HABITAT UTILIZATION BY THE AMERICAN WOODCOCK IN NORTHERN MICHIGAN

Thesis for the Degree of M. S.

MICHIGAN STATE UNIVERSITY

Dale Leslie Rabe

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ABSTRACT

HABITAT UTILIZATION BY THE AMERICAN WOODCOCK
IN NORTHERN MICHIGAN

By

Dale Leslie Rabe

Habitat utilization by woodcock was studied during the spring of 1975 and 1976 on six quarter townships that were clearcut to approximately 25%, 50%, and 75%. Standard census routes were used as a measure of the population response to the treatments. Vegetational measurements in the clearings along the routes included: species composition, density and height of the regenerating vegetation in the clearing, and the forest community types bordering the clearing. Woodcock habitat utilization was greatest where the interspersion of field and forest is maximized. Aspen communities were preferred to oak and pine as diurnal habitat. The proximity of suitable diurnal habitat was more important than the gross vegetational features of a clearing in determining the use of a particular clearing as a singing ground.

Diurnal habitat preference and vegetational structure were studied on 31 plots of four community types between 19 April and 21 October 1976. Woodcock were located with the aid of a pointing dog. The vegetational characteristics measured at each flush site include: canopy height, basal area, number of trees, saplings and shrubs, horizontal density, soil moisture, and distance to the nearest clearing. Discriminant analysis was used to compare the structural characteristics of: nest sites, non-flying broods, flying broods, and solitary woodcock during the breeding season. Habitat utilized and not utilized by solitary woodcock during the spring, early and later summer in immature aspen, aspen, mixed deciduous, and alder community types was analyzed to identify important structural variables. A preference by woodcock for the aspen community type occurred during the summer, an increased use of immature aspen was noted during the spring and fall migration periods, and there was a steady increase in the use of alder until the fall migration. The density of understory vegetation of utilized woodcock habitat is very consistent and predictable between all the community types. Woodcock nests tend to be located in areas of relatively open habitat and broods have a tendency to move to denser habitat which is similar to that used by solitary woodcock during the spring. Although woodcock shift to habitats with a greater number of saplings during the summer, the structure of the understory vegetation remains constant. Woodcock also show a preference to use diurnal habitat which is located close to an opening.

HABITAT UTILIZATION BY THE AMERICAN WOODCOCK
IN NORTHERN MICHIGAN

By

Dale Leslie Rabe

A THESIS

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INTRODUCTION

The niche has been described in theory as an n-dimensional hypervolume enclosing the complete range of conditions that are necessary for an organism to successfully replace itself (Hutchinson 1957). Each dimension of the space represents a unique environmental variable (Pianka 1974). Habitat is one of the more important dimensions of an animal's niche. Lack (1944, 1949) developed the theory that interspecific competition of birds has led to adaptations which cause individuals to select favorable environments for survival. Baker (1938) used the terms proximate and ultimate to distinguish two types of environmental factors which influence habitat selection. Hilden (1965) defined food, shelter, and structural and functional characteristics of the species as ultimate factors. He further suggested that landscape, terrain, other animals, and nest, song, lookout, feeding, and drinking sites are some of the proximate factors that birds use. In studies he conducted, Hilden found that in some avian species habitat selection is induced by proximate factors and finally selected on the basis of suitable ultimate factors.

The theory of habitat selection by a species implies the existence of some underlying continuity in the factors that individuals utilize. An apparent contradiction of this premise is found in woodcock (Philohela minor) literature. Many of the studies on woodcock have emphasized the diversity of habitats that woodcock use. Marshall (1958) found that the presence of shrubs and woody vegetation was the only common characteristic of the singing grounds he studied. Maxfield (1961) was unsuccessful in using plant species as an indicator of woodcock singing grounds. Mendall and Aldous (1943) and Sheldon (1967) reported finding woodcock nests in open fields, conifer plantations, mixed hardwoods of various ages, and even blueberry fields. Wenstrom (1973) found that woodcock broods in Minnesota exhibited preferential use of aspen, birch, mixed deciduous, and mixed conifer-deciduous cover types at various times during the breeding season. Dunford (1971), Mendall and Aldous (1943), and Wishart (1973) documented a seasonal habitat shift from upland deciduous communities during the spring to lowland communities during the summer or in drought conditions.

One of the reasons for the apparent variability in woodcock habitat is that many studies examined the vegetational composition and not the structural characteristics of the habitat. Some more recent investigations (Bourgeois 1976, Wenstrom 1973, Wishart 1973) have begun to examine woodcock habitat from a structural aspect. The purpose of this study is to describe and compare some of the structural characteristics of woodcock habitat that determine the underlying continuity in the structure of both the breeding and diurnal habitats.

STUDY AREA

This study was conducted within the boundaries of the Houghton Lake State Forest, which is located in the north-central part of Michigan's lower peninsula (Fig. 1). Most of the work was done on six quarter township research units (3 X 3 miles) which are part of a large scale habitat manipulation study being supported by the Michigan Department of Natural Resources. Five of these units are located in Roscommon County and one is located in Kalkaska County. Data were also collected on selected areas around these units and in Missaukee County.

The topography is characterized by rolling uplands and flat outwash plains. The entire area is interspersed with numerous marshes and bogs. The soils of the uplands are mostly textured, sandy types with small amounts of loams, silt loams, and clay loams (Veatch 1924). Organic soils predominate in the lowland areas. The important plant communities of the uplands are aspen (*Populus spp.*), oak (*Quercus spp.*), maple (*Acer spp.*), and pine (*Pinus spp.*). The lowland communities are mostly white cedar (*Thuja occidentalis*), spruce (*Picea spp.*), and to a lesser extent larch (*Larix spp.*), and alder (*Alnus spp.*).

Agriculture and lumbering dominated the region in the late 1800's and early 1900's. Today many abandoned fields remain in the area, and the upland forests are mostly second growth hardwoods.

Areas of various sizes within each quarter township research unit were clearcut until a total treatment of 25%, 50%, or 75% was attained

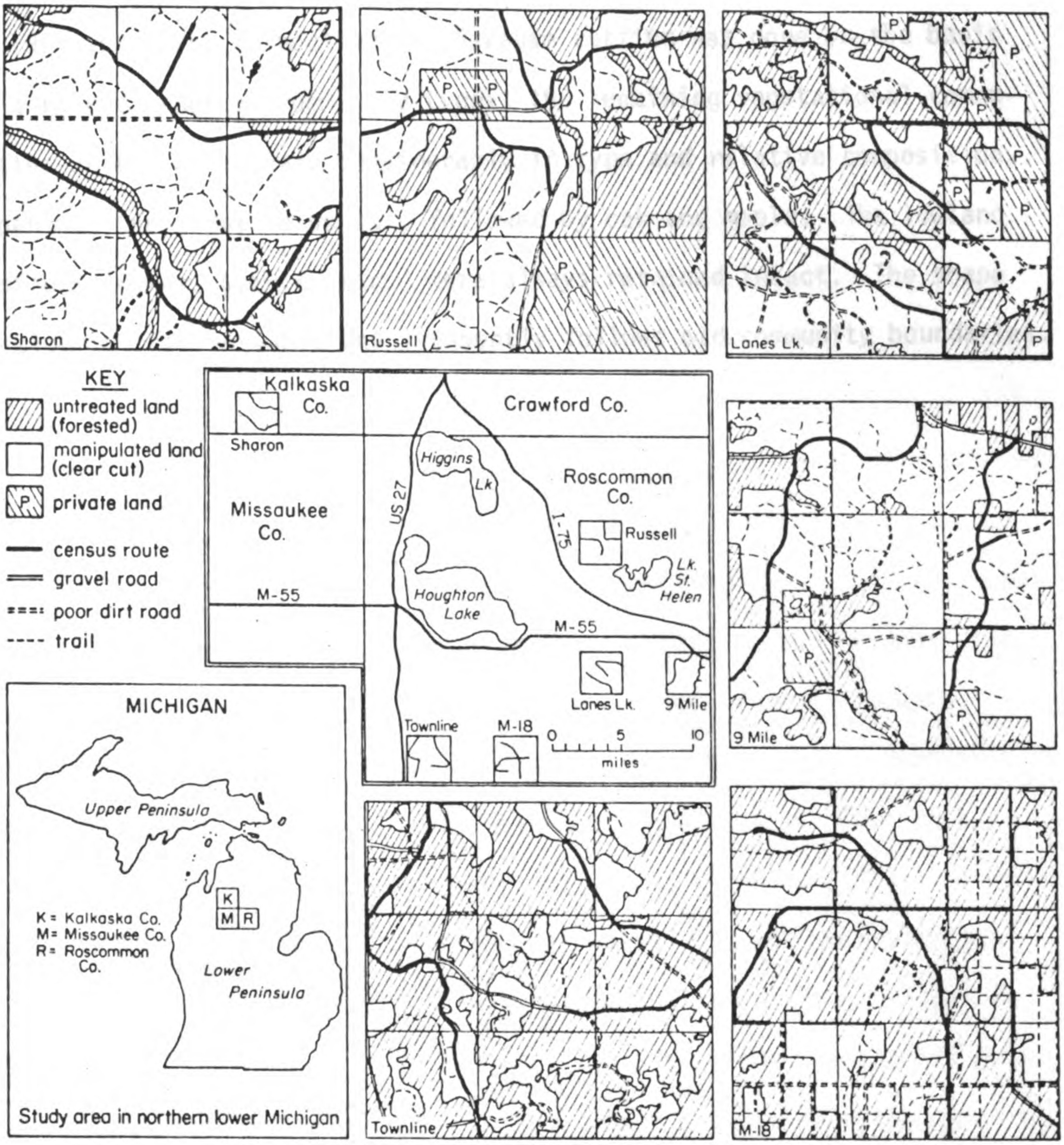


Figure 1.--Location of study area in northern lower Michigan and woodcock singing ground census routes on each research unit.

(Fig. 1). Each treatment level was replicated twice. The size of clearings ranges from 10 to over 1,500 ha, and is largely related to the treatment level of the unit. Cutting on the 25% units was done during 1972. The majority of the cutting on the 50% and 75% units was completed by 1974 and 1975, respectively. Because cutting was done on the basis of a ranked order of community types, the remaining vegetational communities on the units vary considerably in type and relative composition. Aspen was the first to be cut, followed by oak and maple. The lowland conifers (cedar, spruce, etc.) were always retained intact. The shape of clearings is variable and frequently follows old community boundaries.

METHODS

Singing Ground Study

Woodcock singing ground censuses were conducted on all of the research units between 25 April and 17 May in 1975 and 1976. The censuses were used as an index of population size in order to evaluate woodcock response to the three treatment levels. Two, 4-mile census routes were used to sample each unit. Each route had ten listening stations at 0.4 mile intervals. Since the maximum distance that a woodcock can be heard peenting on the ground is 0.2 miles (Duke 1964), an effort was made to keep the two census routes separated by at least 0.4 miles. At the same time an effort was made to keep the routes located in the interior portions of the units to reduce possible interference from surrounding areas. The total amount of clearing along the two routes on each unit was commensurate (± 5%) with the prescribed treatment for that unit. Evening counts along each route were replicated three times in 1975 and 1976. Routes within a unit were run simultaneously whenever possible. Starting time and weather conditions for censusing followed the guidelines established for the federal census routes (Blankenship 1957, Duke 1964, Goudy 1960, Westfall 1954). The number of woodcock heard peenting in a 2-minute period was recorded for each listening station. The sequence of sampling was determined by random selection of routes within a replicate group. Counts of the two routes within a unit were summed for the data analysis.

Since woodcock were never heard at stations in forested areas, the seven vegetational parameters were recorded only at listening stations which occurred in a clearing. The dominant species of regeneration in the clearing was classified as either aspen or oak-maple. The average height of regeneration in the clearing was visually estimated and classified as: low (0-2 m), medium (2-4 m), or high (>4 m). The density of regenerating vegetation was also categorized as: sparse (0-25%), open (26-50%), moderately dense (51-75%), or dense (76-100%). In addition, a record was made of all community types bordering the clearing and within 250 m from the listening station.

Diurnal Habitat Study

In 1976, a study was designed to evaluate diurnal habitat use by woodcock. A total of thirty-one search plots of four community types were chosen from areas throughout the described study area. The community types used in this study were selected because of the different structural characteristics each possess, and because woodcock are known to use these community types to some extent. Eight of the plots were in immature aspen, eight were in aspen, eleven were in mixed deciduous, and three were in alder. The immature aspen, aspen, and mixed deciduous types were all aspen dominated communities which differ primarily in age. The immature aspen plots were less than 10 years old and were comprised of seedling sized stems ($\leq$2.5 cm. dbh) of a fairly high density. These areas were the result of regeneration after recent forest clearcutting. The aspen type on the other hand, ranged from 10-20 years and was composed primarily of sapling sized trees (2.5 to 12.7 cm. dbh). These plots occasionally contained a light mixture of conifers or other hardwoods along with the aspen. Because of natural thinning, this habitat type is somewhat more open than the immature aspen. Mixed deciduous, which was the oldest and most open habitat type, is dominated by pole sized timber (12.7 to 22.9 cm. dbh) and varied in composition from nearly pure aspen to nearly an even mixture of aspen and other hardwoods. Conifers were rare in these plots. Finally, the alder communities were older than 10 years and were composed entirely of alder.

All 31 plots were searched seven times from April to October 1976. Each searching period was designed to correspond to some event in the chronology of the woodcock throughout the time it is in Michigan. The first searching period (19 April to 20 May) encompasses the breeding season. The second and third searching periods (28 June to 19 July and 4 August to 16 August) are chronologically related to the postbreeding dispersal of the juveniles, and the initiation of the molting period. The fourth searching period (11 September to 14 September) is associated with premigratory staging activities. The fifth period (16 September to 22 September) follows the start of woodcock hunting season and relates habitat selection to hunting pressure. Finally, the last two searching periods (2 October to 8 October and 18 October to 21 October) were an attempt to evaluate habitat use during migration.

The amount of time spent searching a plot ranged from 0.5 to 1.0 hours depending on the size of the contiguous habitat. One hour was the maximum time spent searching regardless of its size. Flush rates were computed by dividing the total searching time (hours) into the total number of woodcock contacted. Nest sites and broods were counted as a single contact. Constancy in effort was maintained by using the same searching crew and pointing dog. Searching was not attempted during rainy weather or when temperatures went above 27°C. Searching of plots was systematic, and every effort was made to avoid counting reflushed birds. A vegetational analysis was made of all woodcock flush sites during the first three searching periods. During the breeding season all woodcock contacts were classified as: nests, non-flying broods, flying broods, or solitary birds. After the breeding season, woodcock become indistinguishable when contacted and all birds were classified as solitary birds. Additional searching was done during the spring to supplement the vegetational analysis of nest and brood sites found on the searching plots. All searching effort was classified by community type, total searching time, and number of woodcock contacted (by class).

Twelve structural measurements of the habitat (Table 1) were taken at each indicated woodcock flush site. Six randomly selected sites were also sampled in each search plot where less than two woodcock were contacted during the first three searching periods. All vegetation measurements were made within 5 days after contact with the bird, except during the spring when horizontal density measurements were postponed until after leafout to allow seasonal comparisons of habitat. All vegetation sampling was centered about the flush site. The tree-sapling vegetation plot (7.5 X 15 m) was arbitrarily oriented in a north-south direction. If the plot transected a community boundary, it was rotated until it was contained in a homogeneous community type. Of the 336 plots sampled, about 20% required rotating, and only one needed to be moved. The shrub plot (2 X 7.5 m) was oriented perpendicular to the tree-sapling plot. Canopy height was measured with a Haga altimeter. A Biltmore stick was used to measure the diameter of all trees. Trees, saplings, and shrubs were counted only if they were rooted within the plot. Percent

Table 1.--Summary of twelve habitat structure variables measured at each woodcock flush site.

Variable name	Description
Canopy height*	Average height of overstory canopy.
Basal Area*	Basal area of all trees greater than 2.5 cm dbh in a .01 ha plot.
Trees*	Number of trees greater than 7.6 cm dbh in .01 ha plot.
Saplings*	Number of trees 2.5 to 7.6 cm dbh in .01 ha plot.
Shurbs*	Number of woody plant stems greater than .45 m in height and less than 2.5 cm dbh in a .003 ha plot.
Ground cover**	Percent of ground covered with herbaceous plants less than .45 m in height, measured by 50 point intercepts.
Density (.5)**	Average horizontal obstruction of vegetation from ground level to .5 m (%).
Density (1.5)**	Average horizontal obstruction of vegetation .5 to 1.5 m above ground level (%).
Density (2.5)**	Average horizontal obstruction of vegetation 1.5 to 2.5 m above ground level (%).
Min. density**	Minimum horizontal obstruction of vegetation 0 to 2.5 m above ground level (%).
Soil moisture**	Moisture content of soil measured as percent of dry weight.
Distance to edge*	Distance from flush site to clearing greater than .1 ha (m).

*Transformed by $\sqrt{X+.5}$

**Transformed by arcsin $\sqrt{X}$

ground cover was calculated by counting the number of point intercepts on a 50-point grid that contacted herbaceous plants and multiplying by two. All horizontal density measurements were made with a density board marked off in 0.5 m intervals. The board was rotated at the flush site and obstruction measurements were made from the corners of the tree-sapling plot. Soil moisture was determined from six, 15 cm core samples extracted around the flush site. The distance to the nearest clearing was measured (in meters) from the flush site to the opening in the overstory canopy larger than 0.1 ha.

Data Analysis

A partially nested analysis of variance model was employed in the experimental design to test the effects of time and amount of clearing on the number of singing male woodcock, and the effect of time and community type on the flush rate of woodcock in diurnal habitat. In each case, the dependent variable was tested for normality and heterogeneous variance using the Kolomogorov-Smirnov and Bartlett's test, respectively (Sokal and Rohlf 1969). The number of displaying woodcock was found to be normally distributed ($P>.05$) and have homogeneous variances between treatment groups ($P>.05$), so a parametric analysis of variance was used to test the main effects and interactions. The flush rates of woodcock in diurnal habitats were not normally distributed ($P<.05$), and transformations were unsuccessful in normalizing the data. As a result, a Kruskal-Wallis one-way analysis of variance was used to test the effects of habitat, and a Friedman two-way analysis of variance was used to test the effect of time (Siegel 1956). The interactions could not be evaluated with these non-parametric tests.

For analyzing the structural features of woodcock habitat, discriminant analysis was used to statistically distinguish between various groups (community types, seasons, and utilization classes). The discrimination is accomplished by measuring a number of parameters (p) for which all of the groups (g) are believed to differ (Lachenbush 1975). The discriminant analysis plots each case (individual within a group) in a p-dimensional space. A maximum of n (g-1) linear discriminant functions are used to separate the groups (Cooley and Lohnes 1971). The n orthogonal functions are computed in such a way as to maximize the among group variation for each function. The absolute value of the discriminant function coefficient is a measure of the relative discriminating power of each variable in a function (Green 1971). The group means (location of a typical group number) gives the relative location of the groups in the n-dimensional space. The percent of among group variation is a measure of the relative importance of each function to the discriminant analysis. Examination of the correctly classified, known-group memberships is a good indication of the overall discriminating ability of the analysis.

A stepwise discriminant analysis procedure (Nie et al. 1975) was used for all habitat comparisons (except singing ground vegetation) to eliminate those variables which did not contribute significantly to the discriminating power of the functions. The stepwise method used in this study is designed to maximize the overall group separation. The minimum criteria for entry into the analysis was set at F = 2.80, which roughly corresponds to the P = .10 significance level. Discriminant function coefficients of habitat variables that could individually account for 20% or more of the discriminating power were considered important in that function. It was necessary to transform all habitat variables (Table 1) in order to meet the assumption of normality (Kolomogorov-Smirnov, $P > .05$). Variables expressed as percentages were transformed with arcsin $\sqrt{X}$, and all other variables were transformed with $\sqrt{X + .5}$. Horizontal density (0 to .5 m) was the only variable not normalized by the transformation. Discriminant analysis is robust enough to tolerate such moderate deviations from the underlying assumptions (Nie et al. 1975). The correlation matrix of habitat variables (Table 2) indicates that all correlation larger than .14 were significant ($P < .01$), and the largest correlation was .84, which occurred between the horizontal density (.5 to 1.5 m) and minimum density (0 to 2.5 m). Even this correlation is not large enough to cause any problem in computing the discriminant functions or interpreting the results (Nie et al. 1975).

All statistical procedures were run on the Michigan State University CDC 6500 computer using a programmed statistical package.

Table 2.--Correlation matrix of untransformed habitat variables (N = 336).

	CH	BA	NT	NS	SH	GC	D1	D2	D3	MD	SM	DE
CH												
BA	.72*											
NT	.57*	.70*										
NS	-.42*	-.19*	-.30*									
SH	-.33*	-.32*	-.25*	.04								
GC	-.17*	-.12	-.18*	.21*	.20*							
D1	-.22*	-.20*	-.16*	.01	.22*	.29*						
D2	-.29*	-.28*	-.27*	.04	.36*	.20*	.61*					
D3	-.47*	-.32*	-.37*	.26*	.45*	.14	.19*	.57*				
MD	-.39*	-.34*	-.35*	.12	.38*	.20*	.58*	.84*	.72*			
SM	.05	-.05	-.00	-.06	.09	-.03	-.08	-.14	-.02	-.16*		
DE	.37*	.23*	.21*	-.11	-.17*	-.09	-.14*	-.24*	-.25*	-.25*	.14	

Habitat Variables

CH	Canopy Height	SH	Number of Shrubs	D2	Horizontal Density (.5-1.5 m)	MD	Minimum Horizontal Density (0-2.5 m)
BA	Basal Area	GC	Ground Cover (%)				
NT	Number of Trees	D1	Horizontal Density (0-.5 m)	D3	Horizontal Density (1.5-2.5 m)	SM	Soil Moisture (%)
NS	Number of Saplings					DE	Distance to Edge

*Significant at P <.01

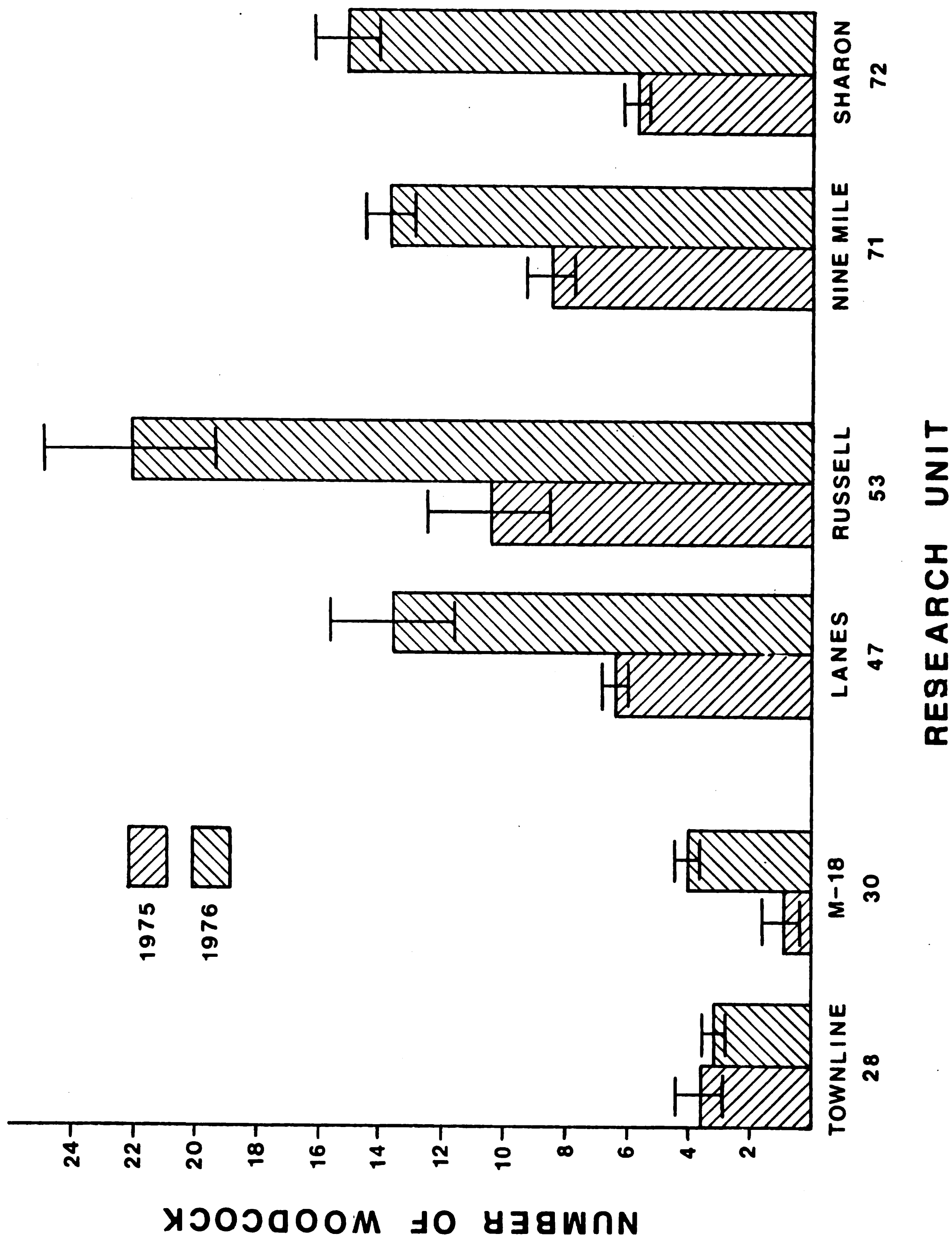
RESULTS

Census Routes

The number of displaying male woodcock using the research units increased significantly ($P = .013$) between 1975 and 1976 (Fig. 2). There was however, a disproportionate increase between the 25%, 50%, and 75% treatments as evidenced by the moderately significant ($P = .120$) interaction between treatment and census year (Table 3). The 25% treatment units showed a 40% increase in woodcock use between the 2 years, while the 50% and 75% treatments increased by 114% and 105% respectively. The woodcock use between treatment levels showed a marginally significant ($P = .097$) response, but the individuality of routes (research units) within a treatment level was found to be more significant ($P = .001$). Examination of the within route variance relative to the between route variance reveals why that is the case (Fig. 2). The significance ($P = .082$) of the interaction, route within treatment X census year, is caused by a slight decrease in woodcock use of the Townline unit in 1976, while the M-18 unit increased substantially. To determine where significant ($P < .05$) differences occurred, treatment levels were tested by census year using Tukey's multiple range test (Sokal and Rohlf 1969). The results for both 1975 and 1976 showed no difference in the number of displaying woodcock between the 50% and 75% treatments, while the 25% treatment was significantly lower than the other two.

There was a significant ($P < .05$) curvilinear relationship between the amount of clearing along census routes and the number of displaying

Figure 2.--Number ($\overline{X}$ ± S.E.) of displaying male woodcock per census route for 1975 and 1976 based on three counts per route. Percent clearing along each route is listed below unit name.



NUMBER OF WOODCOCK
2
4
6
8
10
12
14
16
18
20
22
24
1975
1976
TOWNLINE
28
M-18
30
LANES
47
RUSSELL
53
NINE MILE
71
SHARON
72
RESEARCH UNIT

Table 3.--Analysis of singing ground census routes. Dependent variable is the number of displaying male woodcock per research unit.

Source of variation	df	Mean square	F	Significance
Main effects				
Amount of opening along census route (treatment)	2	265.58	5.595	.097
Census route within treatment	3	47.47	10.421	.001
Year of census	1	330.03	28.768	.013
Two-way interactions				
Amount of opening X census year	2	53.69	4.680	.120
Route within treatment X census year	3	11.47	2.518	.082
Residual error	24	4.56		

male woodcock for both 1975 and 1976 (Fig. 3). The equation accounted for 41.8% and 77.4% of the variation for 1975 and 1976, respectively. It also predicts a maximum number of displaying males at 52% and 58% clearing along census routes for the two years.

A discriminant analysis was used to compare various habitat parameters related to the use of clearings as singing grounds by one or more woodcock (Table 4). The presence of an established aspen community bordering the clearing was the most significant (X^2 = 20.01, P <.001) parameter associated with utilized clearings. This parameter accounted for 33.5% of the total discriminating power of the function. Although height of the vegetation in the clearing was the second most significant (X^2 = 4.72, P <.10) parameter, it did not discriminate as well as the two variables describing the dominant species of regeneration in the clearings, which were statistically insignificant. Oak and pine communities bordering the clearings were the least significant and least powerful parameters in the function.

Diurnal Habitat Selection

Eleven woodcock nests, 10 non-flying broods, 25 flying broods, and 76 solitary birds were located during 71.9 hours of searching in four plant communities between 19 April and 7 June 1976 (Table 5). Chi-square analysis was used to test habitat preferences of flying broods, solitary birds and all utilization classes combined. Woodcock do not appear to select between habitats (P >.10 for all comparisons). Analysis was not performed on nests and non-flying broods because of the small sample sizes.

Since no habitat preference was apparent, the number of vegetation plots in each community type and utilization class was statistically

Figure 3.--Regression analysis on the number of singing male woodcock and the amount of clearing along the census routes for 1975 and 1976.

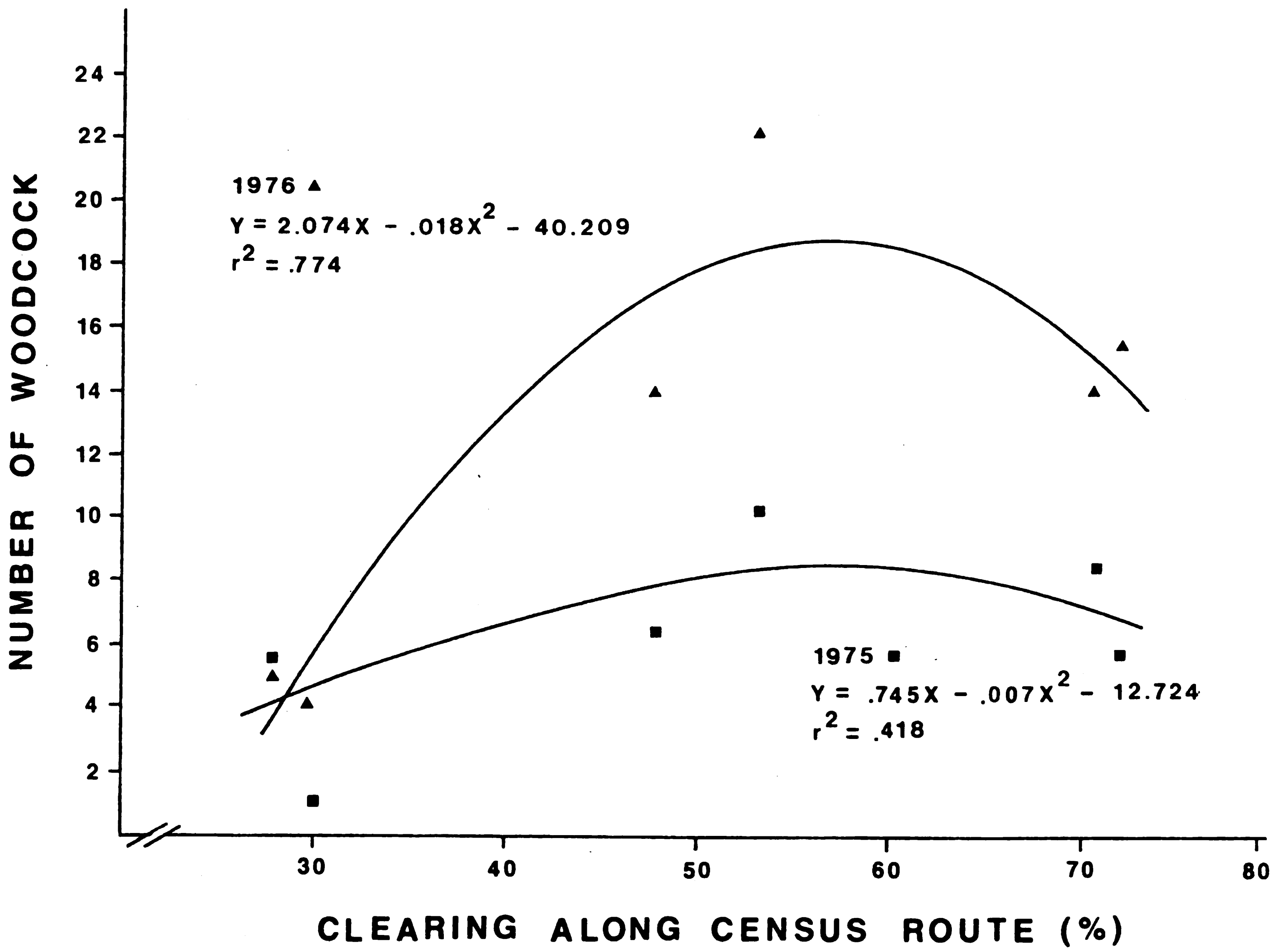

1976 ▲
Y = 2.074X - .018X² - 40.209
r² = .774
1975 ■
Y = .745X - .007X² - 12.724
r² = .418
NUMBER OF WOODCOCK
CLEARING ALONG CENSUS ROUTE (%)
2
4
6
8
10
12
14
16
18
20
22
24
30
40
50
60
70
80

Table 4.--Summary of discriminant analysis on seven habitat parameters contrasting utilized and non-utilized clearings as singing fields by displaying male woodcock, including the normalized discriminant function coefficients, scaled eigenvector coefficients, and Chi-square statistic.

Parameter	Discriminant function coefficient	Scaled eigenvector** coefficient	Chi-square (df)
Aspen community bordering clearing	1.217	33.5	20.01*(1)
Oak-maple as dominant species in clearing	-.720	19.8	1.67 (1)
Aspen as dominant species in clearing	-.651	17.9	.22 (1)
Height of vegetation in clearing	.533	14.7	4.72 (2)
Density of vegetation in clearing	-.223	6.1	2.23 (3)
Oak community bordering clearing	-.160	4.1	.98 (1)
Pine community bordering clearing	-.129	3.6	.36 (1)

*Significant at $P < .001$.

**Relative contribution of the variable to the discriminant function.

Table 5.--Time spent searching and number of woodcock contacted, divided into four utilization classes, by community for spring period (19 April to 7 June) 1976.

		Utilization class			
Community type	Hours Searched	Nest	Non-flying brood	Flying brood	Solitary
Immature aspen	8.5	0	1	0	17
Aspen	34.5	4	3	10	33
Mixed deciduous	19.2	7	6	11	16
Alder	9.7	0	0	4	10

equalized to remove sampling bias. Discriminant analysis yielded three significant functions that accounted for 43.0%, 38.3%, and 18.7% of the among group variation (Table 6). The functions were able to classify correctly 75.0% of the nest sites, 43.8% of the non-flying broods, 62.1% of the flying broods, and 54.4% of the solitary birds. Minimum density of vegetation (0 to 2.5 m) was the most important habitat variable in Function I. Function II is dominated by canopy height and basal area. The important variables in Function III are canopy height, vegetative density (.5 to 1.5 m), and minimum density of vegetation (0 to 2.5 m). These functions are combined in a three dimensional representation of habitat volume (Fig. 4). According to this representation, the understory density is greater in areas utilized by solitary birds than those used by nesting birds and broods. Nest sites, on the other hand, are distinguished from broods and solitary woodcock by a more open habitat with higher canopy and smaller basal area (Table 7).

Mean flush rates of solitary woodcock in four plant communities ranged from 0 to 7.3 birds per hour over a 6 month period (Fig. 5). Chi-square analysis revealed that there was a significant relationship ($X^2 = 7.22$, $P < .01$) between the absence of an opening near the search plot and the absence of woodcock using the plot. Consequently, only the 26 plots near openings were used in the analysis of flush rates. Although statistical significance between community types at $P < .05$ was not achieved for any of the sampling periods, probabilities of 0.15, 0.12, and 0.07 for differences between community types were calculated for the May, June, and August sample periods. During the spring period (19 April to 20 May) woodcock use of immature aspen, aspen, and mixed deciduous was essentially equal, but use of alder was noticeably lower.

Table 6.--A comparison of habitat utilization by four groups of woodcock during the spring, expressed by three discriminant functions (I, II, III). The percent of among group variation is a measure of the importance of each function. The amount of group overlap is expressed by the percent of plots correctly classified, with 100% indicating no overlap. Largest differences between group means indicate the groups being discriminated. Variables contributing the greatest separation between groups in a function are identified by the largest absolute discriminant function coefficient.

		Discriminant function*			Percent of plots correctly classified
		I	II	III	
		Percent of among group variation accounted for			
		43.0	38.3	18.7	
		Utilization group means in standardized discriminant space (Mean of 0, standard deviation of 1)			
Group	(N)				
Nest	(14)	.098	1.231	.413	75.0
Non-flying brood	(28)	-.126	.174	-.600	43.8
Flying brood	(49)	.586	-.387	.141	62.1
Solitary bird	(26)	-1.025	-.375	.288	54.4
		Standardized discriminant function coefficients (Mean of 0, standard deviation of 1)			
Variable					
Canopy height		.635	1.197	.707	
Basal area		-.191	-1.081	.297	
Trees		-	-	-	
Saplings		.663	-.432	.096	
Shrubs		-	-	-	
Ground cover		-	-	-	
Density (.5)		-.576	-.407	-.374	
Density (1.5)		.277	-.250	-.625	
Density (2.5)		-	-	-	
Min. density		-1.123	-.048	.600	
Soil moisture		-	-	-	
Distance to edge		-.348	-.353	-.073	

*All functions significant at $P < .001$.

Figure 4.--Graphical representation of utilization group means in standardized (mean of 50, standard deviation of 1) discriminant space. Scaling of axes is proportional to the among group variation accounted for by each function. Arrows indicate the direction of increase for the major discriminating variables.

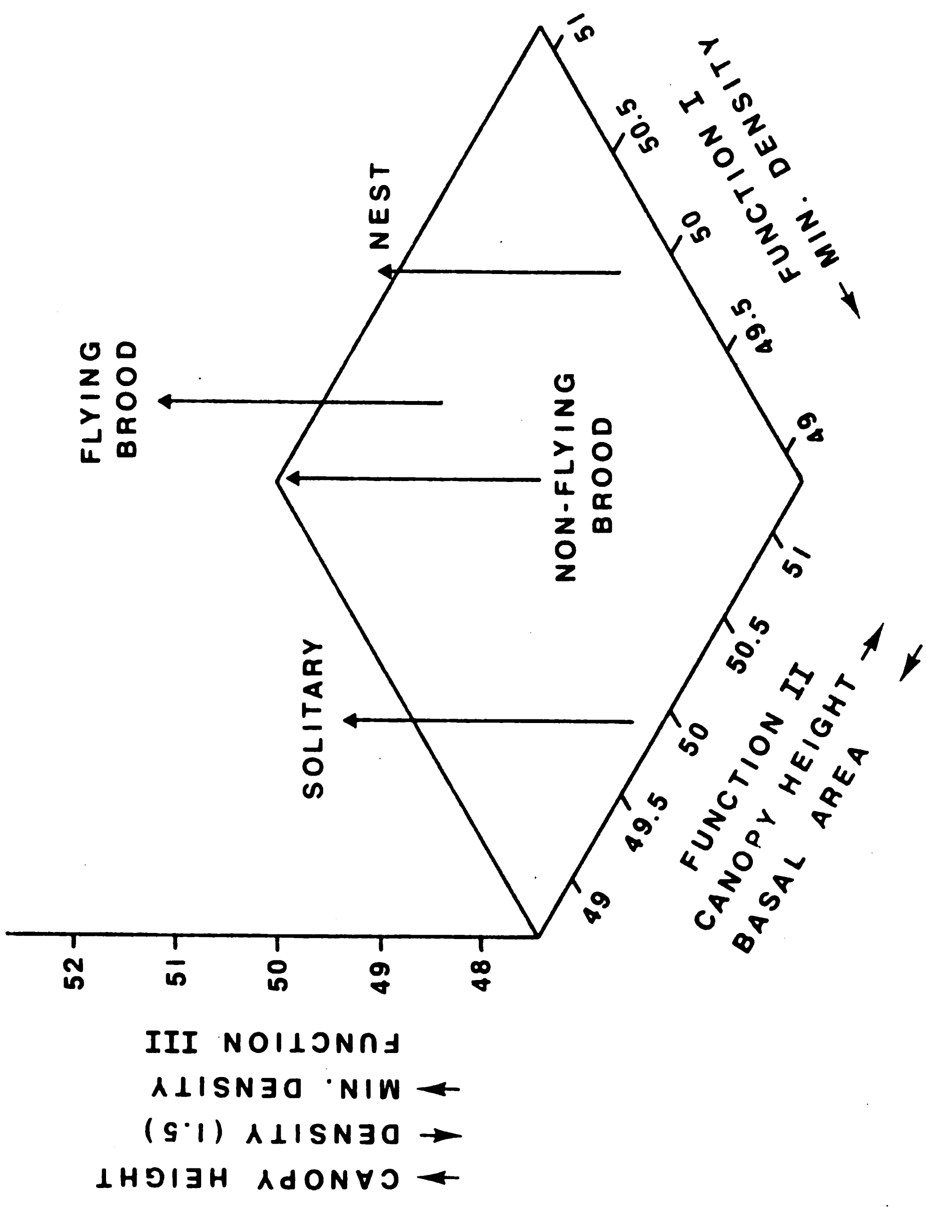
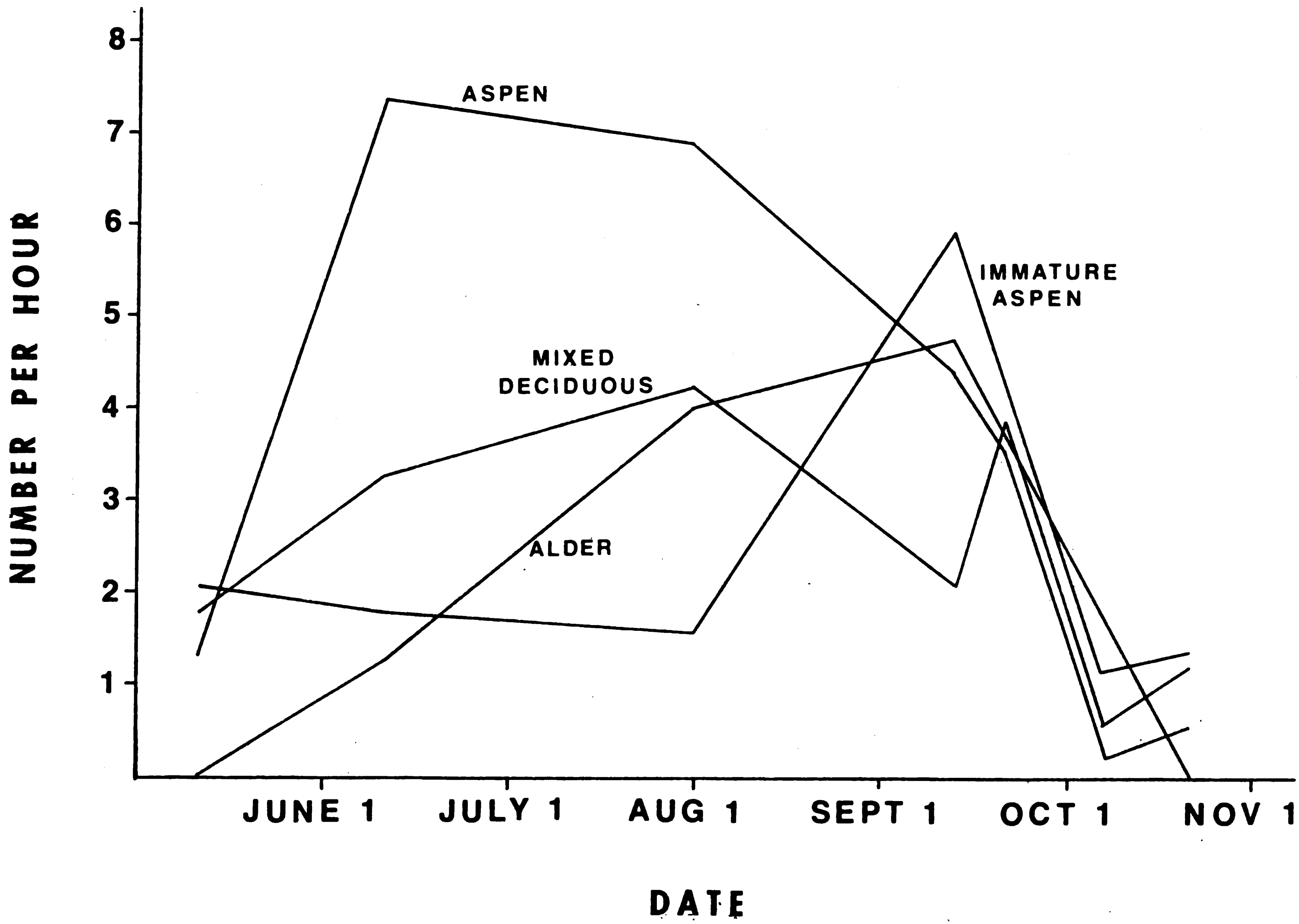

NEST
FLYING BROOD
NON-FLYING BROOD
SOLITARY
51
50.5
50
49.5
49
FUNCTION I
MIN. DENSITY
51
50.5
50
49.5
49
FUNCTION II
CANOPY HEIGHT
BASAL AREA
52
51
50
49
48
FUNCTION III
MIN. DENSITY
DENSITY (1.5)
CANOPY HEIGHT

Table 7.--Group means ± S.E. and univariate F-ratio of untransformed habitat variables by site utilization. Habitat plots were statistically equalized to remove sampling bias between community types (F, $df_1 = 3$, $df_2 = 113$).

Variable	Nest	Non-flying brood	Flying brood	Solitary	F-ratio
Canopy height	12.9 ± 0.6	9.1 ± 0.7	11.2 ± 0.5	10.9 ± 1.0	5.73*
Basal area	10.5 ± 1.3	10.0 ± 1.1	16.1 ± 0.9	16.9 ± 2.1	10.24*
Trees	4.6 ± 0.6	4.2 ± 0.5	6.9 ± 0.6	5.8 ± 0.7	5.61*
Saplings	16.5 ± 2.7	27.8 ± 3.5	42.2 ± 3.1	27.4 ± 3.7	13.36*
Shrubs	33.3 ± 2.8	39.2 ± 4.4	22.6 ± 2.0	36.1 ± 3.9	5.09*
Ground cover	31.0 ± 4.1	28.2 ± 2.6	24.7 ± 1.6	20.5 ± 2.0	2.08
Density (.5)	75.2 ± 3.8	81.0 ± 2.4	75.8 ± 2.7	80.9 ± 2.7	1.45
Density (1.5)	31.9 ± 2.4	44.3 ± 2.6	42.7 ± 2.5	58.1 ± 4.4	2.04
Density (2.5)	36.4 ± 3.2	42.4 ± 2.7	43.7 ± 2.4	64.9 ± 4.0	6.63*
Min. density	30.0 ± 2.0	30.3 ± 2.0	29.6 ± 1.8	46.7 ± 4.0	9.19*
Soil moisture	26.3 ± 2.8	24.2 ± 1.4	23.1 ± 1.1	22.5 ± 1.5	.67
Distance to edge	22.3 ± 6.1	19.0 ± 4.2	19.2 ± 2.5	22.2 ± 3.3	1.90

*Significant at $P < .05$.

Figure 5.--Mean flush rate (number per hour) of solitary woodcock by community type from May through October of 1976.


ASPEN
IMMATURE ASPEN
MIXED DECIDUOUS
ALDER
NUMBER PER HOUR
8
7
6
5
4
3
2
1
JUNE 1
JULY 1
AUG 1
SEPT 1
OCT 1
NOV 1
DATE

In early summer (28 June to 19 July), woodcock flushes per hour increased from 1.3 to 7.3 in aspen. Although use in mixed deciduous and alder also increased moderately, immature aspen remained unchanged. In late summer (4 August to 16 August), utilization of aspen by woodcock remained substantially higher than the other community types, but began to decline in September. Mixed deciduous and alder continued to increase in August and immature aspen remained the same. In September, the use of immature aspen and alder by woodcock increased, while mixed deciduous and aspen declined. From the beginning of woodcock hunting season (15 September) through October, use of all four community types by woodcock was indistinguishable.

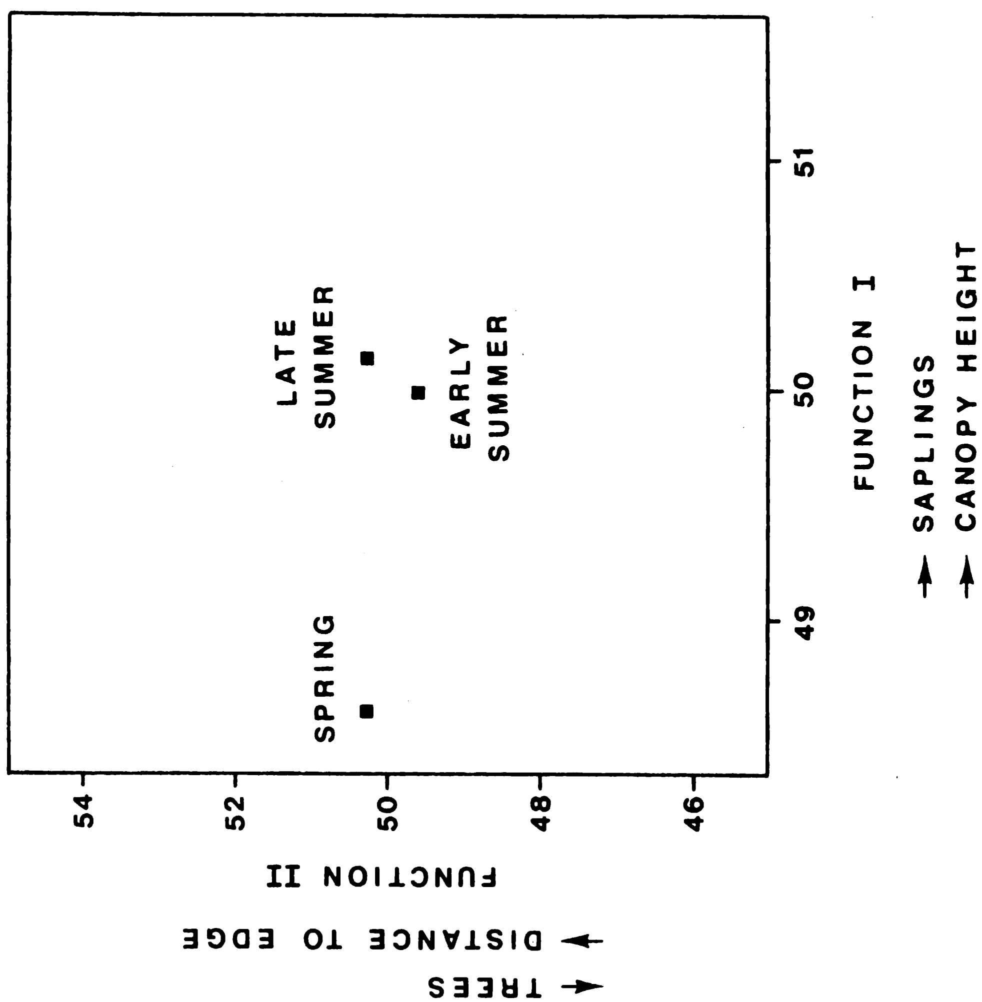
Comparisons were made between the structural characteristics of habitat used by solitary woodcock during the spring, and early and late summer. The discriminant analysis was statistically equalized for searching time in each community type to remove sampling bias. The number of vegetation plots in each community type was weighted to reflect the mean flush rate for each sampling period. Ground cover and soil moisture were not included in the analysis because of the temporal changes which occur in all community types. The results of this analysis produced two significant ($P < .001$) functions which accounted for 73.9% and 26.1% of the among group variation (Table 8). These two functions classified correctly 72.5% of the spring sites, 58.5% of the early summer sites, and 53.3% of the late summer sites. The most important variables in Function I were canopy height and the number of saplings (Fig. 6). The number of trees and distance to a clearing edge were the two most important variables in Function II. Structural differences between hatitats used in spring and summer are based primarily on a

Table 8.--A comparison of habitat utilization by solitary woodcock for three seasonal periods, expressed by two discriminant functions (I, II). The percent of among group variation is a measure of the importance of each function. The amount of group overlap is expressed by the percent of plots correctly classified, with 100% indicating no overlap. Largest differences between group means indicate the groups being discriminated. Variables contributing the greatest separation between groups in a function are identified by the largest absolute discriminant function coefficient.

		Discriminant function*		Percent of plots correctly classified
		I	II	
		Percent of among group variation accounted for		
		73.9	26.1	
		Seasonal group means in standardized discriminant space (Mean of 0, standard deviation of 1)		
Group	(N)			
Spring	(26)	-1.455	.280	72.5
Early summer	(78)	.023	-.420	58.5
Late summer	(72)	.425	.316	53.3
		Standardized discriminant function coefficients (Mean of 0, standard deviation of 1)		
Variable				
Canopy height		.782	.095	
Basal area		-	-	
Trees		.107	-.961	
Saplings		.982	.249	
Shrubs		-	-	
Density (.5)		-.504	-.118	
Density (1.5)		.336	-.398	
Density (2.5)		-.491	-.198	
Min. density		-	-	
Distance to edge		-.419	.621	

*All functions significant at P <.001.

Figure 6.--Graphical representation of seasonal group means in standardized (mean of 50, standard deviation of 1) discriminant space. Scaling of axes is proportional to the among group variation accounted for by each function. Arrows indicate the direction of increase for the major discriminating variables.


SPRING
LATE SUMMER
EARLY SUMMER
54
52
50
48
46
49
50
51
FUNCTION I
SAPLINGS
CANOPY HEIGHT
FUNCTION II
DISTANCE TO EDGE
TREES

fewer number of saplings and a lower mean canopy height (Table 9). Function II showed relatively little separation between the three groups.

A discriminant analysis on the descriptions of sites used by solitary woodcock between community types compared the variables that were most similar and dissimilar relative to woodcock use in these communities (Table 10). The analysis computed three significant (P <.001) functions which accounted for 76.6%, 14.1%, and 9.3% of the among group variation. These functions were able to correctly classify 91.2%, 80.5%, 81.5%, and 90.9% of the sites into immature aspen, aspen, mixed deciduous, and alder communities, respectively. The most important variables for the functions are: Function I, canopy height; Function II, number of saplings, basal area, and number of trees; and Function III, number of trees and basal area. The variables that were least different between these distinct community types are the number of shrubs, percent ground cover, distance to the nearest clearing, and four of the density classes. Canopy height (Function I) is by far the most important variable in distinguishing between structural features of the community types (Fig. 7). The other two functions and corresponding variables are relatively unimportant in discriminating between these groups.

Comparisons of non-utilized search plots were made with utilized sites of the same community type (Table 11). Although some non-utilized plots showed little discrimination from the utilized sites for any of the structural features, most plots did have good separation on one or more features. Of the 13 non-utilized plots, five were significantly different in the upper horizontal vegetation density class (1.5 to 2.5 m); four differed in minimum vegetation density (0 to 2.5 m), number of saplings, and distance to edge; three based on the percent ground cover;

Table 9.--Group means ± S.E. and univariate F-ratio of untransformed habitat variables for solitary woodcock over three seasonal periods. Vegetation plots were weighted to equalize searching time in each community type (F, $df_1 = 2$, $df_2 = 173$).

Variable	Spring	Early Summer	Late Summer	F-ratio
Canopy height	9.0 ± 1.2	11.2 ± 0.5	11.1 ± 0.6	3.18*
Basal area	13.5 ± 2.5	14.6 ± 1.0	15.5 ± 1.1	1.56
Trees	4.7 ± 0.9	7.3 ± 0.6	5.2 ± 0.5	5.95*
Saplings	27.4 ± 4.6	32.6 ± 3.0	53.5 ± 4.7	8.30*
Shrubs	39.8 ± 5.2	25.5 ± 2.8	25.5 ± 2.0	4.78*
Density (.5)	83.2 ± 3.3	93.8 ± 1.2	94.9 ± 1.1	6.76*
Density (1.5)	61.4 ± 5.3	67.1 ± 2.2	66.2 ± 2.1	5.47*
Density (2.5)	69.1 ± 5.1	48.8 ± 2.7	47.4 ± 2.9	3.03*
Min. density	50.7 ± 5.0	48.3 ± 2.1	49.9 ± 1.9	.41
Distance to edge	18.2 ± 3.8	12.5 ± 1.7	16.2 ± 1.8	1.72

*Significant at $P < .05$.

Table 10.--A comparison of the habitat utilization by solitary woodcock in four community types, expressed as three discriminant functions (I, II, III). The percent of among group variation is a measure of the importance of each function. The amount of group overlap is expressed by the percent of plots correctly classified, with 100% indicating no overlap. Largest differences between group means indicate the groups being discriminated. Variable contributing the greatest separation between groups in a function are identified by the largest absolute discriminant function coefficient.

		Discriminant function*			Percent of plots correctly classified
		I	II	III	
		Percent of among group variation accounted for			
		76.6	14.1	9.3	
Group	(N)	Community group means in standardized discriminant space (Mean of 0, standard deviation of 1)			
Immature aspen	(34)	-2.315	.847	.633	91.2
Aspen	(77)	-.016	.109	-.678	80.5
Mixed deciduous	(54)	2.113	-.173	.512	81.5
Alder	(11)	-3.106	-2.533	.277	90.9
Variable		Standardized discriminant function coefficients (Mean of 0, standard deviation of 1)			
Canopy height		1.378	-.222	.157	
Basal area		.275	-.893	.800	
Trees		.177	.605	-1.363	
Saplings		-.414	-1.000	-.658	
Shrubs		-	-	-	
Ground cover		-	-	-	
Density (.5)		.085	.054	.511	
Density (1.5)		-	-	-	
Density (2.5)		-.255	.201	.467	
Min. density		-	-	-	
Distance to edge		-	-	-	

*All functions significant at P <.001.

Figure 7.--Graphical representation of community type group means in standardized (mean of 50, standard deviation of 1) discriminant space. Scaling of axes is proportional to the among group variation accounted for by each function. Arrows indicate the direction of increase for the major discriminating variables.

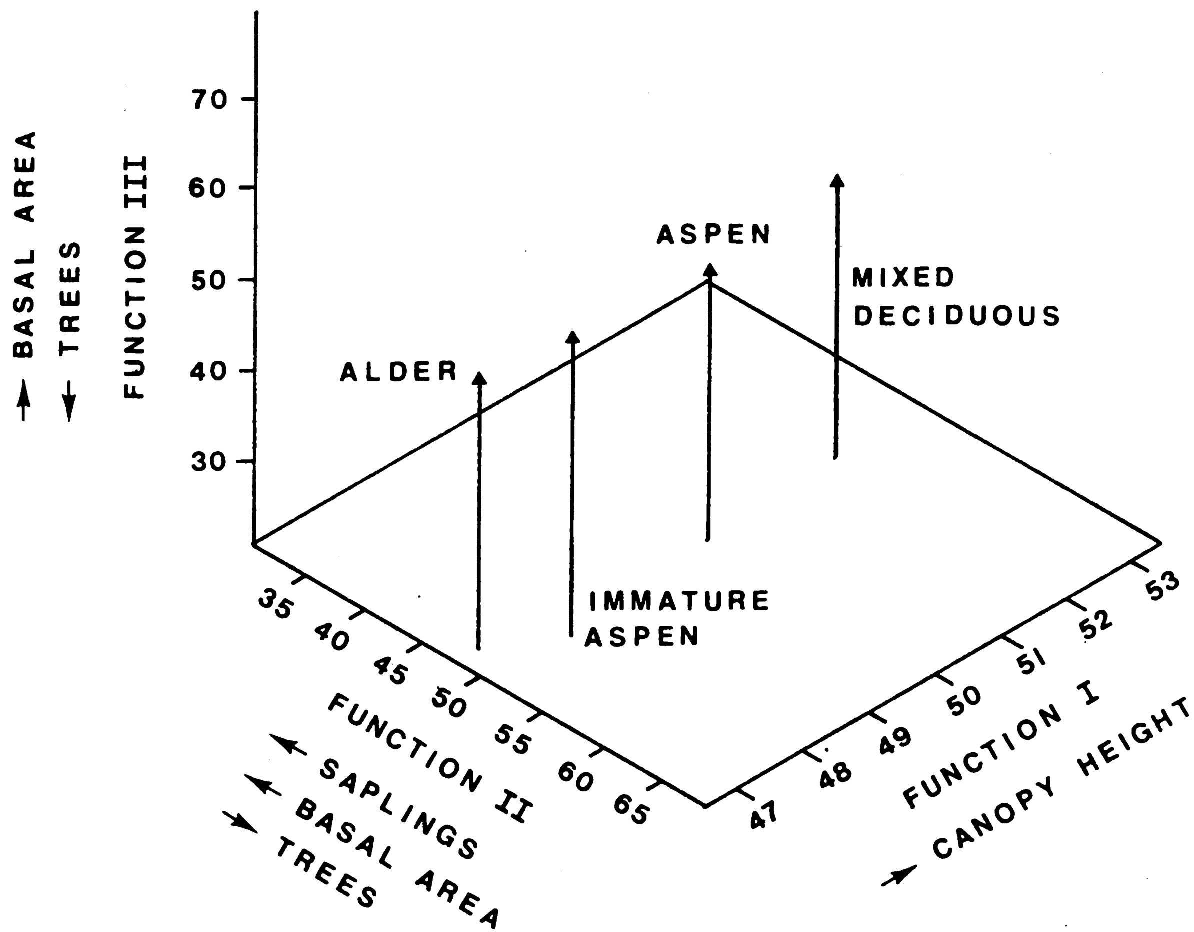

BASAL AREA
TREES
FUNCTION III
70
60
50
40
30
ALDER
ASPEN
MIXED
DECIDUOUS
IMMATURE
ASPEN
35
40
45
50
55
60
65
FUNCTION II
SAPLINGS
BASAL AREA
TREES
47
48
49
50
51
52
53
FUNCTION I
CANOPY HEIGHT

Table 11.--Group means ± S.E. and univariate F-ratio (F, $df_1 = 3$, $df_2 = 172$) for untransformed habitat variables of solitary woodcock by community type. Underscored values indicate variables that were most important in discriminating between utilized and non-utilized plots within a community type. The symbol indicates whether the non-utilized plots were less than (<) or greater than (>) utilized values. Bracketed values indicate the number of non-utilized plots that were discriminated on the basis of that variable.

Variable	Immature aspen	Aspen	Mixed deciduous	Alder	F-ratio
Canopy height	5.1 ± 0.3	10.7 ± 0.4	17.7 ± 0.6	<<u>5.2 ± 0.2</u> (1)	141.93*
Basal area	<<u>4.7 ± 0.5</u> (2)	13.4 ± 0.8	25.4 ± 1.6	11.3 ± 1.1	57.70*
Trees	1.6 ± 0.4	7.6 ± 0.6	8.9 ± 0.6	0.5 ± 0.2	47.15*
Saplings	><u>32.1 ± 3.9</u> (1)	><u>33.9 ± 2.4</u> (1)	<<u>18.5 ± 1.7</u> (2)	122.8 ± 10.5	45.17*
Shrubs	41.4 ± 4.7	22.3 ± 2.4	<<u>22.6 ± 2.4</u> (2)	39.9 ± 10.3	7.71*
Ground cover	33.2 ± 3.6	34.2 ± 2.8	<<u>38.0 ± 2.3</u> (2)	><u>64.5 ± 8.1</u> (1)	5.75*
Density (.5)	93.8 ± 1.9	94.8 ± 1.3	89.7 ± 1.9	92.7 ± 4.7	2.70*
Density (1.5)	75.2 ± 3.5	65.2 ± 2.3	60.0 ± 3.4	<<u>69.5 ± 5.8</u> (1)	1.07
Density (2.5)	78.0 ± 4.0	<<u>41.1 ± 2.7</u> (1)	<<u>38.2 ± 3.3</u> (2)	<<u>75.2 ± 4.2</u> (2)	14.81*
Min. density	><u>63.6 ± 4.1</u> (2)	<<u>45.9 ± 2.1</u> (1)	<<u>41.6 ± 2.5</u> (1)	56.9 ± 4.4	7.09*
Distance to edge	><u>5.1 ± 0.8</u> (2)	><u>13.4 ± 1.8</u> (2)	25.3 ± 3.1	11.4 ± 3.5	4.86*

*Significant at $P < .05$.

and two based on basal area and number of shrubs. Canopy height, number of trees, and the two lower horizontal density classes were the least important variables in discriminating between utilized and non-utilized plots.

DISCUSSION

The use of singing grounds by displaying male woodcock is influenced by the interspersion of diurnal habitat (forest) and singing ground habitat (fields). The response by singing males to an increased amount of clearing is a non-linear relationship. Based on the regression equation, all indications are that the maximum woodcock use can be expected when there is roughly an equal (50:50) interspersion of the two habitat types. As the balance shifts toward excess forest, singing fields appear to become limiting, and when the shift is in the opposite direction, the diurnal habitat becomes limiting.

The vegetational characteristics of diurnal and singing ground habitat are also important in determining the suitability of an area for woodcock use. The presence of an aspen community adjacent to a clearing is very important in determining if a clearing will be used as a singing field. When aspen is compared to oak or pine communities, it is rather conclusive that aspen is a preferred habitat in this region. There is some additional evidence that the height and density of vegetation in the clearing are also important, but to a lesser degree. Sheldon (1971) concluded that the only requirement for a singing ground is a "get away" route for the bird's aerial flight. Maxfield (1961) found that the height of vegetation in an opening tolerated by woodcock varied directly with the size of the singing field. Woodcock are known to be opportunistic in use of openings for singing (Blankenship 1957, Mendall and Aldous 1943), and even clearings with extremely dense regeneration will generally have a number of grassy pockets that meet the requirements.

The number of singing male woodcock on the quarter township units increased from 1975 to 1976. This increase was compared to 33 federal census routes in northern Michigan that also were censused in both years. A t-test showed no significant (P >.25) change in the number of displaying birds. This suggests that the increases on the units are in response to the habitat manipulations and not a regional population increase. Time and treatment are confounded and it is not clear if the change represents improvement in the habitat condition between the two years or a delayed response to the units. Since the 50% and 75% units increased more than the 25% units, and since cutting on the 25% units was completed about 2 years before the others, it leads me to believe that the increase is a delayed response by the woodcock to the newly created habitat.

The next question that arises is whether or not the structural features preferred by the male woodcock are the same as those preferred by the females during the breeding season. Comparisons were made between the habitat structure selected by nesting females, non-flying broods, flying broods and solitary birds (presumably males). The discriminant analysis affirms that there are some distinct differences between the groups. The solitary woodcock shows a distinct tendency to select diurnal habitat that has 50% more vegetational obstruction in the understory than sites used by nesting birds and broods. The implication is that the solitary birds perfer the extra seclusion offered by the denser vegetation. This type of habitat would allow the birds to move without increasing their vulnerability to predators. Nesting females, on the other hand, seem to prefer habitat with a higher canopy and smaller basal area than broods or solitary birds. After the eggs hatch, there appears to be a tendency for the female to move the brood into a younger, more dense habitat. This would allow the foraging chicks to move about freely with less chance of being detected by a predator. Bourgeois (1976) found similar results in analysis of nest and brood habitat in northern Michigan. Nest sites are most distinctly different from the other utilization classes. Sites used by broods and solitary woodcock overlap more in habitat parameters preferred.

There is a certain amount of shifting in habitat use by solitary woodcock throughout the seasons. In the early spring, and again after the beginning of woodcock hunting season, there is no indication of a habitat preference. There is evidence that alder communities are avoided in the spring. This is understandable, since alder is frequently inundated with water during that period. Throughout the summer months (June to September), aspen excels as a preferred habitat type. Although mixed deciduous communities are utilized by woodcock throughout all seasons, there is a great deal of variation in the degree of use between search plots. This appears to be related to the greater variability of critical structural features within the mixed deciduous community type. Alder shows a progressive increase in woodcock use until mid-fall. This is probably related to a shift in food supply as soil moisture in the various community types change. Dunford (1971) observed that woodcock moved to lowland coverts during periods of drought. Mendall and Aldous (1943) found birds in mixed and deciduous woods in the spring but in alder later in the year. Immature aspen shows its greatest use during the spring and early fall, relative to the other habitat types. It is interesting to note that the greatest use of immature aspen is associated with the arrival and departure of woodcock in northern Michigan. The use of this type may be primarily related to woodcock migrations. Wenstrom (1973) found that female woodcock had a distinct preference for upland brushy habitat during the spring migrational period. Flush rates indicate that most woodcock had migrated by 1 October. The slight increase in all habitats for mid-October may be caused by late migrants moving through the area.

Structural differences in habitat selected by solitary birds are related to the number of saplings and average canopy height. Summer use by woodcock tends to be in older habitats with slightly more sapling-sized trees (2.5 to 7.6 cm. dbh). This type of structural shift would be predicted from examination of the flush rate data. The percentage of correctly classified plots is an indication that there is better discrimination between spring and summer than between early and late summer. The subtle structural shifts that do occur are probably related to the onset of the molting period.

Some interesting relationships develop when discriminant analysis is used to contrast the structural features of solitary woodcock sites between community types and also utilized and non-utilized sites within each community type. It is evident that the discriminant functions are able to do an extremely good job of classifying the various community types. However, the variables that are important in discriminating between community types are largely unimportant in discriminating between utilized and non-utilized areas. There is one exception, the number of saplings is important in both contrasts. This can be attributed to the difference in growth form of sapling-sized trees in alder compared to aspen communities. The understory structure (saplings, shrubs, horizontal density, and ground cover) is the most important feature determining the use of an area by woodcock and is consistent between all community types.

All deviations from utilized parameters in immature aspen indicate that non-utilized areas tend to be younger and much denser in the understory structure. It appears that woodcock are reluctant to penetrate expansive plots of the immature aspen type. Mixed deciduous tends to be too open in the understory to satisfy woodcock requirements. There is an indication that aspen may occasionally be too open in the understory, but the most prevalent problem appears to be related to the distance to a clearing. The two non-utilized aspen plots were distantly separated from any openings by other forest types. Apparently, woodcock are reluctant to seek out these areas. The causes of non-utilization of alder communities is less clear, but, in one case, seems to be related to excessive grassy ground cover. Also, there is evidence that older stands of alder become too open in the understory.

All evidence indicates that woodcock are closely associated with specific habitat structure and the proximity to a clearing. Among the three aspen community types, it is interesting to note that woodcock penetration of the habitat is directly related to the age of the community and density of the understory. Even so, there seems to be a limit to the depth of penetration for each community type.

SUMMARY

1. The density of woodcock use during the breeding season is directly related to the amount of interspersion between suitable diurnal and singing ground habitat.
2. In general, aspen seems to be the preferred community type in Michigan. There is a strong tendency towards the middle-aged stands (10-20 years) for most of the summer and early fall.
3. Gross vegetational features of a clearing are not as important in determining the use of a singing ground as the distance to suitable diurnal habitat.
4. Understory vegetational density and proximity to a clearing are the most important features in determining utilized woodcock habitat. Middle-aged aspen communities most consistently meet these habitat requirements. Immature aspen and mixed deciduous communities frequently fall outside the acceptable range of habitat structure for woodcock.
5. Woodcock nest sites tend to be in more open areas relative to broods and solitary woodcock. Solitary woodcock prefer areas with the highest vegetational density of any utilization class.
6. Habitat structure related to seasonal use by solitary woodcock shows a shift towards the middle-aged aspen communities during the summer, but no significant change in the understory structure occurs.

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