1978

Bird Utilization of Woodland Habitat in the Eastern Quarter of South Dakota

John M. Emmerich

Recommended Citation

Emmerich, John M., "Bird Utilization of Woodland Habitat in the Eastern Quarter of South Dakota" (1978). *Theses and Dissertations*. 83.
http://openprairie.sdstate.edu/etd/83

BIRD UTILIZATION OF WOODLAND HABITAT IN THE EASTERN QUARTER OF SOUTH DAKOTA

BY

JOHN M. EMMERICH

A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science, Major in
Wildlife and Fisheries Science
(Wildlife Option)
South Dakota State University

1978

BIRD UTILIZATION OF WOODLAND HABITAT IN THE EASTERN QUARTER OF SOUTH DAKOTA

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Paul A. Vohs
Thesis Adviser

Date

Charles G. Scalet, Head
Department of Wildlife
and Fisheries Sciences

Date

ACKNOWLEDGMENTS

I wish to express my sincere gratitude to P. A. Vohs for his advice and encouragement throughout this study.

W. L. Tucker, Agricultural Experiment Station Statistician, is thanked for his assistance in the design, analysis, and interpretation of the statistics used in this study. I also thank Professors L. D. Flake and J. T. Ratti for their useful comments on writing the manuscript. Joyce Bailey is thanked for typing this manuscript.

Special thanks are extended to Debby Schmitt for her friendship and support during the final stages of manuscript preparation.

Financial support for this project was provided by the South Dakota Agricultural Experiment Station, Projects 7116-654 and 7116-735.

WOODLAND HABITAT UTILIZATION BY BIRDS IN THE EASTERN QUARTER OF SOUTH DAKOTA

Abstract

John M. Emmerich

Bird utilization of narrow, riparian woodland; block-like, tree claim; and linear, single-row windbreak habitats in the eastern quarter of South Dakota was studied during the spring migration, reproductive, and winter seasons. The relative importance of these three habitats and multi-row shelterbelt habitat was evaluated using bird species diversity (BSD), bird population density, and habitat preferences of individual bird species. Cluster analysis delineated distinctive vegetation cover types in each of the three habitats studied. Bird communities associated with each cover type were tabulated for comparison purposes and prediction capabilities. Multiple regression analysis predicted physical and vegetation features of each habitat type that correlated with BSD, population density, and density of common nesting and wintering birds.

Maintenance of BSD at present levels in woodlands of the eastern quarter of South Dakota is dependent primarily upon preservation of riparian woodland habitat, and secondly tree claim habitat. Shelterbelt and windbreak habitats supported bird diversities lower ($p < 0.05$) than riparian woodland or tree claim habitats during all seasons studied, but supported

significantly higher ($p < 0.05$ level) population densities during all seasons except winter. Single-row windbreaks were not suitable for supporting winter bird populations.

Sparse stands of trees ($\bar{x}$ = 32.2 trees/0.4 ha) with occasional shrubs ($\bar{x}$ = 54.0 m^3/0.4 ha) supported all but one of the bird species associated with dense tree stands ($\bar{x}$ = 144.2 trees/0.4 ha) with a moderately developed shrub layer ($\bar{x}$ = 678.8 m^3/0.4 ha) in riparian woodlands during the reproductive season. Elimination of the shrub layer and loss of tree vigor, however, caused a decrease in number of species using tree claim habitat. Unique transients occurred in tree claims with dense tree stands ($\bar{x}$ = 216.0 trees/0.4 ha) and developed shrub layers ($\bar{x}$ = 1082.6 m^3/0.4 ha) and in the denser riparian woodland study plots during spring migration.

Maintaining maximum bird diversity in riparian woodland habitat during spring migration and reproductive seasons was most dependent on the area of habitat present. Minimum plot sizes of 6.0 ha and 5.9 ha were predicted to support 95% of the maximum BSD supported by riparian woodland habitat during the spring migration and reproductive seasons, respectfully.

Population densities increased with increasing canopy cover, ground cover, and shrub volume during the reproductive season in riparian woodland habitat. Both population density and BSD increased more in response to increasing tree density and shrub volume during spring migration than during the reproductive season. During the winter season, BSD had positive correlations with the proximity of farm buildings and corn stubble and density of cottonwoods and green ash.

Tree claims composed of tall trees, short trees, and a shrub layer were most suitable for achieving a balance between maximum bird diversity and maximum bird density during the seasons studied. The proximity of farm buildings had a positive correlation with BSD during the winter season in tree claim habitat. Diversity and density of birds can be maximized in windbreaks by presence of tall, full canopy trees trees with an accompanying layer of shrubs between or under the trees.

The most prominent bird species during nesting season included Mourning Dove, Blue Jay, American Robin, and Northern Oriole in riparian woodland habitat; Common Flicker, American Robin, Brown Thrasher, Common Grackle, and Starling in tree claim habitat; Red-winged Blackbird, Mourning Dove, Brown Thrasher, Eastern Kingbird, and Black-billed Cuckoo in windbreak habitat. The White-breasted Nuthatch, Downy Woodpecker, Hairy Woodpecker, and Black-capped Chickadee were most prominent during winter in riparian woodland habitat. Habitat requirements for each species for the appropriate season were discussed.

TABLE OF CONTENTS

INTRODUCTION. 1

STUDY AREA. 4

General Description. 4

Climate. 4

Physiography 5

Vegetation 7

Study Plots. 8

METHODS AND MATERIALS 12

Study Plot Selection 12

Vegetation Analysis. 14

Avifauna 21

Diversity Estimates. 25

Habitat Evaluation 26

Multivariate Analysis. 28

RESULTS AND DISCUSSION. 32

Reproductive Season. 32

Avian communities 32

Bird population density 36

BSD 39

Spring Migration Season. 41

Avian communities 41

Bird population density 43

BSD 44

Winter Season. 45

Avian communities 45

Bird population density 47

BSD 48

Vegetation Cluster Analysis. 50

Riparian woodland habitat 50

Tree claim habitat. 59

Single-row windbreak habitat. 66

Multiple Regression Analysis 73

Bird species diversity and population density, riparian woodland habitat 73

Bird species diversity and population density, tree claim habitat. 81

Bird species diversity and population density, single-row windbreak habitat. 86

Common nesting birds, riparian woodland habitat 90

Common nesting birds, tree claim habitat. . . . 93

Common nesting birds, single-row windbreak habitat 95

Common wintering birds, riparian woodland habitat 98

SUMMARY AND CONCLUSIONS 102

LITERATURE CITED. 109

APPENDICES. 114

LIST OF TABLES

Table		Page
1	Twenty-eight independent variables calculated for each riparian woodland and tree claim study plot	19
2	Twenty-two independent variables calculated for each single-row windbreak study plot	20
3	Mean densities and percent frequencies of birds observed in four woodland habitats of the eastern quarter of South Dakota during the 1977 reproductive season	33
4	Mean densities and percent frequencies of transient birds observed in four woodland habitats of the eastern quarter of South Dakota during the 1977 spring migration season	42
5	Mean densities and percent frequencies of birds observed in four woodland habitats of the eastern quarter of South Dakota during the 1976 winter season	46
6	Orthogonal t-tests for significant differences in bird population densities and bird species diversities supported by four woodland habitats in the eastern quarter of South Dakota	49
7	Vegetation and physical variables used to describe the riparian woodland vegetation cover types.	52
8	Bird communities associated with three riparian woodland cover types during the 1977 reproductive season	54
9	Bird communities associated with three riparian woodland cover types during the 1977 spring migration season	56
10	Bird communities associated with three riparian woodland cover types during the 1976 winter season	58

Table Page

11 Vegetation and physical variables used to describe the tree claim vegetation cover types. 61

12 Bird communities associated with two tree claim cover types during the 1977 reproductive season 62

13 Bird communities associated with two tree claim cover types during the 1977 spring migration season 64

14 Bird communities associated with two tree claim cover types during the 1976 winter season. . . . 65

15 Vegetation and physical variables used to describe the single-row windbreak vegetation cover types. 68

16 Bird communities associated with three single-row windbreak cover types during the 1977 reproductive season 70

17 Bird communities associated with three single-row windbreak cover types during the 1977 spring migration season 71

18 Results of stepwise forward multiple regression analysis of bird species diversity in riparian woodland habitat including all independent variables accounting for significant variation at the $p < 0.10$ level ($N = 14$) 74

19 Results of stepwise forward multiple regression analysis of standardized bird population density in riparian woodland habitat including all independent variables accounting for significant variation at the $p < 0.10$ level ($N = 14$) 79

20 Results of stepwise forward multiple regression analysis of bird species diversity in tree claim habitat including all independent variables accounting for significant variation at the $p < 0.10$ level ($N = 14$). 32

Table		Page
21	Results of stepwise forward multiple regression analysis of standardized bird population density in tree claim habitat including all independent variables accounting for significant variation at the $p < 0.10$ level ($N = 14$)	84
22	Results of stepwise forward multiple regression analysis of bird species diversity in single-row windbreak habitat including all independent variables accounting for significant variation at the $p < 0.10$ level ($N = 14$)	87
23	Results of stepwise forward multiple regression analysis of standardized bird population density in single-row windbreak habitat including all independent variables accounting for significant variation at the $p < 0.10$ level ($N = 14$)	90
24	Results of stepwise forward multiple regression analysis of common birds associated with riparian woodland habitat during the 1977 reproductive season including all independent variables accounting for significant variation at the $p < 0.10$ level ($N = 14$).	91
25	Results of stepwise forward multiple regression analysis of common birds associated with tree claim habitat during the 1977 reproductive season including all independent variables accounting for significant variation at the $p < 0.10$ level ($N = 14$).	94
26	Results of stepwise forward multiple regression analysis of common birds associated with single-row windbreak habitat during the 1977 reproductive season including all independent variables accounting for significant variation at the $p < 0.10$ level ($N = 14$).	96
27	Results of stepwise forward multiple regression analysis of common birds associated with riparian woodland habitat during the 1976 winter season including all independent variables accounting for significant variation at the $p < 0.10$ level ($N = 14$)	99

LIST OF FIGURES

Figure		Page
1	Location of study area, study plots, and area of film coverage by NASA remote sensing.	13
2	Phenogram of vegetation cover types resulting from vegetation cluster analysis of 19 vegetation variables measured in riparian woodland habitat	51
3	Phenogram of vegetation cover types resulting from vegetation cluster analysis of 19 vegetation variables measured in tree claim habitat.	60
4	Phenogram of vegetation cover types resulting from vegetation cluster analysis of 15 vegetation variables measured in single-row windbreak habitat.	67
5	BSD-area curve for riparian woodland habitat during the 1977 reproductive season using $\log_n$ transformation of plot size.	75
6	BSD-area curve for riparian woodland habitat during the 1977 spring migration season using $\log_n$ transformation of plot size	77

LIST OF APPENDICES

Appendix Page

A Calculated independent variables used to describe the physical and vegetative features of each study plot. 115

B Summary of bird species diversity and population density calculated for each study plot 119

C Scientific names of birds identified during the study 123

D Correlation matrices of the independent variables calculated for riparian woodland, tree claim, and single-row windbreak habitats 127

INTRODUCTION

The objectives of this study were as follows: (1) to quantify and qualify the bird communities utilizing riparian woodland, tree claim, and single-row windbreak habitat types in the eastern quarter of South Dakota during the spring migratory, reproductive, and winter seasons; (2) to evaluate the relative importance of riparian woodlands, tree claims, single-row windbreaks, and multi-row shelterbelts using bird species diversity (BSD), bird population density, and habitat preferences of individual bird species; (3) to identify the vegetative and physical features of riparian woodlands, tree claims, and single-row windbreaks that exhibited correlation with bird species diversity, bird population density, and densities of individual bird species. Information concerning the effects of managing, removal, or adding woodlands on birds will be augumented by the quantitative data presented. Quantitative information describing the relationships of various woodland habitats and supported bird populations, and the relative importance of artificially established woodland habitats and natural woodland habitats to birds has not been available for South Dakota or the remaining agricultural areas in the Great Plains Region. The only known published work on an eastern South Dakota woodland habitat and any portion of its associated bird community is a study of the winter ecology of woodpeckers and nuthatches along the Missouri River by Smith (1971).

The Timber Culture Act of 1873 and South Dakota's tree-planting bounty laws of 1890 and 1920 were the initial monetary incentives for planting 0.4-16.0 ha tracts of trees, called tree claims, on the prairies of South Dakota. The passage of The Prairie States Forestry Project in 1935 resulted in the subsequent planting of 32,000 km of multi-row shelterbelts in 6 of the Great Plains States including South Dakota. Numerous miles of single-row windbreaks have been added to this inventory in the past 20 years. These tree claims, multi-row shelterbelts, single-row windbreaks, and naturally occurring riparian woodlands comprise almost all the woodland habitat in the eastern quarter of South Dakota. Approximately 150 bird species are associated with these woodlands. An estimated 3,200,000 trees are planted per year in South Dakota. The number of farmstead windbreaks is declining while the number of single-row windbreaks is increasing (Griffith 1976). Acreage of riparian woodlands and tree claims is being reduced. The reduction is due primarily to more intensive agricultural practices. The agricultural to nonagricultural land-use ratio of 28:72% in 1944 has changed to 48:52% in 1974 along an unchannelized portion of the Missouri River in southeastern South Dakota (R. L. Linder, pers. comm.). The greatest percentage increase in the conversion of riparian woodlands to agricultural land-use (4.14%) occurred between 1969 and 1974.

STUDY AREA

General Description

As defined for this study, the eastern quarter of South Dakota is located in the northeastern portion of the North American Great Plains and lies east of 98° 43' W Longitude. Agriculture prevails as the major land-use in the 5,731,083 ha area. The percentage of land in cultivated crops varies from 40 along the western border to 70 in the southeastern corner (Westin et al. 1967). Small grains and flax are the main cultivated crops in the north, while more diversified farming that includes feed grains occurs in the south. Processing agricultural products dominates South Dakota's industrial activity.

Climate

A continental climate with extremes of summer heat, winter cold, and rapid fluctuations of temperature occurs on the study area. Average annual precipitation ranges from 55.9 cm to 66.0 cm in the southeastern portion to 48.3 cm in the northwestern portion. Most precipitation occurs from thundershowers in the spring and early summer. Winter snowfall ranges from 53.3 cm to 105.4 cm. Periodic deviations substantially below the average annual mean precipitation occur. In 1976, a severe drought year, annual precipitation in the northern portion of the area averaged 23.0 cm, or 29.5 cm below the average annual mean. Precipitation recorded in the southern part was 37.0 cm, or 23.5 cm below the annual mean. In 1977, annual precipitation totaled 74.2 cm. Average annual temperatures range from 6.1°C in the north to 8.7°C in the south. Mean temperatures of -8.3°C in December and 18.6°C in June occur in the north. A mean of -5.1°C in December and 20.6°C in June occur in the south (Climatological Data 1976).

Prevailing winter winds flow from the northwest, while warmer season winds flow from the southeast (Spuhler et al. 1971). The annual average surface wind speed is 18 km per hour. Evaporation exceeds precipitation throughout the area with approximately 80% of the evaporation occurring from May to October. The growing season varies from 130 days in the north to 154 days in the south.

Physiography

Pleistocene glaciation was the principal factor that determined the dominant land features of the study area. Glacial ice entered the state from the northeast or north and flowed south and west. Ice covered the entire eastern quarter of the state and produced the present soil parent materials of primarily glacial till, glacial outwash, and glacial lake deposits (Westin et al. 1967).

Two dominant relief forms resulted from the glacial activity within the study area; the Coteau des Prairies and the James River Lowland (Westin et al. 1967). The southern border of both regions is formed by the Missouri River. The Coteau des Prairies is a glacial highland occupying approximately the eastern half of the study area. It slopes gently to the south and west with its eastern and western edges forming steep escarpments at the northern end. Elevations range from 610 m above mean sea level in the north to 490 m in the south. The topography is undulating in the north and gently undulating in the south. The Big Sioux River drains the southern part of this region and enters the Missouri River along the southern border of the state. A closed drainage system containing a high density of shallow lakes and marshes occurs in the northern part of the region.

The James River Lowland is a gently undulating plain of lower elevation (395-420 m) than the Coteau des Prairies and occupies the western half of the study area. The northern portion, known as the Lake Dakota Plain, is nearly level. The James River drains this entire region from north to south and enters the Missouri River on the southern border of the state.

All soils are classified in the Chernozem Zonal Group (Westin et al. 1967). Soils vary from silty sands to clay loams with highest organic matter content and nitrogen content occurring in soils of the northeast. The lowest organic matter content and nitrogen content occurs in the soils of the southwest.

Vegetation

Eastern South Dakota lies in the transitional vegetation zone between tall grass prairie to the east and mixed grass prairie to the west. Dominant native grasses consist of big bluestem (*Andropogon gerardii*), little bluestem (*Andropogon scoparius*), indiangrass (*Sorghastrum nutans*), and switchgrass (*Panicum virgatum*) with the addition of western wheatgrass (*Agropyron smithii*), porcupine grass (*Stipa spartea*), and prairie dropseed (*Sporobolus cryptandrus*) as one moves from east to west (Johnson and Nichols 1970). Introduced brome grasses (*Bromus* spp.) presently dominate in many roadside ditches, tree claims, multi-row shelterbelts, and single-row windbreaks. Both bluegrasses (*Poa* spp.) and brome grasses are common in many pastures. Principal forbs are leadplant (*Amorpha canescens*), groundplum milkvetch (*Astragalus crassicarpus*), American licorice (*Glycyrrhiza lepidota*), white and purple prairie-clover (*Petalostemon* spp.), the scurfpeas (*Psoralea* spp.), wild onion (*Allium* spp.), black sampson (*Echinacea angustifolia*), perennial sunflowers (*Helianthus* spp.), and prairie coneflower (*Ratibida columnifera*) (Johnson and Nichols 1970). Giant ragweed (*Ambrosia tridida*), stinging nettle (*Urtica dicica*), thistles (Carduus spp. and Cirsium spp.), and wild hemp (Cannibis sativa) predominate in many disturbed sites lacking grass cover.

The original, unbroken, native prairie has been replaced by a mosaic of vegetation types (Westin et al. 1967). From 1961 to 1966, the percentage of land area in row crops was 25 in the northwestern portion of the study area and 60 in the southwestern portion. The percentage of land area in pasture, alfalfa hay, and wild hay was 60, 5, and 10 respectively in the southeast portion of the study area.

Woodland habitats consisting of tree claims, multi-row shelterbelts, and single-row windbreaks are dotted about the uplands; and forested ravines occur along the steep, eastern slope of the Coteau des Prairies. Northern floodplain forest occurs along the Big Sioux, James, Vermillion, and Missouri rivers. Approximately 2.6% of the study area is forested (Choate and Spencer 1969).

Study Plots

Single-row windbreaks, hereafter referred to as windbreaks, were defined as any single row of trees, or shrubs, or combination of trees and shrubs at least 100 m in length and 2 m in height. The term shelterbelt refers to multiple, linear rows of trees and/or shrubs. The vegetative composition of windbreaks was primarily of one species. The most commonly occurring species were Siberian elm (Ulmus *pumila*), green ash (*Fraxinus pennsylvanicus*), and cottonwood (*Populus* spp.). A combination of two species such as green ash and caragana (*Caragana arborescens*) or green ash and Tatarian honeysuckle (*Lonicera tatarica*) did occur secondarily in windbreaks.

The vegetative composition of the study plots used for evaluating windbreak habitat varied. Plot S1 was composed of mature (30 years old) cottonwood with an occasional peachleaf willow (*Salix amygdaloides*) and an intermittent American plum (*Prunus americana*) and common chokecherry (*Prunus virginiana*) shrub understory. Plot S3 was 20 years old and equally composed of boxelder (*Acer negundo*) and Siberian elm. Plot S4 was composed of mature (> 80 years old) green ash with no shrub understory. Plots S6 and S7 were 8 years old and composed of alternating green ash and caragana. Plot S12 was 32 years old and composed of Siberian elm, green ash, American elm (*Ulmus americana*), common chokecherry, American plum, Tatarian honeysuckle, and an occasional snowberry (*Symphoricarpos albus*). Plot S14 was composed of mature (> 80 years old) green ash with occasional common chokecherry understory and tree foliage that extended to the ground. Plot S17 was 6 years old and composed of alternating green ash and Tatarian honeysuckle. Plots S5, S11, S13, S15, S16, and S13 were Siberian elm and ranged from 5 to 11 years of age. Average plot length was 684 m (range 259-793 m).

Riparian woodland habitat was defined for this study as a strip of woodlands at least 20 m wide and running 250 m parallel to the shore of a permanent stream. Plots R1, R1A, R2, R4, R7, R8, R9, R12, R13, R14, R15, and R18 were located along the Big Sioux, James, and Vermillion rivers. A mixed climax association of green ash, boxelder, slippery elm (*Ulmus rubra*), and American elm with an occasional bur oak (*Quercus macrocarpa*), silver maple (*Acer saccharinum*), peachleaf willow, hackberry (*Celtis occidentalis*), and cottonwood predominated along these three rivers. Common shrubs include gooseberry (*Ribes* spp.), snowberry, common chokecherry, wild rose (*Rosa* spp.), poison ivy (*Rhus radicans*), and American plum. Plots R5 and R6 were located along the Missouri River where successional associations of cottonwood and willow (*Salix* spp.) or cottonwood and dogwood (*Cornus* spp.) intermixed with other occasional tree species predominated. Virginia creeper (*Parthenocissus inserta*) and riverbank grape (*Vitis riparia*) occurred frequently along all four river systems. Average plot size was 2.9 ha (range 0.7-8.7 ha).

Tree claim habitat was defined as any stand of trees 2.1 ha or larger in size, square or rectangular in shape, lacking the multi-row shelterbelt configuration of individual rows of separate tree and shrub species, and with evidence from owner recollection, tree age, and location, of an initial human establishment between 1873 and 1935. Plots T3, T4, T6, T9, T12, T17, and T22 were composed predominantly of green ash. Plots T7, T16, and T18 were co-dominated by green ash and boxelder, and T2, T5, T10, and T19 were composed of a mixed association of green ash, boxelder, slippery elm, and American elm with occasional cottonwoods and silver maples. Common shrubs included American plum, common chokecherry, Tatarian honeysuckle, and European buckthorn (Rhamnus cathartica). Average plot size was 3.7 ha (range 2.1-4.6 ha). Total tree density, shrub layer development, and herb layer composition varied substantially depending on past land use, especially grazing, in both tree claims and riparian woodlands. Values for each variable used to describe the vegetative and physical features of each study plot (Tables 1, 2) are summarized in Appendix A.

METHODS AND MATERIALS

Study Plot Selection

Fourteen windbreak, 14 riparian woodland, and 14 tree claim study plots were selected for study (Fig. 1). Riparian woodland study plots were selected by assigning a unique number to each 1.6 km section encompassing a portion of the Big Sioux, James, and Vermillion rivers or those portions of the Missouri River between Fort Randall Dam and Lewis and Clark Lake and downstream from Gavins Point Dam and selecting fourteen 1.6 km sections from among all possible 1.6 km sections using a table of random numbers. The actual site studied within each section was chosen on the basis of its homogenous physiognomy and extensiveness. Thirty-six windbreaks and 22 tree claims were located within the study area by close inspection of NASA High Altitude Color I.R. Film (scale 2.5 cm = 1.6 km), obtained from the Remote Sensing Institute, South Dakota State University, Brookings. Film was available for approximately 53% of the study area (Fig. 1). Fourteen study plots for each of these two habitat types were randomly selected from among those located. Vegetative composition and avian populations of the study plots selected for sampling were assumed representative of these three habitat types in the eastern quarter of South Dakota.

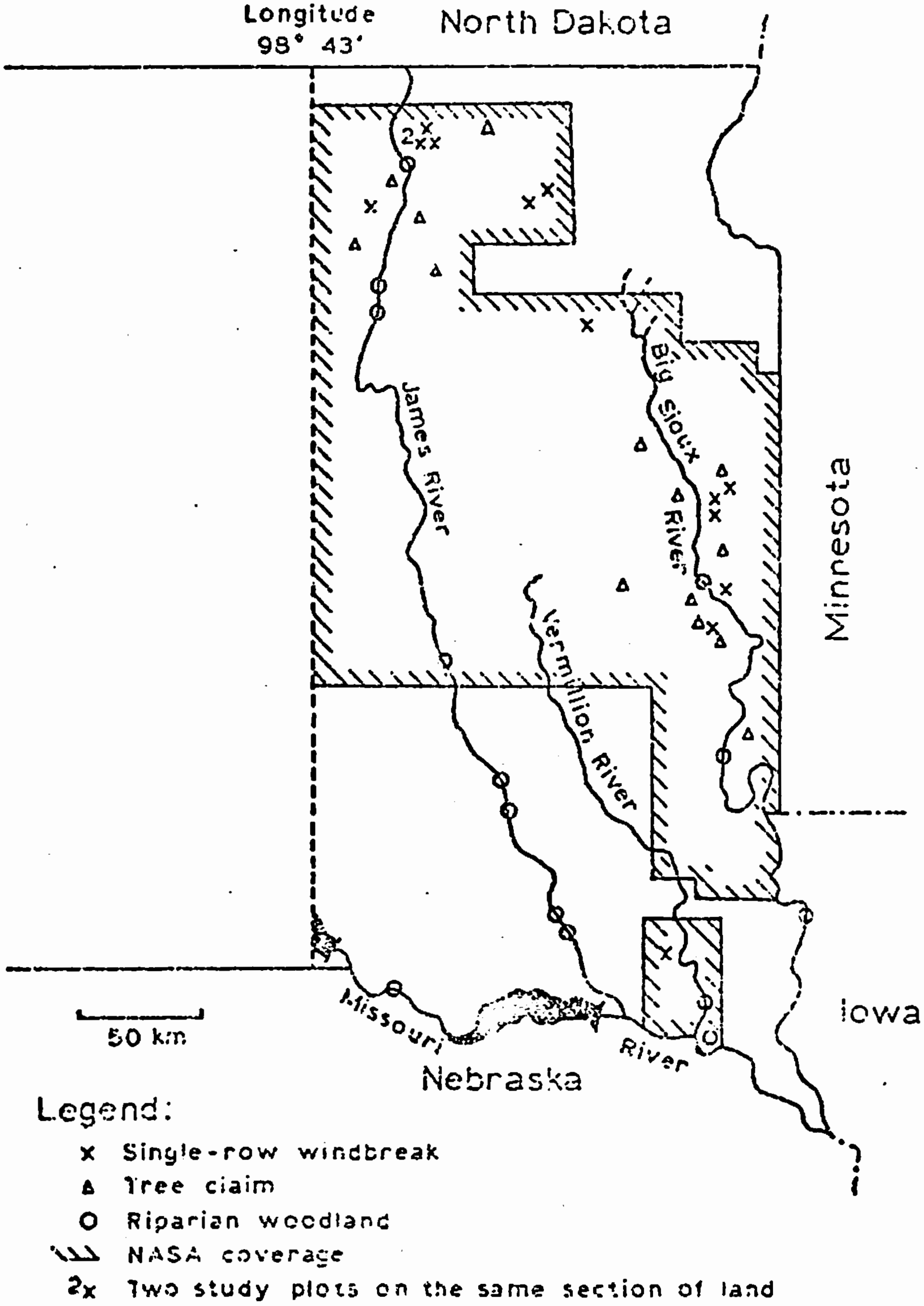

FIGURE 1. Location of study area, study plots, and area of film coverage by NASA remote sensing.

Vegetation Analysis

In riparian woodland and tree claim study plots, vegetation measurements were made in each of a series of randomly located 0.04 ha circles. Sets of paired numbers composed of distance and bearing values were selected from a table of random numbers. From an initial location at the northeast corner of each study plot, the first distance and bearing was utilized to locate the center of the first 0.04 ha circle within the plot. The center of the second 0.04 ha circle was located by walking the second randomly determined distance and bearing from the center of the first 0.04 ha circle. The process was repeated until all plots were selected or when the sequence of distance and bearing combinations had to be modified because plot size and shape restricted the location of the 0.04 ha circles. The next appropriate bearing in the random listing was used to continue the selection. Adequate sampling was determined to have occurred when the estimated tree density per 0.4 ha, determined from each of the last two 0.04 ha circles, differed by less than 10% in low density plots or by less than 25 trees in high density plots (James and Shugart 1970).

Within each 0.04 ha circle, a Brunton pocket transit was used to estimate maximum tree height and shrub height, a meter stick was used for measuring maximum herb height, and two density board readings (Giles 1971) were taken across the circle; one along the north and south axis and one along the east and west axis. Each of these four measurements were averaged over all 0.04 ha circles sampled within each study plot. DBH was measured for each tree within the 0.04 ha circles using a Biltmore "reach stick". Percent ground cover, percent canopy cover, total tree density, tree species densities, and shrub stem density (stems $<$ 7.7 cm DBH) were determined for each study plot using the methods described by James and Shugart (1970). Tree and shrub volumes were calculated in each 0.04 ha circle using the method and HTVOL Program developed by Mawson, Thomas, and DeGraff (unpubl. manuscript, Univ. of Mass., Amherst) with one program modification. A relative density classification of one to five was assigned to each tree or shrub clump whose volume was estimated. A one corresponded to maximum density, two to 80% of maximum, three to 60% of maximum, four to 40% of maximum, and five to 20% of maximum. Calculated volumes were reduced in accordance with the respective density value assigned. Volume measurements from all 0.04 ha circles sampled within each study plot were used to estimate the total tree volume and shrub volume per 0.4 ha. Any tree with more than half of its basal area within a circle was included for measurements of DBH, volume, and density.

In order to measure the degree of openness within each study plot, each 0.04 ha circle was divided into quarters and the number of quarters occupied by trees was recorded. The percentage of total quarters void of trees was used to reflect the degree of openness.

The uniform physiognomy of windbreaks allowed representative measurements to be taken in two 40 m lengths of each windbreak. The first 40 m length was located 13.5 m from the most accessible end of each windbreak, and the second 40 m length was located 100.5 m from the same end. The exact location of a 40 m length was occasionally shifted to avoid isolated sections of dead or stunted trees. Field measurements were the same as those described for the riparian woodland and tree claim sampling procedures, with the following exceptions: an estimate of relative stem density was obtained by counting the number of stems hit with outstretched arms while walking four transects, 10 m apart, perpendicularly through the windbreak in each of the two lengths sampled; one density board reading was taken along each transect route by reading the board through the windbreak from a distance of 10 m; percent canopy cover and percent ground cover were not measured. Relative stem density was expressed as number of stems per transect, and the density board readings were expressed as the average of all eight readings taken per windbreak.

The distance of each study plot from water (PW) and buildings (PH) was measured in all three habitat types and categorized as follows: (1) less than 1/4 mile; (2) less than 1/2 mile but greater than 1/4 mile; (3) greater than 1/2 mile. For purposes of multiple regression these categories were coded as two dummy (dichotomous) variables: (1) whether the distance category was [1] or was not [0] less than 1/4 mile for water [PW4] or buildings [PH4]; (2) whether the distance category was [1] or was not [0] less than 1/2 mile for water [PW2] or buildings [PH2] (Blalock 1972).

The presence of two vegetation categories, pasture/alfalfa and cultivated grains, was recorded when either or both were adjacent to a study plot. A value of one to four was assigned for each of the two vegetation categories according to the number of plot sides that were adjacent to these two categories. Plot area or length, as appropriate, was determined by pacing. A plant species diversity (PSD) index was calculated using the Shannon-Weaver (1963) formula:

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

where p_i is the proportion of total tree and shrub foliage volume represented by the ith species ($i = 1,2,3,\ldots,S$) of tree or shrub. An increment borer aided in determining age of trees. A minimum of two cores was obtained from trees within each sampling site within each study plot. Maximum plot age was determined by the oldest core sample obtained. All variables describing vegetative and physical features (independent variables) determined from field measurements are summarized in Tables 1 and 2.

Methods selected for vegetation analysis were evaluated during June 1976. The sampling intensity achieved using the 0.04 ha circles was not adequate for estimating tree foliage volume when the sample included cottonwood trees that occurred only once or twice in a study plot. Cottonwoods have relatively large foliage volume as compared to green ash. If only one cottonwood occurred on a study plot, and was included in the sample, the density estimate for cottonwoods was too high and the cottonwood's foliage volume had a large escalating effect on the estimated tree foliage volume for the plot. A correction factor was calculated by dividing the apparent density of the cottonwood estimated from the sample by the actual density of the cottonwood determined by surveying the entire plot. The cottonwood's volume was then divided by the correction factor. Independent variables used in final analysis were obtained from field measurements made during each visit to census birds in May and June 1977.

TABLE 1. Twenty-eight independent variables calculated for each riparian woodland and tree claim study plot.

Variables	Mnemonic
Percent canopy cover	PCCC
Percent ground cover	PCGC
Density of trees 7.7-22.9 cm DBH (#/0.4 ha)	DT39
Density of trees 22.9-38.1 cm DBH (#/0.4 ha)	DT95
Density of trees > 38.1 cm DBH (#/0.4 ha)	DT>5
Density of dead trees > 15.2 cm DBH (#/0.4 ha)	DDT6
Tree foliage volume (m^3/0.4 ha)	TFVT
Shrub[a] foliage volume (m^3/0.4 ha)	SFVT
Total tree density (#/0.4 ha)	TTD
Average density board reading (0-21)	DC
Plant species diversity	PSD
Plot area (ha)	SIZE
Average maximum canopy height (m)	CH
Average maximum shrub[a] height (m)	SH
Average maximum herb height (m)	HH
Presence of cultivated grains (1-4)	CROP
Presence of pasture or alfalfa (1-4)	PAST
Proximity of water < 1/4 mile (0-1)	PW4
Proximity of water < 1/2 mile (0-1)	PW2
Proximity of buildings < 1/4 mile (0-1)	PH4
Proximity of buildings < 1/2 mile (0-1)	PH2
Stem density (#/0.4 ha)	STEM
Degree of interior openness (%)	OPEN
Percent density green ash	PCGA
Percent density cottonwood	PCCW
Percent density American or slippery elm	PCAE
Percent density boxelder	PCBO
Shrub and tree foliage volume (m^3/0.4 ha)	TFVL

[a] Any shrub or tree sapling < 7.7 cm DBH.

TABLE 2. Twenty-two independent variables calculated for each single-row windbreak study plot.

Variables	Mnemonic
Tree foliage volume (m^3/m)	TFVT
Shrub[a] foliage volume (m^3/m)	SFVT
Number of trees 7.6-15.2 cm DBH (#/m)	NT36
Number of trees 15.3-22.9 cm DBH (#/m)	NT69
Number of trees > 22.9 cm DBH (#/m)	NT>9
Average density board reading (0-21)	DC
Average maximum canopy height (m)	CH
Average maximum shrub[a] height (m)	SH
Average maximum herb height (m)	HH
Length (m)	LENG
Plant species diversity	PSD
Presence of cultivated grains (1-4)	CROP
Presence of pasture or alfalfa (1-4)	PAST
Number of shrub[a] species	SSPT
Number of tree species	TSPT
Proximity of water < 1/4 mile (0-1)	PW4
Proximity of water < 1/2 mile (0-1)	PW2
Proximity of buildings < 1/4 mile (0-1)	PH4
Proximity of buildings < 1/2 mile (0-1)	PH2
Stem density (#/transect)	STEM
Average distance between each planting (m)	SBP
Shrub and tree foliage volume (m^3/m)	TFVL

[a] Any shrub or tree sapling < 7.7 cm DBH.

Avifauna

The Emlen (1971) transect method was used for estimating bird densities during all census periods in riparian woodland and tree claim study plots. Transects in the riparian woodland study plots ran perpendicular to the stream channel to minimize censusing bias that may have been induced by linear distribution patterns of birds parallel to the stream. Transects in tree claims crisscrossed at right angles. Emlen's method was adopted because of its efficiency and applicability for all seasons of the year.

Each study plot was visited once during each of the three census periods. Because the size of all study plots was less than 20 ha, multiple transects were required for proper application of the Emlen method (Emlen 1971). During June 1976, two transects were conducted during each study plot visit, but a high degree of variation in density estimates among fairly similar plots indicated insufficient sampling intensity. Also, two transects were not sufficient to detect several of the infrequently occurring bird species. In the 1976 winter census, and the 1977 spring migratory and reproductive censuses, four transects were conducted in each plot during each plot visit. A time lag of approximately 30 to 45 minutes between the initiation of each transect minimized disturbance induced by presence of the investigator. Observations made in each study plot during the analysis of vegetation in 1977 indicated that four transects were adequate to detect most of the infrequently occurring bird species. The degree of variation in estimates of density among similar plots was also substantially reduced using four transects.

The method recommended by Emlen to adjust the density estimates for each species to account for variable conspicuousness required comparing results of two or more different census techniques (Emlen 1971). This adjustment was not employed since only one census technique could be accomplished with the time and manpower available. House Wren territories, however, were mapped for 82% of the riparian woodland and tree claim study plots in an effort to evaluate the effect of nonadjustment for conspicuousness. The number of territories was determined by locating all singing males within each plot during the 1977 reproductive census period. Comparing the wren density estimates obtained from both methods indicated that the Emlen transect method using four transects provided an accurate estimate of the House Wren's relative densities, but underestimated the House Wren's actual densities by approximately 11.3% (range +20 to -39%, SD 11.6). Estimates of bird density for riparian woodland and tree claim habitat were considered minimum estimates of the actual bird densities present. Estimates of bird density in each of these two habitats were standardized by expressing the densities for regression analysis as birds per minimum plot area (area of the smallest plot in each habitat) and were expressed as birds per 40 ha for tabulated results.

Density estimates for the American Robin, Blue Jay, House Wren, Mourning Dove, Common Grackle, Starling, Red-headed Woodpecker, Hairy Woodpecker, House Sparrow, and Brown Thrasher (Appendix C lists the scientific names of all bird species detected during the study) were judged similar between the 1977 spring migratory and the 1977 reproductive census periods. The density estimates for each species from the two census periods were averaged. The resulting average was used to represent the density of these 10 species for both the 1977 spring migratory and the 1977 reproductive census periods. Each hawk, owl, Common Crow, Belted Kingfisher, Bald Eagle, and Merriam's Turkey detected while censusing was represented by a standard density of 0.1 bird per hectare since their large territory requirements made any density estimate within the study plots meaningless. This procedure allowed inclusion of these birds in diversity estimates and caused minimal effects on estimation of population density for each plot.

Bird densities in windbreaks were determined by walking parallel to the row of trees, approximately 5 m from the outside foliage, and making total counts. In June 1976, only those birds detected while walking along one side of the windbreak were recorded. During the 1976 winter, 1977 spring migratory, and 1977 reproductive census periods, any bird detected while walking along one side was recorded. In addition, while walking along the other side in the opposite direction, initial density estimates were evaluated and any additional birds detected were recorded. The increased sampling intensity for windbreaks balanced the greater sampling effort in tree claim and riparian woodland habitats during the same census periods. Estimates of bird density were standardized for regression analysis by expressing the densities as birds per minimum plot length (length of the shortest windbreak). Estimates of density were expressed as birds per 40 ha in tabulated results. Each windbreak was censused once during each of the three census periods.

Inconsistency in census results due to intermittent bird inactivity was minimized by conducting censuses within set climatic parameters and time periods. Censuses during the spring migratory and reproductive periods were conducted between 06:00-09:30, and from 19:00-21:00. Morning counts were conducted only when wind speeds were $<$ 12.0 km per hour, and when no rain had occurred during or 1 hour prior to censusing. Evening counts were conducted only under calm, clear conditions. Winter censuses were conducted throughout the day when wind speeds were < 24 km per hour and when no precipitation was falling.

The winter bird census was conducted from 18-25 December 1976, when only winter residents remained in the study plots. The spring migratory bird census was conducted from 8-28 May 1977, when spring transients were believed most abundant in the study plots. Species detected only during the spring migration census period were classified as transients. Selection of the migratory period was determined from reviewing migration records reported by Houston (1971, 1972) and Reynaud (1973). The reproductive bird census was conducted from 31 May-25 June 1976 and from 1-21 June 1977. Only resident, nesting bird species were present in the study plots during these dates. Due to the change in sampling intensity, the data from the 1976 reproductive period were used only qualitatively for indicating the presence of species not detected during the 1977 reproductive census period.

Diversity Estimates

Bird species diversity (BSD) was calculated for each study plot in order to evaluate the suitability of each plot in terms of the variety of birds that each supported. The Shannon-Weaver formula (Shannon and Weaver 1963) used in most BSD calculations is:

$$H' = -\sum_{i=1}^{S} p_i \log p_i \qquad (A)$$

where p_i is the proportion of individuals in the ith species ($i = 1,2,3,\ldots,S$). Poole (1974) points out that equation A is a biased estimate of H' and that the expected value to H' is best represented by:

$$H' = -\sum_{i=1}^{S} p_i \log p_i - ((S-1)/2N) \qquad (B)$$

where S is the total number of species (species richness) detected and N is the bird population estimate. Equation B was used for all BSD calculations.

Habitat Evaluation

The relative importance of riparian woodland, tree claim, windbreak, and shelterbelt habitats was evaluated according to the following criteria: (1) the number of bird species supported by each habitat; (2) the number of bird species which preferred each habitat; (3) the BSD and the average population densities supported by each habitat. The term unique was used to denote bird species which occurred in a minimum of two study plots in one habitat type and not another. Preferred habitat was defined as that habitat which supported the highest mean density (average density per all plots sampled within one habitat type) and the highest percentage frequency of occurrence of an individual bird species. The term preferred was not used to imply a behavioral response for a particular habitat type. When a species occurred most densely in one habitat type yet occurred most frequently in another habitat type, both habitats were usually considered preferred. In case of indecision the final decision was based on percent frequency of occurrence. Percent frequency of occurrence was considered a better predictor of habitat preference because there was a large difference in average plot size (Table 3) among habitat types and average plot size was inversely related to population density. Mean density was calculated for all bird species that occurred in two or more study plots in one habitat type during one census period. Data for shelterbelt habitat were obtained from 14 shelterbelts randomly selected from a possible 69 shelterbelt study plots censused in eastern South Dakota by Martin (unpubl. Masters Thesis, Brookings, South Dakota). Orthogonal t-tests were used to test for significant statistical differences in BSD and average bird population densities supported by the four habitats. Population density for each study plot was expressed as birds per 984.2 m^2 (minimum shelterbelt plot size) for the orthogonal t-tests.

Multivariate Analysis

Cluster analysis was used to group study plots within each habitat type according to similarities in vegetative cover type. The analytical procedure for the vegetative clustering was as follows:

1. A row by column matrix was prepared with the habitat variables of Tables 1 and 2 (except SIZE, LENG, CROP, PAST, PW, PH, and TFVL) as columns and study plots as rows.

2. Habitat variables were standardized by setting the maximum value in each column equal to 100 and scaling all other values accordingly.

3. An initial matrix of similarity was computed between all possible combinations of study plots using Horn's measurement of overlap (Horn 1966):

$$C = 2\left(\sum_{i=1}^{S} x_i y_i\right) / \left(\sum_{i=1}^{S} x_i^2 + \sum_{i=1}^{S} y_i^2\right)$$

where out of a total of S habitat variables, variable i is represented x_i times in plot x_o and variable i is represented y_i times in plot y_o.

4. The initial similarity matrix was then subjected to cluster analysis by the unweighted pair-group method discussed by Sneath and Sokal (1973).

The group of bird species detected in one plot during a plot visit was defined as a bird community. Bird communities from both the 1976 and 1977 reproductive period censuses were compared among all plots occurring within a distinctive vegetation cover type. Similar comparisons were made for the 1976 winter and 1977 spring migratory census periods. All bird species that occurred in a minimum of 25% of the bird communities compared were grouped into a composite community. These composite communities were compiled to serve as predictive communities representative of the vegetation cover types defined by the cluster procedure.

Multiple, step-wise regression analysis was used to test for correlations between the set of independent variables in Tables 1 and 2 (except PAST which is a perfect reciprocal of CROP) and the following dependent variables: BSD, standardized population density, standardized winter densities of the White-breasted Nuthatch, Downy Woodpecker, Hairy Woodpecker, and Black-capped Chickadee in riparian woodland habitat, and standardized densities of those birds which occurred most frequently in the study during the reproductive season. These species included the Mourning Dove, Blue Jay, American Robin, and Northern Oriole in riparian woodland habitat; the Common Flicker, American Robin, Common Grackle, Starling, and Brown Thrasher in tree claim habitat; and the Brown Thrasher, Eastern Kingbird, Red-winged Blackbird, Mourning Dove, and Black-billed Cuckoo in windbreaks.

Multiple, step-wise regression analysis allowed determination of which set of independent variables, taken together, was the best predictor of the dependent variable being tested. Coefficients of determination, regression coefficients, standardized regression coefficients, and simple correlation coefficients were calculated by the multiple regression program employed. Independent variables within each habitat type were tested with each habitat's respective dependent variables. The analysis was accomplished using South Dakota State University's computer facility and programs contained in the SPSS program package (Nie et al. 1975).

Standardized regression coefficients (Beta) were used to indicate the direction of influences, whether positive or negative, and the relative importance of the influences of the independent variables incorporated into the regression equations. The Beta value for a particular variable reflects the variable's relative influence in the regression equation when the effects of all other variables within the same regression equation are held constant. This condition can be satisfied only when the independent variables are free of intercorrelations. Many of the independent variables used in the multiple regression analysis were highly intercorrelated as indicated in Appendix D. Because of these intercorrelations caution is warranted in interpreting the Beta values. Unstandardized regression coefficients (B) were tabulated to provide prediction capabilities.

RESULTS AND DISCUSSION

Reproductive Season

Avian Communities. Riparian woodlands supported the most bird species (57) followed, in descending order, by tree claims (41), windbreaks (36), and shelterbelts (29) during the 1976 and 1977 reproductive seasons (Table 3). The House Wren and Mourning Dove were the two most frequently occurring species in both riparian woodland and tree claim habitat. The Mourning Dove was the sixth most frequently occurring species in windbreak habitat. The Mourning Dove, American Robin, and Common Grackle occurred in 100% of the study plots in shelterbelt habitat. The five most frequently occurring species in windbreak habitat, in order of decreasing frequency, were Vesper Sparrow, Eastern Kingbird, Orchard Oriole, Brown Thrasher and American Robin.

Although many of the bird species were common to all four habitat types, some of these species exhibited specific habitat preferences (indicated by a "p" superscript). Other species were associated only with one or two habitat types. Twenty-two, 13, 10, and 9 bird species indicated preferences for riparian woodland, tree claim, shelterbelt, and windbreak habitat, respectively (Table 3).

The Dickcissel, Lark Sparrow, and Clay-colored Sparrow were the only species that occurred in a minimum of two study plots within one habitat type, and that were

TABLE 3. Mean densities and percent frequencies of birds observed in four woodland habitats of the eastern quarter of South Dakota during the 1977 reproductive season.

	Habitat							
	Riparian woodland		Tree claim		Single-row windbreak		Multi-row shelterbelt	
Species	D^{a}	F^{b}	D^{a}	F^{b}	D^{a}	F^{b}	D^{a}	F^{b}
Red-tailed Hawk		7^{c}		21^{p}				
Swainson's Hawk				21^{p}				
American Kestrel		7						
Bobwhite Quail		7						
Killdeer	4.6	21^{p}						
American Woodcock		7						
Mourning Dove	76.4	100	86.2	100	131.4	71	804.7	100^{p}
Yellow-billed Cuckoo		7^{c}						
Black-billed Cuckoo	10.6	50	12.0	100^{p}	100.0	57^{p}	11.6	29
Screech Owl				7^{c}				
Great Horned Owl		21		71^{p}		7		
Belted Kingfisher		14^{p}						
Common Flicker	33.6	100^{p}	28.2	100^{p}	27.2	36	5.8	14
Red-bellied Woodpecker		7						
Red-headed Woodpecker	21.4	71^{p}	16.6	86^{p}	9.0	14		14
Yellow-bellied Sapsucker		7						
Hairy Woodpecker	12.6	64	15.2	93^{p}		7		
Downy Woodpecker	20.2	79^{p}	12.6	64		7	11.6	21
Eastern Kingbird	27.0	64	14.0	50	288.5	93^{p}	58.1	64
Western Kingbird		7	4.6	21	32.0	21	92.9	57^{p}
Great Crested Flycatcher	13.6	50^{p}	4.2	50				
Empidonax Flycatcher		7						
Eastern Wood Pewee	6.0	43^{p}		7		7		14
Rough-winged Swallow		7^{c}						
Blue Jay	17.6	93	23.4	100^{p}	5.8	29	8.7	14
Common Crow				21^{p}				
Black-capped Chickadee	37.8	79^{p}	20.4	71		7	17.4	14
White-breasted Nuthatch	16.0	71^{p}	3.6	14		7^{c}		
House Wren	147.2	100^{p}	106.0	100^{p}	38.0	14	29.0	43
Gray Catbird	10.2	50^{p}	0.9	14	4.8	14		7
Brown Thrasher	9.0	57	12.2	86	102.2	79^{p}	66.8	79^{p}
American Robin	49.2	93	24.6	93	66.6	79	232.0	100^{p}
Wood Thrush		7						
Olive-backed Thrush		7						
Eastern Bluebird	10.6	21^{p}		14^{c}				
Starling	29.4	79	56.8	79^{p}		7		21^{c}
Bell's Vireo		7						
Red-eyed Vireo			1.2	14^{p}		7		
Philadelphia Vireo	1.8	14^{p}		7^{c}				
Warbling Vireo	12.2	29^{p}				7		
Yellow Warbler	5.4	14^{p}				7		7
Common Yellowthroat	20.6	57	8.0	79	49.6	50	49.4	71^{p}
Mourning Warbler		7^{c}						
Wilson's Warbler		7^{c}						
Canada Warbler		7^{c}						
House Sparrow	19.0	50	31.6	64	20.6	21	577.7	86^{p}
Western Meadowlark	2.2	14^{p}						7^{c}
Red-winged Blackbird	72.3	36	0.6	29	301.2	64^{p}	95.8	36
Common Grackle	27.0	50	37.8	93	74.2	57	949.6	100^{p}
Brown-headed Cowbird	29.4	71^{p}	5.4	50	43.0	43	34.3	36
Orchard Oriole	15.2	57	3.2	36	72.4	86^{p}	87.0	71^{p}
Northern Oriole	35.8	93^{p}	7.2	57	24.6	29		21
Scarlet Tanager				7^{c}				
Cardinal	1.4	36^{p}						
Rose-breasted Grosbeak	30.9	93^{p}	1.4	21		7		7
Black-headed Grosbeak		7^{c}						7^{c}
Blue Grosbeak				7				
Indigo Bunting	11.4	36^{p}	4.2	36		7		
American Goldfinch	13.6	64	2.2	21	44.4	43	78.4	71^{p}
Dickcissel					44.6	29^{p}		7
Rufous-sided Towhee		7						
Vesper Sparrow			4.5	43	293.4	93^{p}		
Lark Sparrow					17.8	14^{p}		
Clay-colored Sparrow					87.4	36^{p}		
Field Sparrow		7^{c}		7^{c}				
Fox Sparrow		7^{c}						
Song Sparrow	33.2	50^{p}	13.8	86^{p}	4.2	21	66.8	43^{p}

TABLE 3. (Continued)

	Habitat			
	Riparian woodland	Tree claim	Single-row windbreak	Multi-row shelterbelt
Number of species	57	41	36	29
Number of species preferring each habitat	22	13	9	10
Avg. population density (birds/40 ha)	846.2	559.4	1952.6	3205.5
Avg. plot size (ha)	2.9	3.6	0.5	1.0

[a] Mean density (birds/40 ha) based on 1977 census results.
[b] Percent frequency of occurrence based on 1976 and 1977 census results.
[c] Detected only during the 1976 reproductive season census period.
[p] Preferred habitat.

associated with shelterbelt and windbreak habitats but not associated with riparian woodland and tree claim habitats. These species, however, do not require woody vegetation for nesting (Austin 1968). All other species occurring in a minimum of two shelterbelt or windbreak study plots were associated with riparian woodland and/or tree claim habitat.

The Swainson's Hawk, Common Crow, Red-eyed Vireo, and Vesper Sparrow were the only species that occurred in a minimum of two tree claim study plots and that did not occur in riparian woodland habitat. The Vesper Sparrow is the only member of this group not requiring woody vegetation for nesting (Sutton 1960, Wiens 1969).

All birds of prey and the Common Crow indicated a preference for tree claim habitat during all seasons of the year (Tables 3, 4, and 5). The large, block-like shape and high tree density of tree claims relative to riparian woodlands, shelterbelts, and windbreaks offered more seclusion for breeding raptors and crows, as well as breeding or roosting owls. The only riparian woodland study plot (R5) that supported raptors was large (8.7 ha) and had a high tree density (72 trees/0.4 ha). The only riparian woodland study plots which supported Great Horned Owls (R1A, R3, R5) were large ($\bar{x}$ = 5.3 ha), although total tree density varied from 28-72 trees/0.4 hectares. A Great Horned Owl was detected in a small (1.9 ha) riparian woodland plot (R1), but the study plot was surrounded by more than 6 ha of open-riparian woodlands. The apparent tree claim habitat preferences of birds of prey and Common Crow were believed related to plot size and tree density. The habitat preference of the Great Horned Owl appeared related to plot size.

Bird Population Density. Shelterbelts supported the highest average bird density (3305.9 birds/40 ha) followed, in descending order, by windbreaks (1952.6 birds/40 ha), riparian woodlands (846.2 birds/40 ha), and tree claims (559.4 birds/40 ha) during the reproductive season (Table 3). Differences among habitats were highly significant (Table 6). Densities for shelterbelt and windbreak habitats were expressed as birds per unit area solely for comparison purposes. It must be emphasized that the densities expressed for these two habitats in Tables 3, 4, and 5 can only be supported in shelterbelts or windbreaks that are not in close proximity. Forty, 1 ha windbreaks contained in a contiguous 40 ha area are no longer windbreak habitats, but would resemble one block of woodland habitat and would probably support bird densities similar to the densities reported for tree claim habitat.

Average population density was inversely related to the average plot size for each habitat. Windbreak habitat, however, had the smallest average plot size, yet supported fewer birds than shelterbelt habitat (Table 3). This departure from the overall inverse relationship between average population density and average plot size was mainly attributed to the drop in mean densities of the Mourning Dove, American Robin, House Sparrow, and Common Grackle in windbreak habitat. Windbreaks were not as attractive as shelterbelts to these four species. The differences in percent frequency of occurrence between shelterbelt habitat and windbreak habitat (Table 3) for these species support this concept. The closer proximity of shelterbelt habitat to farm yards, as compared to the proximity of windbreak habitat to farm yards, also contributed to the higher mean density of House Sparrows in shelterbelt habitat.

The inverse relationship between the average plot size of the habitats and population densities appeared to be a function of plot size and its influence on two factors: (1) the total number of bird species within a habitat type that forage in adjacent treeless fields, and (2) the extent with which each of the species forages in these adjacent fields. Extent is defined as the area utilized in adjacent fields relative to the area utilized in the woodland habitat.

If the differences in average population densities among habitats were due solely to the differences in plot size and its influence on the foraging location of birds, then population densities would not differ among habitats if the plots were the same size. Average population densities of six riparian woodland and six tree claim plots of comparable size were not different at the $p < 0.05$ level (p = 0.336), in contrast to the difference (p = 0.004) obtained when all plots were compared (Table 6). Beecher (1942) also found that population density was higher in smaller woodland tracts relative to larger tracts. Kendeigh (1944) and Johnston (1970) found bird densities increased when smaller woodland tracts were created by opening a previously closed forest.

During the reproductive season the bird population densities supported by shelterbelt, windbreak, riparian woodland, and tree claim habitats were a minimum of 100% higher than the average population densities reported by Hicks (1935), Damback (1941), and Kendeigh (1944) for larger blocks of deciduous woodlands in the eastern United States. The higher population densities supported by the woodland habitats in the eastern quarter of South Dakota were probably due to their proximity to large areas of prairie and agricultural land.

Carothers et al. (1974) found that dense bird populations in narrow riparian woodlands of Arizona could be attributed to four factors: (1) relatively few class A territories (Nice 1941), (2) relative productivity of adjacent habitats such as cropland, second growth fields, and pastures, (3) relative absence of nesting bird species in the adjacent habitats resulting in the absence of intra and/or interspecific competition for the food in the adjacent habitat, and (4) large body size of the birds making it energetically feasible to fly long distances for food. Factors (2) and (3) seem applicable to this study because of the agricultural nature of eastern South Dakota. Also, large bird species such as the Mourning Dove, Eastern Kingbird, Brown Thrasher, American Robin, Common Grackle, Brown-headed Cowbird, and Orchard Oriole observed foraging in adjacent habitat occurred in high mean densities, especially in the shelterbelt and windbreak habitats (Table 3). The House Sparrow, Dickcissel, Vesper Sparrow, and Clay-colored Sparrow, although smaller in size, were also observed foraging in adjacent habitat and occurred in high densities. The Common Flicker and Starling were two large species occurring at high densities in tree claim and riparian woodland habitat, and were observed foraging in treeless fields adjacent to woodlands.

BSD. The difference in bird species diversity between windbreak and shelterbelt habitat was nonsignificant at the $p < 0.05$ level ($p = 0.725$). The difference in bird species diversity between tree claim and riparian woodland habitat was also nonsignificant at the $p < 0.05$ level ($p = 0.188$). The BSD pooled mean for windbreak and shelterbelt habitats was, however, lower ($p = 0.001$) than the pooled mean of BSD for tree claim and riparian woodland habitats (Table 6).

The significantly lower BSD values for windbreak and shelterbelt habitats were probably related to small plot size and relatively simple vegetation structure. Work by

Galli (1974), and results of regression reported in this study, indicated a significant, positive correlation between plot size and BSD. Work by MacArthur and MacArthur (1961), MacArthur (1964), Karr (1968), and Karr and Roth (1971) showed significant, positive correlations between BSD and vertical vegetation complexity measured as foliage height diversity (FHD). MacArthur (1964) concluded that vertical complexity was sufficient to account for changes in BSD among small homogenous woodlands. Horizontal diversity or "patchiness", however, has been shown to be an additional predictor of BSD for series of similar habitats such as shrublands (Roth 1976). Roth also found that closed-canopy forests were less patchy and supported a lower BSD than forests with broken canopies. Windbreaks and shelterbelts had minimal "patchiness". Tree claims had minimal "patchiness" as indicated by an average interior openness of 5.5% and a 70.0% average canopy coverage. Riparian woodlands had considerable "patchiness" as suggested by an average openness value of 40.2% and a 46.0% average canopy coverage. A herb, shrub, and tree layer were present in all habitat types, but the shrub and tree layers were reduced to one layer in all windbreak study plots except three (R1, R12, and R14). Also, tall, rank weeds that tended to increase vertical complexity were found only in riparian woodland habitat.

Plot size and vegetative complexity increased in tree claim and riparian woodland habitats when contrasted to windbreaks and shelterbelts and were believed responsible for the significantly higher BSD values for the former types. The concept of a direct relationship between vegetation complexity and BSD appeared applicable to the riparian woodland and tree claim habitats if plot sizes are comparable. Riparian woodland habitat supported a higher BSD ($p = 0.020$) than tree claim habitat when the influence of plot size was reduced (Table 6).

Spring Migration Season

Avian Communities. Riparian woodlands supported the most transient species (25) followed, in descending order, by tree claims (18), shelterbelts (16), and windbreaks (10) during the 1977 spring migration season (Table 4). The Tennessee Warbler and Blackpoll Warbler were the two most frequently occurring transients in riparian woodland habitat. The Olive-backed Thrush, Empidonax Flycatcher, Tennessee Warbler, and Blackpoll Warbler, in that order, were the four most frequently occurring transients in tree claim habitat. The Chipping Sparrow, Empidonax Flycatcher, and Yellow Warbler were the three most frequently occurring transients in shelterbelt habitat. The Empidonax Flycatcher was the most frequently occurring transient in windbreak habitat.

Eleven, 12, 3, and 3 species indicated preferences for riparian woodland, tree claim, shelterbelt, and windbreak habitat, respectively (Table 4). The Red-eyed Vireo,

TABLE 4. Mean densities and percent frequencies of transient[a] birds observed in four woodland habitats of the eastern quarter of South Dakota during the 1977 spring migration season.

	Habitat							
	Riparian woodland		Tree claim		Single-row windbreak		Multi-row shelterbelt	
Species	D^b	F^c	D^b	F^c	D^b	F^c	D^b	F^c
Swainson's Hawk[f]		7		$14^{d,p}$				
Merriam's Turkey[f]		7						
Wood Duck[f]	1.8	14^p						
Hairy Woodpecker	8.4	$64^{d,p}$	11.6	$57^{d,p}$				7
Empidonax Flycatcher	27.0	$57^{d,p}$	18.6	64^p	71.4	21	31.9	43
Brown Creeper		7						
Winter Wren		7						
Olive-backed Thrush	23.6	43^d	37.8	73^p	28.0	14	11.6	7
Red-eyed Vireo		7	5.6	$43^{d,p}$		7^d		
Warbling Vireo	13.4	$36^{d,p}$	3.6	36	17.0	14^d		
Black-and-white Warbler		7		7				7
Tennessee Warbler	29.4	57^p	16.6	57^p	22.2	14	14.5	29
Orange-crowned Warbler	2.6	14^p						
Nashville Warbler		7	2.2	14^p				7
Yellow Warbler	11.4	$29^{d,p}$	5.8	36^p	35.6	$21^{d,p}$	25.1	$36^{d,p}$
Magnolia Warbler				7				
Cape May Warbler								7
Yellow-rumped Warbler	1.8	14					11.6	29^p
Black-throated-green Warbler								7
Chestnut-sided Warbler			1.8	14^p				
Blackpoll Warbler	10.2	36	12.2	43^p				
Ovenbird	3.0	14^p	2.8	14^p	8.2	14^p		
Northern Waterthrush	7.6	14^p						
Yellow-breasted Chat				7				
Wilson's Warbler				7				7
Canada Warbler						7		
American Redstart		7	7.6	29^p				7
Rufous-sided Towhee								7
Chipping Sparrow		7	9.4	14	21.4	14	53.8	43^p
Clay-colored Sparrow	6.0	14			320.0	$50^{d,p}$	17.4	21
Harris' Sparrow	5.6	14^p						
White-crowned Sparrow		7						7
Lincoln Sparrow	2.6	14^p						
Number of species	25		18		10		16	
Number of species preferring each habitat	11		12		3		3	
Avg. population density (birds/40 ha)[e]	901.0		703.8		2905.8		2389.2	

[a] Occurring only during the spring migration census period.
[b] Mean density (birds/40 ha).
[c] Percent frequency of occurrence based on 1977 census results.
[d] Spring migration results for species which were observed during the reproductive census period. Included for comparison among habitat types, when the species was transient in one or more habitat types.
[e] All species which occurred during the spring migration census period.
[f] Known to nest in study area. Included with transients because the species was not detected during the reproductive census period.
[p] Preferred habitat.

American Redstart, and Blackpoll Warbler indicated a preference for tree claim habitat. The Empidonax Flycatcher showed no apparent habitat preference. Although tree claim habitat supported fewer total species than riparian woodland habitat, more transient species preferred tree claim habitat during the spring migration season.

No unique species occurred in shelterbelt or windbreak habitats. The Chestnut-sided Warbler was the only species that occurred in a minimum of two tree claim study plots and not in riparian woodland habitat (Table 4).

Bird Population Density. Windbreak habitat supported the highest average bird density (2905.8 birds/40 ha) followed, in descending order, by shelterbelts (2389.2 birds/40 ha), riparian woodlands (901.0 birds/40 ha), and tree claims (703.8 birds/40 ha) (Table 4). The only difference ($p = 0.001$), however, was between the pooled mean of population density for shelterbelt and windbreak habitats and the pooled mean of population density for tree claim and riparian woodland habitats (Table 6). Average population density during spring migration was inversely related to average plot size for each habitat and paralleled the findings during the reproductive season.

Average population densities were greater during migration than for the reproductive season in all habitats except shelterbelts. Higher average population densities were expected because of the presence of both transients and nesting species during the spring migration season.

The date of census initiation in shelterbelt habitat was earlier than in the other three habitat types during the 1977 migration census period. Many transients were not in the state during the early portion of the shelterbelt census period (T. E. Martin, pers. comm.). The earlier census initiation was the probable cause for the drop in average population density for shelterbelt habitat and the nonsignificant difference ($p = 0.801$) in average population densities between windbreak and shelterbelt habitats.

Average population density was not significantly different between tree claim and riparian woodland habitats at the $p < 0.05$ level ($p = 0.164$), unlike the significant difference which existed during the reproductive season. The difference in population densities between tree claims and riparian woodlands was smaller during spring migration because tree claims were more attractive to transients.

<u>BSD</u>. The difference in BSD between windbreak and shelterbelt habitats was not significant at the $p < 0.05$ level ($p = 0.812$). The difference in BSD between tree claim and riparian woodland habitats was also nonsignificant ($p = 0.498$). The BSD pooled mean for windbreak and shelterbelt habitats was, however, lower ($p = 0.001$) than the BSD pooled mean for tree claim and riparian woodland habitats (Table 6). The lower BSD values for windbreak and

shelterbelt habitats relative to tree claim and riparian woodland habitats were probably due to small plot size and simple vegetative structure.

The nonsignificant difference in BSD between tree claim and riparian woodland habitats paralleled results of the reproductive season, but mean BSD for tree claim habitat (2.600) was larger than mean BSD for riparian woodland habitat (2.512) during spring migration. During the reproductive season the mean BSD was larger in riparian woodland habitat. BSD between six tree claim and six riparian woodland study plots of comparable size was not significantly different at the $p < 0.05$ level ($p = 0.483$). This was a reversal of the results from the reproductive season.

Winter Season

Avian Communities. Riparian woodlands supported the most bird species (14) followed, in descending order, by tree claims (10), shelterbelts (9), and windbreaks (2) (Table 5). The Black-capped Chickadee and White-breasted Nuthatch were the first and second most frequently occurring and abundant species, respectively, in both riparian woodland and tree claim habitats. The Hairy and Downy Woodpeckers occurred frequently in both riparian woodland and tree claim habitats. The House Sparrow was the most frequently occurring and abundant species in shelterbelt habitat. The Downy Woodpecker and Black-capped Chickadee

TABLE 5. Mean densities and percent frequencies of birds observed in four woodland habitats of the eastern quarter of South Dakota during the 1976 winter season.

	Habitat							
	Riparian woodland		Tree claim		Single-row windbreak		Multi-row shelterbelt	
Species	D^a	F^b	D^a	F^b	D^a	F^b	D^a	F^b
Bald Eagle		7						
Mourning Dove								7
Great Horned Owl		21		64^P				14
Common Flicker	3.0	14^P						
Hairy Woodpecker	14.4	57^P	4.4	43				
Downy Woodpecker	15.2	57^P	14.8	64^P		7	29.0	14
Blue Jay		7					29.0	14^P
Common Crow				7				
Black-capped Chickadee	54.6	57^P	21.8	43		7	29.0	14
White-breasted Nuthatch	19.4	57^P	15.4	64^P				
American Robin				7				
Bohemian Waxwing								7
Starling	3.4	21	10.2	36^P				
House Sparrow	8.0	29	16.2	21^P			194.5	36^P
Red-winged Blackbird		7						
Cardinal		7						
Dark-eyed Junco	13.4	14^P		7			8.7	14
Tree Sparrow							139.3	36^P
Harris' Sparrow		7						
Number of species	14		10		2		9	
Number of species preferring each habitat	6		4		0		3	
Avg. population density (birds/40 ha)	150.2		86.6		15.4		586.2	

[a] Mean density (birds/40 ha).
[b] Percent frequency of occurrence.
[P] Preferred habitat.

were the only two species observed in windbreak habitat and occurred in only one plot.

Six, 4, 3, and 0 species indicated preferences for riparian woodland, tree claim, shelterbelt, and windbreak habitats, respectively (Table 5). The Common Flicker, Hairy Woodpecker, Black-capped Chickadee, and Dark-eyed Junco indicated a preference for riparian woodland habitat, while the Great Horned Owl and Starling indicated a preference for tree claim habitat. The Downy Woodpecker and White-breasted Nuthatch indicated a similar preference for both riparian woodland and tree claim habitats. The Blue Jay, House Sparrow, and Tree Sparrow indicated a preference for shelterbelt habitat (Table 5).

The Common Flicker was the only species unique to riparian woodland habitat. The Blue Jay and Tree Sparrow were unique to shelterbelt habitat.

Bird Population Density. Shelterbelts supported the highest average bird density (586.2 birds/ 40 ha) followed, in descending order, by riparian woodlands (150.2 birds/40 ha), tree claims (86.6 birds/40 ha), and windbreaks (15.4 birds/40 ha) (Table 5). Average densities of birds in tree claim and riparian woodland habitats were not significantly different at the $p < 0.05$ level ($p = 0.282$). No t-test was possible between windbreaks and shelterbelts. The average bird density in shelterbelts was higher ($p = 0.018$) than the pooled density for tree claim and riparian woodland habitats (Table 6).

Windbreak habitat was not suitable for supporting wintering birds. Tree claim and riparian woodland habitats were equally suitable for supporting the more common wintering species. Although shelterbelts supported the highest average bird density, House Sparrows comprised 33% of this density.

BSD. No t-test was possible between windbreaks and shelterbelts. The difference in BSD between tree claim and riparian woodland habitats was not significant at the $p < 0.05$ level ($p = 0.958$). Also, the mean BSD associated with six tree claim study plots was not different ($p = 0.970$) from the mean BSD associated with six riparian woodland study plots of comparable size. The BSD pooled mean for tree claim and riparian woodland habitats was, however, higher ($p = 0.005$) than the pooled mean of BSD for shelterbelts (Table 6).

In terms of overall habitat, riparian woodlands supported the most bird species during the winter season. The presence of open water, wintering waterfowl, and available fish was the probable reason the Bald Eagle was attracted to riparian woodland habitat and not the other three habitat types. The Cardinal and Harris' Sparrow were probably attracted to riparian woodland habitat because of the presence of tall, rank weeds.

TABLE 6. Orthogonal t-tests for significant differences in bird population densities and bird species diversities supported by four woodland habitats in the eastern quarter of South Dakota.

		Season																	
		Winter 1976						Spring migration 1977						Reproductive 1977					
Habitat	Sample size	Mean	SD	Significance level	Pooled mean	SD	Significance level	Mean	SD	Significance level	Pooled mean	SD	Significance level	Mean	SD	Significance level	Pooled mean	SD	Significance level
							Bird species diversity[a]												
Single-row	14	0.028	0.103					1.761	0.586	0.812	1.786	0.542	0.001	1.745	0.610	0.725	1.711	0.495	0.001
Multi-row	14	0.352	0.512				0.005	1.811	0.515					1.677	0.365				
Tree claim	14	0.864	0.357	0.958	0.869	0.530		2.600	0.228	0.498	2.556	0.335		2.330	0.148	0.188	2.397	0.757	
Riparian	14	0.875	0.675					2.512	0.421					2.465	0.341				
							Bird population density[b]												
Single-row	14	0.043	0.160					7.150	6.306	0.517	6.514	5.048	0.001	4.706	2.431	0.080	6.461	4.970	0.001
Multi-row	14	1.443	1.592				0.018	5.879	3.505					8.136	6.273				
Tree claim	14	0.214	0.175	0.282	0.292	0.375		1.743	0.723	0.164	1.986	0.912		1.386	0.464	0.004	1.739	0.679	
Riparian	14	0.371	0.498					2.229	1.037					2.093	0.638				
							Bird species diversity[a,c]												
Tree claim	6	0.942	0.207	0.970				2.543	0.210	0.483				2.234	0.149	0.020			
Riparian	6	0.955	0.799					2.626	0.185					2.591	0.221				
							Bird population density[b,c]												
Tree claim	6	0.250	0.187	0.596				1.883	0.895	0.889				1.617	0.542	0.336			
Riparian	6	0.400	0.629					1.817	0.711					1.793	0.697				

[a] Shannon-Weaver index.
[b] Number of birds/934.2 m^2.
[c] Tree claim and riparian woodland study plots of comparable size (T15, R18, T6, R6, T4, R7, T18, R8, T22, R14, T3, R12).

Vegetation Cluster Analysis

Results of vegetation cluster analysis for each habitat type are presented in three phenograms (Figs. 2, 3, and 4). Study plots are listed on the horizontal axis of the phenograms while the vertical axis represents the percentage similarity of the vegetation characteristics within the study plot. The 70% level of similarity was chosen for analysis of the phenograms. This level, represented by the horizontal dotted line on each phenogram, separates each habitat type into the same number of distinctive clusters as vertical lines intersected. Each cluster, which contains those study plots with vegetation characteristics 70% similar or greater, represents one vegetation cover type.

Riparian Woodland Habitat. Three distinct clusters (cover types) labeled A, B, and C were delineated in riparian woodland habitat (Fig. 2). Cover type A was parklike and characterized by sparse stands of mixed deciduous trees and shrubs. Cover type B was characterized by a dense stand of cottonwood trees and a dense shrub layer. Cover type C was characterized by a dense stand of mixed deciduous trees and a moderately dense shrub layer (Table 7).

The reproductive bird communities associated with cover types A, B, and C were similar in species composition, although type C supported the fewest species. Thirty-three.

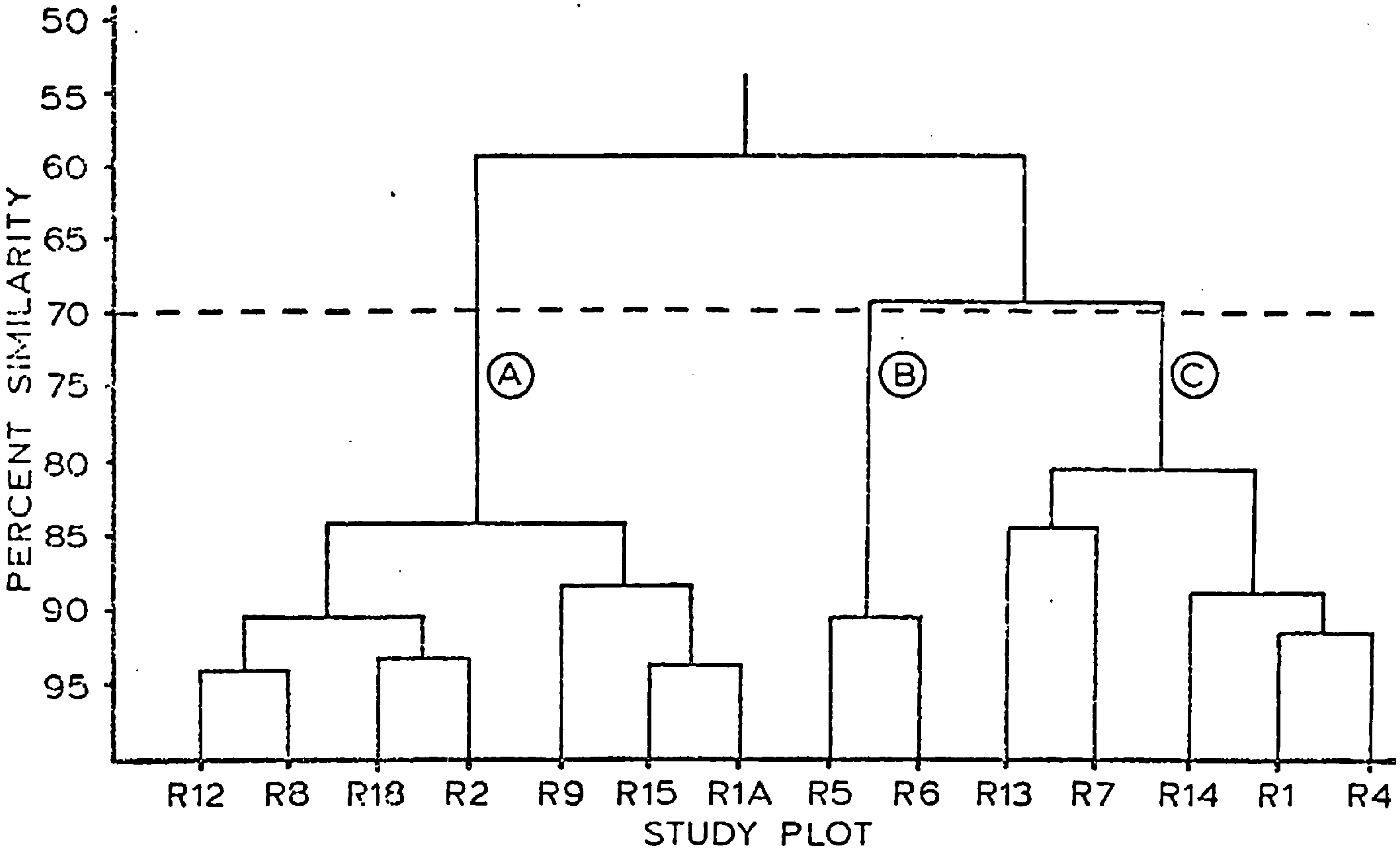

FIGURE 2. Phenogram of vegetation cover types resulting from vegetation cluster analysis of 19 vegetation variables measured in riparian woodland habitat. The phenogram was analyzed at the 70% level of similarity (---). The three cover types delineated are described in Table 7.

TABLE 7. Vegetation and physical variables used to describe the riparian woodland vegetation cover types (Fig. 2).

Vegetation and physical variables	Cover type					
	A		B		C	
	Range	Mean	Range	Mean	Range	Mean
Total tree density (#/0.4 ha)	23.0-46.0	32.2	72.0-111.0	91.5	95.0-180.0	144.2
Tree foliage volume (m^3/0.4 ha)	3178.0-9204.0	5352.7	4697.0-9655.0	7176.0	4348.0-6521.0	5408.0
Shrub foliage volume (m^3/0.4 ha)	1.0-220.0	54.0	2789.0-5331.0	4060.0	15.0-1440.0	676.8
Canopy height (m)	14.1-18.3	15.6	21.6-23.8	22.7	17.0-19.3	17.7
Herb height (m)	0.3-1.4	0.7	0.8-1.4	1.1	0.1-1.7	0.9
Plot size[b] (ha)	0.7-5.3	2.8	3.6-8.7	6.2	0.9-2.9	1.7
Dominant tree species	green ash, elm[a], and boxelder		cottonwood		green ash, elm[a], and boxelder	

[a] Slippery and American.
[b] Average plot size of all study plots included in a cover type.

35, and 26 species were associated with types A, B, and C, respectively (Table 8). Cover type B supported eight unique species, while Killdeer, Belted Kingfisher, and Western Meadowlark were the only species unique to type A. The Eastern Bluebird was the only species unique to the dense tree habitat of cover type C. Six species were associated in common with the sparse tree habitat of cover type A and moderately dense tree habitat of type B and not with type C. No species were associated in common with the moderately dense tree habitat of type B and the dense tree habitat of type C and not with cover type A.

Cover type B was composed of two study plots located along the extensive Missouri River floodplain in southeastern South Dakota. These plots were sufficiently extensive to be similar to the deciduous forests of the eastern United States. These two study plots supported the highest tree foliage volume and shrub foliage volume of all the study plots analyzed in riparian woodland habitat (Table 7). The eight unique species associated with cover type B probably occurred because of the location, size, and vertical vegetation complexity of the two study plots comprising this cover type.

The small, average plot size of cover type C relative to both types A and B (Table 7) possibly influenced the number of bird species associated with type C. MacArthur and MacArthur (1961) pointed out that the number of bird

TABLE 8. Bird communities[a] associated with three riparian woodland cover types during the 1977 reproductive season.

	Cover type A (7)[b]	Cover type B (2)[b]	Cover type C (5)[b]
		Red-tailed Hawk (50)	
	Killdeer (43)[c]		
		American Woodcock (50)	
	Mourning Dove (100)	Mourning Dove (100)	Mourning Dove (80)
	Black-billed Cuckoo (43)	Black-billed Cuckoo (100)	Black-billed Cuckoo (40)
	Great Horned Owl (29)	Great Horned Owl (50)	
	Belted Kingfisher (29)		
	Common Flicker (100)	Common Flicker (100)	Common Flicker (100)
	Red-headed Woodpecker (86)	Red-headed Woodpecker (100)	Red-headed Woodpecker (40)
	Hairy Woodpecker (57)	Hairy Woodpecker (100)	Hairy Woodpecker (60)
	Downy Woodpecker (71)	Downy Woodpecker (100)	Downy Woodpecker (30)
		Red-bellied Woodpecker (50)	
	Eastern Kingbird (71)	Eastern Kingbird (100)	Eastern Kingbird (60)
	Great Crested Flycatcher (43)	Great Crested Flycatcher (100)	Great Crested Flycatcher (50)
	Eastern Wood Pewee (57)	Eastern Wood Pewee (100)	
	Blue Jay (100)	Blue Jay (100)	Blue Jay (80)
	Black-capped Chickadee (71)	Black-capped Chickadee (100)	Black-capped Chickadee (80)
	White-breasted Nuthatch (71)	White-breasted Nuthatch (100)	White-breasted Nuthatch (50)
	House Wren (100)	House Wren (100)	House Wren (100)
	Gray Catbird (43)	Gray Catbird (100)	Gray Catbird (40)
	Brown Thrasher (71)	Brown Thrasher (100)	
	American Robin (86)	American Robin (100)	American Robin (100)
			Eastern Bluebird (40)
	Starling (71)		Starling (60)
		Bell's Vireo (50)	
		Philadelphia Vireo (50)	
		Warbling Vireo (100)	
	Common Yellowthroat (71)	Common Yellowthroat (50)	Common Yellowthroat (40)
	House Sparrow (57)	House Sparrow (50)	House Sparrow (40)
	Western Meadowlark (29)		
	Red-winged Blackbird (57)	Red-winged Blackbird (50)	
	Common Grackle (57)		Common Grackle (60)
	Brown-headed Cowbird (71)	Brown-headed Cowbird (100)	Brown-headed Cowbird (60)
	Orchard Oriole (71)	Orchard Oriole (100)	Orchard Oriole (40)
	Northern Oriole (86)	Northern Oriole (100)	Northern Oriole (60)
	Cardinal (29)	Cardinal (50)	Cardinal (40)
	Rose-breasted Grosbeak (71)	Rose-breasted Grosbeak (100)	Rose-breasted Grosbeak (100)
		Black-headed Grosbeak (50)	
	Indigo Bunting (43)	Indigo Bunting (50)	
	American Goldfinch (57)	American Goldfinch (100)	American Goldfinch (60)
		Rufous-sided Towhee (50)	
	Song Sparrow (57)		Song Sparrow (60)
Number of species	33	35	26
Unique[d] species	3	8	1

---

[a] All birds occurring in 25% or more of the study plots composing each cover type.
[b] Number of study plots in each cover type.
[c] Percent frequency of occurrence based on 1976 and 1977 census results.
[d] Birds associated with only one cover type.

species increases as size of the area censused increases. Galli (1974) demonstrated this relationship statistically. Additional research using study plots of equal size is required to substantiate that dense tree stands with heavy shrub understories do not support unique bird species as compared to those species supported by parklike, riparian woodland habitat during the reproductive season in the area of study.

The bird populations associated with cover types A, B, and C during spring migration contained many of the same species. Thirty, 34, and 23 species were associated with cover types A, B, and C, respectively (Table 9). The fewest species for the spring migration season were associated with cover type C, paralleling the reproductive season findings. No unique species were associated with type C during the spring migration season. The moderately dense tree habitat of cover type B and the dense habitat of cover type C, however, supported four species in common--the Warbling Vireo, Yellow Warbler, Gray Catbird, and Blackpoll Warbler. These species were not associated with cover type A. Four unique species were associated with type A, and eight were associated with type B. Although the Eastern Wood Pewee, Orchard Oriole, and Indigo Bunting appeared to be associated with only cover type B, they were also associated with one or both of the other two types during the reproductive

TABLE 9. Bird communities[a] associated with three riparian woodland cover types during the 1977 spring migration season.

	Cover type A (7)[b]	Cover type B (2)[b]	Cover type C (5)[b]
		Swainson's Hawk (50)[c]	
		Merriam's Turkey (50)	
	Killdeer (29)		
	Mourning Dove (86)	Mourning Dove (100)	Mourning Dove (100)
	Common Flicker (71)	Common Flicker (100)	
	Red-headed Woodpecker (71)	Red-headed Woodpecker (100)	Red-headed Woodpecker (50)
	Hairy Woodpecker (56)	Hairy Woodpecker (50)	Hairy Woodpecker (80)
	Downy Woodpecker (43)	Downy Woodpecker (50)	Downy Woodpecker (40)
	Eastern Kingbird (29)	Eastern Kingbird (100)	
	Empidonax Flycatcher (43)	Empidonax Flycatcher (100)	Empidonax Flycatcher (50)
	Great Crested Flycatcher (29)	Great Crested Flycatcher (50)	
		Eastern Wood Pewee (50)	
	Blue Jay (57)	Blue Jay (100)	Blue Jay (80)
	Black-capped Chickadee (43)	Black-capped Chickadee (100)	Black-capped Chickadee (30)
	White-breasted Nuthatch (43)	White-breasted Nuthatch (50)	White-breasted Nuthatch (40)
	House Wren (100)	House Wren (100)	House Wren (100)
		Gray Catbird (100)	Gray Catbird (60)
	Brown Thrasher (71)	Brown Thrasher (100)	
	American Robin (71)	American Robin (100)	American Robin (60)
	Olive-backed Thrush (29)	Olive-backed Thrush (50)	Olive-backed Thrush (50)
	Starling (71)		Starling (80)
		Warbling Vireo (100)	Warbling Vireo (40)
	Tennessee Warbler (43)	Tennessee Warbler (100)	Tennessee Warbler (60)
		Yellow Warbler (50)	Yellow Warbler (40)
		Yellow-rumped Warbler (50)	
		Blackpoll Warbler (50)	Blackpoll Warbler (60)
		Ovenbird (50)	
	Common Yellowthroat (29)	Common Yellowthroat (50)	
	House Sparrow (71)		House Sparrow (60)
	Red-winged Blackbird (29)	Red-winged Blackbird (50)	
	Common Grackle (43)		Common Grackle (50)
	Brown-headed Cowbird (86)	Brown-headed Cowbird (100)	Brown-headed Cowbird (60)
		Orchard Oriole (100)	
	Northern Oriole (57)	Northern Oriole (100)	Northern Oriole (100)
	Rose-breasted Grosbeak (57)	Rose-breasted Grosbeak (100)	Rose-breasted Grosbeak (100)
		Black-headed Grosbeak (50)	
		Indigo Bunting (50)	
	American Goldfinch (29)		
	Chipping Sparrow (29)	Chipping Sparrow (50)	
	Harris' Sparrow (29)		
	Lincoln Sparrow (29)		
	Song Sparrow (43)		Song Sparrow (60)
Number of species	30	34	23
Unique[d] species	4	8	

---

[a] All birds occurring in 25% or more of the study plots composing each cover type.
[b] Number of study plots in each cover type.
[c] Percent frequency of occurrence.
[d] Birds associated with only one cover type.

season (Table 8). The sparse tree habitat of cover type A and the moderately dense tree habitat of cover type B supported seven species not found in cover type C.

The winter bird communities associated with cover types A, B, and C contained three species in common (Table 10). Cover type B supported several unique species in winter and paralleled the uniqueness that also occurred during the reproductive and spring migration seasons. The House Sparrow, Starling, and Dark-eyed Junco were wintering only in type A, while the Black-capped Chickadee was found only in the dense tree habitats of cover types B and C.

Parklike stands of trees with a few shrubs appear to support bird communities similar to or even with more bird species than the communities associated with dense tree stands containing moderate to dense shrub layers in riparian woodland habitat during the reproductive season. The only species listed in Table 8 that were considered "interior" species by Kendeigh (1944) are the Red-bellied Woodpecker, Black-capped Chickadee, White-breasted Nuthatch, Hairy Woodpecker, and Downy Woodpecker. The Red-bellied Woodpecker was the only species identified during the study as being restricted to a large, dense tract of woodlands. Nearly all the species reproducing in the eastern quarter of South Dakota were edge species and apparently utilized parklike habitat (cover type A) or moderately dense tree

TABLE 10. Bird communities[a] associated with three riparian woodland cover types during the 1976 winter season.

	Cover type A (7)[b]	Cover type B (2)[b]	Cover type C (5)[b]
		Bald Eagle (50)[c]	
	Great Horned Owl (29)	Great Horned Owl (50)	
		Common Flicker (50)	
	Hairy Woodpecker (56)	Hairy Woodpecker (50)	Hairy Woodpecker (60)
	Downy Woodpecker (43)	Downy Woodpecker (50)	Downy Woodpecker (80)
		Black-capped Chickadee (50)	Black-capped Chickadee (100)
	White-breasted Nuthatch (43)	White-breasted Nuthatch (50)	White-breasted Nuthatch (80)
	Starling (29)		
	House Sparrow (56)		
	Dark-eyed Junco (29)		
		Tree Sparrow (50)	
Number of species	7	8	4
Unique[d] species	3	3	

[a] All birds occurring in 25% or more of the study plots composing each cover type.
[b] Number of study plots in each cover type.
[c] Percent frequency of occurrence.
[d] Birds associated with only one cover type.

habitat (cover type B) as readily as dense tree habitat (cover type C).

Dense tree stands with heavy shrub understories supported unique species only when transients such as the Ovenbird and Blackpoll Warbler were present during spring migration. The seral cottonwood-dogwood habitat of cover type B was an exception. Several bird species were associated only with cover type B during all three census periods. The southeasterly location of cover type B within the state, extensiveness, and vegetative complexity were factors that may be related to the uniqueness of this community.

<u>Tree Claim Habitat</u>. Two distinct clusters (cover types) labeled D and E were delineated in tree claim habitat (Fig. 3). Cover type D was heavily utilized for grazing, and was characterized by numerous dead trees, low tree foliage volume, and no or virtually no shrubs. Cover type E contained study plots which were lightly grazed, or not grazed, and were characterized by dense tree stands and a sparse to dense shrub layer (Table 11).

Cover type E supported 29 species and eight were unique during the reproductive season. Cover type D supported 24 species including three that were unique (Table 12). The more open cover type D was attractive to the Western Kingbird, Eastern Bluebird, and Eastern Wood Pewee, but was not attractive to the Indigo Bunting, Orchard Oriole,

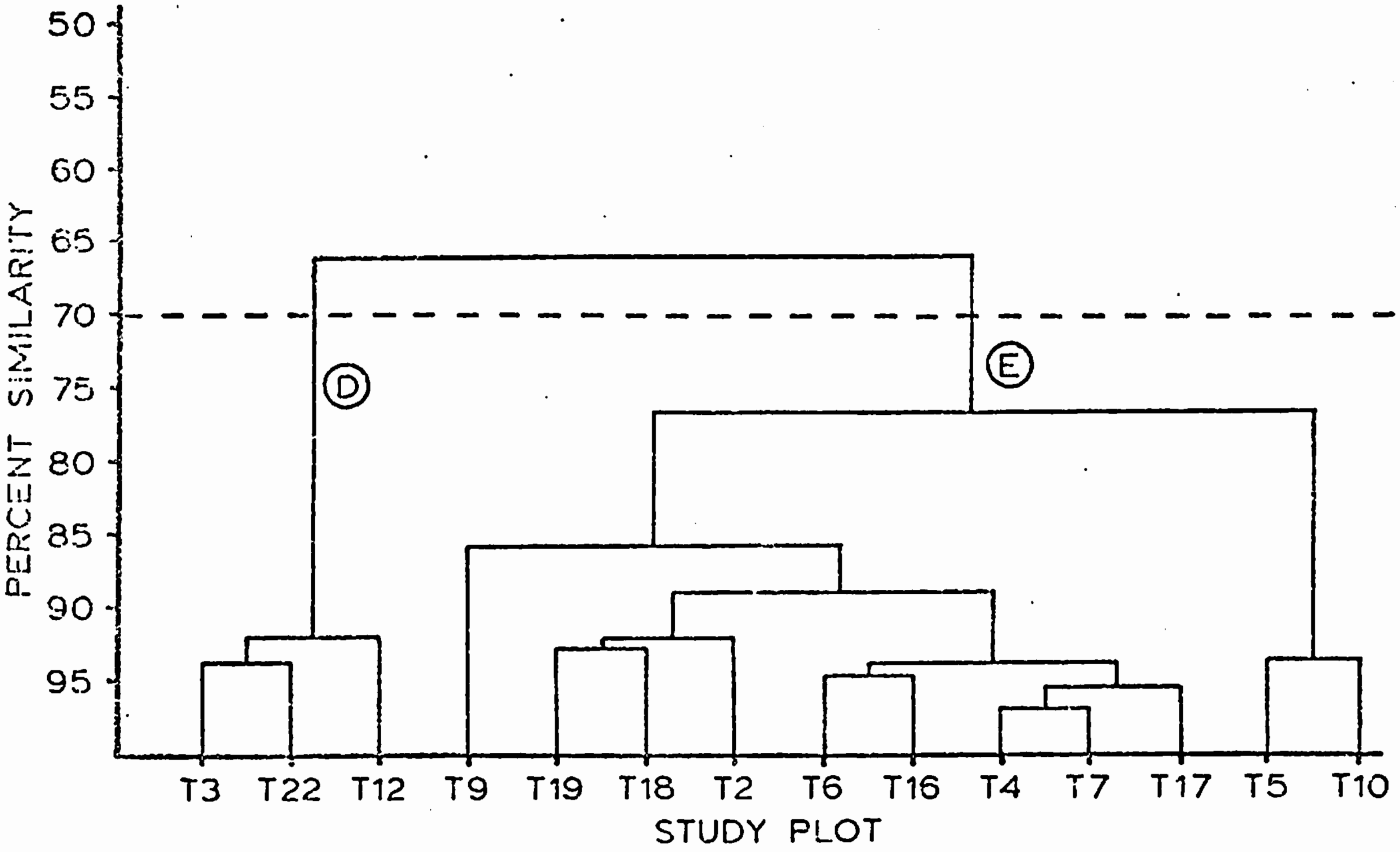

FIGURE 3. Phenogram of vegetation cover types resulting from vegetation cluster analysis of 19 vegetation variables measured in tree claim habitat. The phenogram was analyzed at the 70% level of similarity (---). The two cover types delineated are described in Table 11.

TABLE 11. Vegetation and physical variables used to describe the tree claim vegetation cover types (Fig. 3).

Vegetation and physical variables	Cover type			
	D		E	
	Range	Mean	Range	Mean
Total tree density (#/0.4 ha)	90.0-132.0	112.0	177.0-284.0	216.0
Tree foliage volume (m^3/0.4 ha)	1594.0-3150.0	2213.0	4156.0-7060.0	5800.0
Shrub foliage volume (m^3/0.4 ha)	0.0-10.0	3.7	32.0-3327.0	1082.6
Canopy height (m)	13.8-15.5	14.8	13.7-23.1	17.2
Herb height (m)	0.5-0.7	0.6	0.3-1.3	0.7
Plot size[b] (ha)	3.4-4.3	3.8	2.1-4.6	3.7
Dominant tree species	green ash		green ash, elm[a], and boxelder	

[a] Slippery and American.
[b] Average plot size of all study plots included in a cover type.

TABLE 12. Bird communities[a] associated with two tree claim cover types during the 1977 reproductive season.

	Cover type D (3)[b]	Cover type E (11)[b]
		Red-tailed Hawk (27)[c]
		Swainson's Hawk (27)
	Mourning Dove (100)	Mourning Dove (100)
	Black-billed Cuckoo (100)	Black-billed Cuckoo (100)
	Great Horned Owl (66)	Great Horned Owl (73)
	Common Flicker (100)	Common Flicker (100)
	Red-headed Woodpecker (100)	Red-headed Woodpecker (82)
	Hairy Woodpecker (100)	Hairy Woodpecker (91)
	Downy Woodpecker (66)	Downy Woodpecker (73)
	Eastern Kingbird (100)	Eastern Kingbird (36)
	Western Kingbird (66)	
		Great Crested Flycatcher (64)
	Eastern Wood Pewee (33)	
	Blue Jay (100)	Blue Jay (100)
		Common Crow (27)
	Black-capped Chickadee (33)	Black-capped Chickadee (82)
	House Wren (100)	House Wren (100)
	Brown Thrasher (100)	Brown Thrasher (82)
	American Robin (100)	American Robin (91)
	Eastern Bluebird (66)	
	Starling (100)	Starling (73)
	Common Yellowthroat (66)	Common Yellowthroat (82)
	House Sparrow (100)	House Sparrow (73)
	Common Grackle (100)	Common Grackle (91)
	Brown-headed Cowbird (100)	Brown-headed Cowbird (36)
		Orchard Oriole (36)
	Northern Oriole (66)	Northern Oriole (55)
		Rose-breasted Grosbeak (27)
		Indigo Bunting (45)
		American Goldfinch (27)
	Vesper Sparrow (33)	Vesper Sparrow (45)
	Song Sparrow (100)	Song Sparrow (82)
Number of species	24	29
Unique[d] species	3	8

---

[a] All birds occurring in 25% or more of the study plots composing each cover type.

[b] Number of study plots in each cover type.

[c] Percent frequency of occurrence based on 1976 and 1977 census results.

[d] Birds associated with only one cover type.

Great-crested Flycatcher, American Goldfinch, Rose-breasted Grosbeak, Common Crow, Red-tailed Hawk, and Swainson's Hawk. The loss of all saplings and shrubs was the probable reason that cover type D did not support Indigo Bunting and Rose-breasted Grosbeak as their habitat requirements (Bond 1957, Taber and Johnston in Austin 1968:81, and Austin 1968:36) would suggest. The other six species were probably not found in 25% or more of the study plots in cover type D because the proper combination of vegetative structure and food requirements was not present.

Thirty-five species were associated with cover type D during spring migration, and 33 species were associated with cover type E (Table 13). The Eastern Bluebird, Western Kingbird, and Eastern Wood Pewee were unique to cover type D. Although the Vesper Sparrow appeared unique to this cover type during migration, it also associated with cover type E during the reproductive season. The Common Crow was unique to cover type E during both migratory and reproductive seasons. The same number of transient species was associated with both cover types during migration, although two of the transients in each cover type were unique.

Five species were associated with cover type D, and four species were associated with cover type E during the winter season (Table 14). The Starling and House Sparrow were associated only with cover type D. Cover type D contained a higher density of dead and dying trees relative

TABLE 13. Bird communities[a] associated with two tree claim cover types during the 1977 spring migration season.

	Cover type D (3)[b]	Cover type E (11)[b]
	Mourning Dove (100)[c]	Mourning Dove (100)
	Black-billed Cuckoo (33)	Black-billed Cuckoo (36)
	Great Horned Owl (66)	Great Horned Owl (45)
	Common Flicker (100)	Common Flicker (73)
	Red-headed Woodpecker (100)	Red-headed Woodpecker (64)
	Hairy Woodpecker (66)	Hairy Woodpecker (55)
	Downy Woodpecker (33)	Downy Woodpecker (36)
	Eastern Kingbird (66)	Eastern Kingbird (55)
	Western Kingbird (33)	
	Empidonax Flycatcher (66)	Empidonax Flycatcher (64)
	Eastern Wood Pewee (33)	
	Blue Jay (66)	Blue Jay (91)
		Common Crow (27)
	Black-capped Chickadee (33)	Black-capped Chickadee (64)
	House Wren (100)	House Wren (100)
	Gray Catbird (33)	Gray Catbird (55)
	Brown Thrasher (100)	Brown Thrasher (73)
	American Robin (100)	American Robin (64)
	Olive-backed Thrush (33)	Olive-backed Thrush (91)
	Eastern Bluebird (33)	
	Starling (100)	Starling (73)
	Red-eyed Vireo (66)	Red-eyed Vireo (36)
	Warbling Vireo (66)	Warbling Vireo (27)
	Tennessee Warbler (33)	Tennessee Warbler (64)
		Yellow Warbler (45)
	Chestnut-sided Warbler (33)	
	Blackpoll Warbler (33)	Blackpoll Warbler (45)
		Common Yellowthroat (55)
		American Redstart (36)
	House Sparrow (100)	House Sparrow (64)
	Red-winged Blackbird (33)	Red-winged Blackbird (27)
	Common Grackle (66)	Common Grackle (91)
	Brown-headed Cowbird (66)	Brown-headed Cowbird (55)
	Orchard Oriole (33)	Orchard Oriole (27)
	Northern Oriole (66)	Northern Oriole (55)
	Rose-breasted Grosbeak (33)	Rose-breasted Grosbeak (64)
	Vesper Sparrow (33)	
	Chipping Sparrow (33)	
	Song Sparrow (100)	Song Sparrow (45)
Number of species	35	33
Unique[d] species	4	4

---

[a] All birds occurring in 25% or more of the study plots composing each cover type.

[b] Number of study plots in each cover type.

[c] Percent frequency of occurrence.

[d] Birds associated with only one cover type.

TABLE 14. Bird communities[a] associated with two tree claim cover types during the 1975 winter season.

	Cover type D (3)[b]	Cover type E (11)[b]
	Great Horned Owl (100)[c]	Great Horned Owl (73)
	Hairy Woodpecker (100)	Hairy Woodpecker (27)
		Downy Woodpecker (82)
	White-breasted Nuthatch (66)	White-breasted Nuthatch (64)
	Starling (100)	
	House Sparrow (33)	
Number of species	5	4
Unique[d] species	2	1

[a] All birds occurring in 25% or more of the study plots composing each cover type.

[b] Number of study plots in each cover type.

[c] Percent frequency of occurrence.

[d] Birds associated with only one cover type.

to cover type E. These trees provided abundant roosting cavities for flocks of Starlings and House Sparrows.

The number of bird species associated with tree claim habitat during the reproductive season in the eastern quarter of South Dakota decreased when the habitat was managed so intensely for grazing that the shrub layer was eliminated and tree vigor, as reflected by low tree foliage volume, was reduced.

Analysis of the data for riparian woodland suggested that parklike tree habitat with occasional shrubs experienced no loss in number of bird species relative to dense tree stands with dense understories. Data from tree claim, however, indicated that a loss in number of bird species did occur when the shrub layer was eliminated and tree vigor reduced, even when tree density remained relatively high ($\bar{x}$ = 112 trees/0.4 ha). Strong, positive correlations between BSD and the presence of different vegetation layers, expressed as FHD (MacArthur and MacArthur 1961, Karr 1968, and Willson 1974), suggested that maintaining a shrub layer associated with a woodland habitat helped maximize BSD.

Single-row Windbreak Habitat. Four distinct clusters (cover types) labeled F, G, H, and I were delineated in windbreak habitat (Fig. 4). Cover type I represented a sample size of one and was consolidated with the most similar cover type H. This consolidated cover type was designated HI. Cover type F represented new windbreaks where height of

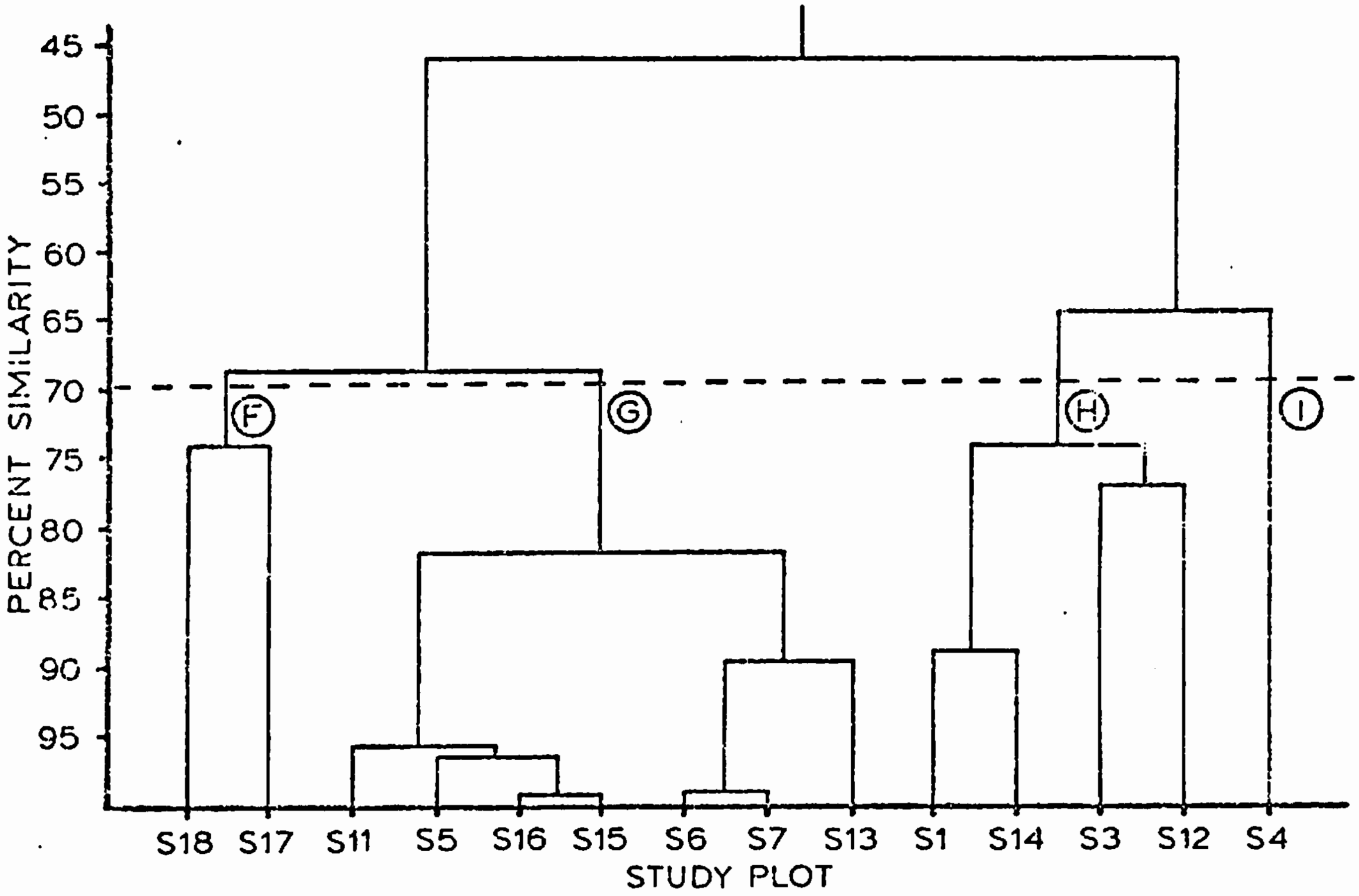

FIGURE 4. Phenogram of vegetation cover types resulting from vegetation cluster analysis of 15 vegetation variables measured in single-row windbreak habitat. The phenogram was analyzed at the 70% level of similarity (---). The three cover types F, G, and HI (combined because of the sample size of 1 for I) are described in Table 15.

TABLE 15. Vegetation and physical variables used to describe the single-row windbreak vegetation cover types (Fig. 4).

	Cover type					
Vegetation and physical variables	F		G		HI	
	Range	Mean	Range	Mean	Range	Mean
Tree foliage volume (m^3/m)			0.3-6.5	3.5	8.3-36.4	22.1
Shrub foliage volume (m^3/m)	0.9-1.4	1.1	0.0-2.0	1.4	0.0-6.3	1.9
Canopy height (m)	2.4-3.2	2.8	4.8-7.6	6.3	9.6-19.6	13.9
Herb height (m)	0.1-0.3	0.2	0.3-0.7	0.4	0.5-1.0	0.8
Length[a] (m)	259.0-784.0	521.5	753.0-793.0	785.9	363.0-762.0	568.6
Dominant tree species	Siberian elm or green ash		Siberian elm or green ash		green ash or cottonwood	

[a] Average length of all study plots included in a cover type.

trees was more characteristic of shrub rows than tree rows. Cover type G represented windbreaks intermediate in height and with continuous foliage volume from the ground to the top of the trees. Cover type HI represented tall, mature windbreaks with a sparse to dense shrub understory (Table 15).

The reproductive bird communities associated with cover types F, G, and HI contained many of the same species, but there was a noticeable increase in the number of species that progressed from type F to G to HI. Five, 14, and 21 species were associated with types F, G, and HI, respectively (Table 16). No unique species were associated with type G. The Dickcissel was the only species unique to type F. Eight unique species were associated with type HI; 10 species were associated with types G and HI and not with type F.

The spring migration bird communities associated with cover types F, G, and HI were nearly identical to the bird communities associated with these types during the reproductive season. Five, 16, and 19 species were associated with types F, G, and HI, respectively (Table 17). Two unique species, the Yellow Warbler and Tennessee Warbler, were associated with type G. Although the Blue Jay, American Goldfinch, and Black-billed Cuckoo appeared to be associated only with type G, these three species also used type HI during the reproductive season. Although eight species appeared to be associated only with type HI, only seven were

TABLE 16. Bird communities[a] associated with three single-row windbreak cover types during the 1977 reproductive season.

	Cover type F (2)[b]	Cover type G (7)[b]	Cover type HI (5)[b]
		Mourning Dove (86)[c]	Mourning Dove (80)
		Black-billed Cuckoo (57)	Black-billed Cuckoo (80)
			Common Flicker (80)
			Red-headed Woodpecker (40)
	Eastern Kingbird (100)	Eastern Kingbird (86)	Eastern Kingbird (100)
			Western Kingbird (40)
			Blue Jay (80)
			House Wren (40)
			Gray Catbird (40)
		Brown Thrasher (100)	Brown Thrasher (80)
		American Robin (86)	American Robin (100)
		Common Yellowthroat (43)	Common Yellowthroat (80)
	Red-winged Blackbird (50)	Red-winged Blackbird (71)	Red-winged Blackbird (80)
		Common Grackle (71)	Common Grackle (60)
		Brown-headed Cowbird (29)	Brown-headed Cowbird (80)
		Orchard Oriole (43)	Orchard Oriole (100)
		Northern Oriole (29)	Northern Oriole (40)
		American Goldfinch (43)	American Goldfinch (60)
	Dickcissel (100)		
	Vesper Sparrow (100)	Vesper Sparrow (100)	Vesper Sparrow (80)
			Lark Sparrow (40)
	Clay-colored Sparrow (100)	Clay-colored Sparrow (29)	
			Song Sparrow (60)
Number of species	5	14	21
Unique[d] species	1		8

[a] All birds occurring in 25% or more of the study plots composing each cover type.
[b] Number of study plots in each cover type.
[c] Percent frequency of occurrence based on 1976 and 1977 census results.
[d] Birds associated with only one cover type.

TABLE 17. Bird communities[a] associated with three single-row windbreak cover types during the 1977 spring migration season.

	Cover type F (2)[b]	Cover type G (7)[b]	Cover type H (5)[b]
		Mourning Dove (71)[c]	Mourning Dove (80)
		Black-billed cuckoo (43)	
			Common Flicker (60)
			Red-headed Woodpecker (40)
	Eastern Kingbird (50)	Eastern Kingbird (71)	Eastern Kingbird (40)
			Empidonax Flycatcher (40)
		Blue Jay (29)	
			House Wren (40)
			Black-capped Chickadee (40)
			Gray Catbird (40)
		Brown Thrasher (56)	Brown Thrasher (60)
		American Robin (56)	American Robin (40)
		Tennessee Warbler (29)	
		Yellow Warbler (29)	
		Common Yellowthroat (29)	Common Yellowthroat (40)
	Red-winged Blackbird (100)	Red-winged Blackbird (59)	Red-winged Blackbird (60)
		Common Grackle (43)	Common Grackle (60)
		Brown-headed Cowbird (71)	Brown-headed Cowbird (60)
		Orchard Oriole (43)	Orchard Oriole (40)
			Northern Oriole (60)
		American Goldfinch (29)	
	Dickcissel (100)		
	Vesper Sparrow (50)	Vesper Sparrow (86)	Vesper Sparrow (60)
	Clay-colored Sparrow (100)	Clay-colored Sparrow (43)	Clay-colored Sparrow (40)
			Song Sparrow (40)
Number of species	5	16	19
Unique[d] species	1	5	8

[a] All birds occurring in 25% or more of the study plots composing each cover type.
[b] Number of study plots in each cover type.
[c] Percent frequency of occurrence.
[d] Birds associated with only one cover type.

considered unique. The Northern Oriole also used cover type G during the reproductive season. The Tennessee Warbler, Yellow Warbler, and Empidonax Flycatcher were the only transients occurring in 25% or more of the study plots within a cover type.

The substantial difference in the number of bird species associated with the three cover types during both reproductive and spring migration seasons was indicative of the substantial difference in vegetation represented by each cover type. Cover type F was essentially a shrub habitat, and the marked increase in bird species associated with cover types G and HI was similar to the rapid increase in BSD that occurred from a shrub to a shrub and tree habitat reported by Karr and Roth (1971), and Willson (1974). Willson pointed out that the addition of bird species is greatest when the tree layer is begun.

Windbreaks were not utilized by transients as much as tree claim and riparian woodland habitat during the spring migration season. Unlike riparian woodland and tree claim habitats, windbreak habitat supported nearly identical bird communities in both the reproductive and spring migration seasons. Windbreaks did not support winter bird communities.

Multiple Regression Analysis

Bird Species Diversity and Population Density, Riparian Woodland Habitat. Two variables accounted for 83% (R^2) of the variation in BSD in riparian woodlands during the reproductive season (Table 18). Log transformation of plot area accounted for nearly all this variation. Bird species diversity increased most rapidly with increasing plot size from 0.0-1.0 ha and increased at a gradually decreasing rate from 1.0-8.7 ha (Fig. 5). Although BSD declined most rapidly when plot size was 1.0 ha or less, a minimum plot size of 5.9 ha was required to support 95% of the maximum BSD predicted within the set of data points (8.7 ha was the maximum plot size).

The positive correlation between the log transformation of plot size and BSD parallels the correlations between plot size and BSD reported by Galli (1974) for woodland habitat. Although area may account for much of the variation in BSD, its influence is related to other factors including habitat diversity, which in turn is correlated with species diversity (MacArthur and Wilson 1967). Significant correlations between various vegetative variables and BSD were apparently masked by the large variation in size of the riparian woodland study plots and the overriding influence of this variation on BSD during the reproductive season.

TABLE 18. Results of stepwise forward multiple regression analysis of bird species diversity in riparian woodland habitat including all independent variables accounting for significant variation at the $p < 0.10$ level (N = 14).

Independent variable	Regression coefficient (B)	Coefficient of determination (R^2)	R^2 increase	Standardized regression coefficient (Beta)
		Reproductive season 1977		
Log transformation of plot area	0.434	0.710	0.710*	0.932
Density of trees 7.7-22.9 cm DBH	0.577	0.827	0.117	0.353
Y intercept	1.982			
		Spring migration season 1977		
Log transformation of plot area	0.669	0.538	0.538*	1.153
Percent canopy cover	1.008	0.749	0.211	0.452
Average maximum canopy height	-0.164	0.791	0.041	-1.059
Density of dead trees > 15.2 cm DBH	-0.093	0.836	0.045	-0.064
Shrub foliage volume	0.001	0.877	0.041	0.227
Presence of cultivated grains	0.241	0.890	0.014	0.440
Percent density green ash	0.108	0.922	0.032	0.078
Density of trees 7.7-22.9 cm DBH	0.027	0.933	0.011	1.329
Degree of interior openness	1.602	0.979	0.045	0.835
Y intercept	2.746			
		Winter season 1976		
Presence of cultivated grains	0.618	0.445	0.445*	0.704
Proximity of buildings < 1/4 mile	0.591	0.582	0.137	0.372
Y intercept	0.042			

*Initial variable significant at the $p < 0.05$ level.

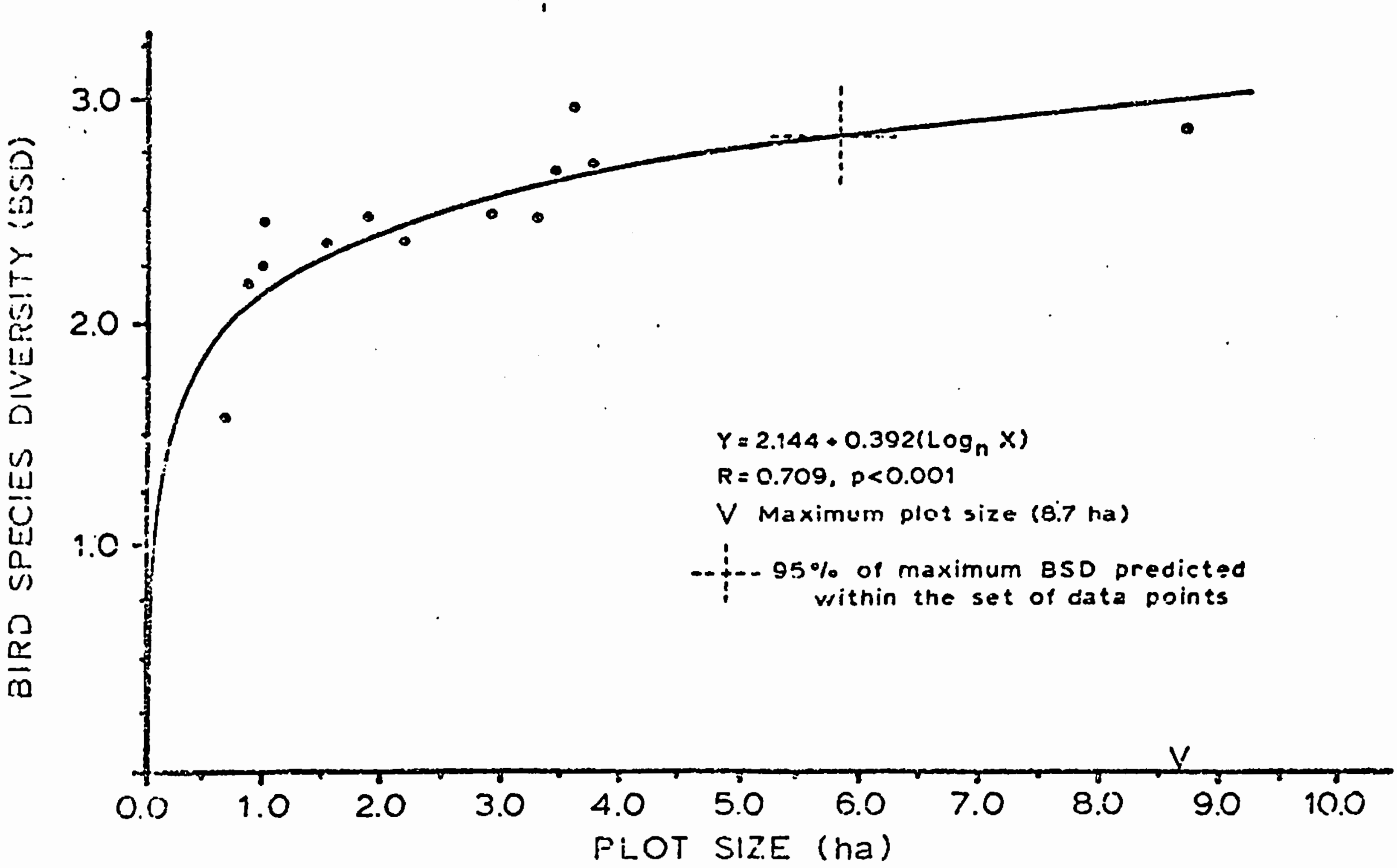

FIGURE 5. BSD-area curve for riparian woodland habitat during the 1977 reproductive season using the log$_n$ transformation of plot size.

Only one vegetation variable (density of trees 7.7-12.9 cm DBH) accounted for variation in BSD during the reproductive season (Table 18). The intermediate canopy and lower foliage provided by trees in the 7.7-12.9 cm DBH size class may have attracted birds not selecting for larger trees.

Nine variables accounted for 98% (R^2) of the variation in BSD in riparian woodlands during the spring migration season (Table 18). The total variation in BSD accounted for by log transformation of plot area was less during spring migration while shrub foliage volume, percent canopy cover, percent density green ash, and density of trees 7.7-22.9 cm DBH accounted for considerable variation in BSD during spring migration as compared to the reproductive season. Bird species diversity increased more in response to increasing tree density and shrub density during the spring migration season than during the reproductive season. The positive influence of degree of interior openness on spring migration BSD (Table 18) was not consistent with this conclusion. The relationship between spring migration BSD and degree of interior openness may not be positive. Degree of interior openness was intercorrelated with percent canopy cover ($r = -0.78$, $p < 0.05$).

The BSD-area curve for the spring migration season is presented in Figure 6. A minimum plot size of 6.0 ha

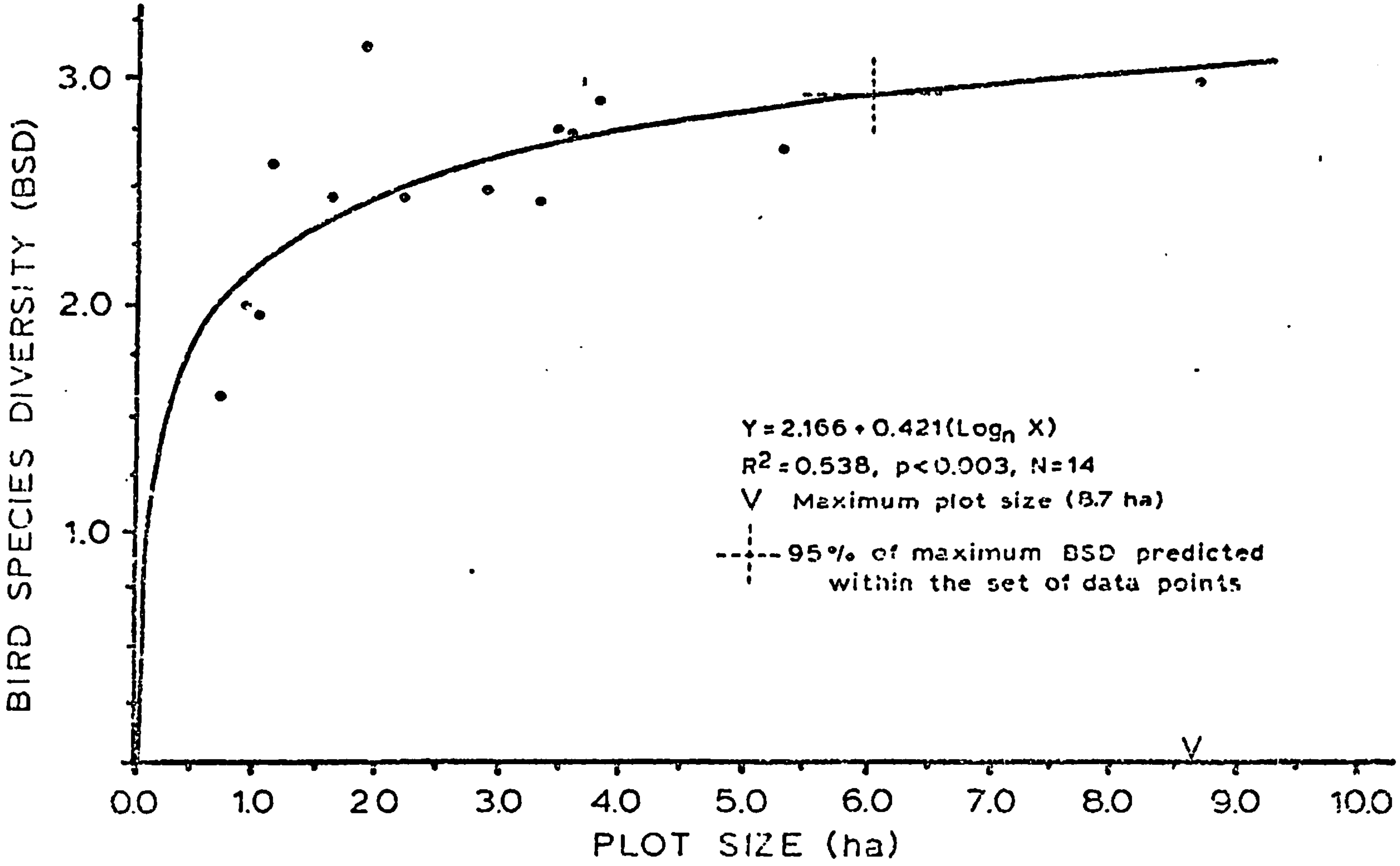

FIGURE 6. BSD-area curve for riparian woodland habitat during the 1977 spring migration season using the log$_n$ transformation of plot size.

was required to support 95% of the maximum BSD predicted within the set of data points. The small sample size (N = 14) involved in both Figs. 5 and 6 warrants further evaluation of minimum plot size.

The significant correlations between winter BSD and presence of cultivated grains and farm houses within 1/4 mile of the study plot (Table 18) were probably due to availabity of food and water. Eight of 11 grain fields adjacent to the study plots during the winter census period contained corn stalks. Both Downy Woodpeckers and Black-capped Chickadees foraged on corn stubble, and one Downy Woodpecker was observed eating insect larva gleaned from the pith of corn stubble. Waste grain and water were available near farm buildings.

Five variables accounted for 79% (R^2) of the variation in standardized bird population density (SBD) in riparian woodlands during the reproductive season (Table 19). The negative Beta values for plot area during both the reproductive and spring migration seasons (Table 19) suggest that smaller plot sizes supported higher bird densities and supported the previous observation that higher bird densities occurred in windbreaks and shelterbelts when compared to larger tree claims and riparian woodlands. The riparian woodland study plots, however, were segments of a continuous woodland habitat. Part of the negative correlation between plot area and SBD may have been due to the census of a

TABLE 19. Results of stepwise forward multiple regression analysis of standardized bird population density[a] in riparian woodland habitat including all independent variables accounting for significant variation at the $p < 0.10$ level ($N = 14$).

Independent variable	Regression coefficient (B)	Coefficient of determination (R^2)	R^2 increase	Standardized regression coefficient (Beta)
	Reproductive season 1977			
Plot area	-1.113	0.281	0.281	-0.508
Density of trees > 38.1 cm DBH	-0.008	0.440	0.159	-0.039
Percent ground cover	19.739	0.534	0.094	0.751
Percent canopy cover	15.248	0.701	0.167*	0.612
Shrub foliage volume	0.001	0.785	0.085	0.354
Y intercept	-5.314			
	Spring migration season 1977			
Total tree density	0.075	0.301	0.301*	0.596
Proximity of buildings < 1/4 mile	-8.292	0.471	0.169	-0.490
Plot area	-1.262	0.598	0.127	-0.378
Y intercept	14.811			
	Winter season 1976			
Presence of cultivated grains	5.769	0.361	0.361	1.305
Percent density green ash	14.420	0.759	0.398	1.280
Degree of interior openness	-9.670	0.777	0.019	-0.624
Total tree density	-0.015	0.791	0.013	-0.254
Percent density cottonwood	12.751	0.819	0.028	1.343
Average maximum canopy height	-1.396	0.929	0.110*	-1.118
Y intercept	16.163			

[a] Birds/0.7 ha.

*Initial variable significant at the $p < 0.05$ level.

higher percentage of birds with partial territories within the smaller plots as compared to the larger study plots. This bias would inflate the standardized density estimates for the smaller study plots. Although I feel there was minimal bias induced, caution is warranted in interpreting the results of multiple regression analysis involving standardized bird population densities during the reproductive and spring migration seasons.

During the reproductive season, SBD increased with increasing percent ground cover, percent canopy cover, and shrub foliage volume (Table 19). Presence of a dense herbaceous layer, sufficient tree density to provide a moderate canopy cover, and shrubs were important for supporting the most dense bird populations during the reproductive season in the area studied.

Only 60% (R^2) of the variation in SBD was accounted for during the spring migration season. A large portion of the variation was probably unaccounted for because the total bird density supported by each study plot during the spring migration season was not solely related to the habitat features present. The census period covered 3 weeks yet the actual spring migration appeared most pronounced during a 1 week period. Bird density on a study plot was influenced by the stage of migration at the time the plot was censused.

Total tree density accounted for 50% of the total variation accounted for in SBD during spring migration, yet did not enter the regression equation for SBD during the reproductive season (Table 19). The increase in explanatory power of total tree density during the spring migration season was probably due to the attractiveness of dense tree stands to spring transients such as the Ovenbird, Red-eyed Vireo, Blackpoll Warbler, Tennessee Warbler, and Olive-backed Thrush.

Six variables accounted for 93% (R^2) of the variation in winter SBD in riparian woodlands. The proximity of cultivated grains, percent density of cottonwoods, and percent density of green ash were positively correlated with winter SBD (Table 19). A moderately dense stand of cottonwoods and green ash trees adjacent to corn stubble appears to have provided the best available habitat for wintering birds.

Bird Species Diversity and Population Density, Tree Claim Habitat. Two variables accounted for 81% (R^2) of the variation in BSD in tree claim habitat during the reproductive season (Table 20). Bird species diversity increased with increasing canopy height and appeared to be negatively influenced by tall shrubs.

During the spring migration season seven variables accounted for 93% (R^2) of the variation in BSD in tree claims (Table 20). Migration BSD increased with increasing canopy height, percent density cottonwoods, and percent density boxelders, and when buildings were within 1/4 mile of the

TABLE 20. Results of stepwise forward multiple regression analysis of bird species diversity in tree claim habitat including all independent variables accounting for significant variation at the $p < 0.10$ level ($N = 14$).

Independent variable	Regression coefficient (B)	Coefficient of determination (R^2)	R^2 increase	Standardized regression coefficient (Beta)
Reproductive season 1977				
Average maximum canopy height	0.047	0.602	0.602	0.919
Average maximum shrub height	-0.048	0.812	0.210*	-0.480
Y intercept	1.662			
Spring migration season 1977				
Proximity of buildings < 1/4 mile	0.187	0.529	0.529	0.426
Percent density cottonwood	3.746	0.705	0.177*	0.247
Percent density boxelder	0.143	0.762	0.056	0.120
Average maximum canopy height	0.038	0.804	0.043	0.471
Presence of cultivated grains	-0.079	0.842	0.039	-0.301
Degree of interior openness	-1.783	0.863	0.020	-0.473
Average maximum shrub height	-0.087	0.932	0.069	-0.568
Y intercept	2.407			
Winter season 1976				
Proximity of buildings < 1/2 mile	0.211	0.354	0.354	0.294
Presence of cultivated grains	-0.181	0.475	0.121	-0.437
Percent density elm	4.240	0.640	0.165*	1.655
Percent density boxelder	3.577	0.704	0.064	1.921
Percent density green ash	2.914	0.778	0.075	2.011
Y intercept	-1.736			

*Initial variable significant at the $p < 0.05$ level.

study plot. Migration BSD apparently decreased when tall shrubs and interior openings in the tree stand were present.

During the winter season, five variables accounted for 78% (R^2) of the variation in BSD in tree claim habitat (Table 20). Proximity of buildings $<$ 1/2 mile accounted for 35% of the variation in winter BSD. Winter BSD increased with increasing percent density of elms, percent density of boxelders, percent density of green ash, and when buildings were within 1/2 mile of the woodlands. The negative Beta value for presence of cultivated grains (Table 20) during the winter season contradicts the indicated relationship between presence of cultivated grains and BSD in riparian woodlands (Table 18). The greater tree density of tree claim habitat, as compared to riparian woodland habitat (Appendix A, Tables 1, 2) may have provided sufficient foraging sites for the birds wintering in tree claims. The small Beta value for presence of small grains relative to the Beta values for percent density green ash, percent density boxelder, and percent density elm (Table 20) supports this hypothesis.

Five variables accounted for 86% (R^2) of the variation in SBD in tree claims during the reproductive season (Table 21). Density of birds increased with increasing shrub foliage volume, with decreasing tree height, and when a patchy, horizontal distribution of trees was present. Five variables accounted for 75% (R^2) of the variation in SBD in tree claims

TABLE 21. Results of stepwise forward multiple regression analysis of standardized bird population density[a] in tree claim habitat including all independent variables accounting for significant variation at the $p < 0.10$ level ($N = 14$).

Independent variable	Regression coefficient (B)	Coefficient of determination (R^2)	R^2 increase	Standardized regression coefficient (Beta)
	Reproductive season 1977			
Shrub foliage volume	0.003	0.164	0.164	0.339
Degree of interior openness	127.124	0.304	0.139	0.762
Average density board reading	2.052	0.413	0.110	1.045
Average maximum canopy height	-4.268	0.611	0.198	-1.211
Percent density elm	53.305	0.863	0.252*	0.736
Y intercept	66.771			
	Spring migration season 1977			
Shrub foliage volume	0.031	0.219	0.219	2.084
Plot area	-9.272	0.340	0.121	-0.451
Stem density	-0.190	0.402	0.062	-3.111
Average density board reading	5.862	0.556	0.154	2.015
Tree foliage volume	-0.006	0.751	0.196	-0.746
Y intercept	65.993			

[a] Birds/2.1 ha.

*Initial variable significant at the $p < 0.05$ level.

during the spring migration season (Table 21). Density of birds increased with increasing shrub foliage volume and understory density during spring migration. Although tree foliage volume appeared to have a negative influence on SBD, Ohmart and Anderson (Ann. Report, No. 4-10-01-01-310, Ariz. State Univ., Tempe) reported positive correlations between total tree and shrub foliage volume and bird population density in woodland habitat along the Colorado River in Arizona.

The positive influence of shrub foliage volume on SBD and the negative influence of shrub height on BSD suggests there is an inverse relationship between diversity and density. The negative influence of canopy height on SBD and the positive influence of canopy height on BSD further suggests an inverse relationship between diversity and density. Green ash and boxelder were short trees relative to the American/slippery elm, cottonwood, and silver maple, and both had positive correlations with the density of Starlings (Table 25). Planting or maintaining tall tree species to favor BSD will probably have a depressing effect on bird population density, but part of the lost density will be Starlings. Starlings were never observed on the two riparian woodland study plots along the Missouri River. These two plots supported very few green ash or boxelder.

Tree claims composed of a mixture of tall trees (cottonwood, elm, and silver maple) and short trees (green ash and boxelder) were probably most suitable for achieving a balance between maximum bird diversity and maximum bird density for all seasons studied. As percent composition of tall trees increased, the tree claim became more suitable for supporting maximum diversity. As percent composition of short trees increased, and shrub foliage volume increased, the tree claim became more suitable for supporting maximum density.

Bird Species Diversity and Population Density, Single-row Windbreak Habitat. Four variables accounted for 94% (R^2) of the variation in BSD in windbreaks during the reproductive season (Table 22). Bird species diversity increased with increasing canopy height, tree foliage volume, and shrub height during the reproductive season. Ten variables accounted for 99% (R^2) of the variation in BSD during the spring migration season. Bird species diversity increased with increasing shrub and tree foliage volume, number of shrub and tree species, and when water and cultivated grains were close to the windbreak during spring migration. The correlations of number of tree species and number of shrub species with BSD during spring migration and not during the reproductive season indicated that windbreaks composed of several species of shrubs and trees supported more

TABLE 22. Results of stepwise forward multiple regression analysis of bird species diversity in single-row windbreak habitat including all independent variables accounting for significant variation at the $p < 0.10$ level ($N = 14$).

Independent variable	Regression coefficient (B)	Coefficient of determination (R^2)	R^2 increase	Standardized regression coefficient (Beta)
	Reproductive season 1977			
Average maximum canopy height	0.066	0.651	0.651	0.600
Average maximum shrub height	0.021	0.765	0.114	0.580
Presence of cultivated grains	-0.216	0.873	0.108*	-0.298
Tree foliage volume	0.032	0.935	0.062	0.620
Y intercept	0.398			
	Spring migration season 1977			
Average maximum canopy height	-0.020	0.416	0.416	-0.189
Proximity of water < 1/2 mile	-0.231	0.580	0.163	-0.185
Number of trees 15.3-22.9 cm DBH	-0.044	0.659	0.079	-0.505
Shrub and tree foliage volume	0.036	0.776	0.117	0.756
Proximity of water < 1/4 mile	0.213	0.863	0.086	0.132
Presence of cultivated grains	0.059	0.881	0.018	0.084
Number of shrub species	0.689	0.887	0.006	1.197
Plant species diversity	-2.304	0.953	0.067*	-1.633
Number of tree species	0.859	0.958	0.005	1.307
Shrub foliage volume	-0.168	0.990	0.032	-0.458
Y intercept	0.579			

*Initial variable significant at the $p < 0.05$ level.

bird species during spring migration than during the reproductive season.

Four variables accounted for 95% (R^2) of the variation in SBD in windbreaks during the reproductive season (Table 23). Bird density increased with increasing shrub and tree foliage volume, and number of tree species. The negative Beta value for presence of cultivated grains reflected a positive Beta value for presence of pasture/alfalfa, because these two variables were 100% reciprocal. The highest density of Red-winged Blackbirds was observed in windbreaks adjacent to alfalfa fields. The Red-winged Blackbirds nested initially in the alfalfa fields, but would renest in the windbreaks after the first alfalfa cutting. A maximum of five active nests was located in a half-mile long windbreak after the first alfalfa cutting. Most nests were observed in windbreaks with a canopy height of 7 m or less.

During the spring migration season, eight variables accounted for 94% (R^2) of the variation in SBD in windbreaks (Table 23). Bird densities increased with increasing tree foliage volume, stem density, number of tree and shrub species, and when water and alfalfa fields were close to the windbreak.

Interpretation of the results of regression for windbreak habitat indicated that diversity and density of birds can be maximized in windbreaks by presence of tall,

TABLE 23. Results of stepwise forward multiple regression analysis of standardized bird population density[a] in single-row windbreak habitat including all independent variables accounting for significant variation at the $p < 0.10$ level ($N = 14$).

Independent variable	Regression coefficient (B)	Coefficient of determination (R^2)	R^2 increase	Standardized regression coefficient (Beta)
	Reproductive season 1977			
Shrub and tree foliage volume	0.637	0.681	0.681	1.123
Proximity of water < 1/4 mile	-10.688	0.823	0.142	-0.559
Presence of cultivated grains	-2.295	0.894	0.071	-0.278
Number of tree species	2.084	0.951	0.056*	0.268
Y intercept	4.048			
	Spring migration season 1977			
Presence of cultivated grains	-5.943	0.251	0.251	-0.589
Tree foliage volume	0.163	0.490	0.239	0.229
Stem density	0.701	0.722	0.232	0.525
Proximity of water < 1/2 mile	1.660	0.811	0.090*	0.092
Length	-0.020	0.844	0.032	-0.443
Number of tree species	5.662	0.851	0.008	0.595
Plant species diversity	-21.599	0.908	0.057	-1.056
Number of shrub species	4.429	0.941	0.033	0.531
Y intercept	13.504			

[a] Birds/259.1 m.

*Initial variable significant at the $p < 0.05$ level.

full canopy trees, and by presence of shrub foliage or tree branches within 1 m of the ground. Cottonwood, green ash, and hackberry will provide the best tall, full canopy selection for eastern South Dakota (P. E. Collins, pers. comm., Brookings, South Dakota). Presence of all three in the same windbreak would be most beneficial during the spring migration season when transient birds are present. Variation in spacing between trees and/or shrubs in windbreaks did not affect either diversity or density of birds.

The green ash/caragana windbreak encountered during the study was a favorable design because it provided foliage close to the ground; a full, tall canopy at maturity; and increased plant diversity. However, few birds nested in caragana. Caragana had many upright stems radiating from a central point near the ground and lacked elevated crotches for support of nests. The form of branching of young siberian elm, common chokecherry, American plum, and Tatarian honeysuckle supported nests and are suggested to replace caragana in windbreak plantings.

<u>Common Nesting Birds, Riparian Woodland Habitat</u>. Density of Mourning Doves increased with increasing percent canopy cover, shrub height, and shrub foliage volume, and decreased with increasing density of trees > 22.9 cm DBH, average density board reading, and canopy height (Table 24)

TABLE 24. Results of stepwise forward multiple regression analysis of common birds associated with riparian woodland habitat during the 1977 reproductive season including all independent variables accounting for significant variation at the $p < 0.10$ level (N = 14).

Independent variable	Regression coefficient (B)	Coefficient of determination (R^2)	R^2 increase	Standardized regression coefficient (Beta)
Mourning Dove				
Percent density boxelder	-1.612	0.373	0.373	-0.203
Density of trees > 38.1 cm DBH	-0.061	0.492	0.119	-1.115
Percent canopy cover	12.575	0.571	0.079	2.508
Average density board reading	-0.141	0.642	0.071	-1.013
Average maximum shrub height	0.183	0.774	0.133	0.330
Percent density green ash	-1.047	0.836	0.061	-0.334
Average maximum canopy height	-0.358	0.897	0.061	-1.029
Density of trees 22.9-38.1 cm DBH	-0.039	0.930	0.033	-0.755
Percent ground cover	2.747	0.947	0.017	0.519
Shrub foliage volume	0.001	0.989	0.042*	0.617
Y intercept	3.096			
Blue Jay				
Shrub foliage volume	0.001	0.478	0.478	0.096
Percent ground cover	-0.648	0.632	0.154	-0.403
Proximity of buildings < 1/4 mile	-0.116	0.747	0.115*	-0.172
Average maximum shrub height	0.136	0.831	0.084	0.807
Average maximum herb height	-0.333	0.905	0.074	-0.539
Y intercept	0.739			
American Robin				
Average density board reading	-0.185	0.336	0.336	-1.923
Percent density green ash	-0.600	0.565	0.229	-0.276
Plant species diversity	-0.559	0.607	0.042	-0.312
Shrub foliage volume	0.001	0.638	0.031	1.309
Percent canopy cover	6.759	0.666	0.028	1.943
Percent ground cover	4.415	0.782	0.116	1.206
Density of trees > 38.1 cm DBH	-0.044	0.900	0.118*	-1.157
Percent density elm	1.369	0.959	0.059	0.386
Y intercept	-2.732			
Northern Oriole				
Percent density cottonwood	1.096	0.379	0.379*	0.616
Y intercept	0.406			

*Initial variable significant at the $p < 0.05$ level.

Mourning Doves selected stands of small trees with a shrub understory for nesting. Percent canopy cover was intercorrelated ($r = 0.82$, $p < 0.05$) with density of small trees (7.7-22.9 cm DBH) and with total tree density ($r = 0.86$, $p < 0.05$).

Two variables associated with shrubs (shrub foliage volume and shrub height) accounted for over 50% of the variation accounted for in the density of Blue Jays. The presence of shrub layer was important to Blue Jays selecting a nest site in riparian woodlands. Anderson and Shugart (1974) found that Blue Jays in eastern Tennessee prefer woodlands with both a dense understory and a well developed canopy.

The results of regression for the American Robin indicated that American Robin density increased with increasing canopy cover, percent ground cover, and presence of small trees. A sparse shrub understory was more predictive of high American Robin density than a dense shrub layer. The American Robin evaluated the tree, shrub, and herb layers before selecting a nesting site in riparian woodland habitat.

Percent density of cottonwoods was the only variable that correlated ($p < 0.10$) with increasing density of Northern Orioles. Bond (1957) found Northern Orioles most abundant in pioneer vegetation types, and James' (1971) ordination work depicted the Northern Oriole habiat as consisting of large trees and a shrub understory. Cottonwood trees were the largest trees in the eastern quarter of South Dakota and were dominant in pioneer stands of riparian woodland habitat. This pioneer riparian habitat was best developed in the study area along those portions of the Missouri River which have not been inundated by reservoir water. The two study plots along the Missouri River supported the highest densities of Northern Orioles.

Common Nesting Birds, Tree Claim Habitat. The Common Flicker occurred most abundantly in tree claims with a "patchy" distribution of trees, presence of moderately large trees (22.9-38.1 cm DBH), and a shrub understory (Table 25). The negative Beta value for presence of cultivated grains suggested that pastureland adjacent to tree claims had a positive influence on the density of Common Flickers using the tree claim. Anderson and Shugart (1974) found a positive correlation between large trees and the presence of Common Flickers.

American Robins selected tree claims which were close to water and cultivated grains during the reproductive season. Tyler (in Bent 1964a:14) stated that American Robins were flexible in the type of vegetative substrate selected for nest sites. Apparently vegetative composition was not as important to American Robins searching for nest sites in tree claim habitat as the presence of adjacent water and cropland.

Common Grackle density increased with increasing plot area, interior openings within the tree stand, percent composition of short trees, and stem density. Tree claims

TABLE 25. Results of stepwise forward multiple regression analysis of common birds associated with tree claim habitat during the 1977 reproductive season including all independent variables accounting for significant variation at the $p < 0.10$ level ($N = 14$).

Independent variable	Regression coefficient (B)	Coefficient of determination (R^2)	R^2 increase	Standardized regression coefficient (Beta)
		Common Flicker		
Density of trees 22.9-38.1 cm DBH	0.053	0.324	0.324	0.676
Tree foliage volume	-0.001	0.527	0.203	-0.901
Plant species diversity	1.002	0.646	0.119	0.404
Presence of cultivated grains	-1.103	0.716	0.071	-0.721
Proximity of water < 1/2 mile	-1.813	0.794	0.077	-0.704
Percent density cottonwood	-56.541	0.840	0.047	-0.641
Average density board reading	0.214	0.909	0.068*	0.830
Degree of interior openness	7.959	0.948	0.039	0.364
Y intercept	2.704			
		American Robin		
Proximity of water < 1/4 mile	2.757	0.521	0.521	1.095
Presence of cultivated grains	0.664	0.675	0.155*	0.444
Percent density boxelder	1.764	0.748	0.073	0.262
Percent density cottonwood	43.970	0.810	0.062	0.509
Average maximum canopy height	-0.170	0.884	0.073	-0.375
Y intercept	0.137			
		Common Grackle		
Density of dead trees > 15.2 cm DBH	-0.093	0.219	0.219	-0.414
Plot area	1.070	0.383	0.164	0.457
Average maximum canopy height	-0.755	0.593	0.210	-1.268
Stem density	0.006	0.740	0.147*	0.803
Percent density elm	7.139	0.807	0.067	0.534
Degree of interior openness	15.759	0.859	0.052	0.560
Proximity of water < 1/4 mile	-1.371	0.932	0.073	-0.413
Y intercept	9.551			
		Starling		
Percent density boxelder	35.225	0.229	0.229	3.218
Proximity of buildings < 1/2 mile	3.080	0.424	0.195	0.729
Percent canopy cover	-8.123	0.503	0.078	-0.728
Percent density elm	46.416	0.620	0.117	3.082
Proximity of buildings < 1/4 mile	-4.010	0.699	0.080	-0.391
Percent density green ash	39.305	0.737	0.038	4.614
Average density board reading	0.566	0.855	0.117	1.385
Total tree density	-0.029	0.979	0.125*	-0.752
Y intercept	-28.980			
		Brown Thrasher		
Shrub and tree foliage volume	0.001	0.238	0.238	1.591
Percent canopy cover	-3.169	0.477	0.238	-0.777
Average density board reading	-0.159	0.669	0.193	-1.064
Shrub foliage volume	0.001	0.754	0.085	1.342
Percent density cottonwood	-46.351	0.940	0.186*	-0.906
Y intercept	0.577			

*Initial variable significant at the $p < 0.05$ level.

composed of short trees and a dense shrub understory supported the highest densities of Common Grackles during the reproductive season.

Starling density increased with increasing percent composition of green ash, boxelder, and elm, and with increasing understory density. The proximity of farm houses within 1/2 mile of a tree claim also had positive influence on the density of Starlings. Starlings were species specific in their habitat selection. This was probably due to the abundant natural cavities and vacant woodpecker holes in green ash and boxelder.

The presence of a shrub layer and tree foliage were important to Brown Thrashers selecting a nest site in tree claim habitat. Brown Thrasher density increased during the reproductive season with increasing shrub and tree foliage volume.

Common Nesting Birds, Single-row Windbreak Habitat. Red-winged Blackbird density increased with increasing windbreak length and diversity, and when foliage was within 1.8 m of the ground (Table 26). In addition, the density of this species increased when alfalfa fields were adjacent to the windbreak, as indicated by the negative Beta value for presence of cultivated grains.

Both large, full canopy trees, such as green ash, and small, dense trees, such as young Siberian elm were selected for nesting by Mourning Doves in windbreak habitat.

TABLE 26. Results of stepwise forward multiple regression analysis of common birds associated with single-row windbreak habitat during the 1977 reproductive season including all independent variables accounting for significant variation at the $p < 0.10$ level ($N = 14$).

Independent variable	Regression coefficient (B)	Coefficient of determination (R^2)	R^2 increase	Standardized regression coefficient (Beta)
		Red-winged Blackbird		
Presence of cultivated grain	-0.939	0.396	0.395	-0.727
Average density board reading	0.152	0.567	0.170	0.575
Average maximum shrub height	-0.088	0.686	0.119	-1.397
Number of shrub species	0.585	0.744	0.058	0.548
Number of tree species	1.091	0.777	0.033	0.895
Proximity of water < 1/4 mile	-3.321	0.865	0.088	-1.103
Length	0.003	0.908	0.042	0.597
Plant species diversity	-2.594	0.991	0.083*	-0.990
Y intercept	0.080			
		Mourning Dove		
Tree foliage volume	0.001	0.232	0.232	0.015
Number of trees > 22.9 cm DBH	0.019	0.488	0.256	0.232
Average density board reading	0.208	0.639	0.152	1.104
Shrub foliage volume	-0.183	0.751	0.112	-0.433
Number of trees 7.6-15.2 cm DBH	0.038	0.933	0.182*	1.046
Average maximum shrub height	-0.045	0.966	0.033	-1.138
Y intercept	-1.312			
		Brown Thrasher		
Number of trees 15.3-22.9 cm DBH	0.035	0.304	0.304	0.629
Average maximum shrub height	0.018	0.652	0.349*	0.847
Tree foliage volume	0.014	0.751	0.099	0.445
Y intercept	-0.513			
		Eastern Kingbird		
Number of tree species	1.305	0.269	0.269	1.959
Length	-0.003	0.405	0.136	-1.108
Plant species diversity	-2.312	0.554	0.149	-1.649
Presence of cultivated grains	-0.265	0.725	0.171	-0.383
Number of trees 15.3-22.9 cm DBH	-0.069	0.777	0.052	-0.793
Average maximum shrub height	-0.031	0.822	0.045	-0.910
Shrub and tree foliage volume	-0.033	0.865	0.043	-0.595
Stem density	0.050	0.953	0.088*	0.545
Y intercept	3.900			
		Black-billed Cuckoo		
Number of trees 15.3-22.9 cm DBH	0.035	0.553	0.553	0.358
Number of trees 7.6-15.2 cm DBH	0.011	0.690	0.137	0.296
Proximity of buildings < 1/4 mile	0.002	0.773	0.083	0.001
Proximity of water < 1/4 mile	-1.149	0.828	0.055	-0.605
Shrub and tree foliage volume	0.045	0.926	0.097*	0.805
Shrub foliage volume	-0.113	0.963	0.037	-0.262
Y intercept	0.027			

*Initial variable significant at the $p < 0.05$ level.

Shrubs apparently had a negative influence on the density of Mourning Doves nesting in windbreaks.

The presence of tall shrubs had a positive correlation with density of Brown Thrashers. The number of trees 15.3-22.9 cm DBH, and shrub foliage volume had additional positive affects on the density of Brown Thrashers. Brown Thrashers were observed nesting in tall shrubs, such as common chokecherry, in the branches of a mature green ash that were within 1 m of the ground, and in windbreaks composed of Siberian elm in the 7.6-22.9 cm DBH size class. Foliage close to the ground was probably the vegetation feature most attractive to Brown Thrashers nesting in windbreaks.

The six negative Beta values, and the apparent contradictory influences of several of the variables in the regression equation for the Eastern Kingbird made it difficult to clearly interpret the results. The Eastern Kingbird apparently selected nesting habitat based on numerous habitat features, such as vegetation diversity, the presence of pasture/alfalfa, shrub height, and total foliage volume instead of one or two distinctive features. This bird may also be selecting nesting habitat based on habitat features not measured in the study.

The presence of Siberian elm in the 7.6-22.9 cm DBH size class accounted for 55% (R^2) of the density of the Black-billed Cuckoo. These birds nested in Siberian elm within 2 m of the ground. Siberian elm provided two vegetative characteristics (numerous crotches and dense foliage close to the ground) that are selected for by nesting Black-billed Cuckoos (Bent 1964b:71). Cuckoos were observed during the study in windbreaks composed of mature green ash, although nests were not located in these trees.

Common Wintering Birds, Riparian Woodland Habitat. The density of trees 22.9-38.1 cm DBH and $>$ 38.1 cm DBH were important to the White-breasted Nutchatch selecting winter habitat (Table 27). The positive Beta value for degree of interior openness suggested that interior openings within riparian woodlands was also attractive to the White-breasted Nuthatch. Intercorrelations between the degree of interior openness and density of trees 22.9-38.1 cm DBH ($r = -0.80$, $p < 0.05$) and between the degree of interior openness and density of trees $>$ 38.1 cm DBH ($r = -0.50$, $p < 0.10$) reduced the surety of the prediction, however. Smith (1971) found that the White-breasted Nuthatch preferred dense stands of trees during the winter.

Downy Woodpecker density increased with increasing density of trees $>$ 38.1 cm DBH in riparian woodlands. Smith (1971) found the Downy Woodpecker most frequently during the winter in riparian woodlands with a dogwood understory. Smith's findings contradicted the negative relationship between stem density and the density of the Downy Woodpecker as indicated in Table 27. Riparian woodlands containing

TABLE 27. Results of stepwise forward multiple regression analysis of common birds associated with riparian woodland habitat during the 1976 winter season including all independent variables accounting for significant variation at the $p < 0.10$ level ($N = 14$).

Independent variable	Regression coefficient (B)	Coefficient of determination (R^2)	R^2 increase	Standardized regression coefficient (Beta)
		White-breasted Nuthatch		
Density of trees > 38.1 cm DBH	0.022	0.481	0.481	0.762
Density of trees 22.9-38.1 cm DBH	0.033	0.612	0.130	1.139
Degree of interior openness	1.905	0.769	0.158*	0.820
Average maximum canopy height	-0.072	0.817	0.047	-0.393
Presence of cultivated grains	0.273	0.899	0.082	0.413
Y intercept	-0.777			
		Downy Woodpecker		
Density of trees > 38.1 cm DBH	0.011	0.790	0.790	0.453
Percent density cottonwood	-0.559	0.824	0.034	-0.434
Proximity of buildings < 1/4 mile	-0.404	0.869	0.045	-0.415
Percent density elm	-0.589	0.908	0.039	-0.263
Degree of interior openness	-1.076	0.925	0.017	-0.570
Density of trees 22.9-38.1 cm DBH	-0.008	0.961	0.037	-0.340
Average maximum canopy height	0.073	0.972	0.010	0.430
Stem density	-0.001	0.989	0.018*	-0.328
Y intercept	-0.394			
		Hairy Woodpecker		
Density of dead trees > 15.2 cm DBH	0.040	0.413	0.413	1.109
Presence of cultivated grains	0.150	0.650	0.237	0.354
Plot area	-0.609	0.847	0.197	-0.402
Density of trees 22.9-38.1 cm DBH	-0.113	0.878	0.031	-0.639
Density of trees > 38.1 cm DBH	0.924	0.965	0.088*	0.494
Y intercept	-0.935			
		Black-capped Chickadee		
Density of trees > 38.1 cm DBH	0.029	0.533	0.533	0.359
Percent density green ash	2.539	0.613	0.081	0.556
Presence of cultivated grains	1.036	0.792	0.179*	0.568
Y intercept	-2.385			

*Initial variable significant at the $p < 0.05$ level.

trees with a DBH greater than 38.1 cm were most suitable for the Downy Woodpecker during the winter. The presence of a shrub understory may also be beneficial for the Downy Woodpecker.

Hairy Woodpecker density increased with increasing density of dead trees > 15.2 cm DBH and density of trees > 38.1 cm DBH in riparian woodlands. Smith (1971) oberved the Hairy Woodpecker more often on dead substrate than the Downy Woodpecker or White-breasted Nuthatch. Cropland adjacent to riparian woodlands indicated a positive influence on the density of the Hairy Woodpecker.

Density of trees > 38.1 cm DBH had the greatest positive correlation with density of the Black-capped Chickadee. The positive Beta values for percent density of green ash, and presence of cultivated grains suggested that a riparian woodland composed of green ash trees and adjacent to cropland was most suitable for the Black-capped Chickadee during the winter.

The correlations between density of trees in the 22.9 cm to > 38.1 cm DBH size class and the densities of all four winter bird species suggest that old, mature stands of riparian woodlands were most suitable as winter habitat for the White-breasted Nuthatch, the Downy Woodpecker, and the Black-capped Chickadee. The presence of dead trees would make this type of habitat suitable for the Hairy Woodpecker.

The different foraging strategies employed by the White-breasted Nuthatch, Downy Woodpecker, Hairy Woodpecker, and Black-capped Chickadee allowed these four species to exploit the same mature woodland habitat with minimum competition. Smith (1971) and Kisiel (1972) found the Hairy Woodpecker foraged more on secondary limbs and larger branches than the Downy Woodpecker. The Downy Woodpecker foraged more on small branches and saplings. Smith also reported that the White-breasted Nuthatch foraged on tree trunks and major limbs. The presence of grain stubble (probably corn) had a positive influence on the density of three of these bird species and on the overall SBD during winter.

SUMMARY AND CONCLUSIONS

Bird species diversity in riparian woodland habitat was not significantly higher than BSD in the block-like tree claim habitat during the spring migration ($p = 0.498$), reproductive ($p = 0.188$) and winter seasons ($p = 0.958$) at the $p < 0.05$ level. BSD in multi-row shelterbelt habitat was not significantly higher than BSD in single-row windbreak habitat during the spring migration ($p = 0.812$) and reproductive ($p = 0.725$) seasons at the $p < 0.05$ level. Windbreaks were not suitable for supporting winter bird populations. The pooled BSD for riparian woodland and tree claim habitats was higher than the pooled BSD for shelterbelt and windbreak habitats during the spring migration ($p = 0.001$) and reproductive seasons ($p = 0.001$). The pooled BSD for riparian woodland and tree claim habitats was also higher ($p = 0.005$) than BSD in shelterbelt habitat during the winter season. Tree claim habitat was preferred by the most transients during spring migration. The largest numbers of bird species, however, were observed in riparian woodland habitat during all seasons studied.

Riparian woodland habitat supported all bird species occurring in a minimum of two study plots of either tree claim, shelterbelt, or windbreak habitats. Exceptions were the Swainson's Hawk, Common Crow, and Red-eyed Vireo, which occurred in tree claim habitat during the reproductive season, and the Chestnut-sided Warbler which occurred in tree claim habitat during spring migration. The Vesper Sparrow, Dickcissel, Lark Sparrow, and Clay-colored Sparrow also occurred in one or more habitat types but not riparian woodland; however, these four species do not need woody vegetation for nesting.

Shelterbelt and windbreak habitats supported bird densities higher (p = 0.001) than riparian woodland or tree claim habitats during the spring migration and reproductive seasons. Rapidly fluctuating bird populations and different census initiation times among habitat types during spring migration reduced the surety of the conclusions for population density during this season. The differences in densities among habitat types were judged to be a function of plot size and the relationship of plot size to the foraging activities of birds. Population density was inversely related to the average plot size of each habitat type during spring migration and reproductive seasons. All four habitats supported population densities at least 100% higher than densities reported in the literature for nesting birds in woodlands of larger area in the eastern United States. The high densities in the area of study were probably due to the scattered distribution of the woodland habitats in a region composed of over 97% agricultural and prairie land.

Shelterbelt habitat supported population densities higher (p = 0.018) than tree claim or riparian woodland habitats during the winter season. House Sparrows, however, comprised 33% of the density supported by shelterbelts during the winter and only 1% and 18% in riparian woodland and tree claim habitats, respectfully. Although tree claim habitat supported a lower population density than riparian woodland habitat during all seasons studied, the only difference significant at the $p < 0.05$ level was during the reproductive season.

Maintenance of BSD at present levels in woodlands of the eastern quarter of South Dakota is dependent primarily upon preservation of riparian woodland habitat, and secondarily tree claim habitat. Shelterbelt and windbreak habitats supported bird diversities lower than riparian woodlands or tree claims, but supported higher population densities.

Birds occurring in more than 25% of the study plots were listed for each distinctive cover type within each habitat studied. These results provide the land owner and/or resource manager the capability to predict the bird communities that will be supported under the different land management practices influencing composition of vegetation in woodland habitat.

Bird communities associated with different vegetative cover types in riparian woodland and tree claim habitats had considerable overlap in bird species composition. Sparse stands of trees ($\bar{X}$ = 32.2 trees/0.4 ha) with occasional shrubs ($\bar{X}$ = 54.0 m^3/0.4 ha) supported all but one of the bird species associated with dense tree stands ($\bar{x}$ = 144.2 trees/0.4 ha) with a moderately developed shrub layer ($\bar{x}$ = 678.8 m^3/0.4 ha) in riparian woodlands during the reproductive season. Elimination of the shrub layer and loss of tree vigor, however, caused a decrease in number of species using tree claim habitat. Unique transients occurred in tree claims with dense tree stands ($\bar{x}$ = 216.0 trees/0.4 ha) and developed shrub layers ($\bar{x}$ = 1082.6 m^3/0.4 ha) and in the denser riparian woodland study plots during spring migration.

Species composition of bird communities associated with the cover types in windbreak habitat differed substantially. This difference in composition reflected the greater difference in vegetative composition of each cover type in windbreak habitat as compared to riparian woodland and tree claim habitats.

Maintenance of maximum bird diversity in riparian woodland habitat during the spring migration and reproductive seasons was most dependent on the area of habitat present. The log transformation of plot area accounted for 54% of the variation in BSD during spring migration and 71% of the variation in BSD during the reproductive season. Minimum plot sizes of 6.0 ha and 5.9 ha are predicted to support 95% of the maximum BSD supported by riparian woodland habitat during the spring migration and reproductive seasons, respectfully.

Population densities increased with increasing canopy cover, ground cover, and shrub volume during the reproductive season in riparian woodland habitat. Both population density and BSD increased more in response to increasing tree density and shrub volume during spring migration than during the reproductive season. During the winter season, BSD had a positive correlation with the proximity of farm buildings and corn stubble, and density had a positive correlation with proximity of corn stubble and percent density of cottonwoods and green ash.

Tree claims composed of tall trees (cottonwood, elms, and silver maple), short trees (green ash and boxelder), and a shrub layer were most suitable for achieving a balance between maximum bird diversity and maximum bird density in the area and during the seasons studied. The proximity of farm buildings had a positive correlation with BSD during winter in tree claim habitat.

Diversity and density of birds can be maximized in windbreaks by presence of tall, full canopy trees and by presence of shrubs that can be planted initially between the trees or underplanted when the initial tree planting is well established. Cottonwood, green ash, and hackberry will provide the best tall, full canopy selection for the area of study. Common chokecherry, American plum, and Tatarian honeysuckle are acceptable shrubs for the eastern quarter of South Dakota.

In riparian woodland habitat, Mourning Dove density increased during the reproductive season with increasing percent canopy cover and shrub volume. The Blue Jay selected nesting habitat with a shrub layer present while the American Robin evaluated the tree, shrub, and herb layers before selecting a nest site. The Northern Oriole had a positive correlation with the presence of cottonwood trees.

The Common Flicker nested in tree claims adjacent to pastureland and containing trees 22.9-38.1 cm DBH, and with a "patchy" tree distribution. The American Robin nested in tree claims close to water and cultivated grains. The presence of both tree foliage and shrubs was important to nesting Brown Thrashers and Common Grackles. Common Grackles also selected larger tree claims, and their density increased with decreasing canopy height. The Starling was associated with tree claims containing green ash, boxelder, and elm. Farm buildings within 1/2 mile of a tree claim had an additional positive correlation with Starling density.

The Red-winged Blackbird nested in windbreaks adjacent to alfalfa, and their density increased with increasing windbreak length and diversity. The Mourning Dove selected full canopy trees (green ash) and small dense trees (Siberian elm) for nesting. The Brown Thrasher and Black-billed Cuckoo nested in windbreaks with foliage close to the ground.

Mature stands of riparian woodlands containing trees in the 22.9 cm DBH to > 38.1 cm DBH size class were most suitable as winter habitat for the White-breasted Nuthatch, Downy Woodpecker, and Black-capped Chickadee. The presence of dead trees > 15.2 cm DBH made this type of habitat suitable for the Hairy Woodpecker.

LITERATURE CITED

Anderson, S. H., and H. H. Shugart. 1974. Habitat selection of breeding birds of an east Tennessee deciduous forest. Ecology 55:828-837.

Austin, O. L. Jr. [ed.] 1968. Life histories of North American Cardinals, grosbeaks, buntings, towhees, finches, sparrows, and allies. U.S. Natl. Mus. Bull. 237, parts 1,2.

Beecher, W. J. 1942. Nesting birds and the vegetation substrate. Chicago Ornithological Society, Chicago.

Bent, A. C. 1964a. Life histories of North American thrushes, kinglets, and their allies. U.S. Natl. Mus. Bull. 196.

Bent, A. C. 1964b. Life histories of North American cuckoos, goatsuckers, hummingbirds, and their allies. U.S. Natl. Mus. Bull. 176, part 1.

Blalock, H. M. 1972. Social statistics. Second ed. McGraw-Hill, New York.

Bond, R. R. 1957. Ecological distribution of breeding birds in the upland forest of southern Wisconsin. Ecol. Monogr. 27:351-384.

Carothers, S. W., R. R. Johnson, and S. W. Aitchison. 1974. Population structure and social organization of southeastern riparian birds. Am. Zool. 14:97-108.

Choate, G. A., and J. S. Spencer. 1969. Forests in South Dakota. U.S. For. Serv. Bull. Int.-8.

Climatological Data. 1976. Annual summary, South Dakota. NOAA, Environ. Data Serv., Natl. Climatic Cent., Asheville, N.C. 18:1-17.

Dambach, C. A. 1941. The effect of land-use adjustments on wildlife populations in the Ohio Valley region. Trans. N. Am. Wildl. Nat. Resour. Conf. 5:331-337.

Emlen, J. T. 1971. Population densities of birds derived from transect counts. Auk 88:323-342.

Galli, A. E. 1974. Bird species diversity and the size of oak woods in central New Jersey. M.S. Thesis. Rutgers Univ., New Brunswick, N.J.

Giles, R. H. 1971. Wildlife management techniques. The Wildlife Society, Washington, D.C.

Griffith, P. W. 1976. Introduction of the problems, p. 3-7. In R. W. Tinus [ed.] Proc. Symp. Shelterbelts on the Great Plains. Great Plains Agric. Counc. Publ. No. 78.

Hicks, L. E. 1935. A ten-year study of a bird population in central Ohio. Am. Midl. Nat. 16:177-186.

Horn, H. S. 1966. Measurement of overlap in comparative ecological studies. Am. Nat. 100:419-424.

Houston, C. S. 1971. Spring migration: northern Great Plains region. Am Birds 25:758-764.

Houston, C. C. 1972. Spring migration: northern Great Plains region. Am. Birds 26:774-777.

James, F. C. 1971. Ordinations of habitat relationships among breeding birds. Wilson Bull. 83:215-236.

James, F. C., and H. Shugart. 1970. A quantitative method of habitat description. Audubon Field Notes 24:727-736.

Johnson, J. R., and J. T. Nichols. 1970. Plants of South Dakota grasslands: a photographic study. South Dakota State Univ. Agric. Exp. Stn. Bull. 566.

Johnston, D. W. 1970. High density of birds breeding in a modified deciduous forest. Wilson Bull. 82:79-82.

Karr, J. R. 1968. Habitat and avian diversity on strip-mined land in east-central Illinois. Condor 70:348-359.

Karr, J. R., and R. R. Roth. 1971. Vegetation structure and avian diversity in several new world areas. Am. Nat. 105:423-435.

Kendeigh, S. C. 1944. Measurement of bird populations. Ecol. Monogr. 14:67-106.

Kisiel, D. S. 1972. Foraging behavior of *Dendrocopos villosus* and *D. pubescens* in eastern New York State. Condor 74:393-398.

MacArthur, R. H. 1964. Environmental factors affecting bird species diversity. Am. Nat. 98:387-397.

MacArthur, R. H, and J. W. MacArthur. 1961. On bird species diversity. Ecology 42:594-498.

MacArthur, R. H., and E. O. Wilson. 1967. The theory of island biogeography. Princeton Univ. Press, Princeton, New Jersey.

Nice, M. M. 1941. The role of territory in bird life. Am. Midl. Nat. 26;441-487.

Nie, N. H., C. H. Hull, J. G. Jenkins, K. Steinbrenner, and D. H. Bent. 1975. SPSS: statistical package for the social sciences, Second ed. McGraw-Hill, Inc., New York.

Poole, R. W. 1974. An introduction to quantitative ecology. McGraw-Hill, Inc., New York.

Reynaud, W. E. 1973. Spring migration: northern Great Plains region. Am. Birds 27:785-788.

Roth, R. R. 1976. Spatial heterogeneity and bird species diversity. Ecology 57:773-782.

Shannon, C. E., and W. Weaver. 1963. The mathematical theory of communication. University of Illinois Press, Urbana.

Smith, L. M. 1971. Winter ecology of woodpeckers and nuthatches in southeastern South Dakota. Ph.D. Diss. Univ. of South Dakota, Vermillion.

Sneath, P. H., and R. Sokal. 1973. Numerical taxonomy. W. H. Freeman and Co., San Francisco, Ca.

Spuhler, W., W. F. Lytle, and D. Moe. 1971. Climate of South Dakota. South Dakota State Univ. Agric. Exp. Stn. Bull. 523.

Sutton, G. M. 1960. The nesting Fringillids of the Edwin S. George Reserve, southeastern Michigan. Jack Pine Warbler 38:3-15.

Westin, F. C., L. F. Puhr, and G. F. Buntley. 1967. Soils of South Dakota. South Dakota State Univ. Agric. Exp. Stn. Soil Survey Series No. 3.

Weins, J. A. 1969. An approach to the study of ecological relationships among grassland birds. A.O.U. Ornithol. Monogr. 8:1-93.

Willson, M. F. 1974. Avian community organization and habitat structure. Ecology 55:1017-1029.

APPENDICES

APPENDIX A

Calculated independent variables used to describe the physical and vegetative features of each study plot.

TABLE 1. Summary of physical and vegetation variables calculated in riparian woodland habitat.

Plot	Independent Variable																							
	PCCC	PCGC	DT39	DT95	DT>5	DDT6	TFVT	SFVT	TTD	DC	PSD	SIZE	CH	SH	HH	CROP	PAST	PW 4:2 PH 4:2	STEM[a]	OPEN	FCGA	PCCW	PCAE	PCBO	TFVL[a]
R 5(45)[b]	56	73	19	10	36	3	9655	2789	72	19	0.68	8.7	23.8	3.4	1.4	2	0	0:0	408	55	2	98	0	0	124
R 5(40)	47	55	48	30	18	8	4697	5331	111	20	1.04	3.6	21.6	4.8	0.8	1	1	0:0	362	25	0	100	0	0	100
R1A(80)	41	90	2	3	22	1	3374	24	28	13	0.52	3.8	16.4	4.0	1.4	2	0	0:0	0	54	75	0	12	12	34
R18(70)	49	71	2	5	30	5	6619	10	43	3	0.85	2.2	15.9	1.5	0.5	2	0	1:1	3	54	28	0	0	35	65
R14(75)	63	78	40	47	17	36	4743	814	160	15	1.58	0.9	17.0	3.5	1.7	1	1	1:1	175	8	52	0	3	38	56
R13(100)	75	95	56	33	80	3	5766	29	180	10	0.33	1.1	19.3	2.0	1.1	2	0	0:0	13	8	85	0	7	7	58
R 7(63)	59	36	42	40	28	14	4348	15	140	2	0.47	2.9	17.3	0.0	0.1	0	2	1:1	10	13	83	0	17	0	44
R 9(50)	23	80	8	8	5	2	3178	2	23	1	0.40	1.0	14.1	0.6	0.5	0	2	0:0	9	63	66	0	0	0	32
R15(63)	24	99	6	10	16	4	3406	220	42	10	0.32	0.7	15.6	1.6	0.9	0	2	0:0	20	70	95	0	0	0	36
R 2(97)	29	88	0	0	18	2	9204	107	20	6	1.15	5.3	18.3	1.9	0.8	2	0	0:1	41	65	44	4	23	4	93
R 8(110)	34	91	6	14	20	4	6817	14	46	1	1.14	3.5	14.7	0.6	0.3	1	1	0:1	5	45	21	0	55	20	68
R 1(50)	66	55	42	50	28	10	6521	1440	146	11	0.92	1.9	17.1	3.9	0.7	1	1	0:0	202	35	70	0	20	0	80
R12(95)	15	83	0	0	20	4	4871	1	24	1	0.71	3.3	14.5	0.5	0.3	1	1	0:0	5	50	41	0	50	0	49
R 4(103)	66	73	37	18	35	5	5662	1096	95	15	0.88	1.6	17.9	5.1	0.9	1	1	0:0	247	19	53	0	0	47	68
Average	45	77	22	20	27	7	5633	849	81	9	0.79	2.9	17.4	2.4	0.8				107	40	51	14	13	12	65

[a] All values x 10^2.
[b] Maximum plot age ± 5 years.

TABLE 2. Summary of physical and vegetation variables calculated in tree claim habitat.

Plot	Independent Variable																								
	PCCC	PCGC	DT39	DT95	DT>5	DDT6	TFVT	SFVT	TTD	DC	PSD	SIZE	CH	SH	HH	CROP	PAST	PW 4:2	PK 4:2	STEM^{a}	OPEN	PCGA	PCCW	PCAE	PCDO	TFVL^{a}
T 4(91)^{b}	83	83	135	53	18	8	5232	1063	233	14	1.18	2.6	18.6	3.6	0.7	4	0	0:0	1:1	245	0	92	1	0	6	63
T 2(95)	83	68	93	58	46	10	6909	557	226	13	1.49	4.3	21.0	3.2	0.7	3	1	1:1	1:1	115	4	32	0	48	17	75
T 3(86)	38	76	44	52	12	16	1895	1	132	1	0.62	3.4	15.5	0.8	0.5	3	1	1:1	0:0	0	10	83	0	0	15	19
T 9(83)	75	96	25	97	30	22	6720	32	182	8	0.12	3.9	15.7	1.9	1.3	4	0	0:0	0:0	36	0	98	0	0	0	68
T 5(63)	80	30	164	46	20	4	5922	2069	242	16	1.68	3.0	18.2	3.5	0.4	3	0	1:1	1:1	301	5	40	3	3	53	80
T 6(90)	80	82	86	86	8	2	5394	898	192	8	0.54	3.6	15.0	3.0	1.0	1	3	1:1	1:1	92	5	99	0	0	1	63
T 7(55)	80	75	120	83	22	5	7060	2041	260	15	1.31	4.1	16.0	2.9	0.4	4	0	0:0	0:0	277	0	69	0	0	20	91
T12(93)	33	54	8	46	26	30	1594	0	114	1	0.00	4.3	15.0	0.0	0.7	2	2	1:1	1:1	0	15	100	0	0	0	16
T10(84)	60	21	68	65	28	10	4156	3327	180	17	1.60	4.6	23.1	2.1	0.5	4	0	0:0	1:1	380	6	52	5	25	14	75
T17(90)	76	85	170	66	22	8	5517	521	284	12	0.74	4.4	14.7	4.0	0.8	3	0	0:1	0:1	112	0	74	0	0	26	60
T16(75)	75	63	70	87	17	15	4441	832	212	11	0.96	2.1	14.5	2.4	0.9	3	0	0:0	0:0	111	0	69	0	0	30	53
T18(58)	80	83	80	55	35	7	5806	517	177	6	0.80	3.5	13.7	3.5	0.5	4	0	0:0	0:0	63	6	49	0	0	51	63
T19(95)	84	23	60	68	37	15	6644	52	188	11	0.99	4.2	19.2	5.9	0.3	3	0	0:1	0:1	54	6	35	0	0	56	67
T22(87)	37	81	8	52	16	14	3150	10	90	6	0.33	3.8	13.8	1.1	0.6	3	0	1:1	1:1	16	20	89	0	0	11	32
Average	70	69	81	65	24	12	5031	851	194	10	0.88	3.7	16.7	2.7	0.7					129	5	70	1	5	21	59

[a] All values x 10^2.
[b] Maximum plot age ± 5 years.

TABLE 3. Summary of physical and vegetation variables calculated in single-row windbreak habitat.

Plot	Independent Variable																			
	TFVT	SFVT	NT36	NT69	NT>9	DC	CH	SH	HH	LENG	FSD	CROP	PAST	SSPT	TSPT	PW 4:2	PH 4:2	STEM	SDP	TFVL
S 1(30)[a]	26.2	6.30	0.06	0.07	0.26	14	19.6	2.5	0.8	762	0.72	2	0	2	3	1:1	0:0	10.8	2.4	32.5
S 2(20)	8.3	0.05	0.30	0.20	0.05	11	9.9	3.0	0.9	363	0.50	2	0	1	2	0:0	0:0	9.4	1.9	8.3
S 6(8)	0.6	1.80	0.14	0.00	0.00	18	4.9	4.6	0.3	793	0.68	2	0	2	1	0:0	0:0	24.5	1.4	2.5
S 7(8)	0.3	2.03	0.05	0.00	0.00	18	4.8	4.7	0.3	793	0.69	2	0	2	1	0:1	1:1	21.2	1.4	2.4
S 5(11)	6.3	1.62	0.48	0.00	0.00	14	7.6	6.2	0.7	793	0.00	1	1	1	1	0:0	0:0	10.3	1.4	7.9
S 4(05)	28.8	0.00	0.04	0.03	0.14	7	16.2	0.0	0.8	762	0.00	1	1	0	1	1:1	1:1	5.1	5.7	28.8
S11(7)	3.5	0.02	0.49	0.00	0.00	13	7.6	4.5	0.4	793	0.60	2	0	1	1	0:0	0:0	12.9	1.5	3.5
S12(32)	10.6	2.78	0.21	0.09	0.09	18	9.6	4.5	0.5	512	1.25	0	2	4	3	0:0	0:0	26.9	2.6	13.4
S13(9)	2.2	1.93	0.09	0.00	0.00	17	6.4	4.6	0.6	753	0.00	2	0	1	1	0:0	0:0	15.0	1.8	4.1
S14(26)	36.4	0.55	0.06	0.16	0.18	20	14.4	2.3	1.0	444	0.00	2	0	1	1	0:1	1:1	18.5	2.7	37.0
S16(8)	6.5	1.88	0.42	0.00	0.00	19	6.5	5.8	0.4	784	0.00	2	0	1	1	0:0	0:0	14.0	1.4	8.4
S15(8)	5.0	1.53	0.43	0.00	0.00	17	6.6	5.8	0.4	782	0.00	0	2	1	1	0:0	0:0	14.3	1.3	6.3
S18(5)	0.0	1.35	0.00	0.00	0.00	13	0.0	3.2	0.3	784	0.00	0	2	1	0	0:0	0:0	8.3	1.3	1.4
S17(6)	0.0	0.85	0.00	0.00	0.00	13	0.0	2.4	0.1	259	0.64	1	1	3	0	0:0	0:0	9.6	1.2	0.8
Average	9.6	1.63	0.29	0.04	0.05	15	8.2	3.9	0.5	670	0.32			2	1			14.3	2.0	11.2

[a] Maximum plot age ± 1 year except in S1, S4, and S14 which are ± 5 years.

APPENDIX B

Summary of bird species diversity and population density calculated for each study plot.

TABLE 1. Bird species diversity[a] and population density[b] calculated for each study plot in riparian woodland habitat.

	Season					
	Winter 1976		Spring migration 1977		Reproductive 1977	
Study plot	Diversity	Density	Diversity	Density	Diversity	Density
R1	0.804	200.0	3.144	1870.6	2.489	929.4
R1A	1.799	664.7	2.883	700.0	2.694	741.0
R2	1.882	123.5	2.665	541.2	2.774	564.7
R4	0.853	105.9	2.462	1129.4	2.327	1147.1
R5	0.986	41.2	2.967	576.5	2.877	629.4
R6	0.939	35.3	2.727	864.7	2.936	847.0
R7	1.315	58.8	2.522	435.3	2.475	458.8
R8		23.5	2.745	1200.0	2.675	1141.2
R9			1.947	635.3	2.245	876.4
R12		11.8	2.429	411.8	2.440	370.6
R13	1.229	511.8	2.619	1558.8	2.491	1329.4
R14	0.757	111.8	1.999	947.1	2.171	941.2
R15			1.601	1017.6	1.598	1076.5
R18	1.679	223.5	2.451	841.2	2.323	794.1

[a] Shannon-Weaver index.
[b] Birds/40 ha.

TABLE 2. Bird species diversity[a] and population density[b] calculated for each study plot in tree claim habitat.

	Season					
	Winter 1976		Spring migration 1977		Reproductive 1977	
Study plot	Diversity	Density	Diversity	Density	Diversity	Density
T2	1.423	149.0	2.798	819.6	2.543	672.6
T3	1.032	21.6	2.508	396.1	2.414	338.3
T4	0.770	58.8	2.761	584.3	2.395	359.8
T5	1.016	217.6	2.818	850.9	2.289	615.8
T6	1.289	100.0	2.657	562.7	2.280	440.0
T7		2.0	2.399	745.1	2.303	688.2
T9	0.347	27.4	2.488	374.5	2.264	334.3
T10	0.994	39.2	3.058	1050.9	2.651	782.0
T12	0.813	27.4	2.733	498.0	2.308	406.6
T16	0.805	137.2	2.672	1378.4	2.210	746.8
T17	0.794	58.8	2.467	647.0	2.248	594.3
T18	0.757	66.7	2.169	652.9	2.025	586.5
T19	1.051	94.1	2.378	352.9	2.306	320.6
T22	0.990	241.1	2.491	1011.7	2.377	950.1

[a] Shannon-Weaver index.
[b] Birds/40 ha.

TABLE 3. Bird species diversity[a] and population density[b] calculated for each study plot in single-row windbreak habitat.

	Season					
	Winter 1976		Spring migration 1977		Reproductive 1977	
Study plot	Diversity	Density	Diversity	Density	Diversity	Density
S1	0.386	214.4 (7.1)[c]	2.363	810.8(27.0)	2.633	1630.6(54.4)
S3			1.144	1425.9(19.9)	1.310	1270.0(17.7)
S4			2.089	947.9(34.5)	2.174	828.5(30.1)
S5			1.966	1189.0(18.0)	1.890	1475.9(22.4)
S6			1.080	608.6(5.9)	1.414	1153.1(11.2)
S7			0.750	512.5(5.0)	1.313	1153.1(11.2)
S11			2.168	2587.1(28.3)	1.754	1850.6(20.2)
S12			2.479	5018.3(99.9)	2.320	2818.6(58.1)
S13			2.107	3514.6(29.8)	1.286	1391.0(11.8)
S14			2.276	2179.0(68.6)	2.559	2522.9(79.5)
S15			2.001	4662.8(56.5)	2.210	3049.2(37.0)
S16			2.041	1690.9(20.5)	1.858	1614.1(19.6)
S17			1.106	9224.1(27.9)	0.443	2049.9(6.2)
S18			1.083	6234.9(22.7)	1.261	4526.7(16.5)

[a] Shannon-Weaver index.
[b] Birds/40 ha.
[c] Birds/0.8 km.

APPENDIX C

Scientific names of birds identified during the study.

TABLE 1. Scientific names[a] of 91 bird species detected during the study.

Wood Duck (*Aix sponsa*)
Red-tailed Hawk (*Buteo jaimaicensis*)[b]
Swainson's Hawk (*Buteo swainsoni*)[b]
Bald Eagle (*Haliaeetus leucocephalus*)
American Kestrel (*Falco sparverius*)
Merrian's Turkey (*Meleagris gallopavo merriami*)
Bobwhite Quail (*Colinus virginianus*)
Killdeer (*Charadrius vociferus*)
American Woodcock (*Philohela minor*)
Mourning Dove (*Zenaida macroura*)[b]

Yellow-billed Cuckoo (*Coccyzus americanus*)[b,c]
Black-billed Cuckoo (*Coccyzus erythropthalmus*)[b]
Screech Owl (*Otus asio*)
Great Horned Owl (*Bubo virginianus*)
Belted Kingfisher (*Megaceryle alcyon*)
Common Flicker (*Colaptes auratus*)[b]
Red-bellied Woodpecker (*Melanerpes carolinus*)
Red-headed Woodpecker (*Melanerpes erythrocephalus*)[b]
Yellow-bellied Sapsucker (*Sphyrapicus varius*)
Hairy Woodpecker (*Picoides villosus*)[b]
Downy Woodpecker (*Picoides pubescens*)[b]

Eastern Kingbird (*Tyrannus tyrannus*)[b]
Western Kingbird (*Tyrannus verticalis*)[b]
Great Crested Flycatcher (*Myiarchus crinitus*)
Empidonax Flycatcher (*Empidonax spp.*)
Eastern Wood Pewee (*Contopus virens*)
Blue Jay (*Cyanocitta cristata*)[b]
Common Crow (*Corvus brachyrhynchos*)[b]
Black-capped Chickadee (*Parus atricapillus*)[b]
White-breasted Nuthatch (*Sitta carolinensis*)[b]
Brown Creeper (*Certhia familiaris*)

House Wren (*Troglodytes aedon*)[b]
Winter Wren (*Troglodytes troglodytes*)
Gray Catbird (*Dumetella carolinensis*)[b]
Brown Thrasher (*Toxostoma rufum*)[b]
American Robin (*Turdus migratorius*)[b]
Olive-backed Thrush (*Catharus ustulatus*)[b]
Gray-cheeked Thrush (*Catharus minimus*)[b]
Wood Thrush (*Hylocichla mustelina*)[b]
Eastern Bluebird (*Sialia sialis*)[b]
Starling (*Sturnus vulgaris*)[b]

Bell's Vireo (*Vireo bellii*)
Red-eyed Vireo (*Vireo olivaceus*)
Philadelphia Vireo (*Vireo philadelphicus*)
Warbling Vireo (*Vireo gilvus*)
Black-and-white Warbler (*Mniotilta varia*)
Tennessee Warbler (*Vermivora perigrina*)
Orange-crowned Warbler (*Vermivora celata*)
Nashville Warbler (*Vermivora ruficapilla*)
Yellow Warbler (*Dendroica petechia*)
Magnolia Warbler (*Dendroica magnolia*)

Cape May Warbler (*Dendroica tigrina*)[d]
Yellow-rumped Warbler (*Dendroica coronata*)
Black-throated-green Warbler (*Dendroica virens*)[d]
Chestnut-sided Warbler (*Dendroica pensylvanica*)
Blackpoll Warbler (*Dendroica striata*)
Ovenbird (*Seiurus aurocapillus*)
Northern Waterthrush (*Seiurus naveboracensis*)
Common Yellowthroat (*Geothlypis trichas*)
Yellow-breasted Chat (*Icteria virens*)
Mourning Warbler (*Oporornis philadelphia*)

Wilson's Warbler (*Wilsonia pusilla*)
Canada Warbler (*Wilsonia canadensis*)
American Redstart (*Setophaga ruticilla*)
House Sparrow (*Paser domesticus*)[b]
Western Meadowlark (*Sturnella neglecta*)
Red-winged Blackbird (*Agelaius phoenicius*)[b]
Common Grackle (*Quiscalus quiscula*)[b]
Brown-headed Cowbird (*Molothrus ater*)
Orchard Oriole (*Icterus spurius*)[b]
Northern Oriole (*Icterus galbula*)[b]

Scarlet Tanager (Piranga olivacea)
Cardinal (*Cardinalis cardinalis*)
Rose-breasted Grosbeak (*Pheucticus ludocicianus*)[b]
Black-headed Grosbeak (*Pheucticus melanocephalus*)
Blue Grosbeak (*Guiraca caerulea*)
Indigo Bunting (*Passerina cyanea*)
American Goldfinch (*Carduelis tristis*)
Dickcissel (*Spiza americana*)
Rufous-sided Towhee (*Pipilo erythrophthalmus*)
Vesper Sparrow (*Pooecetes gramineus*)

Lark Sparrow (*Chondestes grammacus*)
Dark-eyed Junco (*Junco hyemalis*)
Tree Sparrow (*Spizella arborea*)
Chipping Sparrow (*Spizella passerina*)
Clay-colored Sparrow (*Spizella pallida*)

Field Sparrow (*Spizella pusilla*)
Harris' Sparrow (*Zinotrichia querula*)
White-crowned Sparrow (*Zonotrichia leucophrys*)
Lincoln Sparrow (*Melospiza lincolnii*)
Song Sparrow (*Melospiza melodia*)

---

[a] A.O.U. Check-list of North American Birds (Fifth ed., 1957; 32nd Suppl., Auk 90:411; 33rd Suppl., Auk 93:875).
[b] Active nests located during study plot visits.
[c] Species detected only in 1976.
[d] Species not detected during the study but listed because of their association with multi-row shelterbelt habitat.

APPENDIX D

Correlation matrices of the independent variables calculated for riparian woodland, tree claim, and single-row windbreak habitats.

TABLE 1. Correlation matrix (r) for 28 independent variables calculated for riparian woodland habitat (N = 14).

	PCGC	DT39	DT95	DT>5	DDT6	TPVT	SFVT	TTDE	DC	PSD	SIZE	CH	SH	HH	CROP	PH4
PCCC	-0.44*	0.82**	0.71**	0.67**	0.39*	0.19	0.24	0.86**	0.59*	0.14	-0.09	0.51*	0.50*	0.38*	0.27	0.31
PCGC		-0.51*	-0.61**	0.05	-0.33	-0.04	-0.44*	-0.46*	-0.13	-0.15	-0.12	-0.32	-0.15	0.30	0.23	-0.46*
DT39			0.86**	0.53*	0.45*	-0.07	0.45*	0.95**	0.48*	0.08	-0.25	0.49*	0.42*	0.20	-0.10	0.16
DT95				0.25	0.69**	-0.14	0.24	0.92**	0.25	0.22	-0.34	0.20	0.21	0.08	-0.30	0.40*
DT>5					-0.35	0.26	-0.05	0.57**	0.19	-0.30	-0.02	0.41*	0.11	0.20	0.48*	-0.05
DDT6						-0.16	0.09	0.59**	0.22	0.60**	-0.30	0.00	0.16	0.34	-0.24	0.67**
TPVT							0.17	-0.03	0.14	0.37*	0.70**	0.53*	0.10	0.09	0.62**	-0.12
SFVT								0.26	0.74**	0.27	0.36*	0.74**	0.64**	0.24	0.07	-0.20
TTDE									0.39*	0.15	-0.29	0.39*	0.31	0.26	-0.04	0.32
DC										0.21	0.25	0.77**	0.89**	0.77**	0.29	-0.19
PSD											0.10	0.08	0.33	0.22	0.21	0.26
SIZE												0.61**	0.11	0.11	0.50*	-0.23
CH													0.55**	0.46*	0.44*	-0.13
SH														0.66**	0.34	-0.23
HH															0.44*	-0.05
CROP																-0.10

	PH2	STEM	OPEN	PCGA	PCCW	PCAE	PCSO	TPVL	ARE[a]
PCCC	-0.12	0.42*	-0.78**	0.08	0.11	-0.40*	0.36*	0.28	-0.12
PCGC	-0.19	-0.41*	0.47*	0.17	-0.30	0.12	0.07	-0.28	-0.26
DT39	-0.29	0.46*	-0.88**	0.12	0.23	-0.34	0.06	0.19	-0.25
DT95	-0.10	0.27	-0.90**	0.24	-0.01	-0.16	0.04	0.03	-0.31
DT>5	-0.10	0.04	-0.50*	0.17	0.01	-0.13	0.08	0.16	-0.05
DDT6	-0.07	0.19	-0.59**	0.05	-0.08	-0.14	0.37*	-0.07	-0.34
TPVT	0.36*	0.37*	0.13	-0.55**	0.34	0.16	0.03	0.83**	0.62**
SFVT	-0.35	0.88**	-0.21	-0.62**	0.89**	-0.33	-0.17	0.69**	0.32
TTDE	-0.21	0.34	-0.89**	0.20	0.07	-0.26	0.12	0.13	-0.31
DC	-0.59**	0.83**	-0.29	-0.26	0.65**	-0.57**	0.13	0.52*	0.10
PSD	0.21	0.34	-0.25	-0.53*	0.09	0.20	0.49*	0.42*	0.17
SIZE	0.18	0.44*	0.31	-0.63**	0.65**	0.16	-0.30	0.72**	0.92**
CH	-0.20	0.88**	-0.27	-0.45*	0.83**	-0.43*	-0.16	0.80**	0.47*
SH	-0.53**	0.71**	-0.29	-0.23	0.42*	-0.47*	0.32	0.43*	0.08
HH	-0.55**	0.43*	-0.14	-0.01	0.26	-0.51*	0.25	0.20	-0.09
CROP	0.09	0.15	0.04	-0.37*	0.20	-0.01	0.21	0.49*	0.50*
PH4	0.44*	-0.16	-0.38*	0.05	-0.22	-0.20	0.41*	-0.19	-0.18
PH2		-0.41*	0.12	-0.15	-0.25	0.37*	0.12	0.07	0.33
STEM			-0.25	-0.58**	0.61**	-0.39*	0.01	0.77**	0.32
OPEN				-0.10	0.01	0.11	-0.34	-0.02	0.23
PCGA					-0.71**	-0.12	-0.12	-0.75**	-0.64**
PCCW						-0.30	-0.30	0.75**	0.53*
PCAE							-0.17	-0.07	0.34
PCSO								-0.07	-0.25
TPVL									0.63**

[a] ARE = Log_n (SIZE)
*(p < 0.10)
**(p < 0.05)

TABLE 2. Correlation matrix (r) for 27 independent variables calculated for tree claim habitat (N = 14).

	PCGC	DT39	DT95	DT>5	DDT6	TFVT	SFVT	TTDE	DC	PSD	SIZE	CH	SH	HH	CROP	PW4
PCCC	-0.37*	0.64**	0.42*	0.35	-0.64**	0.87**	0.47*	0.79**	0.78**	0.64**	-0.08	0.44	0.80**	0.02	0.30	-0.50
PCGC		-0.21	0.13	-0.22	0.27	-0.19	-0.57**	-0.16	-0.58**	-0.70**	-0.07	-0.69**	-0.45*	0.59**	-0.13	0.12
DT39			-0.06	-0.06	-0.75**	0.52*	0.46*	0.90**	0.69**	0.66**	-0.18	0.20	0.61**	-0.19	0.15	-0.23
DT95				-0.08	-0.06	0.47*	0.05	0.29	0.19	-0.15	-0.04	-0.14	0.15	0.60**	0.02	-0.46*
DT>5					0.18	0.46*	-0.06	0.12	0.20	0.24	0.47*	0.46*	0.35*	-0.16	0.37*	-0.24
DDT6						-0.52*	-0.53**	-0.61**	-0.61**	-0.65**	0.17	-0.17	-0.56**	0.26	-0.07	0.10
TFVT							0.21	0.71**	0.65**	0.46*	0.07	0.26	0.76**	0.06	0.32	-0.45*
SFVT								0.42*	0.76**	0.75**	0.04	0.58**	0.11	-0.31	0.31	-0.24
TTDE									0.74**	0.61**	-0.10	0.24	0.65**	0.01	0.24	-0.45*
DC										0.84**	-0.01	0.64**	0.58**	-0.20	0.40*	-0.42*
PSD											-0.10	0.71**	0.50**	-0.53*	0.36*	-0.18
SIZE												0.29	-0.02	-0.14	-0.02	0.04
CH													0.29	-0.31	0.27	-0.09
SH														-0.27	0.15	-0.47*
HH															-0.21	-0.05
CROP																-0.67**

	PW2	PH4	PH2	STEM	OPEN	PCGA	PCCH	PCAE	PCBO	TFVL
PCCC	-0.41*	-0.12	0.03	0.57**	-0.81*	-0.51*	0.25	0.26	0.39*	0.91**
PCGC	-0.06	-0.12	-0.31	-0.55**	0.05	0.73**	-0.69**	-0.29	-0.58**	-0.41*
DT39	-0.04	-0.01	0.19	0.61**	-0.65**	-0.35	0.23	0.05	0.37*	0.62**
DT95	-0.43*	-0.45*	-0.44*	-0.01	-0.58**	0.21	-0.22	-0.14	-0.20	0.39*
DT>5	-0.08	-0.09	0.06	-0.02	-0.12	-0.65**	0.01	0.60**	0.33	0.34
DDT6	0.08	-0.09	-0.12	-0.57**	0.40*	0.36*	-0.25	-0.12	-0.33	-0.66**
TFVT	-0.27	-0.24	-0.07	0.34	-0.69**	-0.48*	-0.04	0.21	0.36*	0.89**
SFVT	-0.41*	0.29	0.13	0.96**	-0.32	-0.34	0.83**	0.29	0.09	0.62**
TTDE	-0.22	-0.21	0.02	0.57**	-0.87**	-0.36*	0.12	0.13	0.29	0.76**
DC	-0.13	0.15	0.26	0.87**	-0.60**	-0.52*	0.58**	0.37*	0.27	0.86**
PSD	-0.19	0.16	0.18	0.92**	-0.42**	-0.75**	0.60**	0.51*	0.46*	0.79**
SIZE	0.29	0.06	0.32	-0.01	0.24	-0.14	0.09	0.37*	-0.15	0.07
CH	-0.07	0.39*	0.44*	0.63**	-0.20	-0.56**	0.69**	0.71**	0.07	0.47*
SH	-0.01	-0.24	0.21	0.27	-0.55**	-0.60**	0.01	0.04	0.66**	0.67**
HH	-0.17	-0.03	-0.16	-0.32	-0.28	0.60**	-0.29	-0.06	-0.60**	-0.09
CROP	-0.72**	-0.34	-0.40*	0.41*	-0.35	-0.20	0.27	0.09	0.22	0.40*
PW4	0.75**	0.59**	0.34	-0.30	0.64**	0.13	-0.09	0.19	-0.25	-0.47*
PW2		0.29	0.56**	-0.42*	0.52**	-0.05	-0.21	0.08	0.05	-0.40*
PH4			0.75**	0.30	0.40*	0.08	0.44	0.40*	-0.38*	-0.06
PH2				0.20	0.29	-0.11	0.33	0.30	-0.08	0.00
STEM					-0.43*	-0.36*	0.79**	0.28	0.12	0.69**
OPEN						0.18	-0.04	-0.06	-0.14	-0.70**
PCGA							-0.33	-0.53*	-0.79**	-0.53**
PCCH								0.31	0.09	0.34
PCAS									-0.00	0.30
PCBO										0.34

*(p < 0.10)
**(p < 0.05)

TABLE 3. Correlation matrix (r) for 21 independent variables calculated for single-row windbreaks (N = 14).

	TPVT	NT36	NT69	NT>9	DC	CH	SH	HH	LEN	PSD	CHOP	SSPT	TSPT	PW4	PW2
TPVT	0.13	-0.24	0.56*	0.90**	-0.11	0.88**	-0.61**	0.79**	-0.16	-0.10	0.16	-0.24	0.38*	0.63**	0.73**
SPVT		-0.19	-0.07	0.47*	0.28	0.34	0.14	0.02	0.26	0.46*	0.04	0.42*	0.60**	0.41*	0.24
NT36			-0.09	-0.37*	0.09	-0.03	0.58**	-0.02	0.25	-0.29	-0.01	-0.22	0.11	-0.33	-0.51*
NT69				0.56**	-0.04	0.52*	-0.39*	0.71**	-0.62**	0.24	0.19	0.04	0.32*	0.07	0.25
NT>9					-0.13	0.89**	-0.62**	0.69**	-0.36	0.21	0.15	0.03	0.61**	0.74**	0.72**
DC						-0.18	0.60**	-0.22	0.07	0.16	0.16	0.35	0.09	-0.54**	-0.07
CH							-0.44*	0.82**	0.04	0.04	0.28	-0.21	0.68**	0.71**	0.66**
SH								-0.41	0.39*	-0.05	-0.04	0.13	-0.01	-0.64**	-0.57**
HH									-0.12	-0.21	0.32	-0.44*	0.45*	0.44*	0.46*
LEN										-0.37*	0.03	-0.42*	-0.06	0.21	0.07
PSD											-0.06	0.69**	0.59**	0.05	0.05
CROP												-0.22	0.09	0.07	0.11
SSPT													0.38*	-0.21	-0.16
TSPT														0.37*	0.21
PW4															0.64**

	PH4	PH2	STEM	SBP	TPV
TPVT	0.56**	0.56**	-0.14	0.73**	0.99**
SPVT	-0.26	-0.26	0.21	-0.12	0.26
NT36	-0.43*	-0.43*	-0.01	-0.31	-0.26
NT69	0.19	0.19	0.05	0.29	0.53**
NT>9	0.35	0.35	-0.08	0.62	0.93**
DC	-0.02	-0.02	0.79**	-0.51	-0.08
CH	0.35	0.35	-0.09	0.69	0.89**
SH	-0.48*	-0.48*	0.42*	-0.74	-0.58**
HH	0.35	0.35	-0.24	0.59	0.77**
LEN	0.01	-0.01	0.01	-0.02	-0.12
PSD	-0.12	-0.12	0.56**	-0.05	-0.03
CROP	0.19	0.19	0.07	-0.05	0.16
SSPT	-0.27	-0.27	0.60**	-0.28	-0.17
TSPT	-0.13	-0.13	0.32	0.26	0.45*
PW4	0.28	0.28	-0.43*	0.74**	0.67**
PW2	0.82**	0.82**	-0.05	0.58**	0.75**
PH4		1.00**	0.05	0.57**	0.51*
PH2			0.65	0.57**	0.51*
STEM				-0.26	-0.11
SBP					0.69**

*(p < 0.10)
**(p < 0.05)