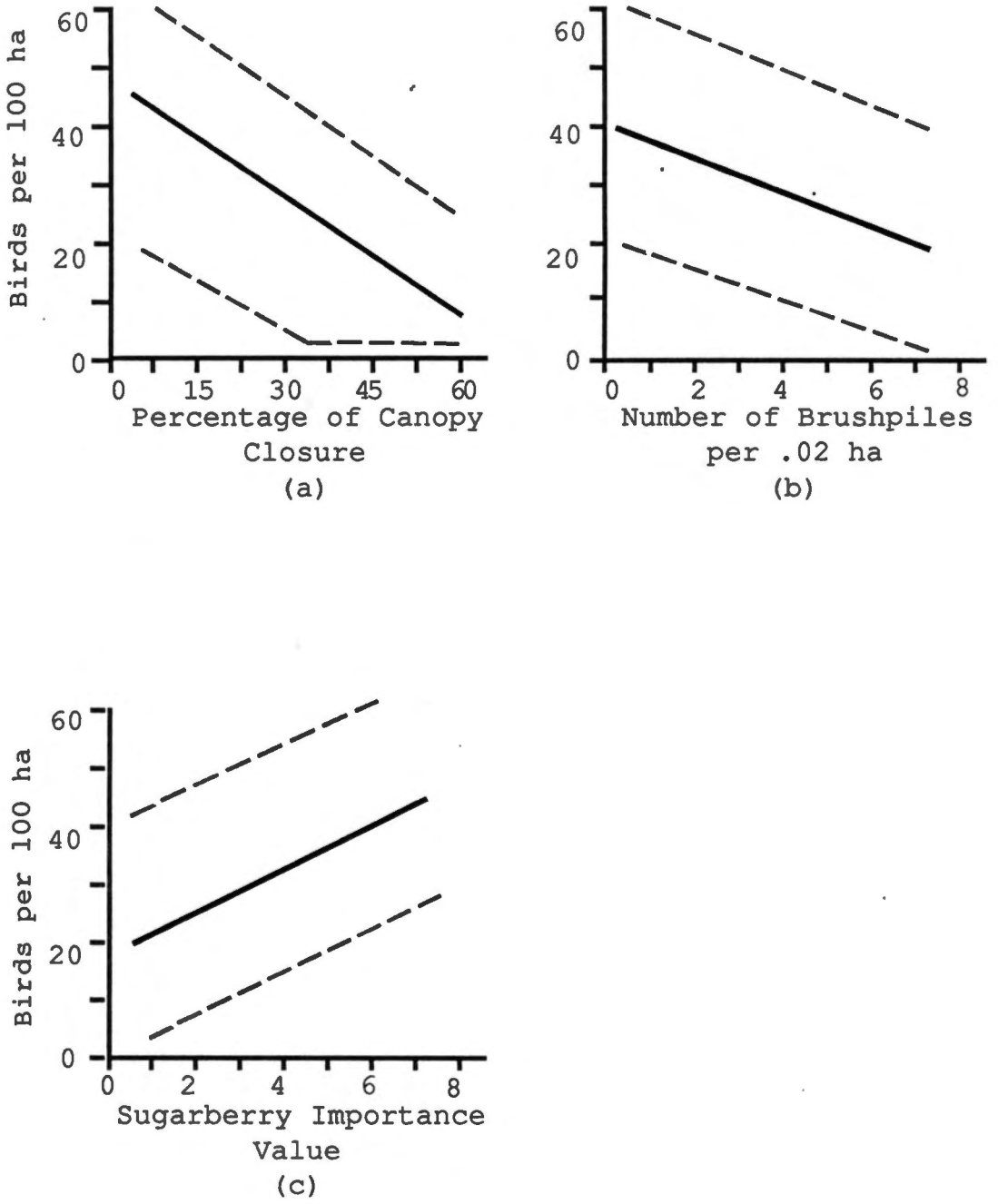


Figure 30. Regression of American Robin density with significant habitat variables of forested wetlands.

strongest predictor of high density. Highest numbers of robins occurred in forests where canopy closure was less than 30%, less than 20 birds per 100 ha occurred in forests that had greater than 45% canopy closure.

American Goldfinch - Density estimates ranged from 0 to 80 birds per 100 ha. Highest winter densities for this permanent resident occurred in sugarberry forests having a tall average shrub height and high number of snags (Figure 31). These elements accounted for 9% of the total variation in this species' density. The number of snags was the strongest predictor of density. Forests with 30 birds per 100 ha averaged 6 snags per .1 ha plot, whereas forests with 20 birds per 100 ha averaged 3 snag per .1 ha plot.

Winter Wren - Density estimates ranged from 0 to 76 birds per 100 ha. This winter resident was most abundant in forests dominated by sugarberry and slippery elm, which had a high total basal area and numerous brushpiles (Figure 32). These elements accounted for 19% of the total variation in this species' density. Total basal area was the strongest predictor of density. Forests with a total basal area of 25 m^2 per ha averaged about 4 or 5 birds per 100 ha. Forests with less than 9 m^2 per ha total basal area averaged about 3 birds per 100 ha.

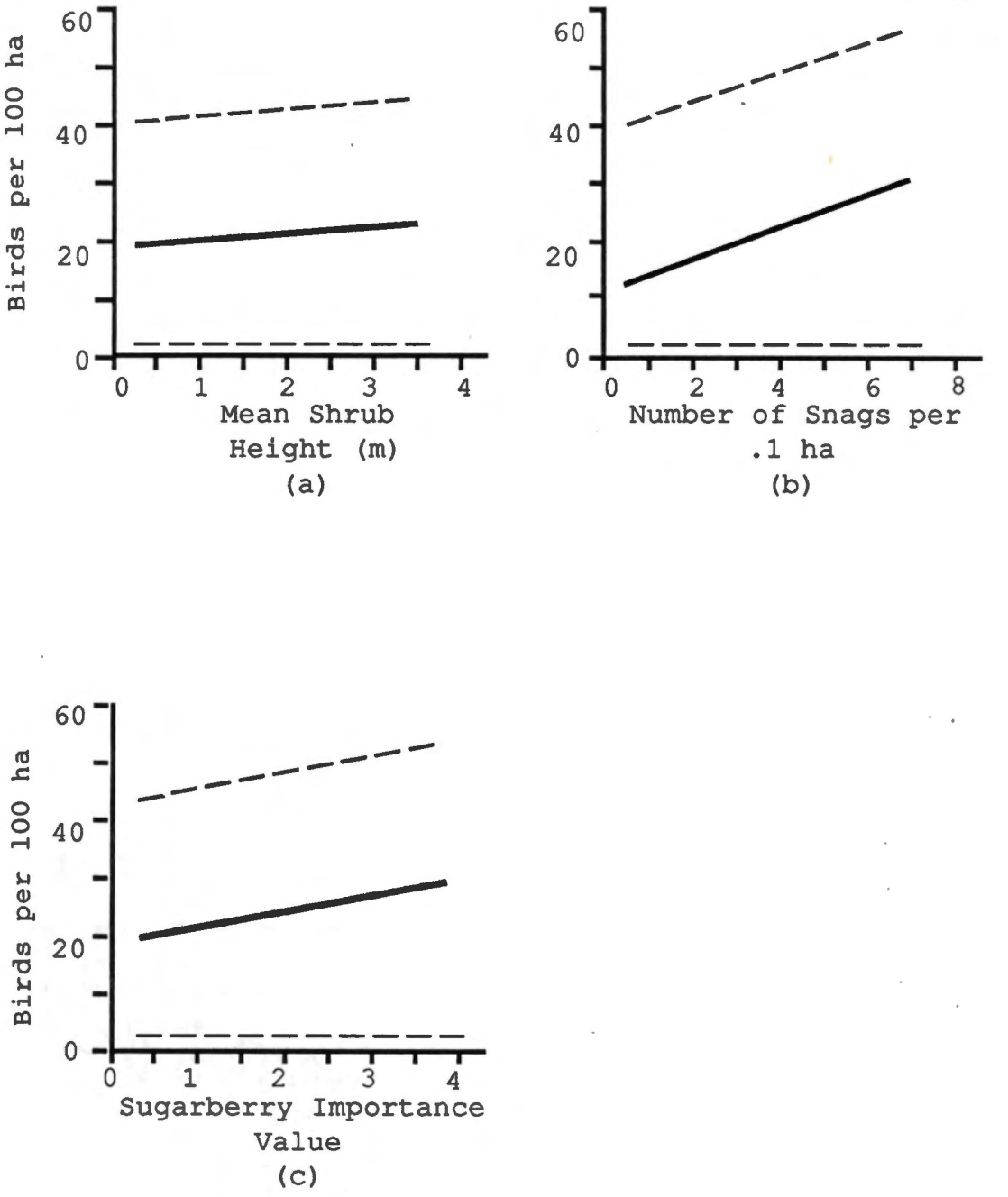


Figure 31. Regression of American Goldfinch density with significant habitat variables of forested wetlands.

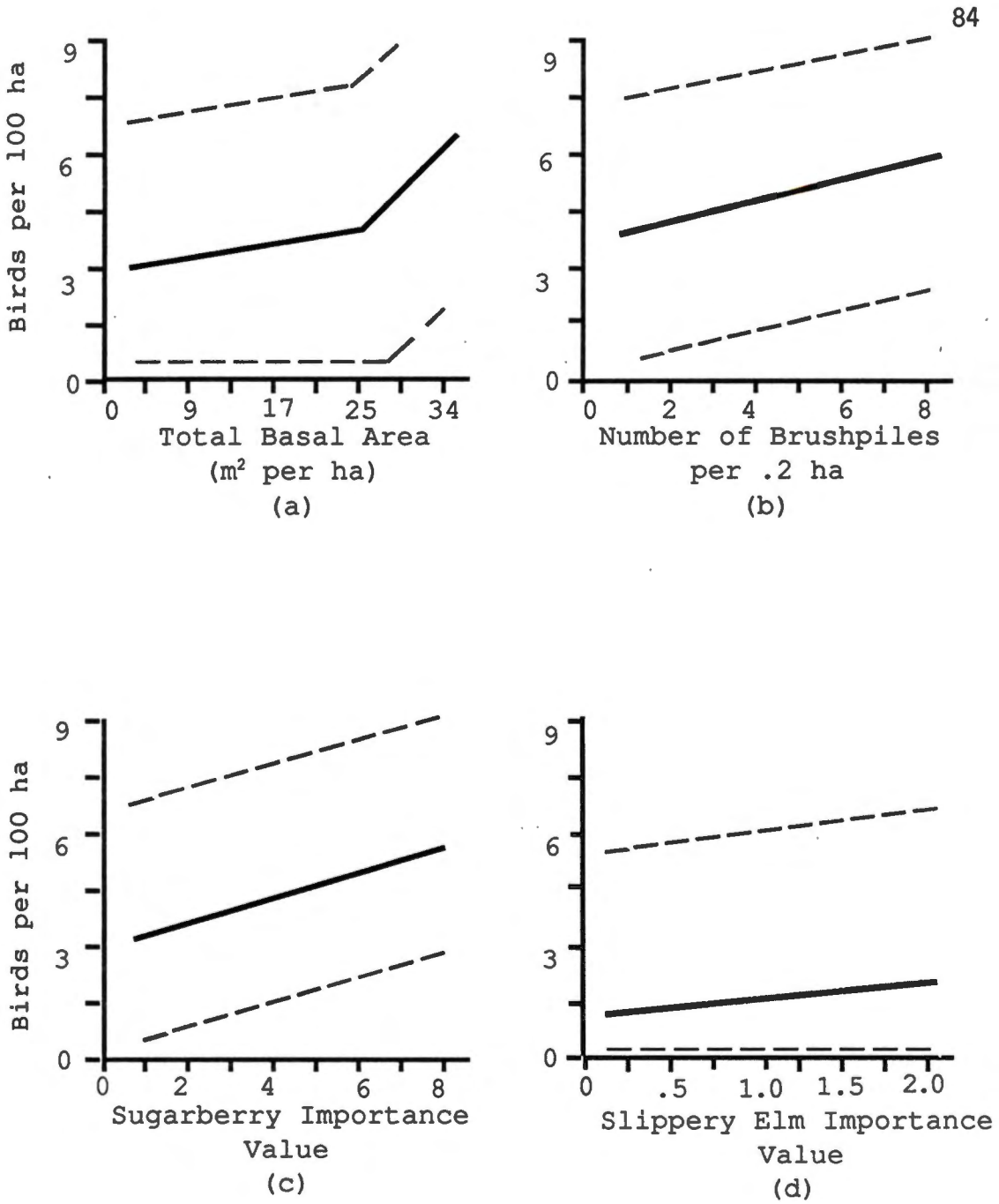


Figure 32. Regression of Winter Wren density with significant habitat variables of forested wetlands.

CHAPTER VI

DISCUSSION

Within the last 200 years, forested wetland acreage in the lower Mississippi River valley has declined from approximately 8.8 million ha to less than 2 million ha (Tiner 1984). Wetland loss was particularly severe from the mid-1950's to the mid-1970's, when conversion rates in the Mississippi Valley were 3 times the national average (OTA 1984). Most wetlands loss was through the cumulative impacts of relatively minor development projects. Cumulative impacts are watershed scale phenomena, and result from "the summation or interaction in space or time of individual minor projects" (Gosselink et al. 1989).

Bird density and species richness in west Tennessee wetland forests are limited by cumulative impacts which reduce forest tract size and alter natural flood regimes. At least 2 species, the Ivory-billed Woodpecker and Carolina Parakeet, have become extinct in the lower Mississippi River valley because of deforestation within the last 150 years. In one watershed in Louisiana, densities of 11 of 37 birds declined, and an estimated 3 to 4 species have been extirpated per decade because of the loss of bottomland hardwood forest (Gosselink et al. 1989). As cumulative impacts in wetland forests continue, ornithological research and habitat modeling become increasingly important.

I. Breeding season birds

Bird density and species richness among watersheds

Density - Highest breeding bird densities occurred in watersheds characterized by large forest tract size and relatively normal flood regimes. Differences in bird density among watersheds were most notable in the wood warbler complex (11 species). The highest densities of warblers occurred in watersheds with more than 40% of forested acreage in tracts greater than 2000 ha. At the other extreme, lowest warbler densities occurred in the watershed with no forest tracts greater than 2000 ha.

Large forest tracts retain microhabitats important to breeding birds, whereas smaller forest tracts may not (Harris 1984, Wilcove and Robinson in press). Low densities of birds in some middle Tennessee forests may be because of the lack of permanent streams in small tracts (Ford and Hamel 1988). In Massachusetts wetlands, microhabitats were critical for high densities of breeding birds (Swift et al. 1984).

Birds in small forested tracts are subject to increased predation and nest parasitism pressures, as well as loss of microhabitats (Wilcove and Robinson in press). Nest predators include a variety of birds and mammals that reach highest densities at forest edge habitats. Predators may be

extremely successful 600 m into the forest interior from the forest edge (Wilcove 1985). Brown-headed Cowbirds are nest parasites, and limit the nesting success of birds. For example, many warblers will not reject cowbird eggs from their nest (Wilcove and Robinson in press). Cowbird populations have increased in the last 90 years, and the species is currently widespread in west Tennessee.

Flood regimes determine forest structure and composition (Cowardin et al. 1977). Bird density in the Mississippi Valley is heavily influenced by vegetation structure and composition, especially as altered by humans (Emlen et al. 1986). Isolation from natural flood regimes caused unnatural drying in many forests, resulting in a loss of standing or running water and a change in forest structure and composition.

Highest densities of birds in west Tennessee occurred in a watershed with an unchannelized river. Lowest bird densities occurred in the floodplain of the most severely channeled river.

Species richness - Highest species richness was found in forests near major continental rivers, the Tennessee and Mississippi. White Oak Creek of the Tennessee River is a relatively large (2,079 ha) tract, internally heterogeneous, and managed by a state agency. Wetlands are rapidly disappearing around this floodplain forest because of conversion to agriculture and flooding from a TVA impoundment. White Oak Creek may be supersaturated with

birds from surrounding lands that have been made unsuitable habitat because of wetland conversion. Noss (1981) described this situation for an Ohio nature preserve under similar conditions, where the avifauna was richer than in comparable temperate zone forests.

Large average tract size increased species richness in forests near the Mississippi River. Species richness generally increases with forest tract size (Galli et al. 1976) because of an increase in the number of specialists (Blake and Karr 1987). In watersheds of west Tennessee where forest tract size is small, specialists are limited.

Differences in warbler populations among watersheds were most notable in quantifiable, rather than qualitative, ways (see density discussion above). However, 2 watersheds had a lower warbler species richness than other watersheds. For example, Louisiana Waterthrush did not occur in the Forked Deer River basin because channelization has created small forest patches isolated from natural hydrology. This species prefers habitats with a high interspersion of wet and dry habitats, often foraging on dry land at the edge of water. Forest patches in the Forked Deer floodplain are extremely wet or dry, with little interspersion of habitats.

Bird-habitat relationships

Habitat models are based on relationships between animals and their environment, and are increasingly important for natural resource planning and decision making.

Schamberger and O'Neil (1986) listed important conditions for forming models; variables should include those that the species responds to, are easily measured, and can be influenced by planning decisions. Species accounts were based on readily quantified variables of vegetation structure and composition to which abundant birds in west Tennessee forested wetlands responded.

Habitat structure - This study supports the hypothesis that structure is a stronger predictor of individual species density than tree species composition. Bird community composition and individual species density may be determined by structure in many community types (Anderson and Shugart 1974, Swift et al. 1984, and others). Structure provides birds with display perches, shelter or nest sites, and suitable foraging areas (Weins 1973). The absence of essential nest structures in forests, such as snags, may limit densities of some species (Stauffer and Best 1982).

Percentage of total shrub cover was the most important habitat element among abundant breeding birds. Less than 13% total shrub cover appeared to be optimum. A high percentage of shrub cover may restrict maneuverability of some birds in these secondary, low canopy forests. Characteristics of the shrub layer were important in determining breeding bird community composition in forested wetlands of Massachusetts (Swift et al. 1984). Total basal area, percent canopy closure, and the number of brushpiles in forests were other important elements of the habitat.

Snags are an important component of forest structure and, increasingly, studies recommend forestry techniques that retain snags in forests (e.g. Brawn et al. 1984). Six birds evaluated for species accounts were cavity nesters and/or used snags extensively as a foraging substrate. Densities of 3 were dependent on snag characteristics within forests. Prothonotary Warbler density, for example, was dependent on snag total basal area. Prothonotary range distribution and density is limited by the availability of nest sites (Emlen et al. 1986, Petit 1989).

Carolina Chickadees, Downy Woodpeckers, and Great-crested Flycatchers are cavity nesters whose densities were not related to snag density. The structure of the forest surrounding snags may be vitally important to cavity nesters (Brawn et al. 1986). Habitat relationships reflect this, and include height and density of the canopy, and density of the shrub cover. Balda (1975) speculated that open space between the understory and shrub layer may be an important habitat structure by increasing vertical edge.

Cavity nesters whose densities were not dependent on snag density may prefer cavities in dead limbs of live trees (dens) for nesting. Great-crested Flycatchers nest more commonly than other species in dead limbs of live trees (Stauffer and Best 1982). Our vegetation sampling scheme did not include dens. However, high densities of den trees may have been common in many forests sampled during this study. Den trees are most common in stream margins or deep

swamps of unmanaged forests greater than 60 years old, and dominated by oak, tupelo, and/or cypress (McComb et al. 1986).

Habitat composition - Tree species composition is an important component of habitat models (Schamberger and O'Neil 1986). Tree species were included in most species accounts, although it was the strongest predictor of density for only Common Grackles, Carolina Chickadees, and Great-crested Flycatchers. Forest composition is more influential to bird density over an entire geographic range (Morrison et al. 1987) than at a specific site.

Geographic range comparison of habitat relationships Most species accounts generally support habitat relationships that have been established for that species in other parts of its range. Northern Cardinal, for example, is a ubiquitous species, a dominant species in clearcuts and mature forests of east Texas (Dickson and Selequist 1979), as well as old growth bottomland hardwoods of South Carolina (Hamel in press). Percentage of shrub cover was the strongest predictor of density in this study. Shrub cover was an important structural component for Cardinals in east Tennessee (Anderson and Shugart 1974), east Texas (Conner et al. 1983), and Wisconsin (Bond 1957).

Habitat relationships often differ across the geographic range of a species (O'Neil et al 1988). Habitat relationships of Downy Woodpecker and Tufted Titmouse in west Tennessee differed slightly from those in other parts

of their ranges. Downy Woodpeckers were considered a "sapling specialist" in east Tennessee forests (Anderson and Shugart 1974), and over most parts of their range (Schroeder 1982). However, Downy Woodpeckers in west Tennessee occurred most commonly in forests with large trees and a low percentage of shrub cover.

Tufted Titmice are generally associated with mature forest stands. In east Texas, Conner et al. (1983) found the species most abundant in forests with large trees and a high percentage of canopy closure. High densities of Tufted Titmice exist in similar conditions in east Tennessee (Anderson and Shugart 1974) and South Carolina (Hamel in press). Snags, subcanopy trees, and brushpiles were important structural components for titmice density in west Tennessee. Although each of these structural components is characteristic of mature forests, none define titmice habitat relationships as such.

II. Winter season birds

Bird density and species richness among watersheds

Density - High winter bird densities were not consistent with the amount of disturbance in watersheds. Highest densities occurred in watersheds with both highest and lowest levels of disturbance; watersheds with intermediate levels of disturbance had lowest densities. Many factors likely account for this.

Bird movement and territory defense during winter suggest a high individual mobility (Grzybowski 1983), which affects density. Severe winter weather caused a 58% decline in the number of species in bottomland hardwood forests of southern Illinois (Graber and Graber 1979). High densities of White-breasted Nuthatch, Red-headed Woodpecker, and Yellow-rumped Warbler shifted from bottomland to upland habitats. Populations of these species are also negatively affected by forest fragmentation (Galli et al. 1976) and cumulative impacts (Gosselink et al. 1989). Cumulative impacts from federal and state water projects since 1928 have negatively impacted habitats for wintering waterfowl and some federally endangered species (U.S. Army Corps of Engineers 1980).

Large flocks of Common Grackles and Mallards inflated densities of winter birds most dramatically in the White Oak Creek watershed of the Tennessee River. Management of the surrounding lands by the state resulted in water impoundment and agricultural use, which increased winter concentrations of both species. Similar situations existed for a wildlife management area in Missouri (Smith 1987).

Excluding flocks of Common Grackles and Mallards, highest winter bird densities were found in the Loosahatchie watershed. This watershed is the most highly disturbed in west Tennessee, with no forest tract greater than 2000 ha. Small forest tracts are often internally heterogeneous because of invasion of edge species and high levels of human

disturbance (Harris 1984). Forest patches in the Loosahatchie watershed were heterogeneous because of beaver ponds. Edge created habitats for high densities of several birds, including White-throated Sparrow and Northern Cardinal.

Watersheds characterized by large forest tract size and relatively normal flood regimes exhibited the second and third highest densities of birds. Large tract size and mature forest contribute to high winter bird densities in these watersheds. Lowest densities of winter birds were found in the floodplain forests of the Wolf River. Nearly half of the river is located in a developed urban environment and has been channelized in the past.

Species richness - Highest species richness occurred in the Tennessee and Mississippi River floodplain forests. Large forest tract size contributed to high species richness in both watersheds. Species richness increases with the size of forest tracts during both winter and breeding seasons (Blake 1987). The presence of waterfowl species other than Mallard added species unique to these watersheds. Waterfowl were not as frequently observed in the interior of west Tennessee.

Lowest species richness occurred in the Obion River watershed, where cumulative impacts of historic and current channelization have reduced the size of forest tracts and produced atypical flood patterns. Highest species richness

is found in forests near natural areas, and lowest in forests near worked or maintained channels.

Bird-habitat relationships

Bird-habitat relationships change from breeding to winter seasons. Determining habitat requirements for birds during an annual cycle is fundamental to habitat modelling. Minimum temperature, length of the frost-free period, vegetation, and annual precipitation and humidity limit continental winter ranges of birds (Root 1988). Within forest tracts, habitat selection by winter birds is primarly based on the presence of food (Hutto 1985) and cover (Morrison et al. 1986). Species accounts contained vegetation structure and composition variables to which abundant winter birds responded.

Habitat structure - Structure of forest vegetation was a stronger predictor of individual species density than tree species composition. Birds increase their use of forests with dense canopy and subcanopy layers during winter (Morrison et al. 1986), and forage at a lower level in the forest (Dickson and Noble 1978), possibly for additional weather protection. Nearly half of the abundant species examined during this study preferred forests with a high total basal area, but low overall percentage of shrub cover.

Small dense patches of vegetation at the forest floor, rather than a continuous layer, were correlated with high densities of some birds during winter in west Tennessee.

High densities of White-throated Sparrows and Northern Cardinals occur in small dense understory patches in winter. Cover was best represented in this study by brushpiles and shrub cover. Winter birds may breed in northern habitats with dense understory patches, and select similar habitat during winter in west Tennessee. For example, Winter Wrens breed in damp, northern coniferous forests where "dead wood in the form of slash, downed trees, or standing skeletal trees seems a requirement" (Laughlin and Kibbe 1985). In west Tennessee, this species was found in mature bottomland hardwood forests with numerous brushpiles.

Habitat composition - Tree species composition, especially the presence or absence of mast-producing trees, is a meaningful component of winter habitat (e.g. Schamberger and O'Neil 1986, U.S. Army Corps of Engineers 1980). Sugarberry was significant for more species of birds than oak or hickory. During severe winter weather in Illinois, Yellow-rumped Warbler moves from bottomland to upland forests to feed on abundant poison ivy berries (Graber and Graber 1979). This bird was most abundant in forests dominated by sugarberry, where poison ivy is a common plant in the herbaceous layer (Patterson and DeSelm 1989).

Mast produced by oak and hickory was important to some abundant winter birds. Red-headed Woodpeckers were commonly found in forests dominated by hickory. Densities of this bird fluctuated with oak, hickory, and beech mast production

in forests of Illinois (Smith and Scarlett 1987). The presence of non-mast producing trees in species accounts probably reflected habitat requirements for birds. For example, Golden-crowned Kinglets were commonly observed near silver maple. Silver maple occurs at stream edges in bottomland hardwood forests of the Hatchie River (Steed 1979). The presence of silver maple may reflect a high interspersion of wet and dry habitats, which is critical to high kinglet densities in forested wetlands.

Seasonal comparisons of bird-habitat relationships - Six abundant winter birds were also abundant during breeding season. Each species has increased in abundance or is found at it's continental center of abundance in the Upper Gulf Coastal and/or Mississippi Alluvial Plain (Robbins et al. 1986). Density estimates calculated for Northern Cardinal, Tufted Titmouse, and Downy Woodpeckers were about the same between seasons. Density of Carolina Chickadee, Red-bellied Woodpecker, and Common Grackle increased notably during winter.

Habitat relationships were approximately the same between seasons for 3 of these species (Common Grackles were not included in a comparison between seasons because the winter model was not statistically significant). Northern Cardinal in Texas was a dominant species in habitats with dense shrub layers during winter (Emlen 1972) and breeding seasons (Conner et al. 1983). Complex forest structure, most notably a dense shrub layer, were important to

Cardinals during both seasons in west Tennessee. Tufted Titmice and Red-bellied Woodpeckers were more abundant in mature forests characterized by large snags during both seasons.

Two species changed habitat preferences from breeding to winter seasons. Downy Woodpeckers broaden their foraging patterns during post breeding and winter months (Conner et al. 1983). Kilham (1970) found an increased use of forest with high total basal area during this time period. During winter months in west Tennessee, Downy Woodpeckers increased use of forests with large canopy trees as compared to summer.

Carolina Chickadee increased their use of forests with dense canopy closure during winter. Many birds have high densities during winter in forests with greater canopy closure in contrast to summer, perhaps for better weather protection (Morrison et al. 1986).

CHAPTER VII

SUMMARY

This thesis is descriptive and comparative in nature. The objectives were to characterize the breeding and winter bird communities of west Tennessee's forested wetlands, assess bird density, composition, and species richness among watersheds with highly variable degrees of disturbance, and provide habitat models for abundant breeding and winter species occurring in forested wetland habitats.

Breeding and winter bird surveys were conducted on 59 sites from 1985 to 1987. Survey sites were in floodplain forests of 7 west Tennessee rivers. Time and amount of landscape level disturbances varied widely among watersheds. At one extreme, near complete channelization and small forest tract size ($\bar{x}$=211 ha) occur in the Loosahatchie watershed. At the other extreme, the Hatchie River retains relatively natural hydrology and large forested tracts ($\bar{x}$=4871 ha).

Bird species composition and density estimates were obtained using the Finnish line transect method (Jarvinen and Vaisanen 1975). Vegetation was sampled independently (see Durham et al. 1988, Patterson and DeSelm 1989). Vegetation data were used in this thesis for developing models explaining bird-habitat relationships.

I. Breeding season birds

Bird surveys were conducted on 180 km of transects on 59 forested wetland sites during breeding seasons. An average of 113 individuals and 28 species were found per site, with an average density estimate of 693 pairs per 100 ha.

Bird density and species richness among watersheds

Density - Breeding bird density within watersheds is limited by a reduction in forest tract size and isolation of forests from natural flood regimes. High densities of birds in the Hatchie and Mississippi River floodplains were attributed to large forested tracts and relatively natural hydrology. Development in narrow floodplains, such as the Loosahatchie, may not allow for retention of forested tracts large enough to retain a large number of microhabitats.

Species richness - Highest breeding species richness was in forests near major continental rivers, the Mississippi and Tennessee. Internal heterogenity and large tract size increased the number of species found at White Oak Swamp of the Tennessee River. In forests near the Mississippi River, large tract size increased species richness.

Highest densities of breeding warblers, birds recognized as being negatively impacted by disturbance, were found in watersheds with the least amount of cumulative

impact. Richness of the warbler species complex differed less among watersheds than did density.

Habitat relationships

Sixteen species were abundant in west Tennessee's forested wetlands during breeding seasons. These species comprised over 80% of the total density. In habitat models derived for each of these, structure was consistently a better predictor of bird density than tree species composition. The percentage of total shrub cover was the most important structure of vegetation in determining bird density. Nearly half the species analyzed reached their highest densities in forests with less than 13% shrub cover.

Snags were an important habitat element for 6 species. However, only 3 species were cavity nesters. Structure of the surrounding forest may be more important to some species than the snag itself. Important vegetation structure of these forests included a dense canopy closure and low percentage of shrub cover. Other species, such as the Great-crested Flycatcher, may prefer to nest in dead limbs of live trees, a structural component not quantified by typical vegetation sampling schemes.

Most species accounts supported habitat relationships documented in other parts of the species' range. Three accounts differed slightly: Downy Woodpecker, Tufted Titmouse, and Northern Parula Warbler. The most notable of these was for Downy Woodpeckers. Although considered a

sapling specialist in most of its range, Downy Woodpeckers in west Tennessee reached their highest densities in forests with scattered large trees (> 50 cm dbh).

II. Winter season birds

Bird surveys were conducted on 162 km of transects on 58 forested wetland sites during winter seasons. An average of 296 individuals and 23 species were found on sites, with an average total density of 830 birds per 100 ha. Flocking tendencies of Common Grackles and Mallards inflated density estimates in all watersheds. Excluding these flocks, average density was reduced to 689 birds per 100 ha.

Bird density and species richness

Density - Winter bird densities were high in both the most and least disturbed watersheds in west Tennessee. In highly disturbed watersheds, high bird density was attributed to high internal disturbance of forested tracts. In these habitats, relatively few species dramatically increased total density. Relatively undisturbed watersheds ranked second and third in bird density. These densities were attributed to natural hydrology and tract size.

Species richness - Species richness was highest in forests near major continental rivers. Species unique to these watersheds were attracted by land management practices of state and federal government agencies, which increased

agricultural production and impoundment of water. Low species richness was found in forests of intermediate, and historic, disturbance. The low number of species was attributed to urbanization and historic channelization.

Habitat relationships

Fifteen birds were abundant during winter. These species comprised over 80% of the total density. Vegetation structure was a better predictor of bird density than tree species composition. Total basal area and percent shrub cover were the most frequently used structural variables in the habitat models. Most species preferred forests with a high total basal area and low percentage of shrub cover. However, cover at the forest floor was important, particularly in the form of brushpiles and shrubs. Small dense patches appeared to be more important than a continuous, or high percentage of, cover at the shrub layer.

Mast trees were valuable habitat components in most species accounts. The most frequently used mast tree was sugarberry, followed by oak and hickory. The availability of mast trees determines densities of at least 2 species; Yellow-rumped Warbler and Red-headed Woodpecker. Yellow-rumped warblers are the only consistent warbler to winter in Tennessee, and this species' dependence on winter berries is well known. Densities of Red-headed Woodpeckers fluctuate with mast production. Highest densities of this species

occurred in oak-hickory dominated bottomland hardwood forests.

Six species were abundant during both seasons. The winter habitat model for Common Grackle was not significant, and that species was not included in these comparisons. Of the remaining species, 3 utilized generally similiar habitat both seasons. These species were Northern Cardinal, Tufted Titmouse, and Red-bellied Woodpecker. Two birds occurred in high densities in forests which differed structurally between seasons. The winter habitat of Downy Woodpeckers contained fewer subcanopy trees than its breeding season habitat. The winter habitat of Carolina Chickadees was characterized by denser canopy closure than favored breeding habitat.

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APPENDICES

Appendix I. River mile of study sites in west Tennessee watersheds, including latitude and longitude.

River	River mile	latitude	longitude
Wolf			
	19	35 07 11	89 47 47
	22	35 06 34	89 44 58
	42	35 03 35	89 32 13
	65	35 00 54	89 14 00
	71	35 04 20	89 34 34
	81	35 04 24	89 23 36
Loosahatchie			
	07	35 15 22	89 50 00
	20	35 16 17	89 48 05
	29	35 18 41	89 38 26
	76	35 19 37	89 47 23
	104	35 18 45	89 33 08
Hatchie			
	04	35 36 08	89 51 57
	13	35 37 30	89 46 42
	28	35 37 54	89 39 06
	36	35 37 32	89 34 38
	37	35 37 31	89 34 00
	54	35 32 12	89 27 38
	77	35 31 17	89 16 03
	89	35 29 39	89 10 20
	94	35 28 38	89 08 14
	99	35 27 30	89 05 07
	103	35 25 22	89 03 32
	116	35 20 10	89 00 19
Forked Deer			
	01	35 49 05	89 39 17
	04	35 49 15	89 39 12
	56	35 16 26	89 19 30
	64	35 43 00	89 12 33
	81	35 39 45	89 54 10
	104	35 28 27	89 36 32
	132	35 01 43	89 10 38
	212	35 45 12	89 19 58
	214	35 44 45	89 18 35
Obion			
	50	36 11 10	89 16 00
	92	36 04 32	88 42 17

River	River mile	latitude	longitude
	101	36 04 58	88 33 16
	110	36 42 13	88 50 07
	133	36 16 13	88 26 42
	160	36 26 22	88 43 00
	163	36 27 45	88 40 47
	180	36 25 38	88 24 35
Tennessee			
	10	35 20 47	88 18 26
	12	35 21 25	88 20 57
	19	35 21 33	88 16 00
	26	35 21 53	88 19 53
	31	35 20 24	88 16 03
Mississippi			
	723	35 00 53	90 10 00
	746	35 17 30	90 04 30
	750	35 20 25	90 04 14
	751	35 21 33	90 04 50
	759	35 26 07	89 58 30
	787	35 41 45	89 49 25
	800	35 47 10	89 42 46
	814	35 51 24	89 40 04
	817	35 50 50	89 39 05
	835	36 05 13	89 35 28
	856	36 12 46	89 34 12
	874	36 25 25	89 24 25
	881	36 29 15	89 21 35
	884	36 26 43	89 20 37

Appendix II. Scientific names of plants mentioned in the text.

Common name	Latin name
Cypress	*Taxodium distichum*
Black willow	*Salix nigra*
Cottonwood	*Populus deltoides*
Sycamore	*Platanus occidentalis*
Sugarberry	*Celtis laevigata*
American Beech	*Fagus grandifolia*
Yellow poplar	*Liriodendron tulipiferia*
Elm	*Ulmus spp.*
American elm	*Ulmus americana*
Slippery elm	*Ulmus rubrum*
Boxelder	*Acer negundo*
Red maple	*Acer rubrum*
Silver maple	*Acer saccharinum*
Green ash	*Fraxinus pennsylvanica*
Sweetgum	*Liquidambar stracifolia*
Oak	*Quercus spp.*
Water tupelo	*Nyssa aquatica*
Overcup oak	*Quercus lyrata*
Cherrybark oak	*Quercus pogodifolia*
Swamp chestnut oak	*Quercus michauxii*
Water oak	*Quercus nigra*
Hickory	*Carya spp.*

Appendix III. Bird densities (column A) and vegetation variables (column B) that required statistical transformation to achieve normal distribution. Bird densities and vegetation variables are listed by the method of normalization. Seasons for birds are included.

Normalization procedure required for: Column A Bird Density	season Breeding	Winter	Column B Vegetation variables
Log normal			
Carolina Chickadee	x	x	Snag height
Ruby-throated Hummingbird	x	-	Number of snags
Prothonotary Warbler	x	-	Snag basal area
Red-winged Blackbird	x	-	Total basal area
Northern Cardinal	-	x	Number of large trees
Yellow-rumped Warbler	-	x	
Downy Woodpecker	-	x	
Deletion of outliers			
Indigo Bunting	x	-	None
Common Grackle	x	-	
Northern Parula Warbler	x	-	
Yellow-rumped Warbler	-	x	
Golden-crowned Kinglet	-	x	
American Goldfinch	-	x	
ARC SIN			
None			Percentage of canopy closure
			Percentage of total herb layer
Sqaure root			
None			Number of stems
			Number of large snags
No transformation required			
Red-bellied Woodpecker	x	x	Number of brushpile
Downy Woodpecker	x	-	Canopy density
Tufted Titmouse	x	x	Shrub layer height
Blue-gray Gnatcatcher	x	-	Herb layer height
Acadian Flycatcher	x	-	Number of trees
Great-crested Flycatcher	x	-	Percentage of total shrub cover
Red-eyed Vireo	x	-	
White-eyed Vireo	x	-	
Northern Cardinal	x	-	
Rusty Blackbird	-	x	
American Robin	-	x	
Winter Wren	-	x	

Appendix IV. Simple regression correlations with vegetation parameters and 16 breeding, and 15 winter, abundant bird species. R-values are presented, an asterisk indicates a significant relationship ($p \leq .05$).

A. Structural vegetation parameters
Breeding season bird species

Bird species	Tall snag	Tall tree	Canopy closure	Mean snag height	Mean tree height	Snag basal area	Total basal area	Number of snags	Number of stems	Total corr.
Blue-gray Gnatcatcher	.23	.39*	.27*	.10	.25*	-.04	.40*	-.14	.04	4
Northern Cardinal	.13	.31*	.38*	.05	.01	-.16	.34*	-.13	.23	3
Acadian Flycatcher	.02	.27*	.35*	-.03	.42*	-.27*	.40*	-.30*	.20	6
Carolina Chickadee	-.09	.26*	.15	.01	-.01	-.14	.31*	-.27*	.08	3
Prothonotary Warbler	-.04	.04	.14	.02	.11	.01	.22	-.11	.02	0
Indigo Bunting	.02	.17	.06	.10	.09	-.14	.14	-.11	.16	0
Tufted Titmouse	.10	.20	.20	.18	.19	-.13	.22	-.03	.22	0
Downy Woodpecker	.01	.25	.30*	.27*	.32*	-.22	.31*	-.17	.06	4
Ruby-throated Hummingbird	.02	.16	.29*	.27*	.26	-.15	.26	-.09	.03	2
Common Grackle	-.17	.18	.09	.09	.08	-.21	.28*	-.28*	-.16	2
Great-crested Flycatcher	-.03	.13	.06	-.09	-.08	-.01	.17	-.15	-.03	0
Red-eyed Vireo	.11	.33*	.43*	.10	.29*	-.24	.40*	-.10	.03	4
Red-bellied Woodpecker	.11	.27*	.33*	.09	.25	-.14	.34*	-.17	.15	3
Northern Parula Warbler	.24	.32*	.23	-.20	.16	-.05	.32*	-.12	.27*	3
White-eyed Vireo	-.12	-.15	-.01	.16	-.12	-.03	-.03	-.04	.34*	1
Red-winged Blackbird	-.45*	-.58*	-.28*	-.09	-.23	.26*	-.15	.17	.01	4
Total corr.	1	8	8	2	4	2	9	3	2	39

Winter season bird species

Bird species	Tall snag	Tall tree	Canopy closure	Mean snag height	Mean tree height	Snag basal area	Total basal area	Number of snags	Number of stems	Total corr.
White-throated Sparrow	.21	.03	-.02	.15	-.11	.09	-.03	.15	.03	0
Common Grackle	.01	.03	.06	.03	-.04	.04	.07	.14	.20	0
Carolina Chickadee	-.08	.27*	.22	.10	.21	-.23	.33*	-.32*	-.01	3
Northern Cardinal	.01	.03	.08	-.01	-.16	-.06	.08	-.12	.05	0
Red-headed Woodpecker	-.14	.20	.26*	.17	.22	-.14	.25	-.14	.01	1
Red-bellied Woodpecker	-.01	.40*	.41*	.05	.32*	.40*	.47*	-.44*	-.14	6
Yellow-rumped Warbler	.02	.15	.09	.08	.21	-.15	.14	-.07	.03	0
Downy Woodpecker	.03	.37*	.27*	.10	.31*	-.18	.37*	-.16	-.03	4
Golden-crowned Kinglet	.13	.35*	.25	.07	.27*	.26*	.28	-.20	-.10	3
Tufted Titmouse	.03	.30*	.27*	.24	.25	-.25	.30*	-.20	.15	3
Rusty Blackbird	.06	-.20	-.18	.17	.04	.18	-.23*	-.29*	-.13	2
Mallard	.02	.01	.01	-.00	.02	-.04	.02	.04	.21	0
American Robin	.04	.09	-.04	.11	-.06	-.12	.01	-.08	.28*	1
American Goldfinch	-.10	-.12	-.10	.16	-.01	.03	-.07	.17	.11	0
Winter Wren	.14	.37*	.19	.30*	.29*	-.11	.32*	-.01	.07	4
Total corr.	0	6	4	1	4	2	6	3	1	27

B. Composition vegetation parameters
Breeding season bird species

Bird species	Hickory	Water Sugarberry	Tupelo	Oak	Cottonwood	Sycamore	Cypress	Red Maple	Sweetgum	Total corr.
Blue-gray Gnatcatcher	.14	.16	-.09	.17	.01	-.20	-.04	-.15	.02	0
Northern Cardinal	.10	.29*	-.11	.11	.10	.12	-.27*	.03	.05	2
Acadian Flycatcher	.19	.06	-.07	.28*	-.08	-.09	-.17	.02	.21	1
Carolina Chickadee	-.01	.03	-.08	.05	.11	-.25	.04	-.04	-.12	0
Prothonotary Warbler	-.06	-.20	.33*	-.01	-.11	-.44*	.20	.05	-.31*	3
Indigo Bunting	-.32	.68*	-.26*	-.23	.11	.35*	-.30*	-.14	-.02	5
Tufted Titmouse	.12	.28*	-.18	.19	.07	-.04	-.34*	-.03	.22	2
Downy Woodpecker	.07	.18	-.02	.18	.03	-.03	-.16	.01	-.01	0
Ruby-throated Hummingbird	.16	.21	-.07	.22	.11	-.06	-.15	-.03	-.02	0
Common Grackle	-.09	-.01	.02	-.09	.04	-.17	.25	-.08	-.19	0
Great-crested Flycatcher	-.04	-.12	.21	.01	-.04	-.30*	.18	.10	-.18	1
Red-eyed Vireo	.56*	.25	-.08	.30*	.16	.10	-.38	-.18	.11	3
Red-bellied Woodpecker	-.06	.26*	.08	-.02	.08	-.08	-.13	-.11	-.01	1
Northern Parula Warbler	.18	.07	-.15	.10	-.01	-.05	-.07	.12	.12	0
White-eyed Vireo	-.07	.09	-.18	-.11	-.12	.08	-.28*	.26*	.31*	3
Red-winged Blackbird	-.26*	-.20	.05	-.29*	-.07	-.18	.03	-.00	-.23	2
Total corr.	3	4	2	3	0	3	5	1	2	23

Winter season bird species

Bird species	Hickory	Sugarberry	Water Tupelo	Oak	Cottonwood	Sycamore	Cypress	Red Maple	Sweetgum	Total corr.
White-throated Sparrow	.22	.13	-.24	.27	-.14	.05	-.25	-.14	.08	1
Common Grackle	.03	-.11	.04	-.01	-.06	-.02	-.03	.17	.20	0
Carolina Chickadee	.19	.09	-.15	.11	-.01	-.18	.09	-.16	-.00	3
Northern Cardinal	.37*	-.07	-.24	.26*	-.09	-.22	-.06	-.15	.02	2
Red-headed Woodpecker	.39*	.02	-.09	.37*	.13	-.13	-.18	-.12	.22	2
Red-bellied Woodpecker	.03	.38*	.02	.07	.01	-.01	.05	-.30*	-.15	2
Yellow-rumped Warbler	-.18	.49*	-.14	-.12	.01	.17	-.17	-.25	.08	1
Downy Woodpecker	-.05	.32	-.07	.06	-.01	.14	.01	-.04	-.14	1
Golden-crowned Kinglet	-.07	.31*	-.10	-.03	.18	-.08	.07	-.12	-.11	1
Tufted Titmouse	.15	.25	-.15	.22	.04	-.04	-.11	-.02	.16	0
Rusty Blackbird	-.13	.13	.05	-.14	-.07	.32*	-.23	-.01	.02	1
Mallard	-.05	.15	-.06	-.07	.05	.03	-.12	.09	.18	0
American Robin	-.27*	.51*	-.21	-.15	.29*	-.05	-.22	.16	.02	3
American Goldfinch	-.16	-.02	-.09	.04	-.05	.11	-.12	.26*	-.03	1
Winter Wren	-.06	.25	-.16	-.05	.02	.10	.12	-.09	.04	0
Total corr.	3	5	0	3	1	1	0	2	0	15

Appendix V. Birds observed on 59 forested wetland sites in west Tennessee during breeding and winter seasons, 1985 to 1987. Number of sites, number of transects, number of individuals, and mean density for birds is compared between breeding and winter seasons Checklist order follows that of the American Ornithologist's Union (1982).

Birds	Number of sites recorded[1]		Number of transects recorded[2]		Mean number of individuals per site[3]		Mean density (pairs per 100 ha)[4]	
	Breeding	Winter	Breeding	Winter	Breeding	Winter	Breeding	Winter
Great Blue Heron (*Ardea herodias*)	17	7	30	14	2.2±.4	1.4±.1	4.6±.9	8.2±2.4
Great Egret (*Casmerodius albus*)	2	-	3	-	1.0	-	NA[5]	-
Little Blue Heron (*Egretta caerulea*)	3	-	3	-	1.3±.33	-	0.0	-
Cattle Egret (*Bubulcus ibis*)	2	-	3	-	3.3±.7	-	NA	-
Green-backed Heron (*Butorides striatus*)	18	-	25	-	1.4±.1	-	8.4±.8	-
Black-crowned Night-heron (*Nycticorax nycticorax*)	1	-	1	-	1.0±0.0	-	NA	-
Yellow-crowned Night-Heron (*Nycticorax violaceus*)	17	-	20	-	1.4±.2	-	6.4±1	-
Canada Goose (*Branta canadensis*)	-	11	-	16	-	4.7±3.2	-	NA
Wood Duck (*Aix sponsa*)	22	22	33	35	2.0±.3	22±3.9	10.4±6	78±47
American Black Duck (*Anas rubripes*)	-	2	-	2	-	.51±3	-	NA
Mallard (*Anas platyrhynchos*)	-	24	-	39	-	13.9±11	-	17.9±15
Hooded Merganser (*Lophodytes cucullatus*)	1	2	1	3	1.0±0	2.7±1.7	NA	40±40
Black Vulture (*Coragyps atratus*)	-	2	-	2	-	4.0±2	-	0.0±0
Turkey Vulture (*Cathartes aura*)	3	11	4	16	2.7±1	1.4±.2	-	0.0±0

Mississippi Kite (*Ictinia mississippiensis*)	1	-	1	-	2.0±0	-	NA	-
Northern Harrier (*Circus cyaneus*)	-	1	-	1	-	2.0±0	-	NA
Sharp-shinned Hawk (*Accipiter striatus*)	-	2	0	2	0	1.0±0	0	NA
Red-shouldered Hawk (*Buteo lineatus*)	37	34	87	70	1.5±.08	1.5±.07	1.4±.1	.8±.09
Red-tailed Hawk (*Buteo jamaicensis*)	3	11	3	12	1.0±0	1.2±.11	NA	1.3±.3
Wild Turkey (*Meleagris gallopavo*)	3	1	3	1	1.3±.3	1.0±0	40±0	NA
Northern Bobwhite (*Colinus virginianus*)	6	1	9	1	.67±.5	.07±.08	.82±.7	NA
Killdeer (*Charadrius vociferus*)	6	1	6	1	.04±.03	1.0±0	NA	NA
Common Snipe (*Gallinago gallinago*)	-	1	-	1	-	1.0±0	-	NA
American Woodcock (*Scolopax minor*)	-	3	-	3	-	1.0±0	-	40±0
Mourning Dove (*Zenaida macroura*)	19	9	35	16	2.1±.24	2.6±.7	2.1±1.1	.8±.3
Yellow-billed Cuckoo (*Coccyzus americanus*)	57	-	156	-	4.1±.2	-	10.5±.7	-
Great Horned Owl (*Bubo virginianus*)	-	4	-	4	-	1.2±.3	-	9.0±3.7
Barred Owl (*Strix varia*)	34	25	49	35	1.3±.09	1.6±.2	5±.6	2±.23
Chimney Swift (*Chaetura pelagica*)	34	-	68	-	2.0±.2	-	6.4±.9	-
Ruby-throated Hummingbird (*Archilochus colubris*)	42	-	82	-	1.9±.1	-	47±2.7	-
Belted Kingfisher (*Ceryle alcyon*)	14	6	12	11	1.0±0	1.1±.15	3.5±0	0.0±0
Red-headed Woodpecker (*Melanerpes erythrocephalus*)	33	53	76	118	2.2±.2	7.6±.6	10.7±.9	50±4.2

Red-bellied Woodpecker (Melanerpes carolinus)	58	59	176	166	5.6±.2	8.9±.4	15.7±.6	35±1.4
Yellow-bellied Sapsucker (Sphyrapicus various)	-	40	-	72	-	2.0±.17	-	14.2±1.4
Downy Woodpecker (Picoides pubescens)	57	59	174	166	3.7±.2	4±.15	27±1	27±1.1
Hairy Woodpecker (Picoides villosus)	29	44	40	83	1.3±.1	1.4±.08	9.7±.6	6.9±.5
Northern Flicker (Colaptes auratus)	21	59	33	157	1.2±.1	5.3±.3	2.7±.5	11.5±.6
Pileated Woodpecker (Dryocopus pileatus)	47	49	113	109	1.5±.08	2±.11	3.08±.2	2.1±.14
Eastern Wood-pewee (Contopus virens)	54	-	154	-	3.3±.16	-	5.5±.4	-
Acadian Flycatcher (Empidonax virescens)	58	-	179	-	8.7±.4	-	58.9±2.6	-
Eastern Phoebe (Sayornis phoebe)	3	4	3	6	1.0±0	.84±.1	7.3±0	8±2.0
Great-crested Flycatcher (Myiarchus crinitus)	54	-	153	-	3.9±.2	-	21±1.4	-
Eastern Kingbird (Tyrannus tyrannus)	2	-	2	-	1.0±0	-	NA	-
Horned Lark (Eremophila alpestris)	-	1	1	-	1.0±0	-	NA	-
Purple Martin (Progne subis)	2	-	2	-	1.0±0	-	NA	-
Tree Swallow (Tachycineta bicolor)	1	-	2	-	5.0±1	-	10.3±2	-
N. Rough-winged Swallow (Stelgidopteryx serripennis)	1	-	1	-	1.0±0	-	NA	-
Barn Swallow (Hirundo rustica)	1	-	1	-	1.0±0	-	NA	-
Blue Jay (Cyanocitta cristata)	48	58	133	108	1.9±.1	3.6±.3	4.5±.3	5.5±.5
American Crow (Corvus brachyrhynchos)	53	49	129	150	3.2±.2	5.9±.7	2.9±.2	.4±.06
Fish Crow								

Carolina Chickadee (*Parus carolinensis*)	59	58	176	164	6.2±.2	9.2±.5	56.2±2	81±5
Tufted Titmouse (*Parus bicolor*)	59	58	180	159	7.7±.2	6.3±.4	27.2±1.1	23±1.3
Red-breasted Nuthatch (*Sitta canadensis*)	-	5	-	5	-	.3±.08	-	0.0±0
White-breasted Nuthatch (*Sitta carolinensis*)	45	50	116	104	2.4±.2	3±.2	7±.5	5.9±.5
Brown Creeper (*Certhia americana*)	5	50	6	116	1.0±0	1.8±.1	7.3±0	18.2±1.1
Sedge Wren (*Cistothorus platensis*)	-	1	-	2	-	1.0±0	-	NA
Carolina Wren (*Thryothorus ludovicianus*)	57	58	158	152	3.3±.2	4±.2	10.6±.5	13±.7
Winter Wren (*Troglodytes troglodytes*)	-	54	-	133	-	2.6±.2	-	20±1.2
Golden-crowned Kinglet (*Regulus satrapa*)	-	52	-	125	-	2.7±.2	-	37±2.5
Ruby-crowned Kinglet (*Regulus calenda*)	-	17	-	28	-	1.3±.1	-	12.3±1.3
Blue-gray Gnatcatcher (*Polioptila caerulea*)	57	-	180	-	5.5±.19	-	150±5	-
Eastern Bluebird (*Sialia sialias*)	10	12	17	19	1.8±.7	1.2±1	1.44±.7	1.2±.6
Gray-checked Thrush (*Catharus minimus*)	1	-	1	-	1.0±0	-	NA	-
Swainson's Thrush (*Catharus ustulatus*)	13	-	18	-	2.8±.4	-	1.5±1.1	-
Hermit Thrush (*Catharus guttatus*)	-	48	-	95	-	2.4±.2	-	16.9±2
Wood Thrush (*Hylocichla mustelina*)	45	-	93	-	3.5±.3	-	9.6±.7	-
American Robin (*Turdus migratorious*)	2	55	2	107	1.0±0	4.3±.4	NA	26.3±2.7
Gray Catbird (*Dumetelk carolinensis*)	13	-	17	-	1.6±.2	-	16.3±2.2	-

Northern Mockingbird (*Mimus polyglottas*)	1	1	1	1	.8±.6	.2±0	NA	NA
Brown Thrasher (*Toxostoma rufum*)	1	9	1	11	1.0±0	1.3±.1	NA	9.4±1.4
Water Pipit (*Anthus spinoletta*)	-	1	-	1	-	1.0±0	-	NA
Cedar Waxwing (*Bombycilla cedorum*)	1	8	1	10	6.0±0	11±3.3	NA	37±15
European Starling (*Sturnus vulgaris*)	2	16	3	21	2.3±1.3	48±19	NA	81±38
White-eyed Vireo (*Vireo griseus*)	48	-	117	-	3.8±.2	-	16±1	-
Red-eyed Vireo (*Vireo olivaceus*)	56	-	146	-	4.6±.3	-	22.1±1.2	-
Yellow-throated Vireo (*Vireo flavifrons*)	35	-	70	-	1.5±.1	-	5.9±.5	-
Warbling Vireo (*Vireo gilvus*)	3	-	3	-	1.0±0	-	NA	-
Tennessee Warbler (*Vermivora peregrinus*)	14	-	18	-	4.5±1.3	-	51.8±14	-
Nashville Warbler (*Vermivora ruficapilla*)	3	-	3	-	1.3±.3	-	15.6±4	-
Northern Parula (*Parula americana*)	55	-	145	-	2.7±.1	-	16.1±.9	-
Yellow Warbler (*Dendroica petechia*)	7	-	8	-	1.1±.1	-	5.3±.6	-
Chestnut-sided Warbler (*Dendroica penslyvanica*)	5	-	5	-	0.3±.5	-	NA	-
Magnolia Warbler (*Dendroica magnolia*)	5	-	5	-	0.6±.3	-	NA	-
Yellow-rumped Warbler (*Dendroica coronata*)	2	51	2	120	3.5±.5	5.9±.6	31±16	46±6.7
Black-throated Green Warbler (*Dendroica virens*)	6	-	7	-	.4±.2	-	NA	-
Blackburnian Warbler (*Dendroica fusca*)	7	-	7	-	.5±.2	-	NA	-
Yellow-throated Warbler (*Dendroica dominica*)	36	-	92	-	2.5±.2	-	10.3±.8	-

Pine Warbler (*Dendroica pinus*)	-	1	-	1	-	1.0±0	-	NA
Bay-breasted Warbler (*Dendroica castanea*)	1	-	1	-	1.0±0	-	NA	-
Blackpoll Warbler (*Dendroica striata*)	1	-	1	-	1.0±0	-	NA	-
Cerulean Warbler (*Dendroica cerulea*)	15	-	43	-	2.7±.3	-	11.9±1.2	-
Black-and-White Warbler (*Mniotilta varia*)	9	-	10	-	1.1±.1	-	15.8±2.4	-
American Redstart (*Setophaga ruticilla*)	37	-	83	-	2.8±.3	-	23.2±2.3	-
Prothonotary Warbler (*Prothonotaria citrea*)	57	-	173	-	7.0±.3	-	54.0±2.3	-
Worm-eating Warbler (*Helmintheros vermivorus*)	1	-	1	-	1.0 ±0	-	NA	-
Swainson's Warbler (*Limnothlypis swainsonii*)	26	-	54	-	1.9±.2	-	6.9±.7	-
Ovenbird (*Seiurus aurocapillus*)	5	-	7	-	.4±.03	-	NA	-
Louisiana Waterthrush (*Seiurus motacilla*)	17	-	21	-	1.2±.08	-	3.4±.5	-
Kentucky Warbler (*Oporonis formosus*)	46	-	101	-	3.0±.2	-	12.3±.9	-
Common Yellowthroat (*Geothlypis trichas*)	29	-	67	-	3.9±.4	-	16.6±1.5	-
Hooded Warbler (*Wilsonia citrina*)	15	-	31	-	1.6±.2	-	10.5±1.1	-
Wilson's Warbler (*Wilsonia pusilla*)	1	-	1	-	1.0±0	-	NA	-
Canada Warbler (*Wilsonia canadensis*)	1	-	1	-	1.0±0	-	NA	-
Yellow-breasted Chat (*Icteria virens*)	24	-	43	-	2.8±.4	-	8.9±1.3	-
Summer Tanager (*Piranga rubra*)	47	-	107	-	2.2±.1	-	9.7±.6	-

Scarlet Tanager (*Piranga olivacea*)	12	-	15	-	1.2±.2	-	5.7±2.6	-
Northern Cardinal (*Cardinalis cardinalis*)	58	59	180	151	8.8±.3	4.9±.2	71±2	40±2.3
Rose-breasted Grosbeak (*Pheuctious ludovicianus*)	3	-	4	-	1.0±0	-	NA	-
Blue Grosbeak (*Guiraca caerulea*)	1	-	1	-	1.0±0	-	NA	-
Evening Grosbeak (*Coccothraustes vespertinus*)	-	8	-	9	-	.2±.4	-	NA
Indigo Bunting (*Passerina cyanea*)	55	-	151	-	6.9±.4	-	42.5±2.9	-
Rufous-sided Towhee (*Pipilo erythrophthalmus*)	21	12	39	23	2.3±.2	2.5±.4	9.5±1	11±3.1
Field Sparrow (*Spizella pusilla*)	-	3	-	3	-	1.7±.7	-	12±7.9
Savannah Sparrow (*Passerculus sandwichensis*)	2	-	2	-	.04±.08	-	NA	
Fox Sparrow (*Passerculus iliaca*)	-	4	-	4	-	1.0±0	-	.4±.2
Song Sparrow (*Melospiza melodius*)	-	21	-	39	-	.69±.2	-	4.7±2
Swamp Sparrow (*Melospiza georgiana*)	-	37	-	64	-	2.7±.3	-	21.7±2.0
White-throated Sparrow (*Zonotrichia albicollis*)	3	58	3	139	1.3±.3	10.2±.8	20±5	148±10.8
Dark-eyed Junco (*Junco hyemalis*)	-	5	-	5	-	2.4±.7	-	21±7.6
Red-winged Blackbird (*Agelaius phoeniceus*)	42	43	80	83	3.8±.5	50±15	23±3.0	9.6±2.7
Eastern Meadowlark (*Sturnella magna*)	-	1	-	1	-	9.0±0	-	NA
Rusty Blackbird (*Euphagus carolinus*)	-	34	-	52	-	17.5±6	-	77±22

Common Grackle (*Quiscalus quiscula*)	55	58	143	133	4.4±3	201±83	23±1	149±78
Brown-headed Cowbird (*Molothrus ater*)	57	10	146	14	2.5±.1	3.3±1.2	9±.7	7.6±2.8
Orchard Oriole (*Icterus spurius*)	4	-	6	-	1.0±0	-	11.7±0	-
Northern Oriole (*Icterus galbula*)	5	-	7	-	1.0±0	-	4±1.3	-
Purple Finch (*Carpodacus purpureus*)	-	30	-	35	-	3.3±1.8	-	2.1±1.0
Pine Siskin (*Carduelis pinus*)	-	5	-	5	-	1.0±0	-	NA
American Goldfinch (*Carduelis tristis*)	34	53	53	109	1.9±.2	3.6±.4	7±.7	26±3.9

1. Total number of sites species occurred at least once, 59 sites were possible during breeding and 58 during winter seasons.
2. Total number of transects species occurred at least once, 184 transects were possible during breeding and 166 during winter seasons.
3. Mean number of individuals (with standard error) per transect where species occurred at least once.
4. Mean density of species per 100 ha (with standard error) where species occurred at least once. Breeding density is expressed as pairs per 100 ha, winter density is expressed as birds per 100 ha.
5. NA denotes "not available", number of observations were too low to calculate density.

VITA

Robert P. Ford was born in Memphis, Tennessee on 26 June 1960. He completed his elementary and high school education in Memphis, and graduated from Bishop Byrne High School in 1978. He attended Memphis State University before transferring to the University of Tennessee at Knoxville in 1980. He received a Bachelor of Science degree in Wildlife and Fisheries Science from The University of Tennessee in 1983. During his undergraduate training, he frequently worked as a naturalist for Tennessee's Division of State Parks.

Mr. Ford conducted ornithological surveys for the Tennessee Department of Conservation from 1983 until entering The Graduate School at The University of Tennessee in 1985. In 1988, he accepted a position as project manager with the Scenic Rivers Program, Tennessee Department of Conservation, and is presently employed by that state. He has published both popular and scientific articles on wetlands and birds in Tennessee, and is currently editor for The Season, a report published in the Tennessee Ornithological Society journal, The Migrant. He received a Master of Science degree in Wildlife and Fisheries Science from the University of Tennessee in August 1990.