AVIAN DIVERSITY OF PINE PLANTATIONS AND DECIDUOUS WOODLANDS ON THE NORTHWESTERN HIGHLAND RIM OF THE INTERIOR LOW PLATEAU

MICHAEL O'NEAL DINSMORE

AVIAN DIVERSITY OF PINE PLANTATIONS AND DECIDUOUS WOODLANDS ON THE NORTHWESTERN HIGHLAND RIM OF THE INTERIOR LOW PLATEAU

An Abstract

Presented to

the Graduate Council of

Austin Peay State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

in Biology

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by

Michael O'Neal Dinsmore

August 1975

ABSTRACT

Bird censuses were conducted in late May, June, and early July 1975 on 12 planted pine stands and 6 deciduous woodlands in Montgomery and Stewart Counties, Tennessee, and Trigg and Christian Counties, Kentucky, on the Northwestern Highland Rim of the Interior Low Plateau. Vegetation was sampled by recording presence or absence of foliage above 40 points per study area in each of three pre-determined layers. Species identities of plants were also recorded. Diversity indices were calculated using Shannon's formula (Shannon and Weaver, 1949). Per cent vegetation cover was calculated per number of points above which foliage was present. Considering all study areas together as representing a gradient of dissimilar habitats, bird species diversity was correlated with foliage height diversity and sum of per cent vegetation cover, but not with plant species diversity. In the pine stands alone all of these correlations were found as well as correlations between bird species diversity and age of pine stands, and per cent pine cover. In the hardwood stands alone bird species diversity did not correlate with foliage height or plant species diversities or with sum of per cent vegetation cover. No significant differences were found in either the number of bird species detected or bird species diversity between pine stands and hardwood stands. Substitution of bird species was found to

be the major effect of pine plantations on the bird communities of the area of the study. Patterns of bird species substitution were comparable to those associated with natural secondary succession in the area.

AVIAN DIVERSITY OF PINE PLANTATIONS AND DECIDUOUS WOODLANDS ON THE NORTHWESTERN HIGHLAND RIM OF THE INTERIOR LOW PLATEAU

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August 1975

To the Graduate Council:

I am submitting herewith a thesis written by Michael O. Dinsmore entitled "Avian Diversity of Pine Plantations and Deciduous Woodlands on the Northwestern Highland Rim of the Interior Low Plateau." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in biology.

David Snyder

Major Professor

We have read this thesis and recommend its acceptance:

Diane S. Findley

Second Committee Member

Edward W. Chester

Third Committee Member

Accepted for the Council:

[illegible]

Dean of the Graduate School

ACKNOWLEDGMENTS

I would first like to thank my wife Dianne who was at times more hindrance than help, but without whose encouragement, faith, and companionship this project would surely have gone unfinished. Secondly, I thank my parents who financed my entire education to this point and for whom I was always motivated to succeed.

I thank my major professor, Dr. David H. Snyder for his constant pressure, criticism, and patience in dealing with my procrastination. His advice throughout the project were my major guidelines and also an original suggestion of his led to the project. My other committee members, Drs. Edward W. Chester and Diane I. Findley supplied advice and discussion on various aspects of the study. Dr. Roger L. Kroodsma was my most faithful correspondent whose help and advice were immeasurable. Mr. Tom Harschbarger, head forester at Fort Campbell, Kentucky, was very helpful in my securing of clearance to work on that military reservation and also in locating study areas. Dr. Ray Nall, director of Land-between-the-Lakes, and Messrs. Bob Drexler and Larry Doyle, both foresters at Land-between-the-Lakes, allowed me to work in that area and helped me in locating study areas. Mr. Billy Smith, soil conservationist of Montgomery County, Tennessee, helped me locate study areas in that county and Messrs. Graham Haynes and John McKinney allowed me to use portions of their property as study areas.

Charles Crow, Jr. and Shawn Snyder helped me with the vegetation sampling. Ms. Rose Beghtol helped with the figures and Ms. Karen Yates typed the manuscript. Also I would like to acknowledge my fellow graduate students, Joe Wallace and Jack Sites, Jr., who through constant debate, discussion, and general comradery made the time pass quickly.

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Chapter I

INTRODUCTION

The widespread belief that pine plantations of the type associated with erosion control and the pulpwood industry provide relatively poor wildlife habitat (Stoddard, 1963) is not adequately substantiated by quantitative data in the literature. Of particular interest are the species composition and relative abundance of the bird communities that utilize such artificial habitats in comparison to natural situations. In this study I have compared pine plantations located on the Northwestern Highland Rim of the Interior Low Plateau in Tennessee and Kentucky with natural woodlands of that same general area.

Braun (1950) classifies the Western Highland Rim as part of the Western Mesophytic Forest Region. She mentions no pine as a natural aspect of the vegetation of the northern portion of this region where my work was conducted. Pine plantations on the northern "Mississippian Plateau" (terminology of Braun, 1950) are therefore plantings of a species exotic to that area.

Diversity of vegetation has been shown to be correlated with bird species diversity (BSD) at least in deciduous forests (MacArthur and MacArthur, 1961) thus suggesting that BSD can be predicted by measuring various aspects of the vegetation. Willson (1974) concurred with that conclusion for the most part, but raised some questions about certain aspects of the theory.

Parameters of vegetation I measured during this study include: foliage height diversity (FHD), per cent vegetation cover (PCVC), and plant species diversity (PSD). The MacArthurs (1961) found BSD to be positively correlated with FHD but not with PSD. Willson (1974) found BSD to be positively correlated with PCVC and FHD in most cases but pointed out possible exceptions. In the study reported herein, I looked for these relationships in pine plantations and deciduous woodlands of the Northwestern Highland Rim area.

Other questions considered include:

1. Of deciduous woodlands and pine plantations, which habitat type supports a higher BSD?
2. What age pine stands support the greatest BSD?
3. What happens to BSD during the maturation of a pine stand and what species of birds are associated with the various stages of that process?
4. Does the size of a pine stand or woodland influence the number of bird species utilizing the area, and if so how?
5. What is the overall effect of introducing pine plantations on an area's bird population?

6. How might pine plantations be managed so that they yield productive habitat for bird populations?
7. What differences exist between natural deciduous woodlands and pine plantations located on the Northwestern Highland Rim, as regards the community of bird species utilizing each habitat type?

The calculation of various ecological diversity indices has received much attention in the literature. Many workers have used information theory in these calculations and there are two popular formulas that are used; Shannon's Formula (Shannon and Weaver, 1949) which has been used extensively and is used in this study, and that of Brillouin (1956, cited by Lloyd, et al, 1968). Although the two formulas are similar, sampling techniques that I used favored Shannon's formula for use in this study.

Chapter II

LITERATURE SURVEY

I could find no study comparing bird communities of the deciduous woodlands characterizing my study areas with those of pine plantations. Perkins (1973) worked with Loblolly Pine plantations in the interior flatwoods of Mississippi comparing them with natural woodlands of that area (which had a canopy of 60% pines and an understory mainly of hardwoods). He studied effects of clearcutting and different types of site preparation on vegetation and several wildlife species. He studied no plantations older than 5 years. Although many bird species and the natural vegetation varied from those characterizing my study areas, he found that the number of bird species in the interior of the uncut forest was higher than that of the same area in the first year after clearcutting. In the second and third years of the plantations however this number increased and was then substantially higher than that of the interior of the uncut forest. He pointed out that these pine stands represented the earliest stages of plant succession.

Johnston and Odum (1956) compared breeding bird populations with various seral stages of plant succession on the Piedmont of Georgia. Some of their areas included variously-aged natural pine forests. Again, the natural vegetation differed from that of my study areas, and no artificial situations were studied. They did find however that both number of breeding pairs per 100 acres and total number of bird species increased with the age of the seral stage. A relative drop in these parameters began in pine forests around 20 years old, but recovered in old pine forests. They found that many bird species were associated with certain seral stages, but also that some species were common in all stages.

Smith (1958) studied conifer plantations in New York as wildlife habitats and, although he was mainly concerned with game species, found that a "succession of wildlife" is associated with increasing height and cover density of the vegetation. Open-field species of wildlife are replaced by shrubland species and when the pine canopy closes, forest species of wildlife slowly begin to dominate.

Lack (1933, 1939) and Lack and Lack (1951) in successive studies of the same pine plantations in England found that the succession of bird species is markedly correlated with the general age of the stand and thus vegetation complexity.

Roberts (1963) studied breeding birds of two pine forests in Georgia, one natural and one planted. He paid special attention to the status of Pine Warblers and stated that in Georgia this species is almost alone in the pine canopy niche. He also reported that all other bird species encountered were concentrated in areas that had undergrowth or dead standing trees. Cleveland (1974) studied a pine plantation in Louisiana and compared breeding bird densities to those of a study of a grassland (which he did not cite). The main differences he found were in what bird species utilized each habitat and in the numbers of each species. He reported that there was a shift from a population of seed eaters in the grassland to one of insect eaters in the pines. Also reported was that grasslands support greater numbers of individual birds than pine plantations, but the latter supports more species.

As mentioned earlier, none of the afore-mentioned studies dealt directly with a comparison of avian diversity of non-pine woodlands with that of planted pine stands. Nor did I find any published data concerning a breeding bird census of a pine plantation in the geographic area of my study.

The relationship of BSD to various habitat parameters has received much attention in the literature. MacArthur and MacArthur (1961) pointed out that the number of available niches is controlled by diversity of the vegetation. Using Shannon's formula (Shannon and Weaver, 1949) the MacArthurs (1961) showed that in a series of similar habitats BSD was correlated with FHD but not with PSD. They stated that BSD can be predicted by measuring FHD. MacArthur, et al (1962) stated that fairly accurate censuses of breeding birds can be predicted from measurements of the amount of foliage in three horizontal layers above the ground.

Willson (1974) assessed foliage profiles by lumping all relevant data into one of 3 categories representing the following layers; 0-1.5 m, 1.5-9 m, and >9 m. She found that BSD was correlated with FHD values calculated using these 3 layers. When considering only forested areas however she found no correlation between BSD and FHD, in contrast with the MacArthurs' (1961) original data for such homogenous habitats. In Willson's (1974) study, neither FHD nor the sum of per cent vegetation cover (PCVC) for all layers considered adequately predicted BSD on study areas containing large trees. In that instance, furthur increases in foliage volume or height diversity had no associated increases in BSD.

Others workers who have found BSD to be correlated with FHD, in a variety of habitat types, include Karr (1968), Karr and Roth (1971), and Recher (1969). Kricher (1973) demonstrated a positive correlation between BSD and age of seral stages of secondary succession in New Jersey. Karr (1968) studied BSD in relation to successional stages on strip-mined land in Illinois and found that BSD increased in the early stages, reached a maximum, and then decreased in the later stages. Recher (1969) found BSD to be correlated with FHD in temperate Australia. Tomoff (1974) has shown that FHD cannot be used to adequately predict BSD in desert scrub. Kroodsma (1975) found that BSD was positively correlated with what he called plant stratum diversity (which is equivalent to FHD) in 11 pine plantations in South Carolina, but was negatively correlated with pine cover. Thinning of plantations resulted in higher BSD, and age of plantations had no effect on BSD. He also found BSD values to be lower than expected in scrub oak forests.

Use of information theory has become prevalent in ecological research in calculation of various diversity indices. Two formulas are seen in the literature: Shannon's formula (Shannon and Weaver, 1949) which has been used extensively, and that of Brillouin (1956, cited by Lloyd, et al, 1968) which has received relatively little attention in comparison to the former. Tramer (1969) described Shannon's formula and discussed its various components which in general also apply to Brillouin's formula. Pielou (1966) described diversity indices based on information theory as representing the amount of uncertainty that exists regarding the species identity of an individual selected at random from a population. Karr (1971) said Shannon's formula belittles the importance of rare species in BSD values. Lloyd, et al (1968) discussed both formulas and gave tables for use in their calculation. They demonstrated that Brillouin's formula uses actual numbers of observations in a sample and Shannon's formula uses proportions of observations in a given category. (When considering species diversity, the categories become species encountered.) Karr (1968) stated that of the two formulas, Shannon's was the least sensitive to sample size.

Chapter III

METHODS AND MATERIALS

From 19 May to 3 July 1975 inclusive I conducted breeding bird censuses on 18 study areas located in Montgomery and Stewart Counties, Tennessee, and Christian and Trigg Counties, Kentucky. Twelve of these were planted stands of Loblolly Pine (*Pinus taeda*) and 6 were natural, though not climax, deciduous woodlands.

THE STUDY AREAS

Pine stands were selected on the basis of size and age as follows; three areas (two large and one small) were selected in each of three age classes (5 to 6 years, 10 to 11 years, and 17 to 20 years). Large and small areas are herein defined as over 40 acres and less than 10 acres respectively. In a fourth age class (over 30 years old) I was unable to find any large stand and therefore used three small areas.

The sizes of the several study areas were determined by drawing a scale map of each area on graph paper, cutting out the map and weighing it, and then calculating the area represented by the map based on the known weight per unit area represented on the graph paper. The maps were drafted either on the basis of my pace-and-compass field data, or of scaled topographic maps.

Summary data for each study area are presented in Table I. Age or size class of trees, size of area in acres, the five most frequently encountered plant species (ordered from most to least frequent), and comments are detailed for each study site. The code of area designations in Table I is used throughout the remainder of this paper. In the code designations, "P" denotes a pine stand and "H" denotes a natural hardwood stand. More complete descriptions of each area, with exact locations, are provided in Appendix A. Sites within Fort Campbell, Kentucky, are designated FC with a number following representing the numbered area within Fort Campbell in which it was located.

All study areas were upland in nature, none were near streams, and no steep slopes or ravines were included.

BIRD CENSUSES

Breeding bird censuses were conducted using a standard singing male count index (Kendeigh, 1944). Since an objective was the detection of all birds using the area, in terms of both species and individuals, birds that were seen or heard on an area but may not have had nests there were counted. This occurred more often on areas of 10 acres or less. Four censuses were conducted on each area: two primary counts, being here defined as those beginning before listed sunrise times, and two secondary counts, being those immediately following a primary count. Every study area was censused in each of four series of counts before the next series

Table I. Summary data for 12 planted pine stands and 6 deciduous woodlands on the Northwestern Highland Rim of the Interior Low Plateau. "P" denotes a pine stand and "H" denotes a deciduous woodland

Study area code	Age of stand or Mean DBH	Area in acres	Most frequent plant species	Comments
P-1	6 yrs.	59.3	*Rhus copallina*, *Pinus taeda*, *Lonicera japonica*, *Smilax* spp., *Rosa* spp.	Homogenous, dense ground cover
P-2	6 yrs.	45.7	*Pinus taeda*, *Lonicera japonica*, *Smilax* spp., *Sassafras albidum*, *Rhus copallina*	Surrounds area H-1, much like P-1
P-3	6 yrs.	2.9	*Smilax* spp., *Pinus taeda*, *Lonicera japonica*, *Rhus copallina*, *Sassafras albidum*	Patchy growth with dense ground cover
P-4	10 yrs.	41.6	*Pinus taeda*, *Smilax* spp., *Rhus copallina*, *Diospyros virginiana*, *Rosa* spp.	Deciduous growth very tangled
P-5	11 yrs.	47.0	*Smilax* spp., *Pinus taeda*, *Rhus copallina*, *Lonicera japonica*, *Rubus argutus*	Similar to area P-4
P-6	11 yrs.	4.3	*Pinus taeda*, *Lonicera japonica*, *Smilax* spp., *Rhus copallina*, *Rubus argutus*	Open area through center
P-7	17 yrs.	6.3	*Pinus taeda*, *Liquidambar styraciflua*, *Lonicera japonica*, *Smilax* spp., *Sassafras albidum*	Ground cover sparse, canopy closed

Table I. (continued)

Study area code	Age of stand or Mean DBH	Area in acres	Most frequent plant species	Comments
P-8	19 yrs.	47.4	*Pinus taeda, Lonicera japonica, Acer negundo, Vitis aestivalis, Cornus florida*	Fairly dense, canopy closed
P-9	17 yrs.	85.8	*Pinus taeda, Lonicera japonica, Rhus radicans, Prunus serotina, Sassafras albidum*	Ground cover sparse, some *Pinus strobus*
P-10	32 yrs.	5.9	*Pinus taeda, Cornus florida, Ulmus alata, Diospyros virginiana, Quercus alba*	Pines over 30 feet tall, canopy closed
P-11	40 yrs.	3.1	*Pinus taeda, Lonicera japonica, Symphoricarpos orbiculatus, Ulmus alata, Ulmus americana*	Much like area P-10 but more dense
P-12	37 yrs.	3.1	*Pinus taeda, Ulmus alata, Lonicera japonica, Rhus radicans, Quercus falcata*	Surrounded by H-2, similar to area P-11
H-1	8.64 in.	9.7	*Cornus florida, Quercus falcata, Lonicera japonica, Sassafras albidum, Rhus radicans*	Surrounded by area P-2, fairly open
H-2	9.81 in.	45.0	*Carya tomentosa, Carya ovata, Acer saccharum, Quercus alba, Cornus florida*	Ground cover sparse, fairly open

Table I. (continued)

Study area code	Age of stand or Mean DBH	Area in acres	Most frequent plant species	Comments
H-3	11.12 in.	3.5	*Quercus velutina, Carya ovata, Carya tomentosa, Cercis canadensis, Quercus alba*	Similar to area H-2
H-4	8.45 in.	121.0	*Quercus stellata, Quercus alba, Carya ovata, Quercus velutina, Nyssa sylvatica*	Plot out of large forest
H-5	10.55 in.	41.1	*Quercus velutina, Nyssa sylvatica, Quercus alba, Acer saccharum, Cornus florida*	Plot out of large forest
H-6	9.40 in.	64.0	*Nyssa sylvatica, Quercus velutina, Cornus florida, Lonicera japonica, Quercus falcata*	Lower layers of vegetation fairly dense

was begun. One primary and one secondary count were made per counting day. As there were 18 areas, each series took 9 counting days. Censusing consisted of recording all birds seen or heard during a 20 minute period at each of four permanent stations on each area. No birds were counted as I moved between stations. The only time lapse between primary and secondary counts was the time needed to walk or drive from one area to the next. The number of stations and censuses ultimately used per area was decided on by evaluating species-area curves constructed with data taken on area H-2 before actual censuses were begun.

Stations within an area were positioned as equidistant from each other as possible to reduce the overlap of the effectively-censused areas. In the case of areas of less than 10 acres, the overlap was nevertheless probably substantial. In those cases stations were positioned near the edge of the area to allow me to more certainly detect whether a singing individual was on or off the area. In most such instances individual birds from all reaches of these study areas could be heard from every listening station, therefore demanding great care in order to avoid recording the same individual more than once. During all censuses, notes were taken as to the sex of sighted birds (when possible), specific identity of birds, and other general information. Field data was analyzed on the basis of birds considered to have been using the area, and final tabulations were recorded as number of breeding pairs detected per area, per census. For this last-named purpose I adopted the common convention of interpreting a singing male as representing one breeding pair.

No attempts to assess absolute density of bird species were made. For purposes of data analysis, the numbers of breeding pairs detected on an area in each census were summed, providing for each study area a single number representing the number of breeding pairs detected there.

Willson, et al (1973) stated that censuses of short duration, such as those used in my study, may serve to indicate the number of individuals of each species using a certain area during that time. Such indication may be as important as knowing numbers over a whole season in understanding community organization. They stated that, at least in temperate forest regions, long and short term censuses should yield similar results in regard to species and number of individuals using a given area. MacArthur (1960) said that in relative abundance figures, discrepancies between predictions and actual populations are negligible when the area sampled is small, random, and does not cover more than one type of habitat.

DESCRIPTION OF VEGETATION

As an index of the maturity of deciduous woodlands, I used mean diameter-breast-high (DBH) instead of age. Mean DBHs were determined using a point-quarter method of random selection (Phillips, 1959). Specific identity of the trees was not considered at that time. I sampled 4 trees at each of 10 points on a transect, thus 40 trees per transect. Two such transects were run in each area. The mean and standard deviation of the DBH data along each transect was calculated. In assessing adequacy of my DBH sampling effort, I adopted the convention that if the mean DBH of the second transect for each area was within one standard deviation of the mean DBH of the first transect of that same area, then I assumed an adequate sample, lumped the raw data from the two transects and calculated a mean of all 80 trees. As it happened, the second transect in every case yielded such a mean DBH value. These statistics were then used as a size description of the trees of that area.

Foliage profiles were sampled using a method described by Emlen (1967). The technique involved recording presence or absence of foliage directly above randomly-positioned ground points. To construct foliage height profiles (or the degree of layering of the vegetation) these data were classified into various pre-selected height intervals. Many variations exist in the literature as regards height intervals sampled (Karr, 1968 and 1971; Karr and Roth, 1971; MacArthur and Horn, 1969; Willson, 1974; and Willson et al, 1973) but almost always the data are lumped into three layers corresponding to shrub-ground cover, middle understory, and canopy (Karr, 1968 and 1971; Karr and Roth, 1971; Willson, 1974; and Willson, et al, 1973). In this study I recorded presence or absence of foliage at heights of 0 to 5 feet, 5 to 30 feet, and over 30 feet. These heights are those used by Willson (1974) in her final analysis. In the field I estimated height of vegetation with regard to those layers. To gather data on plant species composition, I also recorded the species of all plants above each point sampled.

To detect whether foliage was present above a given point, I constructed an instrument that was a combination of ones described by Emlen (1967) and Bonner (1967), but with some modifications. Vertical sightings could be made both up and down to allow allignment over an exact point. The instrument was stabilized by attaching it to a sharpened pole which was inserted into the ground. A diagram of the instrument is given in Figure 1.

The number of points needed to provide an adequate sample, using the device described above, was another question which could not be clearly answered by reference to the literature (Bonner, 1967; Karr, 1971; Willson, et al, 1973). In my study I sampled 40 points per area. Compared to some other studies (Karr, 1971 and Willson, 1974) this number was rather small for some of the larger of my study areas. Willson, et al (1973) however, said that samples of such size, at least in temperate woods of Illinois, usually approximated the foliage distribution determined from larger samples. Kroodsma (1975) used 60 points per 24 acre area in pine plantations in South Carolina. I decided to use 40 points per area after evaluating species area curves constructed from trial data collected on areas H-2 and P-10 and

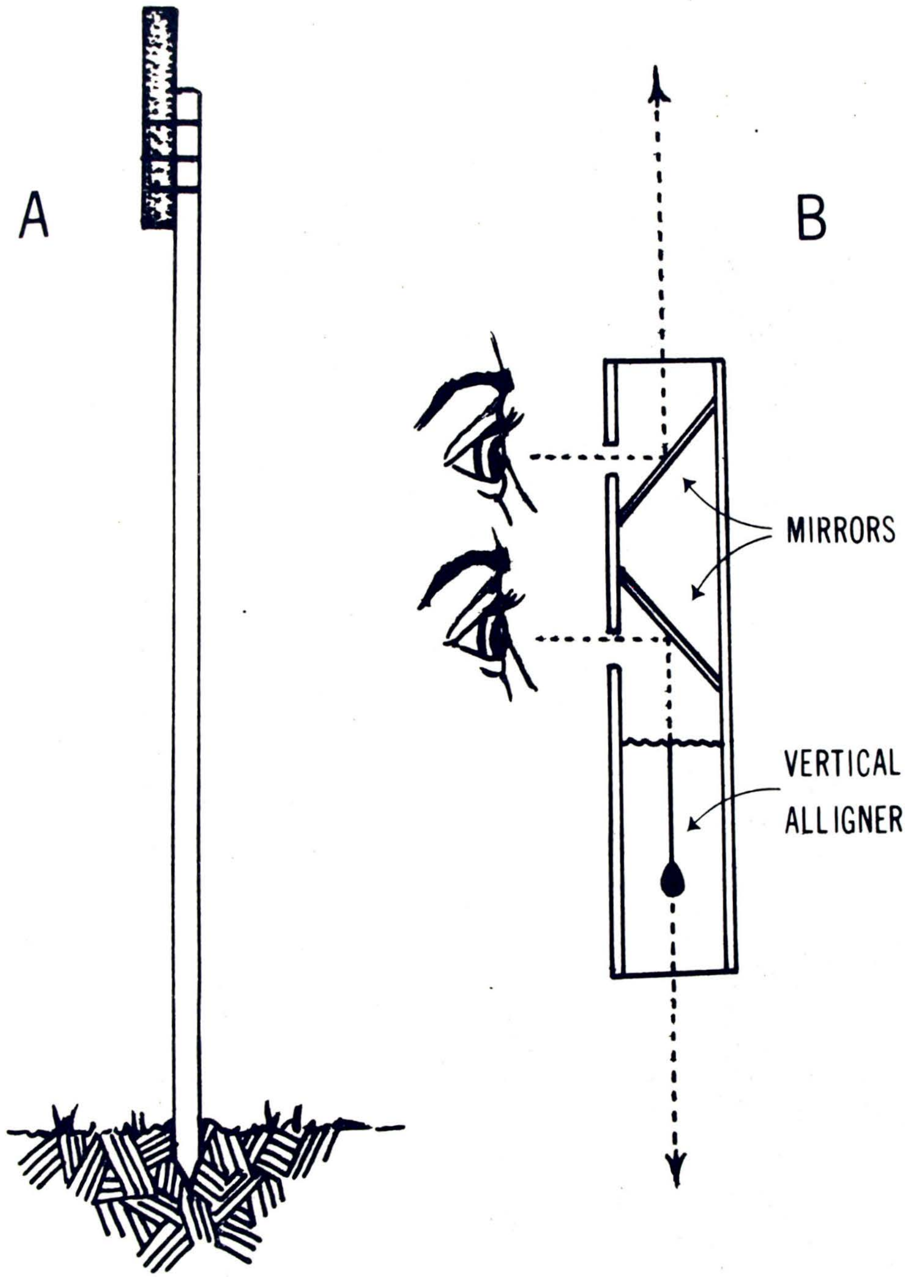

Figure 1. Diagram of the instrument used in detecting presence or absence of foliage in each of three layers above randomly positioned ground points. Drawing A shows the instrument as attached to the stabilizer pole which was inserted into the ground. Drawing B shows a cut-away view of the instrument itself

to allow completion of each study area in the time available.

Vegetation sampling points were located along transects that crossed areas where bird census stations were located. Sampled points were located every 20 paces along a compass line, by dropping, without looking and at arms length in the direction of the compass line, a knife. Wherever the knife stuck was used as my random sample point.

DIVERSITY INDICES AND STATISTICS

I calculated BSD, FHD, and PSD using Shannon's formula

$$H' = -\sum_{i=1}^{s} P_i \log_{10} P_i$$

where s is the number of categories and P is the proportion of observations in the ith category. In addition to FHD another measure of foliage distribution was used: the sum of per cent vegetation cover (PCVC) for all layers sampled (Willson, 1974). A maximum of 300% is therefore possible when sampling three layers. Willson (1974) stated that this measure emphasizes total volume of vegetation while FHD only indexes vertical distribution. PSD values were calculated in regard to woody plant species.

Linear regressions and Spearman rank correlations were used in assessing the relationships between various parameters that were measured. Considering pine stands and hardwoods as two distinct habitat types (disregarding age of pine stands), significance of differences in the number of bird species detected and BSD between the two habitat types were assessed using chi-square and Mann-Whitney U tests. Significance of differences in relative abundance of individual bird species between habitat types were tested using chi-square tests. In all cases unless otherwise indicated the 95% level of significance was used.

Chapter IV

RESULTS

I have approached the data analysis from two points of view: one in which I considered all 18 study areas as representing a gradient of dissimilar habitats by virtue of varying age and vegetation complexity, and one in which I considered pine stands and deciduous woodlands as two distinct habitat types. I hereinafter refer to the former as analysis of lumped data and the latter by the appropriate habitat-describing adjective.

Considering lumped data, BSD was found to correlate significantly (Spearman Rank Correlations) with both FHD and the sum of PCVC (Figures 2 and 3). These two measures of vegetation complexity were also significantly correlated with each other (Figure 4). BSD was not significantly correlated with PSD (Figure 5).

The pine data considered alone revealed generally the same pattern of correlations as was found when considering the lumped data (cf. preceding paragraph) although in some cases the alpha values differed (Figures 2-5). Thus both the lumped data and pine data agreed qualitatively with findings of MacArthur and MacArthur (1961), Karr (1968), and Willson (1974) with regard to the aforementioned correlations. In addition to those relationships already mentioned, in the

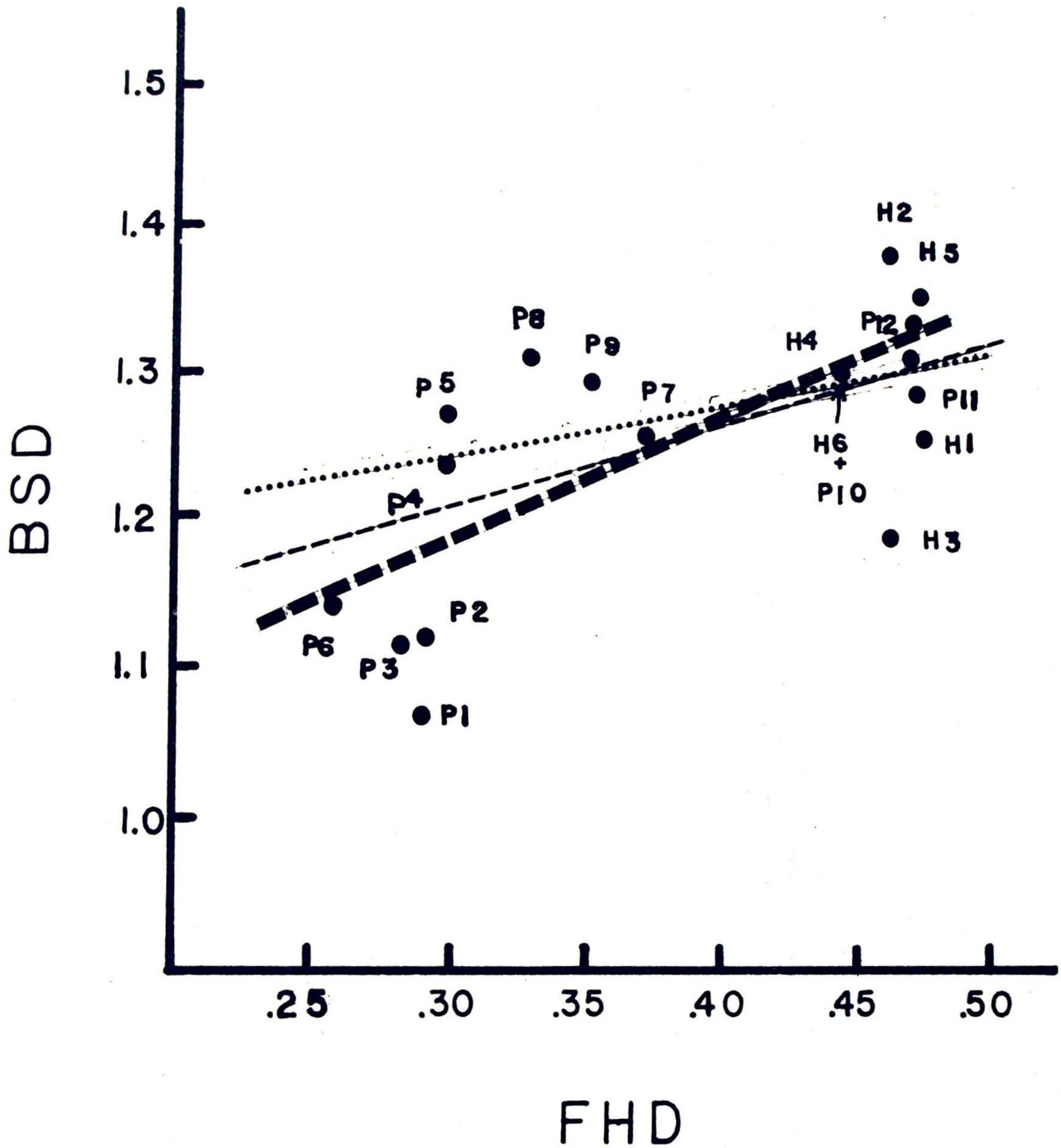

Figure 2. Regression of bird species diversity (BSD) on foliage height diversity (FHD) of lumped data (dotted line) representing 12 planted pine stands and 6 deciduous woodlands ($y = .962 + .772x$, n=18, p=.697, $\alpha < .01$), data on the 12 pine stands alone (heavy dashed line) ($y = .931 + .874x$, n=12, p=.806, $\alpha < .01$), and data on the 6 deciduous woodlands alone (light dashed line) ($y = 1.109 + .434x$, n=6, p=.143, $\alpha > .05$). All study areas were located on the Northwestern Highland Rim of the Interior Low Plateau. (P=pine, H=hardwood)

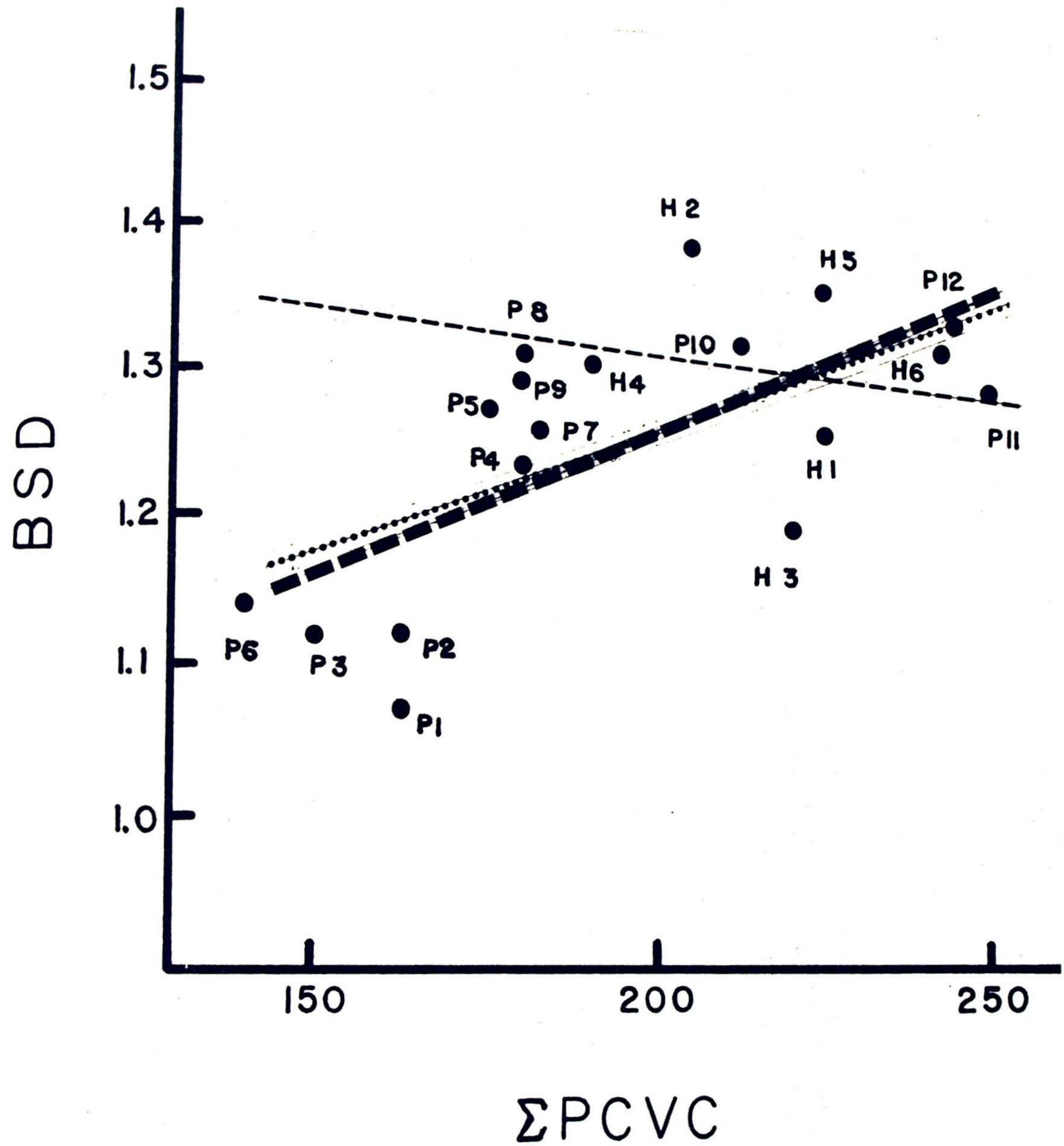

Figure 3. Regression of bird species diversity (BSD) on the sum of per cent vegetation cover (ΣPCVC) for three layers of vegetation sampled, of lumped data (dotted line) representing 12 planted pine stands and 6 deciduous woodlands ($y = .895 + .0018x$, $n=18$, $p=.650$, $\alpha < .01$), data on the 12 pine stands alone (heavy dashed line) ($y = .859 + .002x$, $n=12$, $p=.778$, $\alpha < .01$), and data on the 6 deciduous woodlands alone (light dashed line) ($y = 1.432 - .0005x$, $n=6$, $p=.014$, $\alpha > .05$). All study areas were located on the Northwestern Highland Rim of the Interior Low Plateau. (P=pine, H=hardwood)

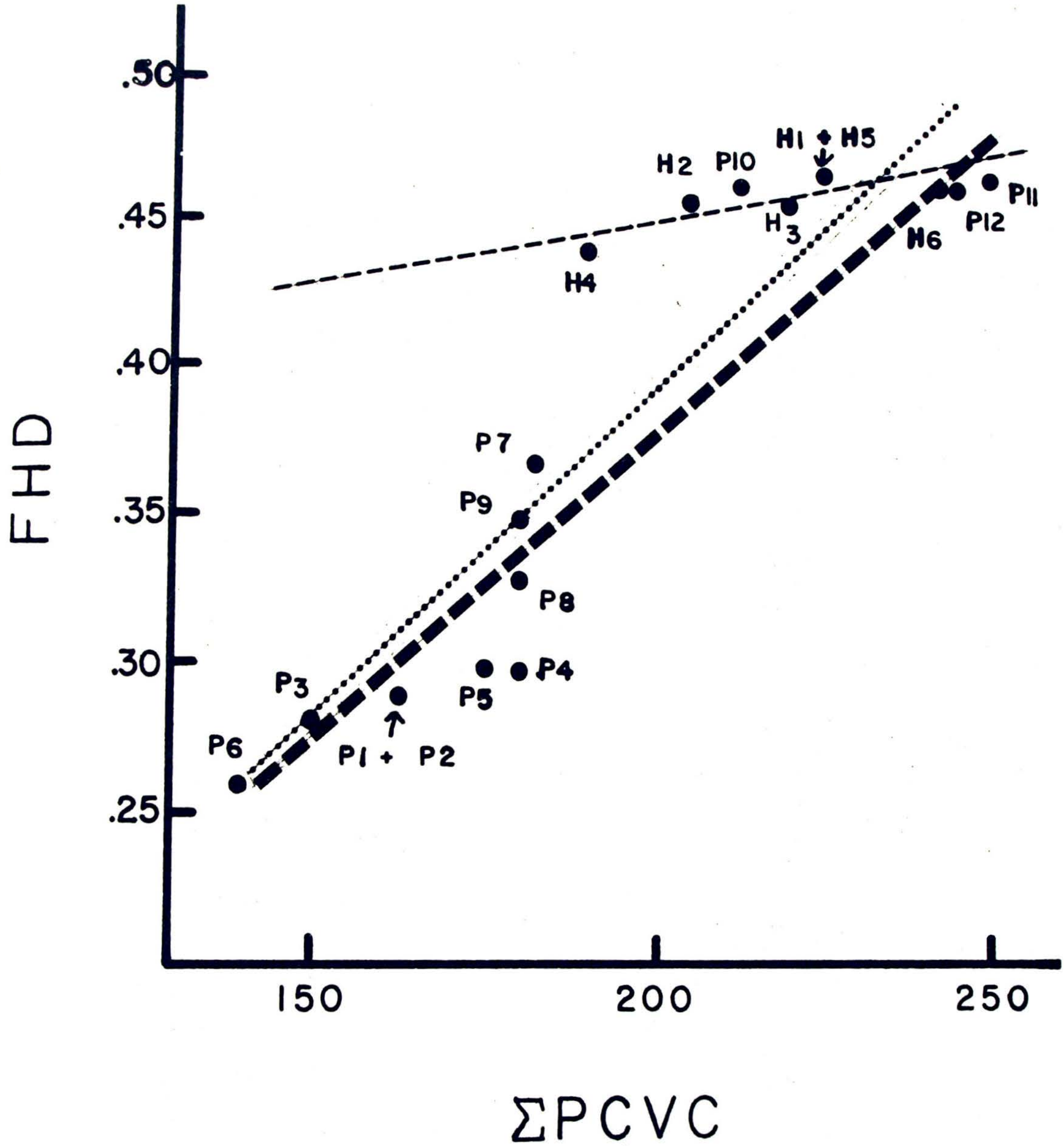

Figure 4. Regression of foliage height diversity (FHD) on the sum of per cent vegetation cover (ΣPCVC) for three layers of vegetation sampled, of lumped data (dotted line) representing 12 planted pine stands and 6 deciduous woodlands ($y = -.075 + .002x$, $n=18$, $p=.950$, $\alpha < .01$), data on the 12 pine stands alone (heavy dashed line) ($y = .058 + .002x$, $n=12$, $p=.986$, $\alpha < .01$), and data on the 6 deciduous woodlands alone (light dashed line) ($y = .352 + .0005x$, $n=6$, $p=.757$, $\alpha > .05$). All study areas were located on the Northwestern Highland Rim of the Interior Low Plateau. (P=pine, H=hardwood)

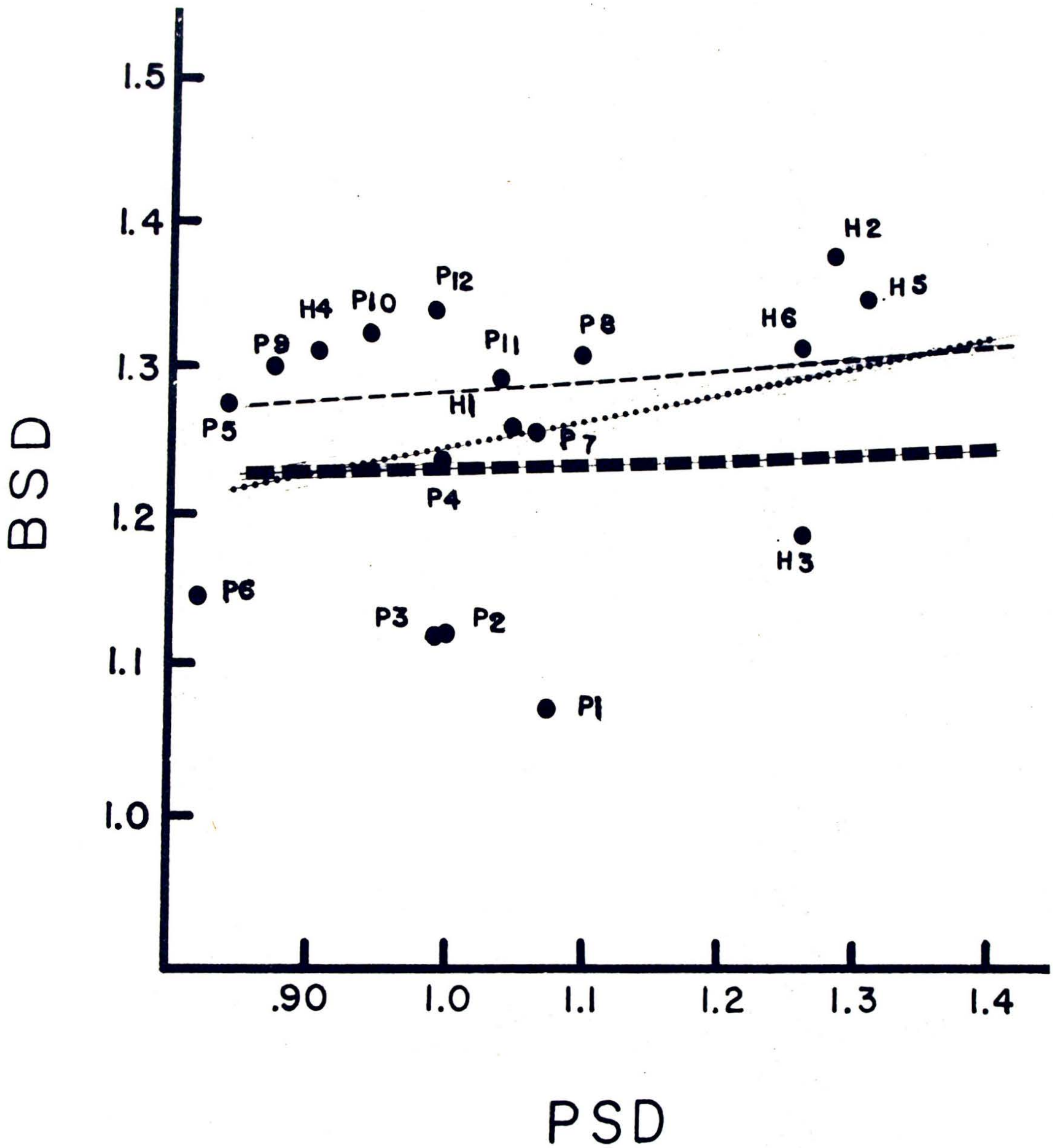

Figure 5. Regression of bird species diversity (BSD) on plant species diversity (PSD) of lumped data (dotted line) representing 12 planted pine stands and 6 deciduous woodlands (y = 1.046 + .207x, n=18, p=.374, ∝> .05), data on the 12 pine stands alone (heavy dashed line) (y = 1.177 + .060x, n=12, p= -.056, ∝> .05), and data on the 6 deciduous woodlands alone (light dashed line) (y = 1.192 + .101x, n=6, p=.543, ∝> .05). All study areas were located on the Northwestern Highland Rim of the Interior Low Plateau. (P=pine, H=hardwood)

pine stands BSD and FHD were highly correlated with age of the stands (Figures 6 and 7). Per cent vegetation cover, considering the pine canopy alone, was highly correlated with both BSD and age of pine stands (Figures 8 and 9).

Considering hardwoods alone, BSD did not correlate significantly with either FHD or sum of PCVC (Figures 2 and 3). These findings disagree with those of MacArthur and MacArthur (1961), but Willson (1974) found that when she considered only areas with mature trees, these same statistics did not correlate. My data showed a correlation between FHD and sum of PCVC of the hardwood stands (Figure 4), but it was not significant at the 95% level. PSD did not correlate with BSD (Figure 5), although this was expected on the basis of studies by Karr (1968), and MacArthur and MacArthur (1961). Table II presents summary statistics on BSD, FHD, PSD, sum of PCVC, PCVC of pine for pine stands only, and number of bird species detected.

The difference between number of bird species detected on all hardwood stands and on all pine stands was not significant, as determined by chi-square tests which were performed on an equal number (6) of pine and hardwood study areas, by using even-numbered pine areas in one comparison with hardwood stands ($0.8 < \alpha < 0.9$) and odd-numbered pine areas in a second comparison ($\alpha = 1$).

The question of the significance of the difference between number of bird species detected on pine versus hardwood stands was also tested using the Mann-Whitney U test

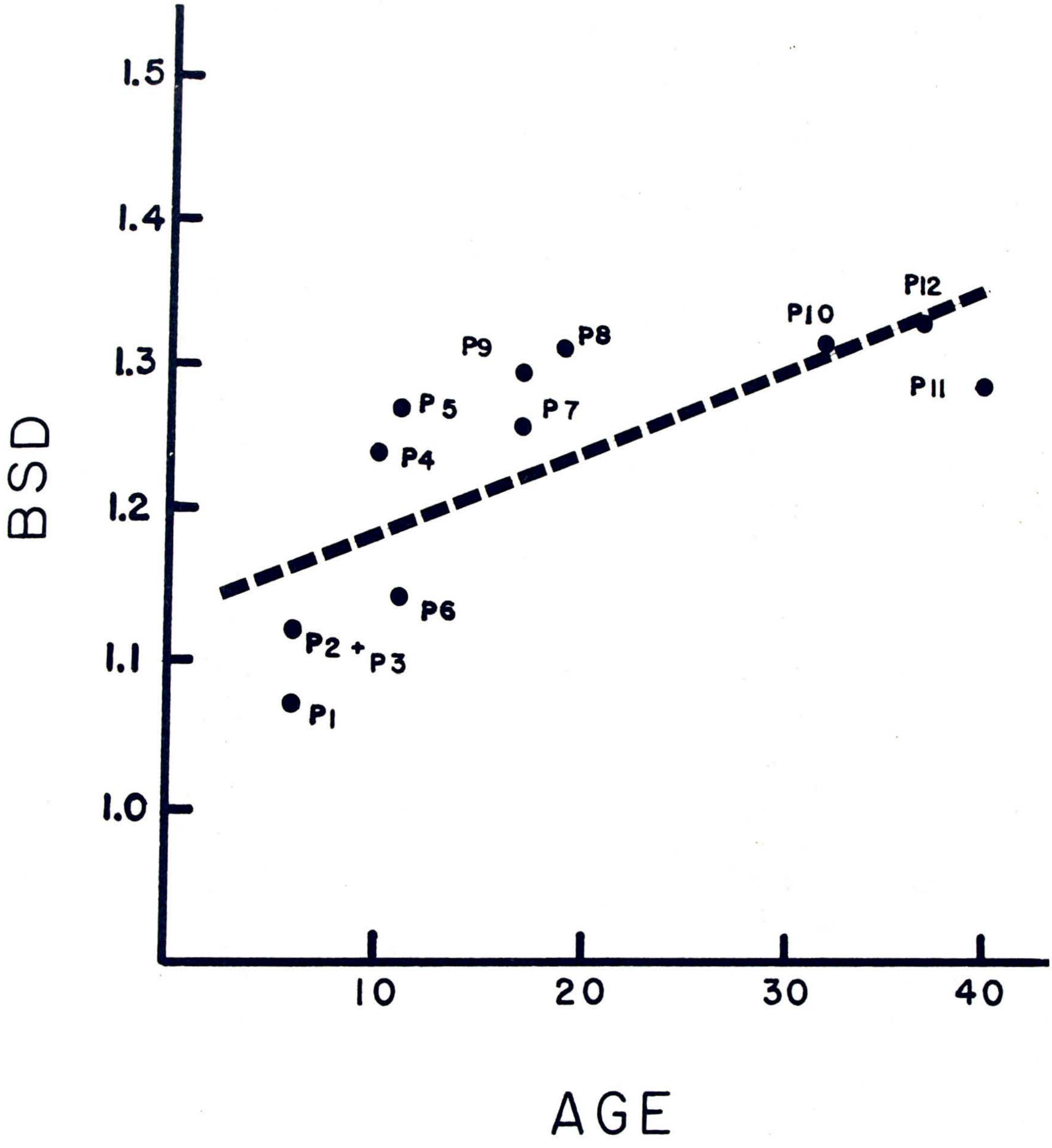

Figure 6. Regression of bird species diversity (BSD) on age of pine stands in years (AGE) ($y = 1.13 + .006x$, $n=12$, $p=.892$, $\alpha < .01$). All pine stands were located on the Northwestern Highland Rim of the Interior Low Plateau. (P=pine)

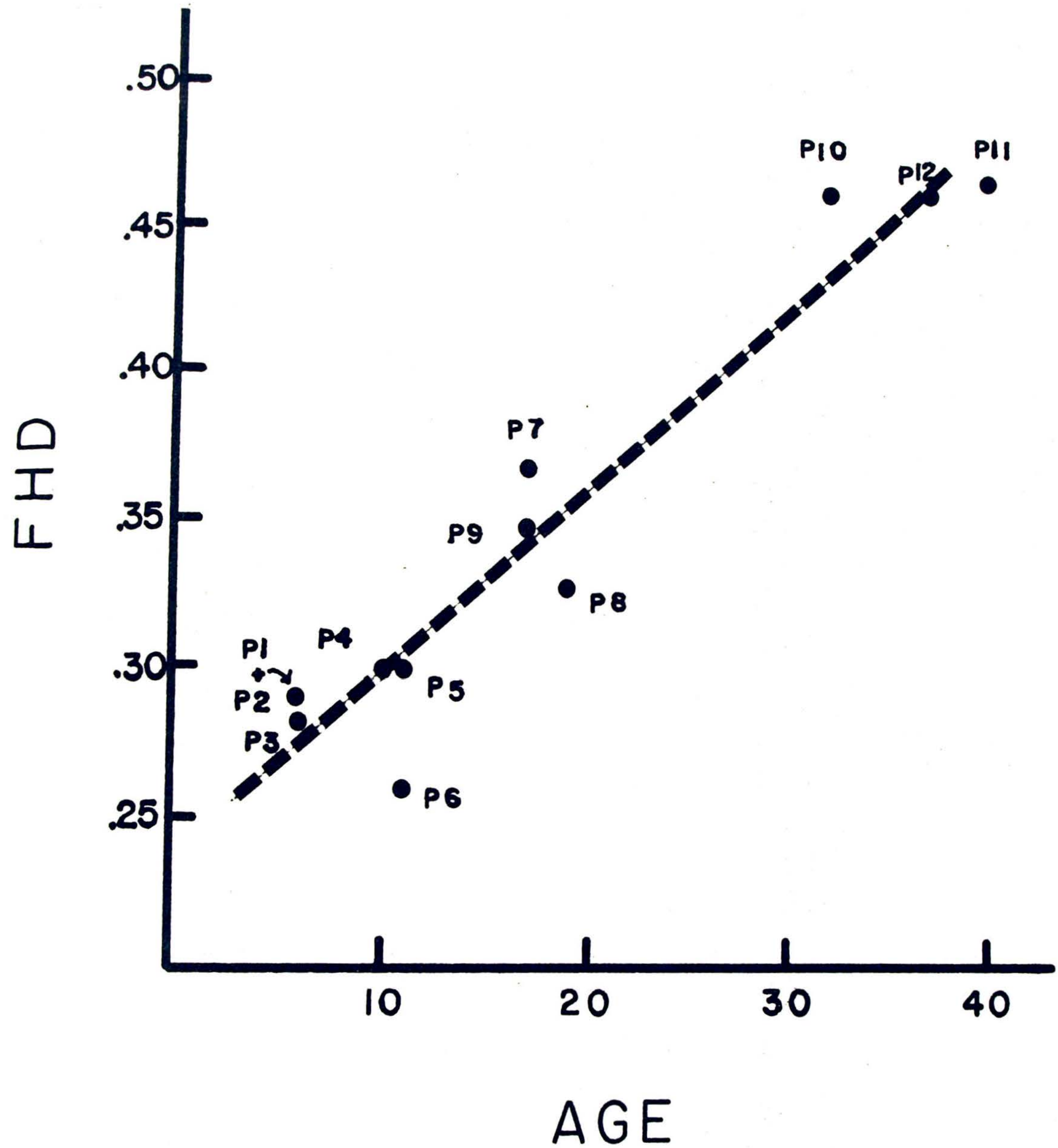

Figure 7. Regression of foliage height diversity (FHD) on age of pine stands in years (AGE) (y = .237 + .006x, n=12, p=.882, $\alpha<.01$). All pine stands were located on the Northwestern Highland Rim of the Interior Low Plateau. (P=pine)

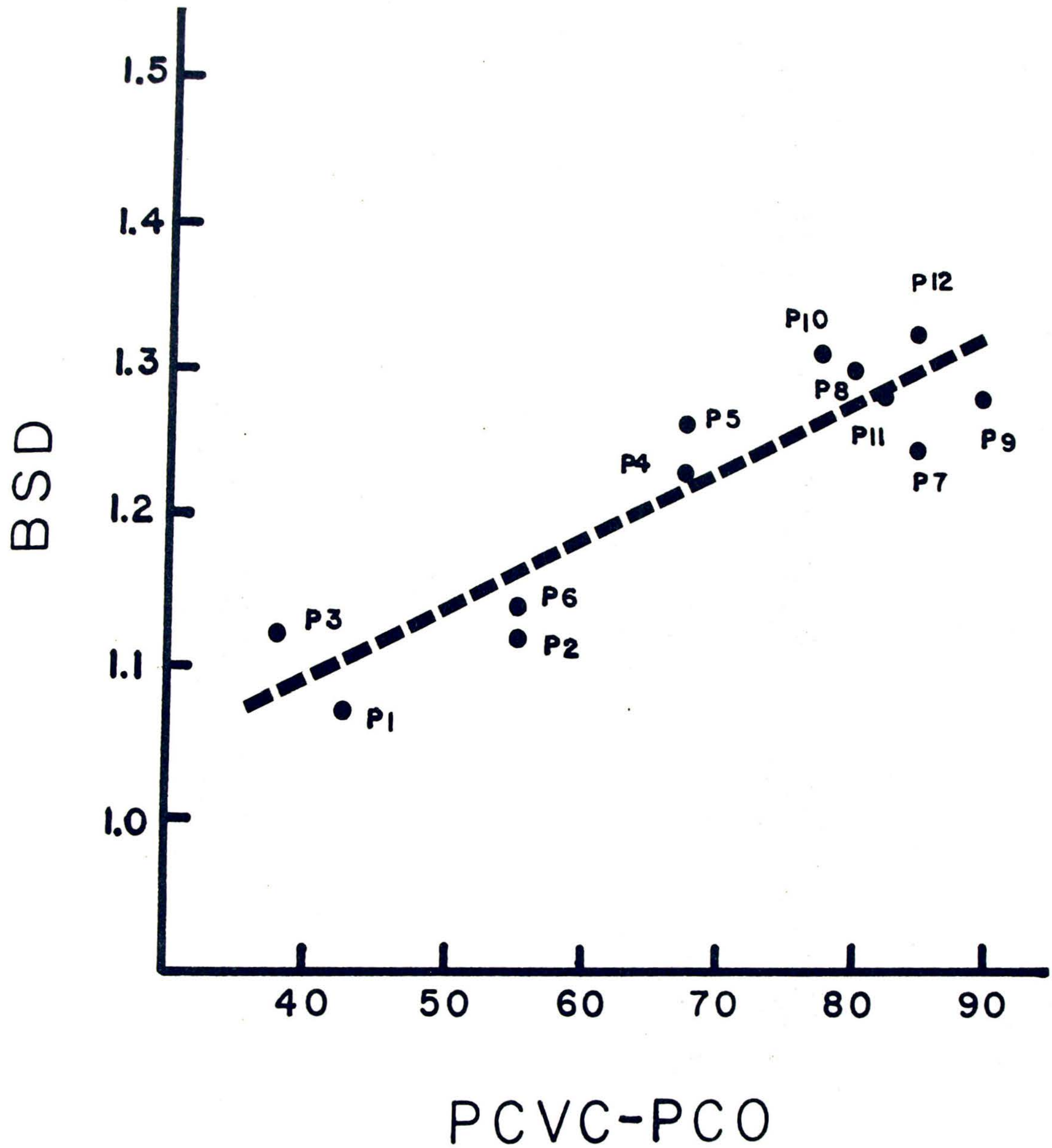

Figure 8. Regression of bird species diversity (BSD) on per cent vegetation cover of pine canopy only (PCVC-PCO) (y = .895 + .005x, n=12, p=.799, $\alpha < .01$). All pine stands were located on the Northwestern Highland Rim of the Interior Low Plateau. (P=pine)

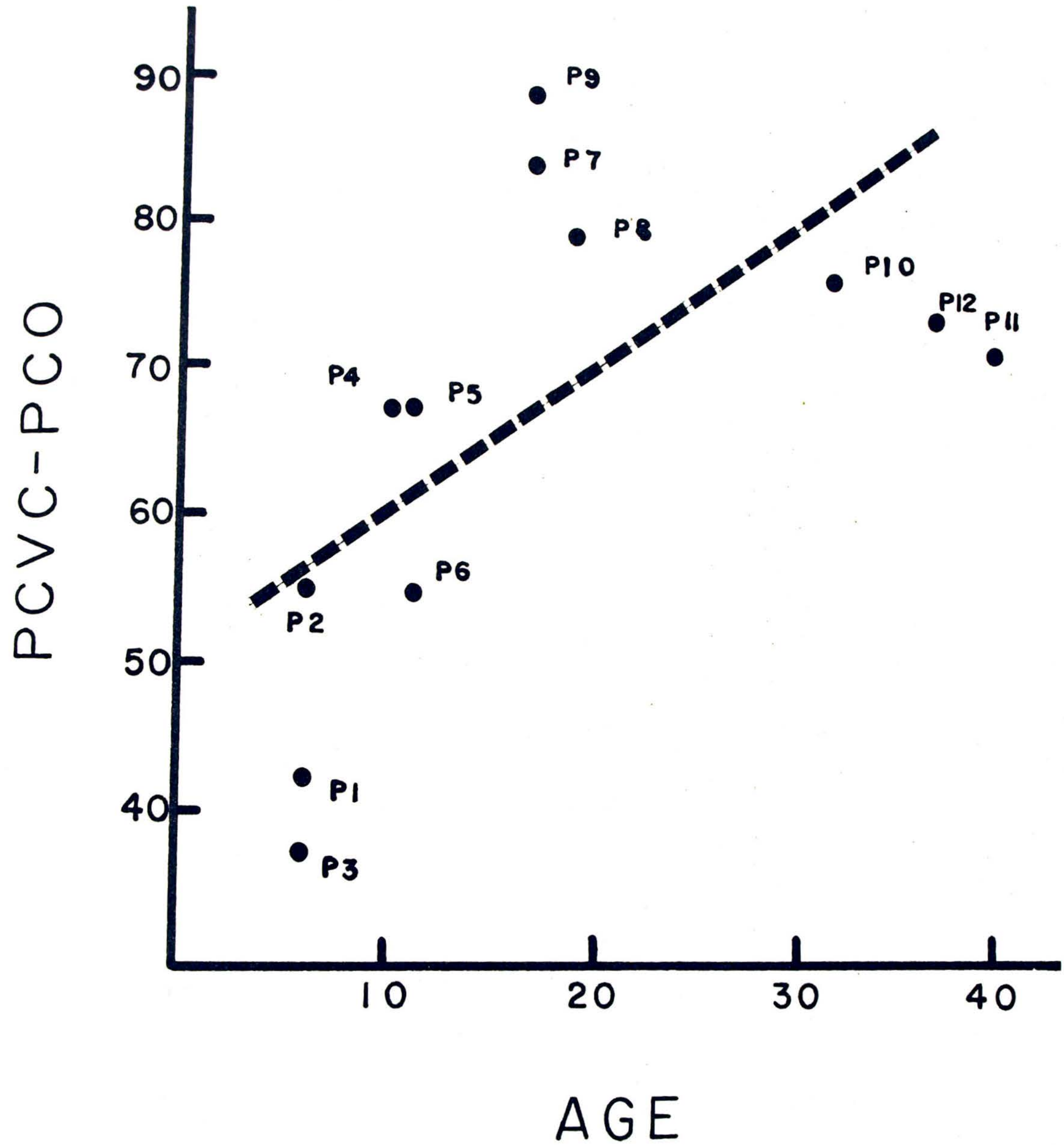

Figure 9. Regression of per cent vegetation cover of pine canopy only (PCVC-PCO) on age of pine stands in years (AGE) ($y = 50.643 + 1.025x$, $n=12$, $p=.797$, $\alpha < .01$). All pine stands were located on the Northwestern Highland Rim of the Interior Low Plateau. (P=pine)

Table II. Summary statistics for 12 planted pine stands and 6 deciduous woodlands on the Northwestern Highland Rim of the Interior Low Plateau. (P=pine, H=hardwood)

Study area	BSD	FHD	PSD	ΣPCVC	PCVC PCO	Number of bird species detected
P-1	1.073	.290	1.022	162.5	42.5	21
P-2	1.122	.290	.999	162.5	55.0	21
P-3	1.120	.282	.991	150.0	37.5	17
P-4	1.242	.299	.970	180.0	67.5	26
P-5	1.275	.299	.841	175.0	67.5	29
P-6	1.143	.259	.822	140.0	55.0	19
P-7	1.265	.371	1.063	182.5	85.0	25
P-8	1.317	.329	1.097	180.0	80.0	31
P-9	1.302	.351	.873	180.0	90.0	33
P-10	1.326	.471	.942	212.5	77.5	28
P-11	1.300	.474	1.037	250.0	82.5	28
P-12	1.347	.471	.989	245.0	85.0	28
H-1	1.268	.476	1.049	225.0		25
H-2	1.397	.464	1.290	205.0		40
H-3	1.198	.463	1.264	220.0		19
H-4	1.312	.445	.903	190.0		33
H-5	1.366	.475	1.313	225.0		35
H-6	1.326	.471	1.262	242.5		33

which similarly indicated no significant difference ($U = 53$, $n_1 = 12$, $n_2 = 6$, $0.1 < \alpha < 0.2$). Using the same test of significance on the difference between BSD in pine stands, representing all ages, and that in all hardwood stands gave similar results ($U = 53.5$, $n_1 = 12$, $n_2 = 6$, $0.1 < \alpha < 0.2$).

Tables III and IV list all the bird species encountered during the study, by official A.O.U. names (American Ornithologists' Union, 1957 and 1973), and the sum of numbers of pairs of each species detected per census on each area.

The results of chi-square tests for significance of differences in relative abundance of individual species between habitat types are given below: Five species that significantly preferred the two youngest age classes of pine stands over the two oldest age classes were Blue-winged Warbler, Prairie Warbler, Common Yellowthroat, Yellow-breasted Chat, and Field Sparrow ($\alpha < .001$ in all cases). Those same five species also significantly preferred pine stands in general over hardwood stands ($\alpha < .01$ in all cases). Six species that significantly preferred the two oldest age classes of pine stands over the two youngest age classes were Red-bellied and Downy Woodpeckers, Acadian Flycatcher, Eastern Wood Pewee, Blue-gray Gnatcatcher, and Pine Warbler ($\alpha < .01$ in all cases). Of those, only the Pine Warbler significantly preferred pine stands in general over hardwood stands ($\alpha < .001$), while Red-bellied and Downy Woodpeckers and Eastern Wood Pewee preferred hardwoods over pines ($\alpha <$ .02 in all cases), and Acadian Flycatcher and Blue-gray

Table III. All bird species encountered on 12 variously-aged planted pine stands located on the Northwestern Highland Rim of the Interior Low Plateau. Names and ordination follow the checklist of North American birds (American Ornithologists' Union, 1957 and 1973). Column entries are sums of four separate censuses of the number of pairs on each area. For comparison, totals for those species also encountered on hardwood stands are given. (P=pine, H=hardwood)

Species	Study areas													
	P 1	P 2	P 3	P 4	P 5	P 6	P 7	P 8	P 9	P 10	P 11	P 12	ΣP	ΣH
Bob White	9	14		7	8			1	6		2		47	14
Mourning Dove	6	2	2	8	6		2	2	7	6			41	21
Yellow-billed Cuckoo	2			5	2	1	5	12	7	4	1	3	42	75
Barred Owl											1		1	
Chuck-will's-widow					1								1	4
Whip-poor-will				2			1	2	1				6	11
Ruby-throated Hummingbird			1				1		1			2	5	5
Belted Kingfisher										1	3		4	
Common Flicker		1		3	3			1	3	2	1	2	16	14
Pileated Woodpecker										1	2	3	6	10
Red-bellied Woodpecker					2		3	10	4	4	6	3	32	71

Table III. (continued)

Species	P 1	P 2	P 3	P 4	P 5	P 6	P 7	P 8	P 9	P 10	P 11	P 12	ΣP	ΣH
	Study areas													
Hairy Woodpecker											2	2	4	12
Downy Woodpecker					2	2		3	2	9	4		22	22
Great Crested Flycatcher		1				1				5	3	2	12	21
Acadian Flycatcher							10	23	23	12			68	29
Eastern Wood Pewee					1	3	5	2	1	12	1	4	29	66
Blue Jay	4	1		11	18	3	3	7	7	3	3	3	63	82
Common Crow				1	13			9	7		3	1	34	20
Carolina Chickadee		2	1	8	5	2	4	9	9	7	2	2	51	12
Tufted Titmouse	2	2	3	2	4	5	12	6	7	10	6	3	62	106
White-breasted Nuthatch										3	1	1	5	18
Carolina Wren		3	4	17	24	3	14	27	15	8	7	2	124	56
Mockingbird	1	2											3	
Gray Catbird				4	5				15	2			26	1
Brown Thrasher	4	10		8	8	1					1		32	8

Table III. (continued)

Species	Study areas P 1	P 2	P 3	P 4	P 5	P 6	P 7	P 8	P 9	P 10	P 11	P 12	ΣP	ΣH
American Robin									1	1			2	1
Wood Thrush					4		6	2	2	21			35	114
Eastern Bluebird	1	3						1		6			11	8
Blue-gray Gnatcatcher			5		1	1	10	5	4	13	1	5	45	32
Starling											2		2	1
White-eyed Vireo	17	11	11	15	21	1	9	19	12	4		1	121	21
Red-eyed Vireo									4	2	2		8	30
Black-and-white Warbler			3										3	
Blue-winged Warbler	6		6	1								1	14	
Yellow-throated Warbler											4	1	5	2
Pine Warbler					2		1	3	11	19	2	2	40	
Prairie Warbler	55	33	15	28	24	3	6	12	2				178	8
Ovenbird								2				1	3	13
Kentucky Warbler				1			3	10	2			3	19	32

Table III. (continued)

Species	Study areas												ΣP	ΣH
	P 1	P 2	P 3	P 4	P 5	P 6	P 7	P 8	P 9	P 10	P 11	P 12		
Common Yellowthroat	4	2		10									16	
Yellow-breasted Chat	40	30	11	32	21		2	2	5				143	3
Eastern Meadowlark	2												2	
Red-winged Blackbird									1				1	
Orchard Oriole				2		1							3	
Common Grackle				2	3				1			1	7	2
Brown-headed Cowbird	6	10	1	6	12	3	9	13	9	14	8	5	96	47
Summer Tanager	1				2	2	2	11	1	11	6	3	39	69
Cardinal	11	6	7	18	10		14	29	37	5	16	6	159	99
Indigo Bunting	16	16	10	10	3	3	6	15	12		10	1	102	13
American Goldfinch	7	10	6	8	9	6	11	10	1	3	5	1	77	9
Rufous-sided Towhee	36	21	13	40	42	11	26	41	32	11	13	11	297	80
Field Sparrow	32	25	8	21	24	10	3	5					128	3

Table IV. All bird species encountered on 6 deciduous woodlands located on the Northwestern Highland Rim of the Interior Low Plateau. Names and ordination follow the checklist of North American birds (American Ornithologists' Union, 1957 and 1973). Column entries are sums of four separate censuses of the number of pairs on each area. For comparison, totals for those species also encountered on pine stands are given. (P=pine, H=hardwood)

Species	Study areas H 1	H 2	H 3	H 4	H 5	H 6	ΣH	ΣP
Red-shouldered Hawk				2			2	
American Kestrel		2					2	
Bobwhite		7			1	6	14	47
Mourning Dove	2	9		5	2	3	21	41
Yellow-billed Cuckoo	3	10	4	23	19	16	75	42
Chuck-will's-widow		4					4	1
Whip-poor-will		4		2	2	3	11	6
Ruby-throated Hummingbird		1			4		5	5
Common Flicker		4	1	3		6	14	16
Pileated Woodpecker		4		4		2	10	6
Red-bellied Woodpecker	6	18	4	16	14	13	71	32
Hairy Woodpecker	2	3	1	1	3	2	12	4
Downy Woodpecker	5	3		7	4	3	22	22
Great Crested Flycatcher	1	4	3	8	2	3	21	12
Acadian Flycatcher		1		7	20	1	29	68
Eastern Wood Pewee	8	11	3	25	13	6	66	29
Purple Martin		2					2	
Blue Jay	7	27	4	19	2	23	82	63
Common Crow		5		5	4	6	20	34
Carolina Chickadee	3	2	2		3	2	12	51

Table IV. (continued)

Species	Study areas H 1	H 2	H 3	H 4	H 5	H 6	ΣH.	ΣP
Tufted Titmouse	8	23	6	22	20	27	106	62
White-breasted Nuthatch	4	2		7	4	1	18	5
Carolina Wren	2	14	6	9	14	11	56	124
Gray Catbird						1	1	26
Brown Thrasher	1	1	1	2		3	8	32
American Robin		1					1	2
Wood Thrush	8	25	2	24	37	18	114	35
Eastern Bluebird	6		1	1			8	11
Blue-gray Gnatcatcher		9	2	1	17	3	32	45
Starling		1					1	2
White-eyed Vireo	6	2			6	7	21	121
Yellow-throated Vireo					1		1	
Red-eyed Vireo	3	2		7	15	3	30	8
Northern Parula Warbler[1]					4		4	
Yellow-throated Warbler		1				1	2	5
Prairie Warbler	2				2	4	8	178
Ovenbird		5		3	2	3	13	3
Louisiana Waterthrush					1		1	
Kentucky Warbler		11		1	15	5	32	19
Yellow-breasted Chat	1					2	3	143
Hooded Warbler					9		9	

[1]Identification is questionable due to an atypical song and the fact that the individual was never visually recorded.

Table IV. (continued)

Species	Study areas H 1	H 2	H 3	H 4	H 5	H 6	ΣH	ΣP
Common Grackle		1		1			2	7
Brown-headed Cowbird	5	11	1	19	8	3	47	96
Summer Tanager	3	14	5	23	10	14	69	39
Cardinal	14	28	8	2	22	25	99	159
Indigo Bunting	3	5	3	1	1		13	102
American Goldfinch	2			2	5		9	77
Rufous-sided Towhee	22	19	6	1	9	23	80	297
Chipping Sparrow		1		3			4	
Field Sparrow		1		1	1		3	128

Gnatcatcher showed no significant preference between pines and hardwoods (respectively, $.3<\alpha<.5$ and $.1<\alpha<.2$). Other species that showed a significant preference of pine stands over hardwood stands were Carolina Chickadee, Gray Catbird, White-eyed Vireo, Indigo Bunting, American Goldfinch, and Rufous-sided Towhee ($\alpha<.02$ in all cases). Species that showed a significant preference for hardwood stands over pine stands were Yellow-billed Cuckoo, Whip-poor-will, Hairy Woodpecker, Great Crested Flycatcher, Blue Jay, Tufted Titmouse, White-breasted Nuthatch, Woodthrush, Red-eyed Vireo, Ovenbird, Kentucky Warbler, Summer Tanager ($\alpha<.01$ in all cases except for Hairy Woodpecker in which $.02<\alpha<.05$). Species that showed no significant preference between pine stands and hardwood stands were Bobwhite ($.05<\alpha<.1$), Mourning Dove ($.9<\alpha<.95$), Ruby-throated Hummingbird ($.2<\alpha<.3$), Common Flicker ($.1<\alpha<.2$), Pileated Woodpecker ($.3<\alpha<.5$), Common Crow ($.5<\alpha<.7$), Carolina Wren ($.5<\alpha<.7$), Brown Thrasher ($.1<\alpha<.2$), Eastern Bluebird ($.3<\alpha<.5$), Brown-headed Cowbird ($.9<\alpha<.95$), and Cardinal ($.05<\alpha<.1$).

A number of other species were detected only a few times or on only one or two study areas. Those, the rare-species complement of BSD, raised the BSD slightly and are listed in Tables III and IV. They do not warrant species by species discussion. Nearly equal numbers of those rare species were found in pine stands exclusively, hardwood stands exclusively, and in both. A summary of the preferences of habitat types of those species discussed is pre-

Table V. Summary data on habitat preferences of all bird species in a study of 12 planted pine stands and 6 deciduous woodlands on the Northwestern Highland Rim of the Interior Low Plateau. Those species detected fewer than 10 times during the study are omitted[2]

Species	H/P	P/H	YP/OP	OP/YP
Bobwhite		.05 < α < .10		
Mourning Dove	.90 < α < .95			
Yellow-billed Cuckoo	*			
Whip-poor-will	**			
Ruby-throated Hummingbird	.20 < α < .30			
Common Flicker	.10 < α < .20			
Pileated Woodpecker	.30 < α < .50			
Red-bellied Woodpecker	*			*
Hairy Woodpecker	****			
Downy Woodpecker	***			**
Great Crested Flycatcher	*			
Acadian Flycatcher		.30 < α < .50		*
Eastern Wood Pewee	*			*
Blue Jay	*			
Common Crow	.50 < α < .70			
Carolina Chickadee		***		
Tufted Titmouse	*			
White-breasted Nuthatch	**			
Carolina Wren		.50 < α < .70		
Gray Catbird		**		
Brown Thrasher		.10 < α < .20		
Wood Thrush	*			
Eastern Bluebird	.30 < α < .50			
Blue-gray Gnatcatcher	.10 < α < .20			*
White-eyed Vireo		*		
Red-eyed Vireo	*			
Blue-winged Warbler		**	*	
Pine Warbler		*		*
Prairie Warbler		*	*	
Ovenbird	*			
Kentucky Warbler	*			
Common Yellowthroat		**	*	
Yellow-breasted Chat		*	*	
Brown-headed Cowbird		.90 < α < .95		
Summer Tanager	*			
Cardinal	.05 < α < .10			
Indigo Bunting		*		
American Goldfinch		*		
Rufous-sided Towhee		*		
Field Sparrow		*	*	

[2]Results of chi-square tests for significance of demonstrated preferences not significant at the 95% level are expressed as alpha values under column headings indicating the comparison made. H/P indicates preference for hardwoods over pines; P/H, pines over hardwoods; YP/OP, young pines over old pines; OP/YP, old pines over young pines. Results significant at or above the 95% level are presented in 4 categories, as follows; *, $\alpha < .001$; **, $\alpha < .01$; ***, $\alpha < .02$; ****, $\alpha < .05$.

Chapter V

DISCUSSION AND CONCLUSIONS

Studies of the relationship of BSD to FHD have been carried out both with groups of similar habitats (MacArthur and MacArthur, 1961) and gradients of dissimilar habitats (Karr, 1968, Karr and Roth, 1971). Although the pine aspect was lacking from my deciduous woodland plots, I feel there was some resemblance of my study areas as a whole to a seral succession from late old field to mature woodland; enough at least to justify looking at the data in this light. Simultaneously I feel it proper to consider my data as representing two distinct vegetation types. For these reasons I have analyzed my data from both perspectives.

My data, as well as that of previous workers, indicates that BSD is generally affected by vegetation complexity. Specifically I found, as did others (Karr, 1968; Karr and Roth, 1971; MacArthur and MacArthur, 1961; Willson, 1974), that BSD was correlated with FHD and with the sum of PCVC, at least as regards lumped data. That these correlations sometimes do not obtain (Willson, 1974) when considering fairly mature deciduous woodlands alone can perhaps be explained by one of the following reasons: 1. As the vegetation of an area progresses in age and complexity, perhaps a peak is reached in the number of avian niches available. If so, then furthur progression of the vegetation in age or complexity would not reflect corresponding increases in BSD. 2. At least two sampling inadequacies may have existed in my study. The methods that I used in sampling the vegetation were much less complicated than those used by the MacArthur's (1961) but have been shown to yield results similar to those of the more complicated methods (Karr, 1971 and Willson, 1974). In fact, Willson (1974) used the same vegetation sampling technique as I did and likewise found no correlation between BSD and FHD when considering mature forests alone. Also, in the MacArthurs' (1961) study, Willson's (1974) study, and in my study, vegetation was classified into essentially the same three layers. The second possible sampling inadequacy concerned the bird censusing. There is a variety of opinion concerning the best method of censusing birds in situations similar to mine. The method I used was not that used in any of the other studies which dealt with BSD and FHD. However, comparisons of BSD of my study areas should not be subject to this criticism since Shannon's formula uses proportions of observations rather than actual numbers. I have made no attempts to compare actual BSD or FHD values of my study with those of any other study. 3. Willson (1974) mentioned the possibility of "island" effect in explaining why BSD did not correlate with FHD in her study areas of mature hardwoods. This effect would be exhibited when an area of vegetation is surrounded by rather wide expanses of very dissimilar habitat. For example, a woodlot located in the center of a large pasture or perhaps in the center of a large pine plantation. The surrounding area does not afford suitable habitat to allow free movement of woodland species into or out of the area. Thus the number of species using the woodlot would be reduced. Willson (1974) discounted this possibility in her study when she stated that some of her forested areas were not "islands". Yet on her plots of BSD versus FHD, points representing her "not islands" study areas clustered with those representing study areas that were "islands". In my study, two hardwood study areas probably fit the "island" description; H-1 and H-3. BSD values of those two areas were the two lowest of the 6 hardwood study areas, but on the graph of BSD versus FHD, all the points representing hardwood study areas were clustered together. At least in the forest types I studied I suspect there was an upper limit to the BSD that could be realized. Willson's (1974) data from areas not greatly different from my deciduous woodlands supports this view.

The high correlation between BSD and FHD in my pine areas was a good indication that those areas were in early stages of plant succession, during which BSD is most influenced by FHD (Kricher, 1973 and Karr, 1968). The maturation of a pine stand, in the geographic area of my study, strikes me as being similar to natural succession in the same region with one added aspect; the pines. My pine stand data showed a high correlation between: 1. BSD and age of stands; 2. BSD and PCVC of the pine canopy only; 3. BSD and FHD in stands; and 4. FHD and age of stands.

All of the preceding correlations indicate that as pine stands mature, BSD increases. The fact that BSD increased with PCVC of the pine canopy only, need not be interpreted as indicating that BSD is a function of the density of the pine trees; it seems more plausible that rather it is a function of the degree of canopy closure associated with increasing age, since my data showed PCVC of pine canopy only correlated with age of pine stands.

Kricher (1973) also found that increases in BSD as a forest aged (once it had reached a near climax condition) were very low as compared with high increases through the earlier seral stages. This supports my belief that the generally positive BSD-FHD correlation approaches zero in mature hardwood forests.

That BSD was correlated with sum of PCVC is not surprising in that the latter correlates with FHD. Both of these measures of vegetation complexity are taken from the same data but reflect different aspects of the habitat. FHD measures vertical distribution of vegetation while sum of PCVC measures horizontal distribution of vegetation. In my study, sum of PCVC was a measure of coverage in three horizontal layers based on the number of sample points above which vegetation was present. FHD is calculated from the same data so I would expect it to correlate positively with sum of PCVC. This correlation of FHD with sum of PCVC was found even in the deciduous woodlands, although it did fall a little short of the 95% level of significance, probably due to the small sample size.

Apparently, PSD did not influence BSD since no correlation was found between those two parameters in either the pines, hardwoods, or lumped data. This finding supports the MacArthurs' (1961) original statement to that effect. Appendix B gives the numbers of individuals of each woody plant species detected on both pine stands and hardwood stands above 40 randomly positioned points per area. No statistical tests were conducted on abundances of individual plant species but it was observed that differences in species composition among the study areas were rather great with only *Lonicera*, *Smilax*, and *Rhus* showing some dominance in pine and *Quercus* and *Carya* in the hardwoods.

The fact that no significant difference in BSD was found between hardwoods and pines, when considered as two distinct habitat types, suggests that there was no appreciable difference in the carrying capacities of the two, as regards avifauna. This is an interesting finding since the concensus of opinion is that even-aged pine stands are rather deficient as productive wildlife habitat (Stoddard, 1963 and Cleveland, 1974). My findings do not support that view, at least as regards avifauna in the geographic area of my study.

The major noticed effect of pine plantings on the bird communities of the geographic area of my study was that on species substitution. The differences in bird species composition encountered among the various habitat types studied presented a pattern much like that of vegetation complexity as measured by differences in FHD. Species such as Prairie Warbler, Yellow-breasted Chat, and Field Sparrow (that were so common in the young pine stands) were encountered less and less often as the pine stands matured and eventually were almost never encountered. Two species that were less commonly recorded were encountered only in the 6 year old pine stands: Blue-winged Warbler and Common Yellowthroat. As all these species began to decrease in abundance, new ones such as Red-bellied and Downy Woodpeckers, Acadian Flycatcher, Eastern Wood Pewee, Blue-gray Gnatcatcher, and Pine Warbler took their place.

Although some might describe the 30 to 40 year old pine stands as mature, I believe this statement must be qualified in light of the natural vegetation of the area. If those stands are left untouched, eventually the hardwood species will dominate and thus these stands constitute a type of sub-climax in this geographic area. This sub-climactic character was suggested by the composition of the bird community in that a few bird species which did not appear until the pine stands reached the two older age classes were found in much greater abundance in hardwood areas. Those species included the Hairy Woodpecker, White-breasted Nuthatch, and Red-eyed Vireo.

Most of the few species encountered exclusively in pines or hardwoods were recorded only a few times. The only species believed to have been dependent on the presence of pines was the Pine Warbler since that species almost always nests in mature pine habitat (Bent, 1953).

A few species showed no significant preference for either pine stands or deciduous woodlands and were fairly common in both, while a few other species did prefer either pines or hardwoods but were encountered on nearly all study areas. This latter group included: Blue Jay, Tufted Titmouse, Carolina Wren, Brown-headed Cowbird, Cardinal, and Rufous-sided Towhee. I would expect those species to occur in natural seral stages of secondary succession in patterns of abundance correspondingly similar to those in my study areas. The species that preferred pine or hardwood stands of a certain age would also, I predict, be found in similar patterns of abundance in seral stages of succession corresponding to their preference on my study areas. I also predict that species which showed no preference among the habitat types represented by my study areas would similarly show no preference among various seral stages of secondary succession. Johnston and Odum (1956) and Kricher (1973) presented data that support the above statements. Some of the differences between my findings and those of the two studies just mentioned were due to the fact that the latter were conducted in different geographic areas. Overall however the similarities are more striking than the differences, and if the data are analyzed at the familial rather than the specific level, most of the differences disappear completely. I interpret this as evidence that the maturation of pine stands, in the geographic area of my study, and its effect on BSD is comparable to the effect of natural vegetative succession on BSD in the same area. Had I known of this relationship before my study, I would have included some hardwood study areas representing earlier seral stages. This would have allowed direct comparison of the effects of maturation of pine stands with those of natural vegetative succession on BSD.

Two statistics are involved in the calculation of BSD values: the number of species and the number of individuals in a sample. My bird censusing technique did not provide data on the absolute individual densities of birds. It instead reflected absolute densities as numbers of individual birds per census station. Thus no quantitative analysis of the relationship of BSD to size of vegetation plot was possible. MacArthur and MacArthur (1961) said that areas of small size can support only a few species due to simple space limitations. As regards my data, the two smallest hardwood plots did give the lowest BSD values of all the hardwood stands. The same was true of the two smallest of the middle-aged stands of pines. All three pine stands of the oldest age class were small in size, but yielded rather high BSD values. In the youngest age class of pine stands, the small plot did not give the lowest BSD value of the three for that age class. When the MacArthurs (1961) stated that BSD should rise with increasing size of area, they were referring to size of census area within a larger area of homogenous vegetation. From that perspective I agree with their statement, but when considering small areas of vegetation similar to the "islands" discussed earlier there are other factors to be considered. One such factor is that of "island" effect as discussed earlier which would tend to reduce the number of species using an area. Another factor to be considered is edge effect. More bird species are found at ecotones between habitat types than in the interior of large areas of homogenous vegetation (Perkins, 1973). The smaller an area of vegetation is the more edge there is present in proportion to the total size of the area. Thus a small area of vegetation should have more species than an area of the same size in the middle of a large area of homogenous vegetation. The edge effect may offset the "island" effect on any small area of vegetation.

Another factor in my study that may have affected my BSD values was that I sampled all birds using an area and not just those known to be nesting within the confines of the area. Therefore in a small area, the number of birds using the area actually sampled from a sampling station as other than a nesting area was probably higher than was true for sampling stations in the interior of a large area. Thus BSD values would be expected to be higher on the smaller areas. Had I counted only birds known to be nesting on my small areas, the BSD values would probably have been significantly lower.

The effect of the introduction of pine plantations on the bird population of an area is multifaceted. As one who appreciates the natural aspect of the vegetation found in the various geographic areas of North America, I find the introduction of even-aged pine plantations aesthetically displeasing. The practice is however becoming more common and the need to be objective in assessing its impact on community structure is imperative. The only documented significant effect of the introduction of even-aged pine stands in the area of my study is substitution of species in a pattern comparable to that associated with natural succession of native local vegetative types. Apparently there is no significant difference in the total number of bird species that use pine stands and deciduous woodlands. Mention should be made here that this conclusion is based on the assumption that the pine plantations are allowed to mature and develop natural deciduous understories. As has been shown, the younger a pine stand is, the lower is the BSD that it can support, and thus pine stands that are not allowed to mature before harvest would definitely show a reduction in BSD as compared to mature or near-mature communities of natural vegetation. It is also noteworthy that many pine plantations, although not usually in the area of the study, are often managed by controlling most understory species that might reduce pinewood production. This practice reduces the BSD. Pine stands should be allowed to undergo "natural" succession if they are not to be detrimental to an area's bird population (and probably its total wildlife population).

Chapter IV

SUMMARY

From 19 May to 3 July 1975 inclusive, censuses of all birds using 18 study areas of various sizes and ages-12 planted pine stands and 6 natural deciduous woodlands-were conducted using a singing male count index in Montgomery and Stewart Counties, Tennessee, and Trigg and Christian Counties, Kentucky, on the Northwestern Highland Rim of the Interior Low Plateau. Vegetation was sampled by recording presence or absence of foliage in each of three layers (0-5 ft., 5-30 ft., and over 30 ft.) above 40 randomly-positioned points on each study area. Species composition of the plant communities was also determined.

Bird species diversity (BSD), foliage height diversity (FHD), and plant species diversity (PSD) were calculated for all study areas using Shannon's formula (Shannon and Weaver, 1949). Per cent vegetation cover (PCVC) was also calculated as the percentage of points per area above which vegetation was present in each of the 3 recognized foliage layers.

Data were analyzed from 2 perspectives: 1. By considering all study areas as representing a gradient of dissimilar habitats, and 2. By assuming that the pine and hardwood plots represented two distinct habitat types. When considering all study areas, BSD was correlated with FHD

and the sum of PCVC for all three layers, but not with PSD. When considering the pine data separately, the same pattern of correlations was found. The separate pine data also showed BSD and FHD were correlated with the age of the pine stands, and PCVC of the pine canopy only was correlated with both BSD and age of the pine stands. In the hardwoods alone, BSD did not correlate with FHD, sum of PCVC, or PSD. The non-correlation between BSD and PSD was expected. The non-correlation of BSD with either FHD or PCVC was possibly due to the fact that the deciduous stands had matured past a point where the plant community provided a peak in the number of available avian niches.

No significant difference in either number of bird species detected or BSD was found between pine stands and hardwood stands. The major effect of introducing pine plantations into the area of the study was on bird species substitution. That substitution was found to approximate the same substitution patterns associated with natural secondary succession in the area.

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APPENDIX A. DESCRIPTIONS OF ALL STUDY AREAS-12 PLANTED PINE STANDS AND 6 DECIDUOUS WOODLANDS-ALL LOCATED ON THE NORTHWESTERN HIGHLAND RIM OF THE INTERIOR LOW PLATEAU[3]

P-1. Loblolly Pine stand.
Age: 6 years. Area: 59.3 acres.
Location: Montgomery Co., TN. FC-25. Adjacent to and North of firebreak at a point 0.3 miles southwest of a point on Engineers Road 0.2 miles south of intersection of same and Mabry Road.
Principal Species: *Rhus copallina, Pinus taeda, Lonicera japonica, Smilax* spp., *Rosa* spp.
Comments: Fairly homogenous, surrounded by firebreaks on 3 sides and hardwoods on the other. Dense ground cover of various members of Poaceae, Compositae, Cyperaceae, Leguminosae. Very hard walking.

P-2. Loblolly Pine stand.
Age: 6 years. Area: 45.7 acres.
Location: Montgomery Co., TN. FC-25. Directly adjacent to area P-1 to the southwest.
Principal Species: *Pinus taeda, Lonicera japonica, Smilax* spp., *Sassafras albidum, Rhus copallina.*
Comments: Similar to P-1 but has deciduous stand in center of pine stand and is surrounded by firebreaks on all sides. Ground cover like that of P-1.

P-3. Loblolly Pine stand.
Age: 6 years. Area: 2.9 acres.
Location: Montgomery Co., TN. FC-25. Adjacent to and west of firebreak at a point 0.3 miles north of a point on Rose Hill Road 0.8 miles west of intersection of same and Palmyra Road.
Principal Species: *Smilax* spp., *Pinus taeda, Lonicera japonica, Rhus copallina, Sassafras albidum.*
Comments: Bordered by hardwoods on 3 sides and a firebreak on the other. Ground cover similar to P-1 and P-2.

P-4. Loblolly Pine stand.
Age: 10 years. Area: 41.6 acres.
Location: Stewart Co., TN. FC-31. Adjacent to and north of Stamper's Chapel Road, 1.2 miles west of intersection of same and Rendevous road.
Principal Species: *Pinus taeda, Smilax* spp., *Rhus copallina, Diospyros virginiana, Rosa* spp.
Comments: Very dense. All of above species form a

dense tangle as high as 8 feet. Walking was impossible in places. Ground cover not as dense as younger stands but same groups are represented. Surrounded by firebreaks on all sides.

P-5. Loblolly Pine stand.
Age: 11 years. Area: 47.0 acres.
Location: Stewart Co., TN. FC-32. Adjacent to and north of U. S. Highway 79, 1.0 miles west of same and Indian Mound road.
Principal Species: *Smilax* spp., *Pinus taeda*, *Rhus copallina*, *Lonicera japonica*, *Rubus argutus*.
Comments: No vast difference from P-4. Dense and tangled. Similar ground cover. Surrounded by firebreaks.

P-6. Loblolly Pine stand.
Age: 11 years. Area: 4.3 acres.
Location: Stewart Co., TN. FC-32. Adjacent to and west of Indian Mound Road at intersection of same and Rendevous road.
Principal Species: *Pinus taeda*, *Lonicera japonica*, *Smilax* spp., *Rhus copallina*, *Rubus argutus*.
Comments: Not as dense in places as were large stands in this age class. Had a telephone line with cleared area running through middle. Ground cover similar to P-4 and P-5. Hardwoods on one side, road on two sides, one side bordered area of burned pines.

P-7. Loblolly Pine stand.
Age: 17 years. Area: 6.3 acres.
Location: Christian Co., KY. FC-41. Adjacent to and east of Patton Road, 2.3 miles north of intersection of same and Angel's road.
Principal Species: *Pinus taeda*, *Liquidambar styraciflua*, *Lonicera japonica*, *Smilax* spp., *Sassafras albidum*.
Comments: Pine canopy completely closed. Ground cover much more sparse. Not nearly so tangled. Understory layer of hardwoods more evident.

P-8. Loblolly Pine stand.
Age: 19 years. Area: 47.4 acres.
Location: Christian Co., KY. FC-16. Adjacent to and north of Angel's road at intersection of same and Mabry road.
Principal Species: *Pinus taeda*, *Lonicera japonica*, *Acer negundo*, *Vitis aestivalis*, *Cornus florida*.
Comments: Somewhat more dense than P-7 mainly due to more *Lonicera*. Pine canopy closed with some open spots. Ground cover still composed of same families, about equal to P-7 in density.

P-9. Loblolly Pine stand.
Age: 17 years. Area: 85.8 acres.
Location: Christian Co., KY. FC-26. Adjacent to and north of Angel's road at intersection of same and Patton road.
Principal Species: *Pinus taeda, Lonicera japonica, Rhus radicans, Prunus serotina, Sassafras albidum.*
Comments: Much more open under pines than other two stands of this age class. Ground cover sparse. Possibly due to army activities. Has some white pine, *Pinus strobus*, intermixed which was recorded at the same number of points as *Sassafras*.

P-10. Loblolly Pine stand.
Age: 32 years. Area: 5.9 acres.
Location: Trigg Co., KY. In Land-between-the-Lakes, Tennessee Valley Authority. Adjacent to and south of Mulberry Flat road at a point 2.3 miles east of intersection of same and The Trace.
Principal Species: *Pinus taeda, Cornus florida, Ulmus alata, Diospyros virginiana, Quercus alba.*
Comments: All pines over 30 feet tall. Pine canopy closed except where hardwoods break it. Ground cover sparse with dense mat of pine needles. Middle layer of deciduous trees well developed. Hardwoods on three sides and a paved road on the other side.

P-11. Loblolly Pine stand.
Age: 40 years. Area: 3.1 acres.
Location: Montgomery Co., TN. In Dotsonville Community 0.2 miles east of Dunbar Road at a point 1.0 miles south of intersection of same, and Dotsonville Road. Owned by John McKinney.
Principal Species: *Pinus taeda, Lonicera japonica, Symphoricarpos orbiculatus, Ulmus alata, Ulmus americana.*
Comments: Not unlike area P-10, but with much more tangled undergrowth. Ground cover was more pronounced with the usual families represented. Surrounded by pasture on all sides.

P-12. Loblolly Pine stand.
Age: 37 years. Area: 3.1 acres.
Location: Montgomery Co., TN. In Dotsonville Community. 0.1 miles south of Chester road directly behind Haynes Chapel Baptist Church, 0.3 miles south of intersection of Chester road and Dotsonville road. Owned by Graham Haynes.
Principal Species: *Pinus taeda, Ulmus alata, Lonicera japonica, Rhus radicans, Quercus falcata.*
Comments: Pine canopy closed. Fairly dense, tangled undergrowth, reflected by higher indidence of

Lonicera. Surrounded by hardwoods on all sides, area H-2.

H-1. Deciduous woodland.
Mean DBH: 8.64 inches. Area: 9.7 acres.
Location: Montgomery Co., TN. FC-25. Totally surrounded by study area P-2.
Principal Species: *Cornus florida*, *Quercus falcata*, *Lonicera japonica*, *Sassafras albidum*, *Rhus radicans*.
Comments: Entire edge composed of young pine stand. *Quercus falcata* was very dominant. Other canopy trees included species of *Quercus*, *Carya*, and others, but none approached dominance of *Quercus falcata*. *Cornus florida* mainly composed the middle foliage layer. Fairly open with sparse ground cover except small hardwoods.

H-2. Deciduous woodland.
Mean DBH: 9.81 inches. Area: 45.0 acres.
Location: Montgomery Co., TN. In Dotsonville Community. Adjacent to and between Dotsonville road and Chester road near intersection of the two. Directly behind Dotsonville Baptist Church and Haynes Chapel Baptist Church. Owned by Graham Haynes.
Principal Species: *Carya tomentosa*, *Carya ovata*, *Acer saccharum*, *Quercus alba*, *Cornus florida*.
Comments: Bordered by paved roads on two sides and pasture on the others. Fairly dense but still sparse ground cover other than hardwoods.

H-3. Deciduous woodland.
Mean DBH: 11.12 inches. Area: 3.5 acres.
Location: Montgomery Co., TN. In Dotsonville Community. Directly adjacent to area P-11 to the east, separated only by a small one acre pasture. Owned by John McKinney.
Principal Species: *Quercus velutina*, *Carya ovata*, *Carya tomentosa*, *Cercis canadensis*, *Quercus alba*.
Comments: Small plot bordered by pasture on three sides and hardwoods on other. Fairly open with reduced ground cover.

H-4. Deciduous woodland.
Mean DBH: 8.45 inches. Area: 121 acres.
Location: Trigg Co., KY. In Land-between-the-Lakes, Tennessee Valley Authority. Directly adjacent to and southeast of study area P-10.
Principal Species: *Quercus stellata*, *Quercus alba*, *Carya ovata*, *Quercus velutina*, *Nyssa sylvatica*.
Comments: Undergrowth very reduced. Area was surrounded by similar habitat. Study area was simply a plot in center of a large forest, but bordered on one side by paved road.

H-5. Deciduous woodland.
Mean DBH: 10.55 inches. Area: 41.1 acres.
Location: Montgomery Co., TN. FC-25. Adjacent to and north of Rose Hill road at a point 0.4 miles west of intersection of same and Palmyra road.
Principal Species: *Quercus velutina, Nyssa sylvatica, Quercus alba, Acer saccharum, Corus florida.*
Comments: Another plot taken from center of large forest. Bordered by dirt road on one side. Fairly open but middle foliage layer well developed.

H-6. Deciduous woodland:
Mean DBH: 9.4 inches. Area: 64 acres.
Location: Stewart Co., TN. FC-31. Adjacent to and north of Stamper's Chapel road at a point 0.8 miles west of intersection of same and Rendevous road.
Principal Species: *Nyssa sylvatica, Quercus velutina, Cornus florida, Lonicera japonica, Quercus falcata.*
Comments: Lower layers were more dense as principal species show. Other canopy dominants included *Quercus stellata, Quercus alba, Carya tomentosa, Quercus rubra.* Area bordered by firebreaks and pasture.

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[3]Areas located in Fort Campbell, Kentucky, are designated by the letters FC with a number following that represents the specific area within Fort Campbell in which the area was located. Directions as to location of these areas follow official topographic maps supplied by the Fort Campbell Department of Forestry. Directions concerning locations of areas in Land-between-the-Lakes follow official Tennessee Valley Authority topographic maps.

APPENDIX B. SUMMARY OF DATA USED IN CALCULATING PLANT SPECIES DIVERSITIES OF 12 PLANTED PINE STANDS AND 6 DECIDUOUS WOODLANDS ON THE NORTHWESTERN HIGHLAND RIM OF THE INTERIOR LOW PLATEAU[4]

Species	A	B
Pinus strobus	6	
Pinus taeda	327	
Juniperus virginiana	4	1
Smilax spp.	155	8
Juglans nigra	1	1
Carya ovata	3	34
Carya tomentosa	1	37
Corylus americana		4
Ostrya virginiana		1
Fagus grandifolia		2
Quercus alba	5	44
Quercus stellata	6	36
Quercus prinus		2
Quercus rubra	1	18
Quercus velutina	3	44
Quercus falcata	22	47
Quercus imbricaria		2
Ulmus rubra	4	6
Ulmus americana	10	15
Ulmus alata	47	19
Celtis laevigata	9	2
Morus rubra	1	4
Maclura pomifera	1	
Liriodendron tulipifera	2	13
Sassafras albidum	35	17
Liquidambar styraciflua	23	
Platanus occidentalis	1	
Amelanchier arborea	2	
Rubus flagellaris	1	
Rubus argutus	29	2
Rosa spp.	30	
Prunus angustifolia	2	
Prunus serotina	24	7
Gleditsia triacanthos	1	
Cercis canadensis	2	13
Robinia pseudoacacia	8	
Ailanthus altissima	1	1
Rhus glabra	8	
Rhus copallina	77	6
Rhus radicans	42	12
Ilex opaca		1
Ilex decidua	1	
Acer saccharum	4	20
Acer rubrum	13	8
Acer negundo	9	
Rhamnus caroliniana	1	
Parthenocissus quinquefolia	19	22
Vitis aestivalis	21	13
Nyssa sylvatica	7	43
Aralia spinosa	1	3
Cornus florida	45	56
Diospyros virginiana	40	9
Fraxinus americana	6	15
Campsis radicans	19	1
Lonicera japonica	178	34
Symphoricarpos orbiculus	22	6
Viburnum rufidulum	1	

[4]Column A figures represent individual totals of each woody species encountered on 12 pine stands as detected above 40 randomly positioned points per area. Column B represents those totals encountered on 6 deciduous woodlands using the same sampling method. Names of plants and taxonomic order follow Fernald (1950).