To the Graduate Council:

I am submitting herewith a thesis written by Carol Lynn Hardy entitled "A Comparison of Bird Communities in Loblolly vs. White Pine Plantations on the Oak Ridge National Environmental Research Park". 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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School

A COMPARISON OF BIRD COMMUNITIES IN LOBLOLLY VS. WHITE PINE PLANTATIONS ON THE OAK RIDGE NATIONAL ENVIRONMENTAL RESEARCH PARK

A Thesis

presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Carol Lynn Hardy

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ABSTRACT

The value of pine plantations as habitat for avian communities has not been extensively studied. Bird communities that occur in pine plantations need to be chronicled and managed to sustain their diversity. The objectives of this study were to 1) characterize breeding and winter bird communities in loblolly and white pine plantations on the U.S. Department of Energy's Oak Ridge Reservation, and 2) assess and compare bird density, species richness, species diversity, and species equitability of the two habitats.

Both loblolly and white pine exhibited well-developed hardwood understories, and supported diverse bird communities. However, the breeding bird density in loblolly pine was higher than in white pine in 1988; loblolly pine had a higher breeding bird density and species richness than white pine in 1989. The understory nesting birds in loblolly were characterized by a number of bird species associated with edge habitat that were not found in white pine; cavity and overstory nesting birds had similar densities in both pine types. The predominance of edge species in loblolly pine may have accounted for the higher bird density and species richness exhibited by this pine type. Certain structural characteristics, such as the more open overstory and dense ground cover of loblolly, may have created habitat attractive to edge bird species. Both pine types were occupied by species normally associated with the interior of

deciduous forests. The small sizes of the pine stands and the close proximity to larger tracts of deciduous forests may have allowed the stands to be utilized as part of several species' territories. Three species listed as either threatened or in need of management by the State of Tennessee were observed exclusively in white pine stands. This highlighted the importance of considering the particular species attracted to a habitat, along with other community values.

Winter bird communities in loblolly and white pine did not differ significantly. Large flocks of mixed and/or single species of birds utilized the overstory and understory of both pine types, and also utilized adjacent habitats. Birds apparently selected structure that provided appropriate food and shelter regardless of forest type.

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CHAPTER I

INTRODUCTION

Pine plantations are widespread in the southeastern United States, yet their value as habitat for avian communities has not been extensively studied. This may be due in part to the assumption that intensively managed pine forests provide structurally sterile habitats for birds (Wiens 1978). Pine plantations have often been viewed as "biological deserts" by wildlife managers. However, forest management techniques that allow for some under-story development have been shown to improve habitat for birds (Noble and Hamilton 1976, Kroodsma 1984, Capen 1979, Childers 1982). Several environmental laws mandating "multiple-use" management and non-game management on federal and state lands (National Environmental Policy Act of 1969, Endangered Species Act of 1973, National Forest Management Act of 1976) have highlighted the need to chronicle bird communities that occur in pine forests and to manage these forests for sustainably diverse bird

communities. The United States Department of Energy (DOE) has established a National Environmental Research Park (NERP) on the Oak Ridge Reservation (ORR) in response to the National Environmental Policy Act of 1969 (Kitchings and Mann 1976). The goals of this program are (1) to develop methods for the continuous and quantitative assessment of man's activities on the environment, (2) to develop models to predict the response of environmental components to proposed technological activities, (3) to provide land-use plans which make preservation of representative regional natural areas compatible with technological activities, and (4) to conduct environmental research, training, and education.

Few studies have been made of bird communities in pine plantations on the ORR. Kitchings and Mann (1976) stated that 15 bird species utilized pine forests during the breeding season. No attempt was made to distinguish between the two types of pine plantations, loblolly pine (Pinus taeda) and white pine (P. strobus). Also, the winter bird communities occupying these pine forests have not been surveyed.

Loblolly pine occurs mainly as a planted species in east Tennessee; white pine occurs naturally on ridge tops in association with oak forest communities (Stokely and Johnson 1981) and in hemlock-northern hardwood forest communities in the Appalachian mountains of east Tennessee (Fowells 1965). It also is planted in plantations.

I censused bird communities for two breeding seasons and one winter season in pine forests that occur in the NERP areas. The objectives of this project were:

1. to characterize breeding and winter bird communities in loblolly and white pine forests, and

2. to assess and compare bird density, species richness, bird species diversity, and bird species equitability between the two habitats.

Loblolly and white pine forests on the ORR were similar in size, age, and management objective (to produce trees of sawtimber classification at 124-247 tree/ha), thus eliminating several variances that would normally occur between two "natural" habitat types. Similarities or differences in the bird communities between the two pine types might therefore be assessed. The particular community variables chosen have been commonly used to analyze avian communities, and provide a basis for comparison with other studies.

The information from this study should help ORR land managers assess management plans for the pine forests. This information should also contribute to a bird list of the ORR area which may be used by the public for educational and recreational purposes.

CHAPTER II

DESCRIPTION OF STUDY AREA

I. Landscape and climate of the Oak Ridge Reservation

The DOE Oak Ridge Reservation consists of 14,400 ha, of which 5008 ha have been designated as the NERP (Parr and Pounds 1987). The NERP areas are scattered throughout the ORR. The ORR is located in Oak Ridge, Tennessee (36 degrees N, 84 degrees W) in Anderson and Roane counties. The Tennessee Valley Authority's (TVA) Melton Hill and Watts Bar reservoirs on the Clinch River form southern, western, and eastern boundaries of ORR (Figure 1).

The ORR lies within the Ridge and Valley Province of the southern Appalachian highlands. It is characterized by parallel ridges and valleys of sandstone, shale, and cherty dolomite oriented northeast to southwest (Kitchings and Mann 1976). The valleys have a substrate of less weather-resistant limestone and shale. The topography of the area results from differential erosion of severely folded and faulted rocks ranging in age from

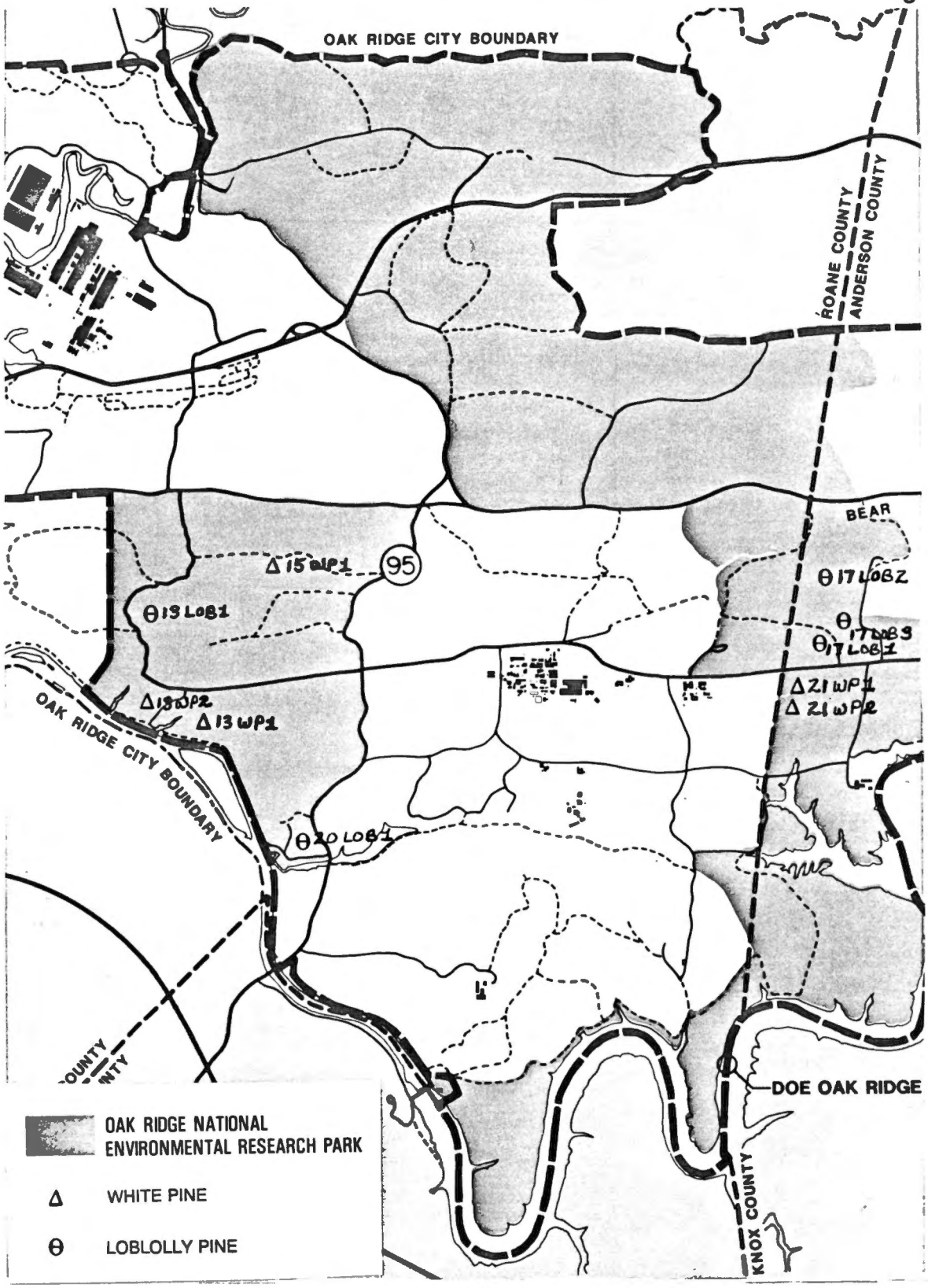

Figure 1. Locations of pine stands on the Oak Ridge National Environmental Research Park, Oak Ridge, Tennessee. Adapted by permission from Parr and Pounds (1987).

early Cambrian to early Mississippian. Elevation ranges from 226 to 413 m above sea level.

The topography is characterized by gently sloping valleys, rolling-to-steep slopes, and ridges. The soils are members of the ultisol group, which includes acid shale, Knox dolomite, and Knox limestone (Chance 1986).

The climate is typically mild, with warm, humid summers and cool winters. No extreme conditions prevail in temperature, precipitation, or winds (Kitchings and Mann 1976, Chance 1986). Mean annual rainfall is 136 cm, including approximately 25 cm of measured snowfall. Peaks of individual storm rainfall occur in early spring and mid to late summer when short-duration, heavy rains associated with thunderstorms are common. Another peak of rainfall occurs in early winter, when rains from passing storm fronts are low in intensity but long in duration (Chance 1986). The year's minimum precipitation usually occurs in the autumn. Five-year cycles in wet seasons and droughts are also evident (Chance 1986).

Mean annual temperature is 14.3 C. Diurnal swings in temperature are relatively constant from month to month at about 11.1 C (Chance 1986).

II. Vegetation of the Oak Ridge Reservation

Vegetation of the ORR is characterized by second-growth mesophytic forests, mixed pine-hardwoods, and mixed upland hardwoods. These are

common to the Ridge and Valley Province, which lies between the Blue Ridge to the east and the Appalachian Plateau (Cumberland Plateau) to the west (Parr and Pounds 1987).

Much of the forested upland of the ORR is vegetated by oak, oak-hickory and oak-yellow pine communities (Kitchings and Mann 1976). Tulip poplar often forms nearly pure stands on well-drained bottomlands and lower slopes, while willow, sycamore, and boxelder border streams and are dominant on poorly drained floodplains. Species more commonly found in the mixed mesophytic community, such as beech, sugar maple, magnolias, buckeye, and basswood, often occur in coves and sheltered slopes. Approximately 2000 ha of ORR were planted in loblolly pine and white pine between 1947 and 1956. Cedar barrens, old fields, and mown grasslands are also found on ORR. For scientific names of plant species used in this thesis, see Appendix I.

CHAPTER III

METHODS

Study sites were selected in loblolly and white pine forests that occur on the ORR. Loblolly and white pine stands were selected for: 1) location on or near NERP areas; 2) pure, even-aged stands; 3) sawtimber size classification (30 + yrs.); 4) stands not unduly influenced or interrupted by adjacent stands of different forest type, power line right-of ways, roads, or miscellaneous openings; 5) similar history of forest management; and 6) a minimum size of 10 ha.

I. Site selection

ORR forestry compartment maps were consulted to determine location of loblolly and white pine stands in relation to NERP areas, size of stand, age of stand, and access locations. Eight loblolly and seven white pine stands fit minimum criteria. These stands were visited to verify age, current forest management, stand size and shape, and relative homogeneity of

vegetation. Five loblolly stands were determined to best fit minimum criteria. - Three white pine stands best fit the minimum criteria. Two more white pine stands were determined to be borderline with respect to similar history of forest management, but were included to have an equivalent number of the two types (Table 1)(Figures 2, 3, 4, 5, and 6).

II. Sampling design

Sampling design was consistent for all study sites. Bird surveys were executed along a 500 m transect for each pine stand. Due to the stands' dimensions, however, most transects were broken into 2 or 3 segments. A buffer zone of at least 25 m was established around the stand edge and around transect segments to minimize edge effect and duplication of results. Transect starting point and azimuth were determined randomly whenever possible. Stands were cruised using a point sample method (Avery and Burkhart 1983) to determine existing overstory characteristics. Understory vegetation was sampled at 10 plots per stand, established randomly along transects.

Table 1. Age, size, and management history of loblolly and white pine stands used for bird censusing on Oak Ridge Reservation NERP, Oak Ridge, Tennessee, 1988.

Stand	Year planted	Hectares	Thinned	Control burned
13 WP1	1951	10	2 times	no
13 WP2	1951	09	2 times	no
15 WP1	1952	12	2 times	no
21 WP1	1953	08	1 time	no
21 WP2	1953	09	1 time	no
13 LOB1	1951	16	3 times	2 times
17 LOB1	1955	11	3 times	3 times
17 LOB2	1955	18	3 times	3 times
17 LOB3	1955	08	3 times	3 times
20 LOB1	1954	17	2 times	2 times

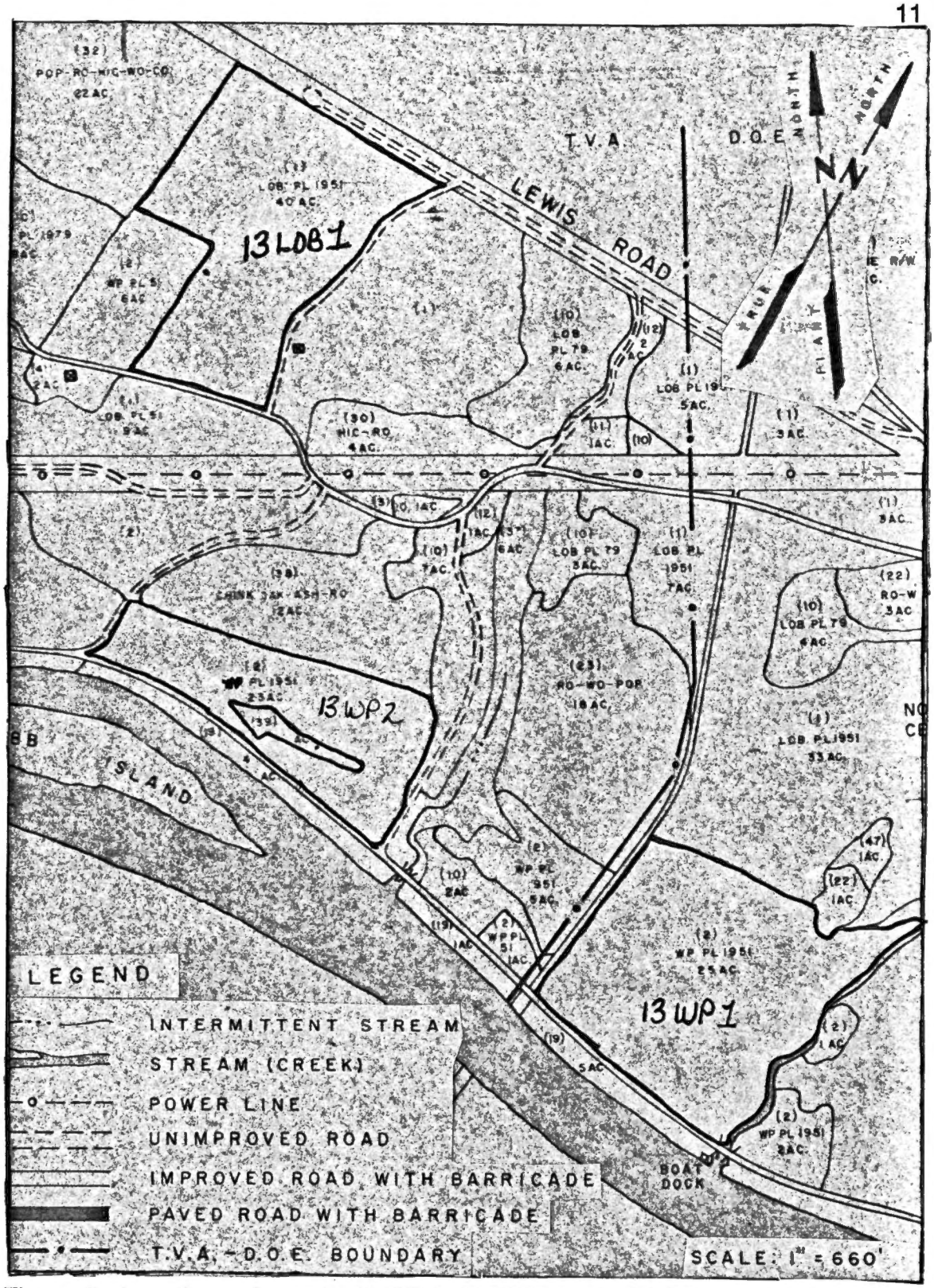

Figure 2. Locations of stands 13 WP1, 13 WP2, and 13 LOB1 on the Oak Ridge National Environmental Research Park, Oak Ridge, Tennessee. Adapted by permission from Oak Ridge Reservation Forestry stand maps.

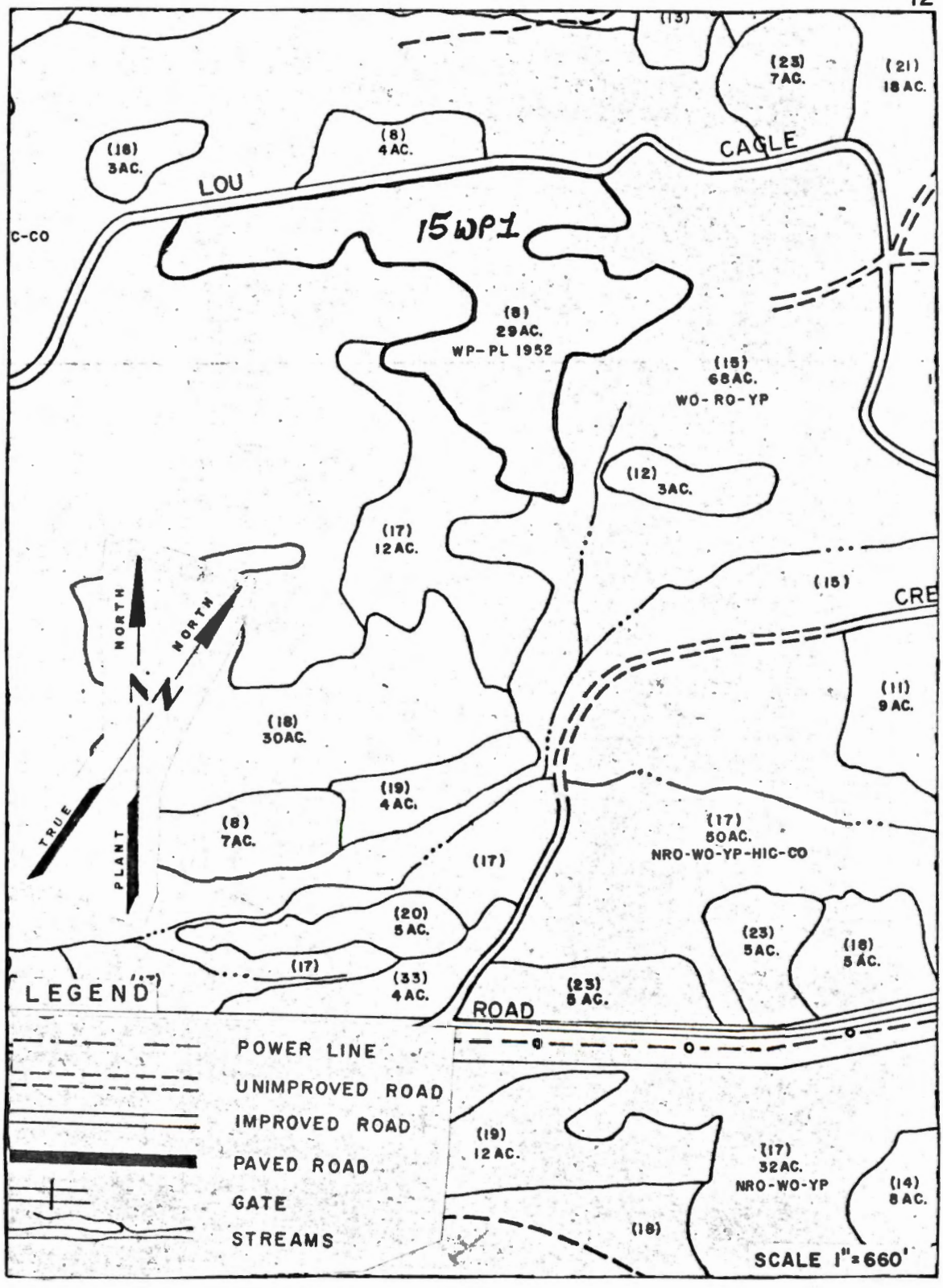

Figure 3. Location of stand 15 WP1 on the Oak Ridge National Environmental Research Park, Oak Ridge, Tennessee. Adapted by permission from Oak Ridge Reservation Forestry stand maps.

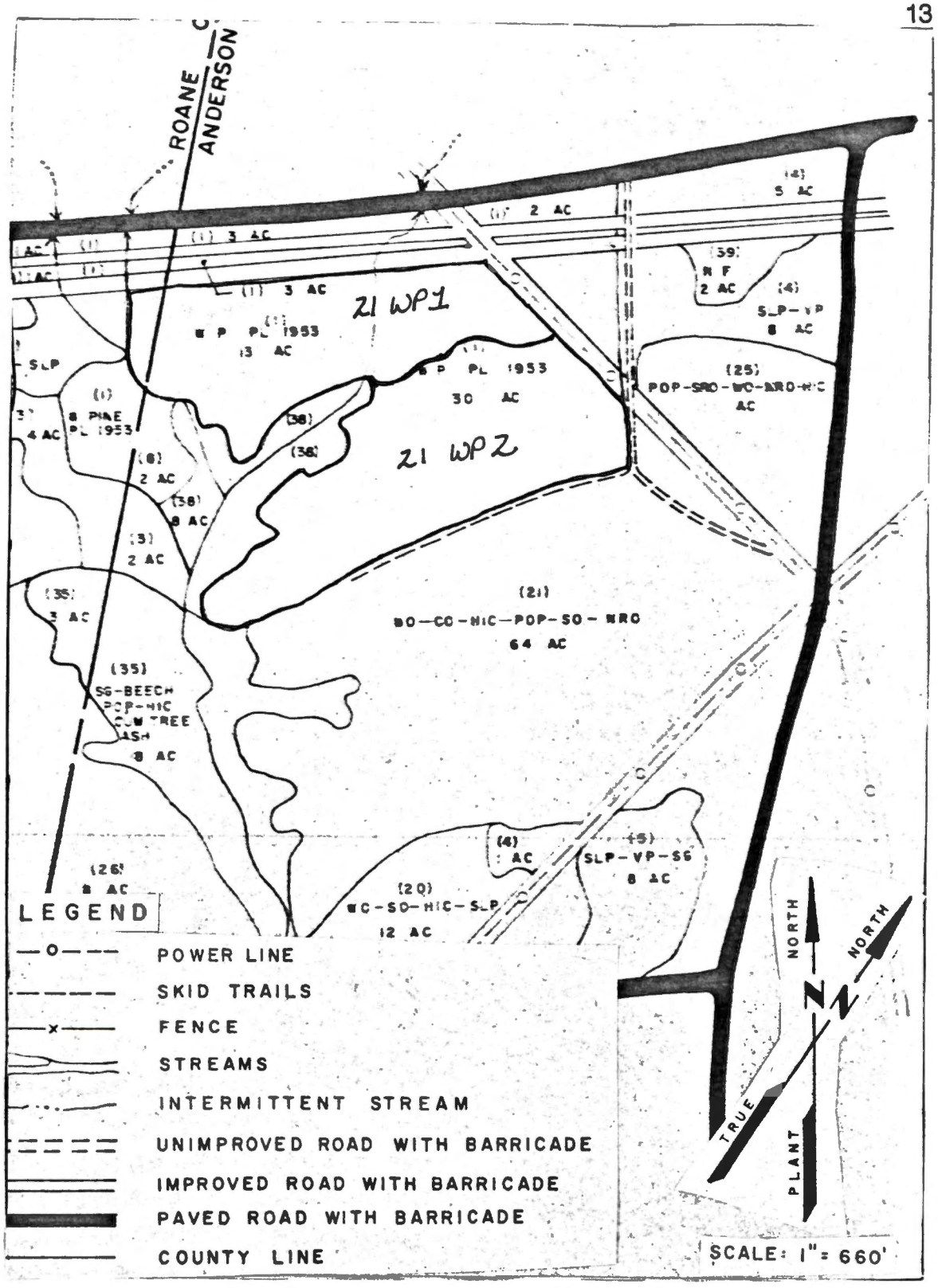

Figure 4. Locations of stands 21 WP1 and 21 WP2 on the Oak Ridge National Environmental Research Park, Oak Ridge, Tennessee. Adapted by permission from Oak Ridge Reservation Forestry stand maps.

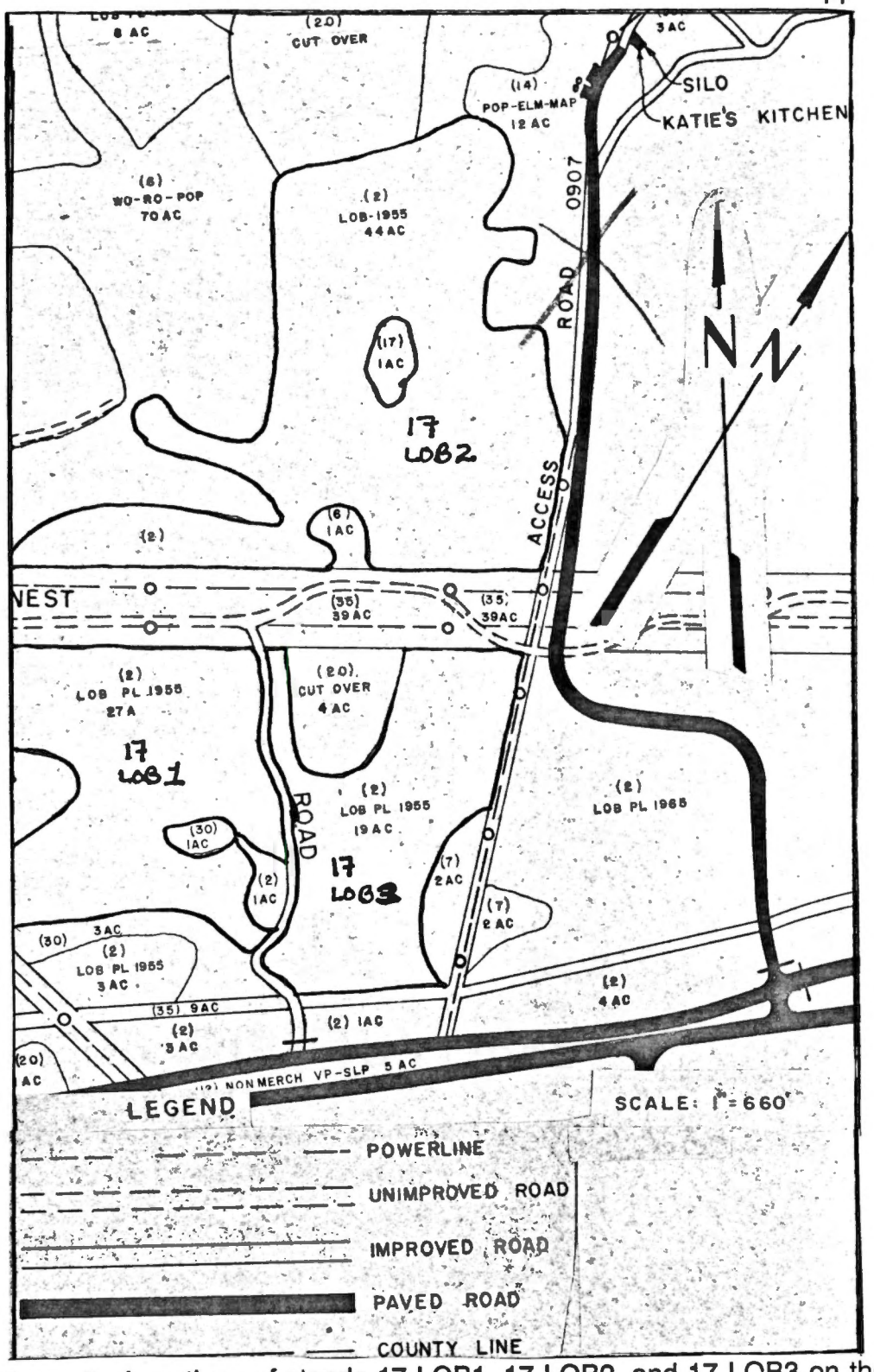

Figure 5. Locations of stands 17 LOB1, 17 LOB2, and 17 LOB3 on the Oak Ridge National Environmental Research Park, Oak Ridge, Tennessee. Adapted by permission from Oak Ridge Reservation Forestry stand maps.

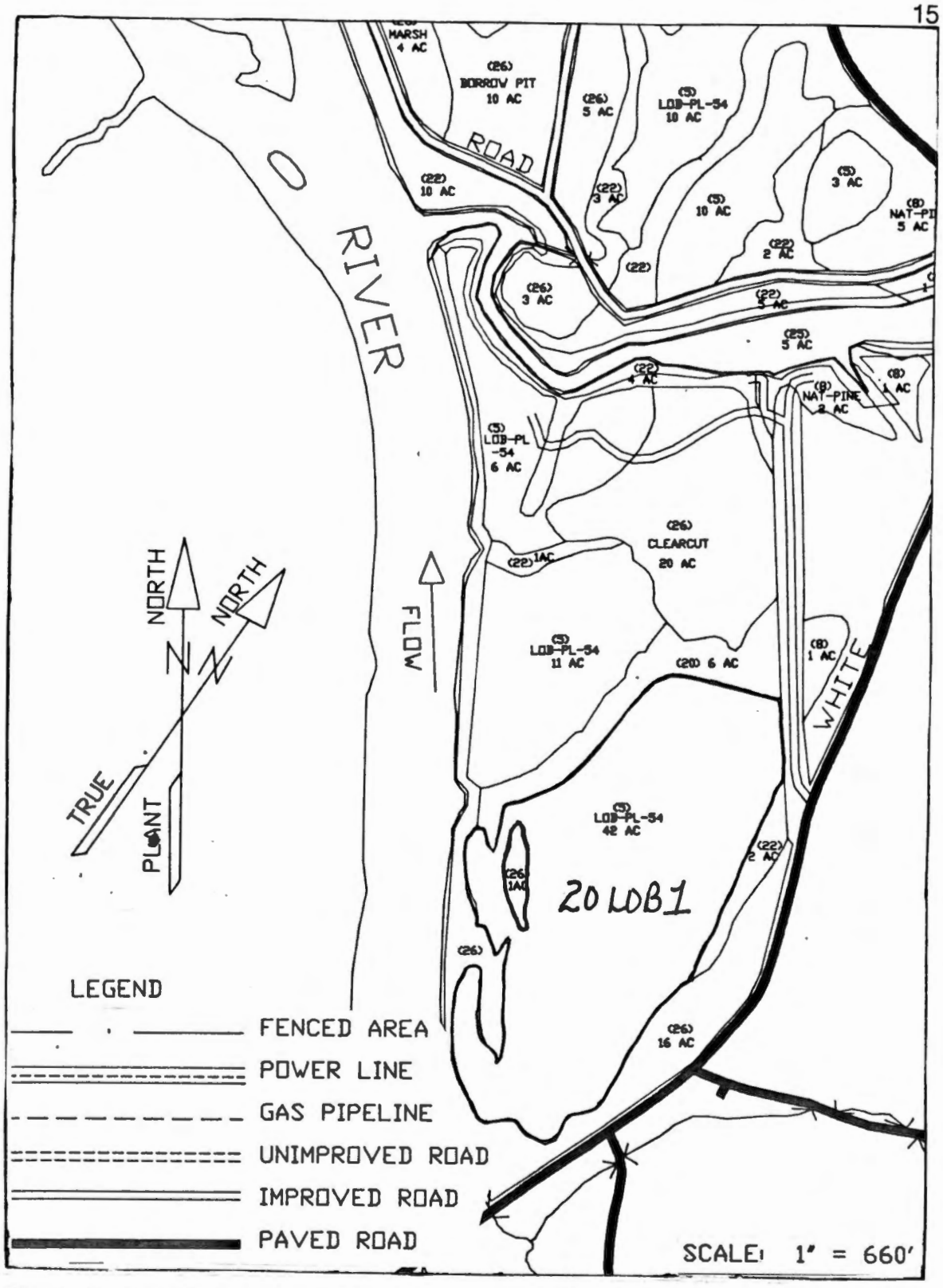

Figure 6. Location of stand 20 LOB1 on the Oak Ridge National Environmental Research Park, Oak Ridge, Tennessee. Adapted by permission from Oak Ridge Reservation Forestry stand maps.

III. Bird sampling

Field Sampling

Birds were surveyed during two breeding and one winter seasons from May 1988 to June 1989. The strip transect method (Conner and Dickson 1980, Eberhardt 1978) was used to sample bird populations. Although other techniques, such as spot-mapping, may yield higher and more accurate estimates of bird populations than transect sampling (Franzreb 1976, Emlen 1971), more area can be covered per unit of census time with transects (Emlen 1971, Robbins 1978). Because only relative differences among pine stands were needed, and because only one field worker was to conduct all censuses, the fastest method was selected. A 500-m transect was walked at a pace of 50 m/3 minutes. Birds were detected by any cue (i.e. sight, song, or chip note) and identified. Individuals were determined to be either in or out of a 50-m belt (0 to 25 m on either side of the transect line). Birds identified out of the belt were used to generate a species list for each pine type (Appendix II).

Fifty transect counts were conducted during each of 2 breeding seasons and 50 during the winter season for a total of 150 transect counts. Breeding season surveys were conducted during May and June of 1988 and 1989. During the breeding season, singing by males is most intensive during the early morning hours (Conner and Dickson 1980). Therefore, sampling started at official sunrise and was completed no later than 4 hours after

sunrise. Winter season surveys were conducted in January, February, and early March of 1989. During the winter months, bird activity and conspicuousness often depend more on weather than on time of day (Grubb 1978). Birds were censused in the morning from sunrise to 3 hours after sunrise, and in the afternoon from 3 hours before sunset to sunset.

Transect counts were repeated 5 times for each stand during the breeding and wintering seasons. Transects were censused in random order whenever possible to avoid time of day and day of week bias. Birds were censused daily except during periods of substantial rain or snow or periods of high winds (> 20 km/h). High weather variability can increase within-treatment variation of bird abundance and bias among-treatment variation (Conner and Dickson 1980). The writer censused all of the birds during this study.

Assumptions

In the analysis and discussion of these data, I made five assumptions. First, I assumed that each bird species was adapted to certain successional conditions of vegetation types, and where those conditions were present, viable populations of that species could occur.

Second, I assumed that the birds detected in the transect counts were stable breeding season or winter season residents in the pine stands. Care was given not to census during periods characterized by significant bird migratory movement (Conner and Dickson 1980, Dickson 1978).

Third, I assumed that the birds counted during the census period represented the birds present in the pine stands. Generally, the more times a transect was repeated, the more species were detected and less variable the mean count of birds. Conner and Dickson (1980), Robbins (1978), and Kolb (1965) recommended 6-10 census trips over transects to get reasonably accurate counts. However, factors such as cost, number of observers, weather conditions during census period, and time available had to be considered. Five repetitions of each stand were considered to give reasonably accurate results.

Fourth, I assumed that during the breeding season, every singing bird was a male with an established territory and a mate.

Fifth, I assumed that during the winter season both sexes were equally likely to be detected, as males were not defending territories at that time.

IV. Vegetation sampling

The vegetation on all stands was measured using two techniques. A point sample cruise (Avery and Burkhart 1983) was conducted to determine number of stems/ha, average diameter at breast height (dbh), number of snags /ha, and basal area of overstory trees greater than 12 cm dbh.

Percent canopy closure was estimated using a LI-COR brand quantum-/radiometer/photometer. During the spring of 1989, light readings were taken in all stands on a clear, cloudless day between 12-2 pm. A reading was taken

outside of the stand and in five randomly selected locations within the stand. An average canopy closure was calculated for each stand.

Understory vegetation samples were taken on ten, 10-m^2 plots per transect. The plots were established randomly along each transect. A count by species was made for all stems between 2 and 12 cm dbh. Percent ground cover (stems below 2 cm dbh) was estimated visually using a 1-m^2 plot nested randomly within each 10-m^2 plot.

V. Terminology

Breeding bird density is expressed as pairs per 2.5 ha. Observations during the 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 2.5 ha. Observations during the winter season were assumed to be of both sexes. Species richness is the number of species found in a community. Bird species diversity is a measurement of the number and numerical distribution of species in a community. This measurement equals zero when only one species is present and increases as the species richness and evenness of their distribution increases (Shannon and Weaver 1949, Hair 1980) . Bird species equitability measures the evenness of the distribution of individuals within the different species of a community. This measurement ranges from zero to one, with a value of one describing a community in which all species have the same

number of individuals (highest degree of evenness) (Shannon and Weaver 1949, Hair 1980).

CHAPTER IV

STATISTICAL ANALYSIS

I. Vegetation data

Choice and development of variables

Seven variables were chosen. Percent canopy closure, diameter at breast height, basal area, number of stems/ha, and number of snags/ha were calculated for the overstory vegetation. Number of stems/ha and percent ground cover were calculated for the understory vegetation.

Statistical tests chosen

Analysis of variance was performed to determine if pine type significantly affected ($p < 0.05$) the chosen variables. All factors were considered fixed, therefore a general linear model analysis was chosen. The Statistical Analysis System (SAS 1985) (Proc GLM) was used to execute analysis of variance. General linear model analysis theory assumes that variables are normally

distributed. Diameter at breast height, basal area, number of stems/ha, and number of snags/ha required square root transformation to achieve a normal distribution for overstory vegetation. The number of stems/ha for understory vegetation also required square root transformation to achieve a normal distribution. Percent canopy closure (overstory) and percent ground cover (understory) required ARC SIN transformation to achieve a normal distribution.

I. Bird data

Choice and development of response variables

Eight response variables were chosen. Breeding bird density, species richness, bird species diversity, and bird species equitability were calculated per transect for the breeding bird communities in loblolly and white pine. Winter bird density, species richness, bird species diversity, and bird species equitability were also calculated per transect for the winter bird communities. Each breeding bird species was assigned to one of three nesting guilds to further define differences in the use of the pine types by bird communities (Harrison 1975, Kroodsma 1984). Understory nesting birds, cavity nesting birds, and overstory nesting birds were the guilds recognized in this study. Breeding bird density, species richness, bird species diversity, and bird species equitability were also calculated per transect for each nesting guild.

The Shannon-Weaver information function (Shannon and Weaver 1949,

Hair 1980) was used to calculate bird species diversity and equitability. This function is one of the simplest and most extensively used indices. It measures the average degree of uncertainty of predicting the species of a given individual picked at random from a community. The formula for bird species diversity is:

$$H' = -\sum_{i=1}^{S} p_i \log_b p_i$$

where S is the species richness, and p is the proportion of the total number of individuals consisting of the ith species (n_i/N).

The formula for bird species equitability is:

$$J' = H'/H' \text{ maximum}$$

where H' is the diversity value and H' maximum is equal to the logarithm of the species richness (Log S), using the same base of logarithms used in the calculations of H'.

Statistical tests chosen

The objectives of this study were (1) to characterize breeding and winter bird communities in loblolly and white pine plantations, and (2) to assess and compare bird density, species richness, bird species diversity, and bird species equitability in the two habitats. Some factors were fixed (nesting guilds and pine type), and one was random (placement of transects). Given these constraints, a mixed model analysis (Stroup 1989, McLean 1989) more accurately tested ($p < 0.05$) whether pine type had a significant effect on the chosen response variables.

The mixed model was characterized as follows:

$$y = Xb + Zu + e$$

where b is a vector of fixed effects and X its associated matrix of design/regression constants, u is a vector of random effects and Z its associated design matrix, and e is a vector of errors (Stroup 1989).

Mixed model analysis theory assumes that random effects are normally distributed. To meet this assumption more closely, I used a square root transformation for the following response variables: breeding bird density, winter bird density, and species richness. Bird species diversity and bird species equitability did not require square root transformation to be normally distributed.

A computer package for general linear mixed models (GLMM) (Blouin and Saxton 1990) was used to execute a mixed model analysis of variance. To test whether pine type had a significant effect on the chosen response variables for each nesting guild, specific contrasts were defined and significance ascertained by GLMM. Differences in the response variables between the two pine type means were compared with a specific separate contrast for each nesting guild. Within each pine type, differences in the response variables within each pine type were partitioned among nesting guilds via another set of contrasts. The contrasts were understory nesters vs. overstory nesters, understory vs. cavity, and cavity vs. overstory nesters.

Significant year by pine type interactions occurred for several breeding season response variables. Therefore, data from the 1988 and 1989 breeding

seasons were analyzed separately.

Because sample sizes were unequal between vegetation and bird data, and degrees of freedom (5 observations per pine type) in the bird data were low, I analyzed vegetation variables and bird variables separately. Significant differences in bird variables that could be explained by differences in vegetation variables were explained by inference.

CHAPTER V

RESULTS

I. Vegetation

The loblolly stands averaged 13.9 ha in size and were characterized by a fairly open overstory of exclusively loblolly, a medium to dense understory comprised mainly of flowering dogwood, tulip poplar, and red maple, and a dense ground cover largely of Japanese honeysuckle, blackberry, and poison ivy. No midstory was present. The white pine stands averaged 9.7 ha in size and were characterized by a closed overstory of exclusively white pine, a medium to heavy understory comprised of mainly flowering dogwood and tulip poplar, and a sparse ground cover of Japanese honeysuckle and poison ivy. No midstory was present.

Overstory vegetation

Average diameter at breast height was 34.3 cm for loblolly and 37.8 cm for white pine stands. Loblolly pine had an average basal area of 17.2 m^2/ha, with

white pine 31.9 m^2/ha. The average number of stems/ha was 189.8 of loblolly, 360.3 for white pine. Number of snags/ha averaged 7.2 for loblolly pine and 24.8 for white pine. Average percent canopy closure was 68.0 for loblolly, 96.4 for white pine stands.

White pine had a higher percent canopy closure and higher number of snags/ha than loblolly pine (Table 2). The average diameter at breast height, basal area, and number of stems/ha of loblolly vs. white pine did not differ significantly.

Understory vegetation

Twenty-eight species were observed in loblolly pine transects. Six species (21%) were abundant, encompassing greater than 80% of the total density of understory vegetation. Twenty-two species occurred in white pine transects. Five species (22%) were abundant, including greater than 80% of the total density of understory vegetation (Table 3). Percent ground cover averaged 82.4 for loblolly and 40.0 for white pine. The understory stems/per ha averaged 25,740.0 in loblolly and 21,440.0 for white pine.

Loblolly pine had a higher percent ground cover than white pine (Table 2). The understory stems/ha in loblolly vs. white pine did not differ significantly.

Table 2. Overstory and understory vegetation characteristics between loblolly and white pine.These variables represent average values (with ranges) for five loblolly and five white pine transects on Oak Ridge Reservation NERP, Oak Ridge, Tennessee.

Variable	Loblolly pine	White pine	Level of significance
Overstory			
% canopy closure	67.90(53.00-90.00)	96.40(95.20-98.40)	0.001*
Number of snags/ha	7.13(4.94-8.47)	24.83(8.89-42.81)	0.026*
Diameter at breast height (cm)	34.26(31.34-40.28)	37.79(29.97-44.45)	0.400
Basal area (m^2/ha)	17.22(15.31-23.01)	31.91(19.11-50.85)	0.088
Number of stems/ha	189.78(129.82-200.42)	360.27(123.34-700.3)	0.327
Understory			
% ground cover	82.40(74.50-93.00)	40.04(25.00-55.00)	0.001*
Number of stems/ha	25,7400.00(9,800-38,300)	21,440.00(14,800-27,200)	0.804
Number of species	5.78(4.90-7.40)	4.30(4.20-4.80)	-----**

* Difference accepted as significant.
** Not tested for significance in differences between means.

Table 3. Abundant understory vegetation of five white pine and five loblolly pine stands on Oak Ridge Reservation NERP, Oak Ridge, Tennessee, 1989.

Vegetation species	Loblolly pine (ind/ha)	White pine (ind/ha)
Flowering dogwood	10,120	8,480
Tulip poplar	3,420	5,600
Red maple	3,300	1,840
Southern red oak	1,620	600
Black cherry	1,320	-------
Sassafrass	960	-------
Sweetgum	-------	740
Subtotal	20,7400	17,260
All other species	5,000	4,180
Total	25,740	21,440

I. Birds

Sixty-three species of birds, encompassing 1,906 individuals, were observed. Twenty-eight species occurred only during the breeding season, 12 occurred only during winter, and 23 were present year-round (Appendix II). Scientific names of bird species used in this thesis are listed in Appendix II.

Breeding season birds

Forty-two bird species were observed during the breeding season in 1988, and 38 in 1989. An average of 9 species and 40 individuals occurred on individual transects in 1988, 10 species and 24 individuals in 1989.

1988 breeding season. Twenty bird species, with 259 individuals, were observed in loblolly pine; 20 species comprising 166 individuals, were observed in white pine during the 1988 breeding season. Seven species (35%) encompassed greater than 80% of the total density of birds in each pine type (Table 4).

The average breeding bird density (414.4 pairs/100 ha) was higher in loblolly pine than in white pine (264.0 pairs/100 ha)(Table 5). Species richness, bird species diversity, and bird species equitability did not differ significantly between pine types.

Ten species of understory nesting birds, 4 cavity nesters, and 6

Table 4. Breeding birds comprising greater than 80% of the total population of five loblolly pine and five white pine stands on Oak Ridge Reservation NERP, Oak Ridge, Tennessee, 1988.

Bird species	Loblolly Pine (prs/100ha)		White pine (prs/100ha)	
Pine warbler	129.6		12.8	
Indigo bunting	62.4		11.2	
Carolina wren	46.4		22.4	
Northern cardinal	36.8		28.8	
Rufous-sided towhee	28.8		------	
Carolina chickadee	24.0		84.8	
Red-eyed vireo	20.8		46.4	
American crow	------		9.6	
Subtotal		348.8		216.0
All other species	65.6		48.0	
Total		414.4		264.0

Table 5. Bird community characteristics between loblolly and white pine during the breeeding season, 1988. These variables represent average values (with ranges) for five loblolly and five white pine transects on Oak Ridge Reservation NERP, Oak Ridge, Tennessee.

Bird community characteristics	Loblolly pine	White pine	Level of significance
Density (pairs/100 ha)	414.40(160.00-752.00)	265.60(160.00-352.00)	0.020*
Species richness	9.60(7.00-14.00)	8.6(3.00-15.00)	0.354
Species diversity value	1.84(1.54-2.31)	1.68(0.58-2.29)	0.580
Species equitability value	0.82(0.70-0.92)	0.79(0.52-0.93)	0.642

* Difference accepted as significant.

overstory nesters were observed in loblolly pine; 10 species of understory, 3 cavity, and 7 overstory nesting birds occurred in white pine (Table 6).

Comparisons of nesting guilds between pine types. Loblolly pine had greater densities than white pine of both understory and overstory nesting birds. Densities of cavity nesters did not differ significantly between pine types (Table 7). Loblolly pine had more species of understory nesting birds, but the species richness of cavity nesters and overstory nesters did not differ between pine types. Species diversity and equitability were not significantly different between pine types for any of the 3 nesting guilds.

Comparisons of nesting guilds within pine types. Among the nesting guilds in loblolly, both understory and overstory nesting birds had higher densities than cavity nesters; understory and overstory nesters did not differ significantly (Table 8). There were more species of understory nesting birds than either cavity or overstory nesters, and more species of overstory nesters than cavity nesters. Understory nesting birds also had higher species diversity than cavity or overstory nesters, with no significant differences in diversity between cavity and overstory nesters. Understory nesting birds and overstory birds showed similar species equitability, as did cavity and overstory nesters. However, understory nesting birds had a higher equitability value than cavity nesters.

Breeding densities did not differ among the guilds in white pine (Table 8). The species richness of understory nesters and overstory nesters was

Table 6. Bird species assigned to nesting guilds in loblolly and white pine transects on Oak Ridge Reservation NERP, Oak Ridge, Tennessee, 1988.

Nest guild	Loblolly	White pine
Understory	Northern bobwhite	Northern bobwhite
	Northern cardinal	Northern cardinal
	Carolina wren	Carolina wren
	Brown-headed cowbird	Brown-headed cowbird
	Hooded warbler	Hooded warbler
	Indigo bunting	Indigo bunting
	White-eyed vireo	White-eyed vireo
	Yellow-breasted chat	Yellow-breasted chat
	Rufous-sided towhee	Black vulture
	American goldfinch	Yellow-billed cuckoo
Cavity	Carolina chickadee	Carolina chickadee
	Hairy woodpecker	Hairy woodpecker
	Tufted titmouse	Tufted titmouse
	Downy woodpecker	
Overstory	Pine warbler	Pine warbler
	Red-eyed vireo	Red-eyed vireo
	Yellow-throated warbler	Yellow-throated warbler
	Blue-gray gnatcatcher	Acadian flycatcher
	Eastern wood pewee	American crow
	Yellow-throated Vireo	Scarlet Tanager
		Blue Jay

Table 7. Bird community characteristics by nesting guild between loblolly and white pine during the breeding season, 1988. These variables represent average values (with values) for five loblolly and five white pine transects on Oak Ridge Reservation NERP, Oak Ridge, Tennessee.

Bird communty characteristics	Loblolly pine	White pine	Level of signifi-cance
Understory guild			
Density(pairs/100 ha)	185.6(128.00-400.00)	89.6(0.00-200.00)	0.043*
Species richness	5.8(5.00-8.00)	2.05(0.00-8.88)	0.045*
Species diversity value	1.49(1.18-1.64)	1.21(0.00-1.63)	0.098
Species equitability value	0.85(0.73-0.92)	0.87(0.00-0.92)	0.509
Cavity guild			
Density(pairs/100 ha)	41.60(0.00-104.00)	91.20(8.00-192.00)	0.100
Species richness	1.00(0.00-2.00)	1.60(1.00-2.00)	0.398
Species diversity value	0.32(0.00-0.69)	0.15(0.00-0.33)	0.878
Species equitability value	0.46(0.00-0.99)	0.21(0.00-0.47)	0.568
Overstory guild			
Density(pairs/100 ha)	187.20(24.00-272.00)	83.20(40.0-136.00)	0.011*
Species richness	2.80(2.00-8.00)	2.10(2.00-5.00)	0.596
Species diversity value	0.57(0.28-0.96)	0.96(0.41-1.43)	0.510
Species equitability value	0.57(0.32-0.81)	0.82(0.37-0.97)	0.470

* Difference accepted as significant.

Table 8. Bird community characteristics by nesting guild within loblolly and white pine during the breeding season, 1988. These variables represent average values for five loblolly and five white pine transects on Oak Ridge Reservation NERP, Oak Ridge, Tennessee.

Bird community characterics	Under-story guild	Cavity guild	Overstory guild	Level of signifi-cance
Loblolly pine				
pairs/100 ha	185.6	41.6	-	0.001*
	185.6	-	187.2	0.332
	-	41.6	187.2	0.001*
Number of species	5.8	1.0	-	0.001*
	5.8	-	2.8	0.007*
	-	1.0	2.8	0.020*
Species diversity value	1.49	0.32	-	0.001*
	1.49	-	0.56	0.013*
	-	0.32	0.56	0.054
Species equitability value	0.85	0.46	-	0.015*
	0.85	-	0.57	0.326
	-	0.46	0.57	0.133
White pine				
Pairs/100 ha	89.6	91.2	-	0.628
	89.6	-	83.2	0.143
	-	91.2	83.2	0.332
Number of species value	2.1	1.6	-	0.066
	2.1	-	2.1	0.878
	-	1.6	2.1	0.047*
Species diversity value	1.21	0.14	-	0.006*
	1.21	-	0.96	0.972
	-	0.14	0.96	0.006*
Species equitability value	0.87	0.21	-	0.038*
	0.87	-	0.81	0.603
	-	0.21	0.81	0.133

* Difference accepted as significant.

similar, as was that of cavity nesters and understory nesters. The species richness of overstory nesters was higher than cavity nesters. Understory nesters and overstory nesters showed similar species diversity and equitability, while cavity nesters had lower species diversity and equitability than understory nesters. Cavity nesters and overstory nesters were similar in species equitability.

1989 breeding season. Twenty-six species, comprising 225 individuals, occurred in loblolly pine during the 1989 breeding season. Ten species (38%) encompassed greater than 80% of the total density of birds. Eighteen species, with 78 individuals, were observed in white pine. Eight species (44%) comprised greater than 80% of the total density of birds (Table 9).

Breeding bird density (360.0 pairs/100 ha) was higher in loblolly pine than in white pine (124.8 pairs/100 ha)(Table 10). Loblolly pine also had more bird species and higher species diversity, while species equitability did not differ significantly between pine types.

Thirteen species of understory nesting birds, 6 cavity nesters, and 7 overstory nesters occurred in loblolly pine. Nine understory, 3 cavity, and 6 overstory nesters were observed in white pine (Table 11).

Comparisons of nesting guilds between pine types. Understory nesting birds and overstory nesting birds in loblolly pine had higher densities than corresponding guilds in white pine. Densities of cavity nesters did not differ significantly between pine types (Table 12). The cavity guilds and overstory guilds in loblolly and white pine exhibited similar species richness. However,

Table 9. Breeding birds comprising greater than 80% of the total population of five white pine and five loblolly pine stands on Oak Ridge Reservation NERP, Oak Ridge, Tennessee, 1989.

Bird species	Loblolly pine (prs/100 ha)		White pine (prs/100 ha)	
Pine warbler	107.2		------	
Rufous-sided towhee	43.2		6.4	
Carolina chickadee	28.8		25.6	
Northern cardinal	20.8		9.6	
American goldfinch	19.2		------	
Blue-gray gnatcatcher	17.6		------	
Carolina wren	16.0		9.6	
Indigo bunting	16.0		8.0	
Red-eyed vireo	11.2		17.6	
Northern bobwhite	11.2		------	
Hooded warbler	------		8.0	
Black vulture	------		8.0	
Subtotal		291.2		92.8
All other species	68.8		17.0	
Total		360.0		109.8

Table 10. Bird community characteristics between loblolly and white pine during the breeeding season, 1989. These variables represent average values (with ranges) for five loblolly and five white pine transects on Oak Ridge Reservation NERP, Oak Ridge, Tennessee.

Bird community characteristics	Loblolly pine	White pine	Level of significance
Density (pairs/100 ha)	360.0(224.00-608.00)	124.80(40.00-280.00)	0.001*
Species richness	13.40(11.00-19.00)	6.20(3.00-12.00)	0.010*
Species diversity value	2.20(2.00-2.44)	1.52(1.04-2.25)	0.029*
Species equitability value	0.85(0.82-0.94)	0.92(0.87-0.95)	0.290

* Difference accepted as significant.

Table 11. Bird species assigned to nesting guilds in loblolly and white pine transects on Oak Ridge Reservation NERP, Oak Ridge, Tennessee, 1989.

Nest guild	Loblolly	White pine
Understory	Northern cardinal	Northern cardinal
	Carolina wren	Carolina wren
	Brown-headed cowbird	Brown-headed cowbird
	Hooded warbler	Hooded warbler
	Indigo bunting	Indigo bunting
	Rufous-sided towhee	Rufous-sided towhee
	White-eyed vireo	White-eyed vireo
	Northern bobwhite	Black vulture
	American goldfinch	Yellow-billed cuckoo
	Kentucky warbler	
	Prairie warbler	
	American woodcock	
	Yellow-breasted chat	
Cavity	Carolina chickadee	Carolina chickadee
	Downy woodpecker	Downy woodpecker
	Pileated woodpecker	Hairy woodpecker
	Red-bellied woodpecker	
	Tufted titmouse	
	White-breasted nuthatch	
Overstory	Blue jay	Blue jay
	Pine warbler	Pine warbler
	Red-eyed vireo	Red-eyed vireo
	Scarlet tanager	Scarlet tanager
	Blue-gray gnatcatcher	American crow
	Ruby-throated hummingbird	Sharp-shinned hawk
	Red-shouldered hawk	

Table 12. Bird community characteristics by nesting guild between loblolly and white pine during the breeding season,1989. These variables represent average values (with ranges) for five loblolly and five white pine transects on Oak Ridge Reservation NERP, Oak Ridge, Tennessee.

Bird community characteristics	Loblolly pine	White pine	Level of significance
Understory guild			
Density(pairs/100 ha)	168.00(88.00-264.00)	56.00(0.00-144.00)	0.049*
Species richness	7.60(6.00-10.00)	2.80(0.00-6.00)	0.001*
Species diversity value	1.84(1.66-2.02)	1.30(0.00-1.66)	0.001*
Species equitability value	0.92(0.82-0.97)	0.91(0.00-0.93)	0.509
Cavity guild			
Density(pairs/100 ha)	43.20(8.00-88.00)	30.40(8.00-56.00)	0.888
Species richness	2.40(1.00-4.00)	1.40(1.00-2.00)	0.317
Species diversity value	0.60(0.00-0.91)	0.25(0.00-0.64)	0.262
Species equitability value	0.50(0.00-0.89)	0.36(0.00-0.92)	0.568
Overstory guild			
Density(pairs/100 ha)	148.80(88.00-256.00)	33.60(8.00-120.00)	0.004*
Species richness	3.40(1.00-6.00)	2.00(1.00-5.00)	0.170
Species diversity value	0.69(0.00-1.27)	0.59(0.00-1.29)	0.319
Species equitability value	0.51(0.00-0.81)	0.34(0.00-0.92)	0.470

* Difference accepted as significant.

loblolly pine had a greater number of species of understory nesters. Understory nesters also had higher species diversity in loblolly than in white pine; cavity and overstory nesters in both pine types had similar species diversities. Species equitability values for each guild were similar for both pine types.

Comparisons of nesting guilds within pine type. Both understory nesting birds and overstory nesters had higher breeding bird densities than cavity nesters in loblolly pine; understory and overstory nesters had similar densities (Table 13). The understory guild was represented by more species and exhibited higher species diversity than either cavity or tree nesters. Neither species richness nor species diversity differed significantly between cavity nesters and overstory nesters. All three nesting guilds exhibited similar species equitability.

In white pine, none of the three guilds differed from any other guild in density, species richness, species diversity, or equitability (Table 13).

Winter season birds

Thirty-two species were observed during the winter season in 1989. An average of 47.28 individuals and 12 species occurred on individual transects. Total density averaged 1,884.8 individuals per 100 ha.

Twenty-six species, with 595 individuals, were observed in loblolly pine during the winter season. Seven species (27%) included greater than 80% of the total density of birds. Twenty-five species, comprising 583 individuals,

Table 13. Bird community characteristics by nesting guild within loblolly and white pine during the breeding season, 1989. These variables represent average values for five loblolly and five white pine transects on Oak Ridge Reservation NERP, Oak Ridge, Tennessee.

Bird community characteristics	Under-story guild	Cavity guild	Overstory guild	Level of signifi-cance
Loblolly pine				
Density(pairs/100 ha)	168.0	43.2	-	0.001*
	168.0	-	148.8	0.615
	-	43.2	148.8	0.001*
Species richness	7.6	2.4	-	0.001*
	7.6	-	3.4	0.001*
	-	2.4	3.4	0.299
Species diversity value	1.85	0.60	-	0.001*
	1.85	-	0.69	0.001*
	-	0.60	0.69	0.751
Species equitability value	0.92	0.50	-	0.072
	0.92	-	0.57	0.081
	-	0.50	0.57	0.081
White pine				
Density(pairs/100 ha)	56.0	30.4	-	0.183
	56.0	-	33.6	0.181
	-	30.4	33.6	0.961
Species richness	2.8	1.4	-	0.267
	2.8	-	2.0	0.612
	-	1.4	2.0	0.544
Species diversity value	1.30	0.25	-	0.070
	1.30	-	0.59	0.169
	-	0.25	0.59	0.650
Species equitability value	0.916	0.36	-	0.427
	0.916	-	0.34	0.370
	-	0.36	0.34	0.917

* Difference accepted as significant.

occurred in white pine. Seven species (28%) encompassed greater than 80% of the total density of birds (Table 14).

The average winter bird density in loblolly pine (952.0 individuals/100 ha) was similar to the density in white pine (932.8 individuals/100 ha)(Table 15). Species richness, species diversity, and species equitability did not differ significantly between pine types.

Table 14. Winter birds that comprised greater than 80% of the total population of five white pine and five loblolly pine stands on Oak Ridge Reservation NERP, Oak Ridge, Tennessee, 1989.

Bird species	Loblolly pine (ind/100 ha)		White pine (ind/100 ha)	
White-throated sparrow	326.4		116.8	
Carolina chickadee	126.0		260.8	
Pine warbler	108.8		-------	
Golden-crowned kinglet	59.2		140.8	
Northern cardinal	59.2		-------	
Dark-eyed junco	46.4		51.2	
Tufted titmouse	40.0		134.4	
Field sparrow	------		46.4	
Subtotal		766.0		750.4
All other species	185.6		182.4	
Total		951.6		932.8

Table 15. Bird community characteristics in loblolly and white pine during the winter season, 1989. These variables represent average values (with ranges) for five loblolly and five white pine transects on Oak Ridge Reservation NERP, Oak Ridge, Tennessee.

Bird community characteristics	Loblolly pine	White pine	Level of significance
Density (individuals/ 100 ha)	952.00(296.00-1,480.00)	932.80(720.0-1,336.00)	0.246
Species richness	12.40(9.00-16.00)	12.20(7.00-19.00)	0.760
Species diversity value	1.90(1.60-2.20)	1.85(1.47-2.40)	0.795
Species equitability value	0.76(0.70-0.85)	0.76(0.67-0.84)	0.979

* Difference accepted as significant.

CHAPTER VI

DISCUSSION

Much attention has been given bird-habitat relationships and the role structure plays in habitat selection by bird species. Wiens (1978) found that habitat structure in coniferous forests of the northwestern United States provided birds with display perches, shelter or nest sites, and suitable foraging areas. MacArthur and MacArthur (1961) concluded that bird species diversity on 13 locations in the eastern United States increased as foliage profile (foliage density plotted against height) increased. MacArthur et al (1962) contended that the variety of vegetation, or "patchiness", within deciduous forests in Pennsylvania and Vermont could increase the number of bird species that bred there. Anderson and Shugart (1974) found that in an east Tennessee deciduous forest some bird species (such as Downy Woodpeckers) were highly correlated with specific habitat structure variables while others (such as Scarlet Tanagers) were weakly correlated to a larger number of habitat variables.

Structure in even-aged pine forests is influenced by forest management

techniques. Noble and Hamilton (1976) noted that controlled burning loblolly pine plantations on an annual basis created sparse understory vegetation during the summer and virtually no understory vegetation during the winter. No midstory vegetation could develop. They also found that periodic thinning created a more open canopy and allowed growth of understory vegetation. Capen (1979) asserted that systematic removal of hardwood understories by thinning or chemical means reduced vertical structure of developing pine stands in the northeastern United States. However, thinning randomly throughout stands created patchiness, and thus increased structural diversity. Kroodsma (1984) observed that controlled burning on a periodic basis (3-5 years), as opposed to annual burning, allowed the development of hardwood understories and increased structure of loblolly pine plantations in South Carolina.

Loblolly and white pine stands in this study had been thinned several times, with loblolly control-burned 2-3 times. These forest management practices allowed the development of medium to dense hardwood understories, but no midstories in both pine types. Loblolly had a lower percentage of canopy closure, fewer snags per ha, and a higher percentage of ground cover than white pine. Otherwise, both pine types exhibited similar structural characteristics (Diameter at breast height, basal area, number of overstory stems/ha, number of understory stems/ha).

I. Breeding Season

During 1988, the bird community in loblolly pine had higher breeding bird densities (414.4 prs./100 ha) than the community in white pine (265.6 prs/100 ha). During 1989, the number of breeding birds decreased significantly in both pine types compared to 1988. The higher than normal rainfall experienced during the 1989 breeding season could have adversely affected surveying efforts. However, loblolly pine again had higher densities (360.0 prs/100 ha) than white pine (124.8 prs/100 ha).

Mature pine plantations have been shown to have fairly high breeding bird densities when compared to pine plantations of younger ages and to different habitat types. Johnston and Odum (1956) concluded that breeding bird densities in the upland Piedmont physiographic region were lowest in recently abandoned fields (67.9 prs/100 ha), increased in shrubland habitat (275 prs/100 ha), decreased in young pine forests (200 prs/100 ha), increased again steadily as the hardwood understory developed in older pine forests (407 prs/100 ha), and reached the highest levels in mature deciduous forests (545 prs/100 ha). James and Rathbun (1981) assessed 37 Breeding Bird Censuses taken from 1973 to 1977 in the United States and Canada. They contended that young coniferous forests sustained the lowest density of birds (131 prs/100 ha), tundra and desert habitat medium densities (277 prs/100 ha), coniferous and mixed coniferous-deciduous higher densities (357 prs/100 ha), and mature

deciduous forests the highest densities (384.6 prs/100 ha).

Working in loblolly pine forests of different seral stages (sapling, pole, and sawtimber) in east Texas, Dickson and Segelquist (1979) found that bird densities were lowest in young loblolly pine (sapling stage) stands (25 prs/100 ha), intermediate in the pole stage of loblolly stands (160 prs/100 ha), and highest in the sawtimber stage (375 prs/100 ha). The authors contended that increasing foliage height diversity, or an increase in hardwood understory development in the case of loblolly pine stands, accounted for the increase in bird density and species diversity. Capen (1979) reported that in the northeastern United States, bird densities increased as white pine forests increased in age from pole stage (250 prs/100 ha) to mature (sawtimber) stage (505 prs/100 ha). He attributed the high densities of birds in the mature stands to an open canopy and diverse hardwood understory.

The bird densities in both loblolly and white pine stands in this study compared favorably to bird densities reported in mature pine stands. Both pine types had well developed hardwood understories. The higher bird densities in loblolly as compared to white pine reflected the comparative abundance of birds in the understory nest guild (densities of cavity and overstory guilds did not differ between pine type). The understory guild of loblolly was characterized by a number of bird species (Indigo buntings, Rufous-sided towhees, American goldfinches, and Prairie warblers) that are associated with edge habitats (Kroodsma 1982). Indigo buntings and Rufous-sided towhees were the most

abundant birds after Pine Warblers, and occurred throughout the stands, not just near stand edges. The open overstory and dense ground cover of loblolly may have created suitable habitat structure for these bird species. The white pine stands in this study did not exhibit this type of habitat structure, and these species were not found in high numbers.

Loblolly pine also exhibited a higher species richness than white pine during the 1989 breeding season (13.4 vs. 6.2 in 1989). The species richness of the understory nesters was higher than in white pine, while the other nesting guilds did not differ between pine type. The bird species associated with edge habitat in loblolly again accounted for the difference in species richness between loblolly and white pine.

Although the number of species in cavity and overstory guilds were the same in both pine types, some of the species that utilized the overstories differed. Three species (Blue-gray gnatcatchers, Eastern wood pewees, Yellow-throated warblers) were unique to loblolly and four (Acadian flycatchers, American crows, Scarlet tanagers, Blue jays) were unique to white pine in 1988. In 1989, three species (Blue-gray gnatcatchers, Ruby-throated hummingbirds, Red-tailed hawks) were unique to loblolly and two (American crows, Sharp-shinned hawks) to white pine. The same cavity nesting species that occupied white pine also occupied loblolly during both years.

Several factors may have accounted for the varied use by birds of loblolly and white pine overstories. Some of the overstory bird species are more

typically associated with the interior of deciduous forests. For instance, white pine stands had a high number of Red-eyed vireos, the second most abundant bird in this pine type. Red-eyed vireos characteristically glean for insects in areas where the canopy is abundant and understory is moderate (Williamson 1971). The needles of white pine are more shade tolerant than loblolly, and thus form a thicker, more abundant crown (Fowells 1965). This, coupled with a lower percent ground cover, may have made white pine more suitable for Red-eyed vireos. This species and others, such as the Scarlet tanager, Yellow-throated vireo, Yellow-billed cuckoo, Hooded warbler, and Eastern wood pewee were also reported by Robbins (1979) to require large areas of unbroken forest during the breeding season. The small size (less than 20 ha) of both loblolly and white pine stands in this study and the fact that all were bordered on at least 1 side by larger tracts of deciduous forests may have encouraged some of these species to utilize the pine stands as part of their home ranges. Childers (1982) observed that a number of bird species normally associated with deciduous forests occupied loblolly pine stands less than 30 ha in size when the stands were adjacent to deciduous forests.

Some of the birds typically associated with hardwood forests, but seen in loblolly or white pine (both in the overstory and understory) could have been unmated males who could not establish territories in adjacent deciduous forests. Gibbs and Faaborg (1990) studied male Kentucky warblers and Ovenbirds in central Missouri. They discovered that 3/4 of the territorial male

Ovenbirds observed were unpaired in small forest stands (< 140 ha), while only 1/4 of the males observed in larger (> 500 ha) forest stands were unpaired.

Three bird species of particular interest were also observed only in white pine. A pair of Sharp-shinned hawks nested in one of the white pine stands. Sharp-shinned hawks are listed as threatened by the state of Tennessee (Kroodsma 1987). This represented the first recorded observation of Sharp-shinned Hawks nesting on the ORR during the breeding season, and one of the few recorded nest sightings in the Ridge and Valley province of east Tennessee (Charles P. Nicholson, TVA, Pers. Comm.). Bent (1961) reported that Sharp-shinned hawks nested preferentially in white pine when it was present. White pine forests may represent important habitat for this species in east Tennessee. Black vultures, listed by the Tennessee Wildlife Resources Agency as in need of management (Kroodsma 1987), also nested in a white pine stand. Two nests of Wild turkeys were discovered, and females with young poults were sighted regularly in several white pine stands. Wild turkeys were recently re-introduced onto the ORR. Minser (unpublished data, Univ. of Tennessee) noted that turkeys favored oak-hickory ridges and mature white pine plantations on the ORR during the spring of 1988, and loblolly pine plantations were used significantly less than expected. The use of white pine by these uncommon birds highlights the importance of considering what particular species are attracted to a particular habitat when assessing the ecological value of that habitat.

During the 1988 breeding season, species diversity did not differ between loblolly (1.84) and white pine (1.68). During the 1989 breeding season, however, bird species diversity was higher in loblolly (2.20) than in white pine (1.52). Species equitability was similar for both years.

Noble and Hamilton (1976) reported that species diversity was lowest in 6-year old (2.14) and 20-year old (2.19) loblolly stands, intermediate in a "control" stand of mature mixed pine-hardwoods (2.41), and highest in a 46-year old stand (2.77). They attributed the progressive increase in diversity to an increase in foliage height diversity as the stands matured. Conversely, Childers et al (1986), found that species diversity peaked in 2- and 8-year old loblolly plantations (2.22, 2.11) and then dropped significantly as the plantations matured (11-24 years)(1.56,1.33). He attributed the higher species diversities of younger loblolly stands to an abundance of snags, hardwood sprouts, and herbaceous plants; the lower diversities of the older loblolly stands were related to a sharply reduced understory foliage density and foliage height diversity caused by canopy closure and annual controlled burning.

The species diversity I detected in both pine types corresponded more closely to those reported by Noble and Hamilton (1976). The difference in species diversity between pine types during the 1989 breeding season was attributed to the greater diversity of the understory nest guild using loblolly pine. Cavity and overstory guilds did not differ between pine types. During 1988, the southeastern region of the United States experienced a prolonged drought

which ended in the early spring of 1989. The higher than normal rainfall that occurred during spring 1989 may have caused an increase in vegetation in both pine types. The open canopy of loblolly may have permitted more rapid growth of vegetation than the closed canopy of white pine. This may have created a habitat differential affecting the species diversity of understory nesters.

The similar bird species equitability of loblolly and white pine may have reflected the structural evenness characterized by both pine types. This allowed a relatively even distribution of bird species throughout the pine stands. Childers et al (1986) found species equitability remained similar across age classes (0.67-0.89). He attributed the similar equitability values found in his study to a uniform structure caused by such factors as the even spacing of overstory trees and controlled burning of the understory.

II. Winter season birds

Winter bird density did not differ significantly between pine types (952 ind/100 ha vs. 932.8 ind/100 ha), nor did species richness (12.4 vs. 12.2), bird species diversity (1.9042 vs. 1.8539), and species equitability (0.7666 vs. 0.9790). Childers et al (1986) also reported no differences in winter density (910 ind/100 ha-2,400 ind/100 ha), species richness (2-5), species diversity (0.39-0.68), or species equitability (0.36-0.82) across 6 seral stages of loblolly stands and a control stand of mature second growth hardwoods. He attributed the

similar characteristics in part to a lack of understory vegetation during the winter due to annual controlled burning, and agreed with Anderson's (1980) hypothesis that birds tended to feed in a wide variety of habitat types during the winter. Noble and Hamilton (1976), however, reported that winter bird density was higher in 6-year old loblolly (289 ind/100 ha) and mixed-hardwood control stands (686 ind/100 ha), and lower in 20-year old (154 ind/100 ha) and 46-year old (139 ind/100 ha) loblolly stands. Species richness was similar across seral stages (21-31 species). Species diversity was greatest in the control stand (2.71), lower in 6-year old (2.65) and 20-year old stands (2.56), and lowest in 46-year old stands (2.38). The authors concluded that annual controlled burning in the older pine stands resulted in very little winter understory vegetation, reduced vertical foliage diversity, and, consequently, lowered bird density and diversity values.

The species density values in this study were similar to those Childers et al (1986) reported, while species richness, diversity and equitability were more similar to values reported by Noble and Hamilton (1976). However, the understory vegetation of both loblolly and white pine in this study was well developed, with an abundance of understory seed- and berry- producing plants. Perhaps structural diversity during the winter months may not be as critical to bird communities as it is during the breeding season. The winter bird communities of both pine types were characterized by large, mixed flocks of birds utilizing either the overstory or the understory. Carolina chickadees, Tufted

titmice, Golden-crowned kinglets, Ruby-crowned kinglets and occasionally Brown creepers were often seen together moving in loose, mixed flocks through the overstory of both pine types. White-throated sparrows, Field sparrows, and Song sparrows were often seen together or in flocks of single species in the understory. Groups of Dark-eyed juncos were seen only around the edges of stands. Occasionally mixed flocks of woodpeckers (Pileated, Hairy, Downy, Common flicker) moved through stands of both pine types. All of these birds tended to move slowly through the stands and also utilized adjacent habitats (such as deciduous forests, powerline right-of-ways, shrub habitats). The observed foraging behavior of the bird communities in this study supported the hypothesis of Anderson (1980) that birds tended to feed in a wide variety of habitat types during winter. Structure that provided winter food and shelter was selected for, which could be very different from habitat selected during the breeding season.

Sharp-shinned hawks and Wild turkeys were once again observed exclusively in white pine stands. Bent (1961) noted that Sharp-shinned hawks used pine forests for cover during winter months. Minser (Univ. Tennessee unpublished data) noted that Wild turkeys utilized white pine mainly for cover during periods of inclement weather and extreme temperatures.

CHAPTER VII

SUMMARY

Breeding and winter bird surveys were conducted during 1988 and 1989 using a strip transect method on 5 stands each of planted, mature loblolly and white pine. The stands, located on the National Environmental Research Park areas in ORR, were similar in size, age, and were managed similarly for sawtimber development (i.e. similar number of trees/ha). Overstory silvicultural characteristics were measured by a point sample cruise. Understory vegetation was sampled using ten 10-m^2 plots per stand.

Both loblolly and white pine exhibited well developed hardwood understories and supported diverse bird communities. However breeding bird density in loblolly pine was higher than in white pine in 1988; in 1989 loblolly pine had both a higher breeding bird density and species richness than white pine. Understory nesting birds in loblolly pine may have accounted for these differences between pine type, due to a high number of edge species utilizing loblolly stands. The open canopy and dense ground cover of loblolly pine may

have created habitat structure suitable for these species. The closed canopy and less dense ground cover of white pine seemed to preclude edge species from utilizing this habitat in high numbers.

Both pine types were occupied by a number of species normally associated with the interior of deciduous forests, species which reportedly require large tracts of unbroken forest during the breeding season. The fact that all of the pine stands were less than 20 ha and were bordered on at least one side by larger tracts of deciduous forest may have allowed these birds to utilize the pine stands as part of their territories. Some birds may have also have represented unmated males that could not establish territories in adjacent deciduous forests.

One bird species listed as threatened, one species as in need of management, and one species recently re-introduced were observed exclusively in white pine stands. These observations highlighted the importance of considering the particular bird species that are attracted to a habitat when assessing habitat values.

Winter bird communities did not differ significantly between pine types in density, species richness, diversity, or equitability. Flocks of single species and flocks of mixed bird species utilized both the overstory and understory of both types. These groups moved slowly through the stands and utilized adjacent habitats as well. Birds selected for structure that provided winter food and shelter. Their mobility and the juxtaposition of several habitat types allowed

them to occupy a variety of habitats.

One threatened bird species and one recently re-introduced species were found exclusively in white pine stands.

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APPENDICES

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

Common name	Latin name
American beech	Fagus grandifolia
Basswood	Tilia spp.
Buckeye	Aesculus spp.
Black cherry	Prunus serotina
Flowering dogwood	Cornus florida
Hickory	Carya spp.
Magnolia	Magnolia spp.
Red maple	Acer rubrum
Sugar maple	Acer saccharum
Boxelder	Acer negundo
Oak	Quercus spp.
Southern red oak	Quercus falcata
Eastern white pine	Pinus strobus
Loblolly pine	Pinus taeda
Sassafrass	Sassafras albidum
Sweetgum	Liquidambar styraciflua
Sycamore	Platanus occidentalis
Tulip poplar	Liriodendron tulipiferia
Willow	Salix spp.
Blackberry	Rubus spp.
Japanese honeysuckle	Lonicera japonica
Poison-ivy	Toxicodendron radicans

Appendix II. Breeding and winter bird species that occured on 10 transects in loblolly and white pine on the Oak Ridge Reservation NERP, Oak Ridge, Tennessee, 1988 to 1989. Checklist order follows that of the American Ornithologist's Union (1982).

Bird Species	Number of transects recorded			Average breeding bird density (pairs per 2.5 ha)				Average winter bird density (ind. per 2.5 ha)	
	Breeding		Wintering	Breeding 1988		Breeding 1989		Winter 1989	
	1988	1989	1989	Loblolly	White Pine	Loblolly	White Pine	Loblolly	White Pine
Black vulture (Coragyps atratus)	1	1	-	-	0.24+0.54	-	0.25+0.5	-	-
Sharp-shinned hawk (Accipiter striatus)	-	1	1	-	-	-	0.08+0.18	-	0.04+0.11
Red-shouldered hawk (Buteo lineatus)	-	1	1	-	-	0.04+0.11	-	-	0.04+0.11
Red-tailed hawk (Buteo jamaicensis)	OT	OT	OT	-	-	-	-	-	-
Wild turkey (Meleagris gallopavo)	OT	-	2	-	-	-	-	-	0.32+0.8
Ruffed grouse (Bonasa umbellus)	-	OT	OT	-	-	-	-	-	-
Northern bobwhite (Colinus virginianus)	4	4	1	0.24+0.26	0.04+0.11	0.28+0.3	-	0.44+0.98	-
American woodcock (Scolopax minor)	-	1	-	-	-	0.04+0.11	-	-	-
Mourning dove (Zenaida macroura)	OT	-	-	-	-	-	-	-	-
Yellow-billed cuckoo (Coccyzus americanus)	2	1	-	-	0.12+0.18	-	0.05+0.11	-	-
Ruby-throated hummingbird (Archilochus colubris)	-	1	-	-	-	0.05+0.11	-	-	-
Red-bellied woodpecker (Melanerpes carolinus)	OT	2	1	-	-	0.08+0.11	-	0.08+0.18	-
Yellow-bellied sapsucker (Sphyrapicus various)	-	-	1	-	-	-	-	-	0.08+0.18
Downy woodpecker (Picoides pubescens)	1	3	4	0.05+0.11	-	0.12+0.18	0.08+0.18	0.05+0.11	0.16+0.17
Hairy woodpecker (Picoides villosus)	3	1	4	0.05+0.11	0.08+1.1	0.05+0.11	-	0.05+0.11	0.05+0.11
Common flicker									

Pileated woodpecker (Dryocopus pileatus)	-	1	8	-	-	0.05+0.11	-	0.36+0.33	0.32+0.18
Eastern wood pewee (Cantopus virens)	1	-	-	0.05+0.11	-	-	-	-	-
Acadian flycatcher (Empidonax virescens)	1	OT	-	-	0.08+0.18	-	-	-	-
Great-crested flycatcher (Myiarchus crinitus)	OT	-	-	-	-	-	-	-	-
Bluejay (Cyanocitta cristata)	1	3	OT	-	0.08+0.18	0.2+0.28	0.05+0.11	-	-
American crow (Corvus brachyrhynchos)	3	1	1	-	0.24+0.18	-	0.08+0.18	0.16+0.36	-
Carolina chickadee (Parus carolinensis)	6	10	10	0.6+1.04	2.12+1.74	0.72+0.44	0.47+0.5	3.16+1.77	6.4+2.09
Tufted titmouse (Parus bicolor)	3	1	7	0.05+0.11	0.08+0.11	0.05+0.11	-	1.0+1.65	3.36+1.58
Red-breasted nuthatch (Sitta canadensis)	-	-	2	-	-	-	-	-	0.12+0.18
White-breasted nuthatch (Sitta carolinensis)	OT	1	4	-	-	0.08+0.18	-	0.28+0.39	0.2+0.35
Brown creeper (Certhia americana)	-	-	4	-	-	-	-	0.12+0.80	0.8+0.81
Carolina wren (Thryothorus ludovicianus)	8	6	3	1.18+0.78	0.56+0.77	0.4+0.37	0.24+0.43	0.05+0.11	0.16+0.22
Winter wren (Troglodytes ludovicianus)	-	-	7	-	-	-	-	0.2+0.24	0.6+0.80
Golden-crowned kinglet (Regulus satrapa)	-	-	8	-	-	-	-	1.48+2.2	3.52+1.31
Ruby-crowned kinglet (Regulus calenda)	-	-	6	-	-	-	-	0.6+0.82	0.72+0.59
Blue-gray gnatcatcher (Polioptila caerulea)	2	3	-	0.16+0.22	-	0.44+0.57	-	-	-
Eastern bluebird (Sialis sialis)	OT	OT	2	-	-	-	-	0.08+0.11	-
Wood thrush (Hylocichla mustelina)	OT	-	-	-	-	-	-	-	-
American robin (Turdus migratorious)	-	-	2	-	-	-	-	0.05+0.11	0.05+0.11
Cedar waxwing (Bombycilla cedorum)	OT	-	2	-	-	-	-	0.64+1.32	-

White-eyed vireo (Vireo griseus)	2	3	-	0.2+0.45	0.05+0.11	0.28+0.44	0.05+0.11	-	-
Red-eyed vireo (Vireo olivaceus)	9	8	-	0.52+0.58	1.16+0.93	0.28+0.23	0.44+0.65	-	-
Yellow-throated vireo (Vireo flavifrons)	1	-	-	0.08+0.18	-	-	-	-	-
Northern Parula warbler (Parula americana)	-	OT	-	-	-	-	-	-	-
Yellow warbler (Dendroica petechia)	-	OT	-	-	-	-	-	-	-
Yellow-throated warbler (Dendroica dominica)	3	-	-	0.05+0.11	0.16+0.22	-	-	-	-
Pine warbler (Dendroica pinus)	8	7	7	3.24+2.06	0.32+0.36	2.68+0.70	0.08+0.11	2.72+2.56	0.32+0.50
Prairie warbler (Dendroica discolor)	OT	1	-	-	-	0.05+0.11	-	-	-
Ovenbird (Seiurus aurocapillus)	OT	-	-	-	-	-	-	-	-
Kentucky warbler (Oporonis formosus)	OT	1	-	-	-	0.05+0.11	-	-	-
Common yellowthroat (Geothlypis trichas)	OT	-	-	-	-	-	-	-	-
Hooded warbler (Wilsonia citrina)	3	7	-	0.20+0.35	0.29+0.40	0.16+0.09	0.20+0.35	-	-
Yellow-breasted chat (Icteria virens)	2	3	-	0.44+0.78	0.05+0.11	0.28+0.26	-	-	-
Summer tanager (Piranga rubra)	OT	OT	-	-	-	-	-	-	-
Scarlet tanager (Piranga olivacea)	1	2	-	-	0.05+0.11	0.05+0.11	0.12+0.27	-	-
Northern cardinal (Cardinalis cardinalis)	9	6	6	0.92+0.81	0.72+0.67	0.52+0.44	0.24+0.36	1.48+1.84	0.16+0.26
Indigo bunting (Passerina cyanea)	8	7	-	1.56+1.29	0.16+0.36	0.40+0.32	0.20+1.22	-	-
Rufous-sided towhee (Pipilo erythrophthalmus)	4	6	3	0.72+0.67	-	1.08+1.04	0.16+0.41	0.32+0.44	-
Field sparrow (Spizella pusilla)	-	-	2	-	-	-	-	0.36+0.70	1.16+1.90
Chipping sparrow (Spizella passerina)	-	OT	-	-	-	-	-	-	-
Song sparrow (Melospiza melodius)	-	-	3	-	-	-	-	0.12+0.18	0.20+0.44

White-throated sparrow (Zonotrichia albicollis)	-	-	7	-	-	-	-	8.16+4.74	2.92+5.76
Dark-eyed junco (Junco hyemalis)	-	-	4	-	-	-	-	1.16+2.08	1.28+1.84
Brown-headed cowbird (Molothrus ater)	2	3	-	0.16+0.35	0.05+0.11	0.20+0.34	0.05+0.11	-	-
Pine siskin (Carduelis pinus)	OT	-	-	-	-	-	-	-	-
American goldfinch (Carduelis tristis)	1	3	6	0.12+0.27	-	0.48+0.62	-	0.60+0.81	0.12+0.18

1. Total number of transects where species occurred at least once; 10 transects were possible during breeding and 10 during winter seasons.
2. OT denotes "out of transect"; species were sighted outside of transects but still within stand.
3. Average breeding bird density expressed as pairs per 2.5 ha (with standard deviation), per transect, where species occurred at least once.
4. Average winter bird density expressed as individuals per 2.5 ha (with standard deviation), per transect, where species occurred at least once.

Vita

Carol Lynn Hardy was born in Dayton, Ohio on 11 November 1962. She completed elementary and middle school education at Spangdahlem AFB and Bitburg AFB, Germany. She completed her high school education at Las Vegas, Nevada, and graduated from Rancho High School in 1981. She attended Clark County Community College at Las Vegas before transferring to the University of Tennessee at Knoxville in 1982. She received a Bachelor of Science Degree with Honors in Wildlife and Fisheries Science from the University of Tennessee in 1987. During her undergraduate training, she worked as a naturalist for Tennessee's Division of State Parks, and for Ijam's Nature Center in Knoxville, Tennessee.

Ms. Hardy entered Graduate School at the University of Tennessee in the fall of 1987. During the course of her graduate work, she has created and taught wildlife awareness classes for Super Saturdays, a program for gifted and talented elementary students at Pellissippi State Technical Community College in Knoxville, Tennessee. She has also designed and taught outdoor avian and mammal classes at the Ecological Study Center at Oak Ridge National Laboratories, Oak Ridge Tennessee. She is currently working in the Environmental Sciences Division of Oak Ridge National Laboratories. She received a Master of Science degree in Wildlife and Fisheries Science from the University of Tennessee in May 1991.

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