Determination of HABITAT REQUIREMENTS FOR BIRDS in Suburban Areas

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ABSTRACT

Songbird populations can be related to habitat components by a method that allows the simultaneous determination of habitat requirements for a variety of species. Through correlation and multiple-regression analyses, 10 bird species were studied in a suburban habitat, which was stratified according to human density. Variables used to account for bird distribution included aspects of vegetation, human activity, and structures.

KEY WORDS: habitat, birds

CONTENTS

THE FORESTER AND WILDLIFE manager have been traditionally concerned with the production of timber, game, and nongame species in rural areas. But the increasing density of people in cities has brought these professions new responsibilities. Government, concerned citizens, and members of the professions themselves have urged the application of resource management skills to the problems of urban environments.

Until recently, wildlife management in cities dealt mainly with pest control. But a new concern has emerged for the wildlife biologist: to provide wildlife in urban and suburban environments solely for the enjoyment it provides.

Foresters are now looking to trees in cities for more than shade, hardiness, and a minimum of litter. Beyond their visual appeal, trees in urban areas have many amenity values, among them improvement of air and water quality, modification of microclimate, screening of unsightly land uses, and provision of wildlife habitat.

Wildlife exists as a byproduct of vegetation, and thus the manipulation of vegetation for the above purposes affects the diversity and composition of wildlife populations. Wildlife—especially songbirds—adds color, movement, and sound to the landscape, and thus can contribute much to the human habitability of cities. Basic to the management of desired urban wildlife species is our understanding of their habitat requirements. Such knowledge could be used to manipulate vegetation to provide the amenities of wildlife in addition to those of the vegetation alone.

This new concept of the management of wildlife in the city solely for the pleasure it affords probably was first articulated by Bennitt in 1946 when he looked forward "... to the day when we shall hear men discuss the management of songbirds, wildflowers, and the biota of a city." The USDA Forest Service, through the Pinchot Institute for Environmental Forestry Research, is working toward the improvement of the quality of life in our cities through research on the amenity values of forest vegetation and wildlife in urban areas.

THE PROBLEM

The traditional approach to the study of wildlife habitat requirements has been to study each species singly and in elaborate detail. In developing management plans for songbirds in urban and suburban areas, we are faced with the problem of determining habitat requirements for more than 100 species. The cost of the traditional species-by-species approach would have been prohibitive. Therefore, we developed a method that would yield statistically reliable estimates of vegetation and bird density and would enable us to identify the habitat components associated with each species.

As suburban communities are ecologically diverse and scarcely studied for wildlife-habitat analysis, it seemed appropriate to utilize such an area for this study. We made four basic assumptions:

1. Birds are nonrandomly distributed *(Preston and Norris 1947, Woolfenden and Rohwer 1969, Hilden 1965)*.
2. Bird distribution is determined by measurable habitat characteristics *(Hilden 1965, Hooper and Crawford 1969)*.
3. The maximum human-bird interaction in a suburban situation takes place along street and roadsides, and such interaction is desirable *(Dagg 1970)*.
4. Identification of the variables affecting bird distribution and density would be valuable for prescribing changes to attract or discourage birds *(Hooper and Crawford 1969)*.

OBJECTIVES

Our objectives were: to develop a technique for identifying and measuring habitat variables important to the occurrence of songbirds during the breeding season, and to test the technique by identifying the key habitat characteristics of 10 bird species during the breeding season in a suburban habitat.

METHODS

Dependent Variables

The dependent variables were the occurrence of 10 locally common breeding songbird species expressed as birds per acre measured on a census plot at 9 sampling dates. The species studied were:

Robin *(Turdus migratorius)*
Gray catbird *(Dumetella carolinensis)*
Blue jay *(Cyanocitta cristata)*
Northern oriole *(Icterus galbula)*
Song sparrow *(Melospiza melodia)*
Chipping sparrow *(Spizella passerina)*
House wren *(Troglodytes aedon)*
Black-capped chickadee *(Parus atricapillus)*
Brown thrasher *(Toxostoma rufum)*
House sparrow *(Passer domesticus)*

Independent Variables

A 1/2-acre circular plot concentric to the bird-census plot was used to measure most of the independent variables. The independent variables are presented in table 1.

Data Collection

The town of Amherst, Massachusetts, was the study area. It contains approximately 100 miles of streets and roads, which we originally stratified into five types on the basis of the density of housing. Ecological-sociological stratifications were suggested by Hooper and Crawford *(1969)*. The need for stratification based on the extent and nature of human activity was also suggested by Bates *(1962)*. However, we later found that stratification was unnecessary, and we limited our analysis to pooled data from three suburban strata.

Pretesting indicated that, within manpower constraints, data could be collected on 80 plots. These were proportionally allocated to the five original strata, and randomly within strata.

Hooper and Crawford *(1969, p. 202)* stated that "... it is important to sample bird(s) ... when the environment and these variables are

Table 1.—Independent variables used to study the habitat associations of 10 songbird species in suburban Amherst, Massachusetts

Variable	Description and measurement
Deciduous tree volume, 0-5 feet, 6-10 feet ... 96-100 feet, and total; coniferous volume, 0-5 feet ... 96-100 feet, and total.	The total and discrete layer volumes of deciduous and coniferous tree crowns on a plot. Individual tree crowns were classified as one of 5 profile shapes and 1 of 3 plan view shapes. Height to crown and total height were measured with an altimeter; crown radii were measured with a steel tape.
Deciduous shrub volume, 0-5 feet, ... 16-20 feet, and total; coniferous shrub volume 0-5 feet... 16-20 feet, and total.	The total and discrete layer volumes of deciduous and coniferous shrubs on a plot. Measurement was made by treating each shrub or cluster as a rectangular prism and estimating the length, width, and height with a range pole graduated in feet.
Area of mowed lawn and herbaceous vegetation.	The area in square feet of mowed lawn and weedy growth on a plot, measured as the sum of the areas of convenient rectangles of each vegetation type.
Volume of structures.	The cubic-foot volume of houses on a plot, measured by treating each house as a rectangle and recording its length, width, and height. Only that percentage of a rectangle falling within the plot was recorded.
Building density.	The sum of the distances from plot center to the nearest 5 buildings, measured on aerial photographs of the study area.
Traffic flow.	Vehicles per hour at peak periods, counted for two 15-minute periods between 0730 and 0830; the values were averaged.
Dogs, cats, children, adults, bird feeders, nest boxes.	The number of each variable per plot was obtained from questionnaires sent to all households within 1/16 mile of plot center. After 2 mailings, nonrespondents were assigned the mean values of data received.
Cultivated fields, fallow fields, woodlots, open water.	The distance, in feet, from plot center to the nearest field or woodlot of at least 1 acre, measured from aerial photographs.
Number of gardens, garden area.	The number of garden plots and the sum of their areas in square feet, within 1/16 mile of plot center. Information obtained by questionnaire.

relatively stable." They suggest "... breeding, post-breeding, and winter." We chose for study the breeding season as the most stable, because of territorial behavior.

We made nine counts of birds seen and heard from 15 May to 30 June on each of the 80 plots. Our sampling required six counts in 1971 and three in 1972, a total of 720 counts.

We conducted counts only under the following circumstances: During the first 2-1/2 hours after sunrise when the wind speed was less than Beaufort scale 3, when the temperature was between 30° and 80°F, when the overcast was less than 50 percent, and when there was no rain either during or 1 hour before the count. Such constraints are useful, because weather has been shown to affect the rate of bird singing *(McClure 1939, McGowan 1953)*.

The plot size for birds censused by direct observation was calculated by estimating the distance from plot center (up to a maximum of 200 feet) that a bird could be seen in a horizontal view. Six such measurements were taken. The average distance was used as a radius for computing the area of a circular plot. The plot size was variable, depending on the visibility from the center. The plot size for birds censused by song alone differed among species and was the mean distance that song could be heard *(Petraborg et al. 1953)*.

Before making the census counts, we sent a letter soliciting cooperation from persons whose properties were part of a study plot. During the census, the observer drove to the plot and observed for 1 minute from within the vehicle, then stood at the plot center for 4 minutes recording the number of each of the 10 species that was seen or heard.

The visibility up and down the road was usually greater than the plot radius for birds seen. Birds seen there were counted if they were within 200 feet.

Analysis

The simple correlation (r) between variables was calculated by using the actual values and a limited number of scale transformations. The mathematical slicing of the vegetation produced a series of variables that were not truly independent—the volume in a layer was usually related to the volume in an adjacent layer—although the correlations were not significant in many pairs. Since our purpose was insight into songbird habitat, we retained all layers and interpreted the results by a consideration of the significant simple correlation between bird density and vegetation volumes appearing in adjacent positions; and thus groups of adjacent layers with significant correlation coefficients formed "factors".

Factors and remaining significant variables were placed in a model that essentially ranked them by position of emergence from multiple-regression analysis in decreasing contribution to reduction in the unaccounted for variation (R^2).

The statistical technique we used is given in Fryer *(1966)*. We could have developed purely predictive equations from this technique if the number of plots in a stratum had been sufficient.

RESULTS AND DISCUSSION

We found that the data for birds censused solely by sound were not useful. Some species could be heard at great distances. Since all vegetational variables and many other variables were measured on an 83-foot radius plot, the plot may not have been representative of habitat of distant birds. We concluded that only in a very homogenous habitat could birds be censused by sound alone.

After examining the multiple-regression models, we arbitrarily retained only 10 stepwise variables for each species. In all species the increase in R^2 was negligible beyond that point. We retained all variables if fewer than 10 came out in the stepwise procedure.

Evaluation of Independent Variables

Since our aim was the simultaneous determination of habitat relationships of many bird species, using the same habitat data, we evaluated the variables across all bird species rather than for each species separately. This was done to give guidance as to which variables were important and should be included in future studies and which could be eliminated. Importance of the surviving variables to individual species was made as a separate part of the study.

Bird-Population Indices

Indices of the populations of the bird species (table 2) were produced by converting the nine 5-minute counts to density as follows: birds by

Table 2.—Frequency and density of bird species in suburban Amherst, Massachusetts, in 1971

Bird species	Bird population		
	Percentage of plots on which birds were observed	Density of birds per acre	Confidence interval, as percentage of density
Robin *(Turdus migratorius)*	86.7	3.15	17.6
Gray catbird *(Dumetella carolinensis)*	26.7	.43	48.5
Blue jay *(Cyanocitta cristata)*	13.3	.08	67.5
Northern oriole *(Icterus galbula)*	45.0	.84	32.6
Song sparrow *(Melospiza melodia)*	35.0	.42	38.3
Chipping sparrow *(Spizella passerina)*	6.7	.58	125.3
House wren *(Troglodytes aedon)*	15.0	.17	64.5
Black-capped chickadee *(Parus atricapillus)*	88.3	3.31	27.4
Brown thrasher *(Toxostoma rufrum*	18.3	.52	67.7
House sparrow *(Passer domesticus)*	61.7	2.21	25.7

species observed per visual plot. Results for the nine counts were averaged.

The mean and 90-percent confidence intervals were calculated for each bird species. Confidence intervals ranged from 17.6 to 125.3 percent and averaged 51.5 percent (table 2). These data can be used in estimating required sample sizes for results to be within desired limits.

Relationships of Bird Density to Habitat

We examined the relationship between density indices and habitat variables by stepwise regression and significant correlation coefficients.

The model for each bird species is based on the significant ($\alpha \geq .1$) stepwise variables. However, statistical and practical significance are not necessarily the same. Any variable that increases the R^2 by less than 3 percent is probably not important from a manager's viewpoint.

ROBIN

Robins were found on 86.7 percent of the plots (table 2) at 3.15 birds per acre. Results of the stepwise multiple-regression analysis are given in table 3.

Coniferous height volume between 6 and 10 feet is the most important variable for robins (table 3). However, coniferous height volumes between 0 and 5 feet, 11 and 15 feet, and 16 and 20 feet were also significantly correlated with the 6- to 10-foot layer, as well as the dependent variable. In the stepwise multiple-regression technique, the independent variable having the highest correlation with the dependent variable is removed first. Thus, when the sum of squares attributable to the 6- to 10-foot layer was removed, the other three layers contributed little to the further reduction in total sum of squares and did not emerge in the model. However, it appears that the 0- to 20-foot layer is an important habitat for robins. This logic was used in pooling other series of layers that by themselves have not shown significant additions to R^2.

We believe that the number of gardens and the distance of the nearest fallow field are related to suitable foraging areas. Deciduous height volume between 11 and 15 feet may represent the combination of layers between 6 and 60 feet, all of which showed significant simple correlations (table 12).

Suitable habitat was frequently associated with coniferous volume in the 5- to 20-foot layer and deciduous overstory (11 to 20 feet most important). This habitat description is compatible with the descriptions of other workers. Kendeigh *(1945)* identified the robin as formerly a forest-edge species, but Howell *(1942)* reported that its requirements were best met in suburban areas with lawns for feeding and trees for cover and nesting. Martin *et al. (1951)* noted the relationship of robins to agricultural areas and suburbs and described a preference for lawns, orchard, and clearings rather than woods.

Hester *(1964)* found that nest success was better when the site was associated with human

Table 3.—Habitat variables associated with the occ rence of breeding robins *(Turdus migratorius)* in A herst, Massachusetts, in 1971.

Independent variable	Multiple R^2	Change in R^2	Simple r
Coniferous tree volume 6-10 feet	0.213	0.213	0.461**
Number of gardens	.428	.215	.421**
Fallow field	.488	.060	.205*
Deciduous tree volume 11-15 feet.	.522	.035	.345**

[a] *p < .05; **p < .01

activity. Conversely, Klimstra and Stieglitz (1967) found success better in rural areas and believed that scarcity of cats was a reason.

GRAY CATBIRD

Gray catbirds were observed on 26.7 percent of the plots (table 2) at a density of 0.43 birds per acre. The model of habitat associations is shown in table 4.

Deciduous height volume, 21 to 25 feet, accounted for 39 percent of R^2. Simple correlation coefficients were significant for deciduous layers between 6 and 45 feet (table 4).

The other variables in the model were all measures of vegetation. Preferred gray catbird habitat included a deciduous shrub layer from 6 to 15 feet with a deciduous overstory at 11 to 35 feet.

Kendeigh *(1945)* described the gray catbird's strong association with shrubs, and identified their habitat as one of mixed shrubs and small trees. Nickell *(1965)* and Martin *et al. (1951)* believed that urban expansion increased the amount of suitable habitat, which they described as relatively indiscriminate dense woody plant associations.

BLUE JAY

Blue jays occurred on 13.3 percent of the plots at low density (0.08 birds per acre). The numbers seen per plot varied greatly (table 2). As a result, the stepwise multiple-regression model was not useful for describing the bird's habitat. Only three correlations were significant: fallow fields, number of gardens, and mowed lawn (table 12).

This species occurs in many habitat types, but was observed on few plots in this study (table 2). Kendeigh *(1945)* described the bird as abundant in both coniferous and deciduous forests. Stewart and Robbins *(1958:217)* defined its habitat as: "Various types of forest, wood margins, and hedgerows." Stone *(1926)* believed the species was becoming tamer and better adapted to man's occupied areas.

Bendire *(1895, in Bent 1946)* described its habitat as mixed woods (especially oak and beech), with a nesting preference for dense coniferous thickets. This species is common in suburbs, but for unknown reasons did not occur on enough study plots to allow a statistical analysis of its habitat.

NORTHERN ORIOLE

Northern orioles were found on 45.0 percent (table 2) of the plots and in moderate densities (0.84 birds per acre). The results of the stepwise multiple-regression analysis of its habitat are shown in table 5.

The habitat of the northern oriole contained deciduous shrub cover with mid-canopy volumes of coniferous and deciduous trees (table 5). The bird seems well adapted to suburban areas; but significant negative correlations with children, dogs, mowed lawn, and building density (table 12) indicated that quieter, older, more established neighborhoods may provide better habitat.

Bagg and Eliot *(1937)* described the northern oriole as a bird of the shade-tree community. Graf *(1966)* found that this bird is best adapted to suburbs with mature vegetation.

Stewart and Robbins *(1958:323-324)* described the bird's breeding habitat as: "Shade trees in residential areas, on farms, and in towns and suburbs; also in open stands of flood-plain forests and most forests on the upland." Kendeigh *(1946)* described the nesting habitat as shrubs and small trees in late stages, which agrees well with our results.

SONG SPARROW

Song sparrows were found on 35.0 percent of the plots (table 2) in moderate densities (0.42 birds per acre). The habitat model is shown in table 6. Only one habitat variable, deciduous height volume at 26 to 30 feet, is important; so we consider the model to be of limited utility for predictive purposes.

Examination of the significant coefficients was more revealing (table 12). Sixteen of 19 significant variables had a negative relationship with the dependent variable. Thus there was more information on what made an area unacceptable than on what made it attractive to song sparrows.

Significant negative correlations with deciduous height volume 11 to 50, 96, to 100, and in total, and with coniferous height volume 11 to 30 feet, indicated that open situations are preferable. Positive correlations with deciduous shrub volume 6 to 10 feet and herbaceous vegetation indicated that a relatively open shrub-herbaceous area as best.

Kendeigh *(1945)* reported that shrubs were an important habitat component. Suthers *(1960)*

Table 4.—Habitat variables associated with the occurrence of breeding gray catbirds *(Dumetella carolinensis)* in Amherst, Massachusetts, in 1971

Independent variable	Multiple R^2	Change in R^2	Simple r [a]
Deciduous tree volume, 21-25 feet	0.391	0.391	0.626**
Deciduous shrub volume, 11-15 feet	.436	.045	.021
Deciduous tree volume, 86-90 feet	.481	.045	-.045
Coniferous tree volume, 21-25 feet	.515	.034	-.096

[a] *p < .05; **p < .01

Table 5.—Habitat variables associated with the occurrence of breeding northern orioles *(Icterus galbula)* in Amherst, Massachusetts, in 1971

Independent variable	Multiple R^2	Change in R^2	Simple r [a]
Deciduous shrub volume, 0-5 feet	0.277	0.277	0.526**
Coniferous tree volume, 26-30 feet	.445	.169	.446**
Deciduous tree volume, 21-25 feet	.527	.082	.509**
Deciduous shrub volume, 6-10 feet	.578	.051	.281*

[a] *p < .05; **p < .01

Table 6.—Habitat variables associated with the occurrence of breeding song sparrows *(Melospiza melodia)* in Amherst, Massachusetts, in 1971

Independent variable	Multiple R^2	Change in R^2	Simple r [a]
Deciduous tree volume, 26-30 feet	0.082	0.082	-0.286*
Deciduous shrub volume, 6-10 feet	.188	.106	.199
Open water	.236	.048	.099
Volume of structures	.293	.057	-.191

[a] * p < .05; ** p < .01

Table 7.—Habitat variables associated with the occurrence of breeding chipping sparrows *(Spizella passerina)* in Amherst, Massachusetts, in 1971

Independent variable	Multiple R^2	Change in R^2	Simple r [a]
Coniferous shrub volume, 11-15 feet	0.388	0.388	0.623**
Cats	.501	.113	.467**
Adults	.579	.078	-.070
Coniferous tree volume, 61-65 feet	.631	.052	-.072

[a] * p < .05; ** p < .01

described absence of overstory to favor development of dense brush with abundant insects as critical.

CHIPPING SPARROW

Chipping sparrows were found on 6.7 percent of the plots, in moderate densities (0.58 birds per acre), but the number of birds seen varied greatly (table 2).

Coniferous shrub volume at 11 to 15 feet was the most important variable, accountng for 38.8 percent of the variation in chipping sparrow occurrence (table 7). Significant correlation coefficients indicated that this layer was more likely 0 to 15 feet (table 12). Deciduous height volume at 41 to 45 feet and coniferous height volumes at 61 to 65 and 66 to 70 feet might retard the shrub layer, but their correlation coefficients were not significant. The negative relationship with people in Amherst conflicted with Stull's *(1968)* report of a general compatibility with man. Positive correlations with cats and dogs were probably due to the coincidental occurrence of species highly adapted to areas of human habitation, correlations not necessarily implying cause and effect.

The correlations added little insight into chipping sparrow habitat requirements, but the habitat is known to be generally characterized by a coniferous shrub volume at 0 to 15 feet, little overstory, and open grassland or lawn. Bull *(1964)* described the habitat as lawns, short grass fields, and bare ground, with nesting in yards, parks, and settled rural country. Forbush *(1927)* called it the most domestic of sparrows. Stull *(1968)* and Martin *et al. (1951)* found the species most common in dooryards, lawns, and orchards. We expected this species to be quite common, and are not sure why we found so few chipping sparrows.

HOUSE WREN

House wrens were found on 15.0 percent of the plots (table 2) in low densities (0.17 birds per acre).

The model contained only four variables; deciduous shrub volume at 16 to 20 feet explained fully three-quarters of the variability in wrens seen (table 8). Examination of the significant coefficients showed that the entire 0- to 20-foot shrub layer was important. The number of gardens added 5.95 percent to R^2, and open water added 3.13. Deciduous height volume at 51 to 55 feet had minor negative effect (table 12). Deciduous height volume at 6 to 25 feet may also be important.

Habitat requirements thus appear to be a dense deciduous shrub layer (0 to 20 feet) combined with a deciduous tree canopy at 6 to 25 feet.

A large body of literature reports that the bird is adapted to dooryards and is found frequently in areas of dense shrubs *(Bent 1948)*. Stewart and Robbins *(1958:231)* described breeding habitat as: "Various edge habitats, including brushland, wood margins, hedgerows, orchards and residential areas."

BLACK-CAPPED CHICKADEE

The black-capped chickadee was found on 88.3 percent of the plots (table 2) at a density of 3.31 birds per acre. Both the frequency and the density are the highest of the 10 bird species studied. The multiple-regression model contains seven habitat components, which together accounted for 72 percent of the variability in chickadee occurrence (table 9).

Coniferous height volume 21 to 25 feet was most important, and examination of the correlations revealed that the layer 6 to 50 feet was important (table 12). The next emergent variable was deciduous height volume at 31 to 35 feet; coefficient examination expanded the layer to 16 to 55 feet. The other coniferous and deciduous height volumes that emerged were included in the expanded layers described above, and they added 16.25 percent to R^2 (table 9).

Deciduous shrub volume at 6 to 10 feet appeared in the model and contributed 3.33 percent to R^2. The simple correlation coefficients showed that the total deciduous shrub volume was important.

Sturman's *(1968)* results indicated that total canopy volume of trees, bushes, and the middle story, considered jointly, showed the greatest predictive power for chickadee abundance, and so were similar to ours. Stewart and Robbins *(1958)* described preferred chickadee habitat as forest edge and woodlands, particularly near weedy fields and pine stands.

BROWN THRASHER

Brown thrashers were found on 18.3 percent (table 2) of the plots in moderate densities (0.52 birds per acre). The model (table 10) contains five habitat variables that together account for

Table 8.—Habitat variables associated with the occurrence of breeding house wrens *(Troglodytes aedon)* in Amherst, Massachusetts, in 1971

Independent variable	Multiple R^2	Change in R^2	Simple r [a]
Deciduous shrub volume, 16-20 feet	0.761	0.761	0.872**
Number of gardens	.820	.060	.252*
Open water	.852	.031	-.095

[a] * p < .05; ** p < .01

Table 9.—Habitat variables associated with the occurrence of breeding black-capped chickadees *(Parus atricapillus)* in Amherst, Massachusetts, in 1971

Independent variable	Multiple R^2	Change in R^2	Simple r [a]
Coniferous tree volume, 21-25 feet	0.408	0.408	0.638**
Deciduous tree volume, 31-35 feet	.500	.092	.452**
Coniferous tree volume, 61-65 feet	.553	.053	-.144
Number of gardens	.597	.045	.145
Deciduous shrub volume, 6-10 feet	.631	.033	.317**
Deciduous tree volume, 26-30 feet	.675	.045	.335**
Deciduous tree volume, 41-45 feet	.723	.047	.338**

[a] * p < .05; ** p < .01

Table 10.—Habitat variables associated with the occurrence of breeding brown thrashers *(Toxoxtoma rufrum)* in Amherst, Massachusetts, in 1971

Independent variable	Multiple R^2	Change in R^2	Simple r [a]
Deciduous tree volume, 6-10 feet	0.128	0.128	0.358**
Deciduous tree volume, 0-5 feet	.188	.060	.055
Deciduous tree volume, 21-25 feet	.314	.126	-.025
Number of gardens	.377	.063	-.063
Cultivated fields	.409	.032	.034

[a] * p < .05; ** p < .01

Table 11.—Habitat variables associated with the occurrence of breeding house sparrows *(Passer domesticus)* in Amherst, Massachusetts, in 1971

Independent variable	Multiple R^2	Change in R^2	Simple r [a]
Cats	0.194	0.194	0.440**
Volume of structures	.308	.114	.432**
Coniferous shrub volume, 11-15 feet	.346	.038	-.131
Coniferous tree volume, 66-70 feet	.407	.061	.190**
Deciduous tree volume, 11-15 feet	.441	.035	.102

[a] * p < .05; ** p < .01

about 41 percent of the variation in brown thrasher occurrence. Only three simple correlation coefficients were significant (table 12). The habitats that we sampled were marginal for brown thrashers.

There were significant correlations not found in the model: deciduous height volume at 11 to 15 feet and the deciduous shrub volume at 16 to 20 feet (table 12). The most important layer was 0 to 20 feet.

The negatively correlated deciduous height volume at 21 to 25 feet in third position in the model indicates that canopies above 20 feet decrease the habitat's attractiveness to brown thrashers. Requirements were described by Kendeigh *(1946)* as mixed shrub-small tree habitat in middle facies. We agree except to emphasize the importance of a deciduous shrub and small tree layer at 0 to 20 feet.

Bent *(1948)* described the brown thrasher in Massachusetts as a bird of rural and farming districts, living in bushy pastures, sproutlands, briar patches, tangles along fences, dry thickets, brushy hillsides, and the edges of woodland, almost always far from human habitation. However, Sherman *(1912)* noted that the bird was a common dooryard species except in New England. The reason for this difference in the bird's habitat is unclear. Our data did not indicate that human density or cats and dogs had any significant effects.

HOUSE SPARROW

These birds were observed on 61.7 percent (table 2) of the plots at a density of 2.21 birds per acre. The model contains five habitat components, which account for a total of 44 percent of the variation in house sparrow occurrence (table 11).

These results were difficult to analyze because of the affinity of the house sparrow for man's habitat. For example, no cause-and-effect relationship should be implied from correlation between cats and house sparrows. Yet, we do not think this spurious; it probably expressed the concurrent presence of two species dependent on man for habitat. This reliance on man is clearly evident from the emergence of volume of structures in the model. And of the 10 significant simple correlations (table 12), four were measures of man's influence: volume of structures, building density, cats, and adults.

The positive correlations between the distance to the nearest fallow field and woodlot and house sparrow occurrence also indicated that man's living places were suitable habitat. The combined negative relationships to herbaceous vegetation and mowed grass were probably the result of positive correlations with gardens and the presence of pavement and bare ground, which were not measured.

There was a deleterious effect of low shrub and tree volume, both deciduous and coniferous, and a positive influence of high canopy, particularly the coniferous height volume at 56 to 70 feet, although this adaptable species is likely responding to the presence of nest sites in buildings rather than vegetative features.

Woolfenden and Rohwer *(1969)* reported that house sparrows accounted for half of the total breeding bird population in their study of suburban habitats in Florida. Suburban areas provide ideal house sparrow habitat because they contain grassy cover and open ground for feeding, dust-bathing, gathering of nest material, and buildings for nesting.

Importance of Vegetation Layers

Birds respond to environmental features, including vegetative physiognomy *(Lack 1933, Breckenridge 1956, and Klopfer 1969)*. Emlen *(1956)* provided a method of describing habitat characteristics of birds, and suggested some variables similar to ours. These included detailed measurements of crown characteristics instead of the relative classes described by Kuchler *(1949)*.

Our work was greatly influenced by that of Sturman *(1968)*, who developed formulae for computing the volumes occupied by the cone-shaped crowns of conifers and the ellipsoid crowns of hardwoods to describe, with other variables, the habitat of chickadees *(Parus atricapillus* and *P. rufescens)* with multiple-regression techniques.

Birds of temperate North America are intermediate in their degree of layer selection *(Klopfer 1969)*. This ability to differentiate between layers, or to recognize more layers, increases the species' diversity of a forested habitat. James *(1971)* and Cody *(1968)* dealt with similar concepts in the discriminate-function habitat analysis of forest birds and grassland birds, respectively.

Layers of vegetation are critical to species diversity *(MacArthur and MacArthur 1961)*, but

Table 12.—Correlation coefficients (r) between bird species and habitat variables in Amherst, Massachusetts in 1971

[Significance levels: * = p < .05; ** = p < .01]

Bird species	Deciduous tree volume						
	Total	0-5	6-10	11-15	16-20	21-25	26-30
Robin *(Turdus migratorius)*	.310**		.282*	.345**	.318**	.292*	.308*
Gray catbird *(Dumetella carolinensis)*	.358**		.282*	.535**	.616**	.626**	.555**
Blue jay *(Cyanocitta cristata)*	—		—	—	—	—	—
Northern oriole *(Icterus galbula)*	.269*		—	.338**	.463**	.509**	.504**
Song sparrow *(Melospiza melodia)*	-.264*		—	-.189	-.226*	-.250*	-.286*
Chipping sparrow *(Spizella passerina)*	—		—	—	—	—	—
House wren *(Troglodytes aedon)*	—		.291*	.317**	.243*	.209	—
Black-capped chickadee *(Parus atricapillus)*	.317		—	—	.175	.209	.335**
Brown thrasher *(toxostoma rufrum)*	—		.358**	.231*	—	—	—
House sparrow *(Passer domesticus)*	—		—	—	—	—	—

Bird species	Deciduous tree volume						
	31-35	36-40	41-45	46-50	51-55	56-60	61-65
Robin *(Turdus migratorius)*	.309*	.224*	.185	.199	.232*	.219*	.172
Gray catbird *(Dumetella carolinensis)*	.418**	.259*	.181	—	—	—	—
Blue jay *(Cyanocitta cristata)*	—	—	—	—	—	—	—
Northern oriole *(Icterus galbula)*	.446**	.347**	.243*	—	—	—	—
Song sparrow *(Melospiza melodia)*	-.283*	-.253*	-.221*	-.186*	—	—	—
Chipping sparrow *(Spizella passerina)*	—	—	—	—	—	—	—
House wren *(Troglodytes aedon)*	—	—	—	—	—	—	—
Black-capped chickadee *(Parus atricapillus)*	.452**	.438**	.338**	.227**	.210	—	—
Brown thrasher *(Toxostoma rufrum)*	—	—	—	—	—	—	—
House sparrow *(Passer domesticus)*	—	—	—	—	—	—	—

Bird species	Deciduous tree volume		Coniferous tree volume			
	66-95	96-100	Total	0-5	6-10	11-15
Robin *(Turdus migratorius)*	—	—	—	.242*	.461**	.384**
Gray catbird *(Dumetella carolinensis)*	—	—	—	—	—	—
Blue jay *(Cyanocitta cristata)*	—	—	—	—	—	—
Northern oriole *(Icterus galbula)*	—	—	.348*	.224*	.226*	.278*
Song sparrow *(Melospiza melodia)*	—	-.187	—	—	—	-.176
Chipping sparrow *(Spizella passerina)*	—	—	—	—	—	—
House wren *(Troglodytes aedon)*	—	—	—	—	—	—
Black-capped chickadee *(Parus atricapillus)*	—	—	.364**	—	.413**	.462**
Brown thrasher *(Toxostoma rufrum)*	—	—	—	—	—	—
House sparrow *Passer domesticus)*	—	—	—	—	—	—

Bird species	Coniferous tree volume 16-20	21-25	26-30	31-35	36-40	41-45	46-50
Robin (*Turdus migratorius*)	* .237	—	—	—	—	—	—
Gray catbird (*Dumetella carolinesis*)	—	—	—	—	—	—	—
Blue jay (*Cyanocitta cristata*)	—	—	—	—	—	—	—
Northern oriole (*Icterus galbula*)	** .333	** .396	** .446	** .394	** .352	** .327	** .309
Song sparrow (*Melospiza melodia*)	-.188	-.180	-.174	—	—	—	—
Chipping sparrow (*Spizella passerina*)	—	—	—	—	—	—	—
House wren (*Troglodytes aedon*)	—	—	—	—	—	—	—
Black-capped chickadee (*Parus atricapillus*)	** .561	** .638	** .615	** .368	** .240	.213	.184
Brown thrasher (*Toxostoma rufrum*)	—	—	—	—	—	—	—
House sparrow (*Passer domesticus*)	—	—	—	—	—	—	—

Bird species	Coniferous tree volume 51-55	56-60	61-65	66-70	71-100	Deciduous shrub volume Total	0-5
Robin (*Turdus migratorius*)	—	—	—	—	—	.189	.170
Gray catbird (*Dumetella carolinensis*)	—	—	—	—	—	—	—
Blue jay (*Cyanocitta cristata*)	—	—	—	—	—	—	—
Northern oriole (*Icterus galbula*)	.197	—	—	—	—	** .438	** .526
Song sparrow (*Melospiza melodia*)	—	—	—	—	—	—	—
Chipping sparrow (*Spizella passerina*)	—	—	—	—	—	—	—
House wren (*Troglodytes aedon*)	—	—	—	—	—	** .423	* .242
Black-capped chickadee (*Parus atricapillus*)	—	—	—	—	—	** .333	** .307
Brown thrasher (*Toxostoma rufrum*)	—	—	—	—	—	—	—
House sparrow (*Passer domesticus*)	—	.200	.188	.190	—	—	—

Bird species	Deciduous shrub volume 6-10	11-15	16-20	Coniferous shrub volume Total	0-5	6-10	11-15
Robin (*Turdus migratorius*)	* .246	—	—	—	.173	—	—
Gray catbird (*Dumetella carolinensis*)	.182	—	—	—	—	—	—
Blue jay (*Cyanocitta cristata*)	—	—	—	—	—	—	—
Northern oriole (*Icterus galbula*)	** .281	—	—	—	—	—	—
Song sparrow (*Melospiza melodia*)	.199	—	—	—	—	—	—
Chipping sparrow (*Spizella passerina*)	—	—	—	** .414	** .306	** .387	** .623
House wren (*Troglodytes aedon*)	* .233	** .522	** .872	—	—	—	—
Black-capped chickadee (*Parus atricapillus*)	** .317	—	—	—	—	—	—
Brown thrasher (*Toxostoma rufrum*)	—	—	* .220	—	—	—	—
House sparrow (*Passer domesticus*)	—	—	—	—	—	—	—

CONTINUED

Table 12.—Continued.

Bird species	Coniferous shrub volume	Habitat variables—			
	16-20	Mowed lawn	Herbaceous vegetation	Volume of structures	Building density
Robin *(Turdus migratorius)*	—	—	-.283*	.252*	-.237*
Gray catbird *(Dumetella carolinensis)*	—	—	—	—	—
Blue jay *(Cyanocitta cristata)*	—	.169	—	—	—
Northern oriole *(Icterus galbula)*	—	-.219*	—	-.198	.305**
Song sparrow *(Melospiza melodia)*	—	—	.169	-.191	—
Chipping sparrow *(Spizella passerina)*	—	—	—	—	—
House wren *(Troglodytes aedon)*	—	—	—	—	.215*
Black-capped chickadee *(Parus atricapillus)*	—	-.319**	—	—	—
Brown thrasher *(Toxostoma rufrum)*	—	—	—	—	—
House sparrow *(Passer domesticus)*	—	—	-.331**	.432**	-.331**

Bird species	Habitat variables—						
	Traffic flow	Dogs	Cats	Children	Adults	Bird feeders	Bird houses
Robin *(Turdus migratorius)*	—	—	—	—	—	.282*	—
Gray catbird *(Dumetella carolinensis)*	—	-.203	—	—	—	—	—
Blue jay *(Cyanocitta cristata)*	—	—	—	—	—	—	—
Northern oriole *(Icterus galbula)*	—	-.199	—	-.184	—	—	—
Song sparrow *(Melospiza melodia)*	—	—	—	—	—	—	.222*
Chipping sparrow *(Spizella passerina)*	—	.399**	.467**	—	—	.269*	—
House wren *(Troglodytes aedon)*	—	—	—	—	—	.396**	—
Black-capped chickadee *(Parus atricapillus)*	—	-.192	—	-.171	—	—	—
Brown thrasher *(Toxostoma rufrum)*	—	—	—	—	—	—	—
House sparrow *(Passer domesticus)*	—	—	.440**	—	.267**	—	—

Bird species	Habitat variables—					
	Cultivated fields	Fallow fields	Open water	Wood lots	Number of gardens	Garden area
Robin *(Turdus migratorius)*	—	-.205	—	.170	.421**	—
Gray catbird *(Dumetella carolinensis)*	—	—	.277*	—	.218	—
Blue jay *(Cyanocitta cristata)*	—	-.170	—	—	-.170	—
Northern oriole *(Icterus galbula)*	—	—	—	-.297*	—	.175
Song sparrow *(Melospiza melodia)*	-.180	—	—	—	—	—
Chipping sparrow *(Spizella passerina)*	—	—	—	—	—	—
House wren *(Troglodytes aedon)*	—	—	—	.252*	—	—
Black-capped chickadee *(Parus atricapillus)*	—	—	—	—	—	—
Brown thrasher *(Toxostoma rufrum)*	—	—	—	—	—	—
House sparrow *(Passer domesticus)*	—	.178	—	.196	—	—

typically only three layers were recognized: herbaceous, shrub, and tree.

We dealt with 5-foot layers of woody vegetation, divided into trees and shrubs, and subdivided into coniferous and deciduous. We did this to better relate bird populations to measurable habitat characteristics. This builds on the ideas of R.H. MacArthur, but describes the habitat requirements of birds in more detail. We made preliminary examination of the effects of vegetation layers with deciduous and coniferous trees and shrubs combined. This resulted in significant declines in total R^2 values.

The 5-foot layers are arbitrary. It should be possible to vary the width or deal with various nonstandard widths by species to derive the best fits. However, this would involve numerous computer runs. A 5-foot layer was selected as the minimum meaningful layer for management, but the inverse was tested. Multiple-regression analyses of 10-foot layers were made, which resulted in a sharp decrease in R^2 values for all 10 bird species.

More layers of less depth add progressively more independent variables. Because of the requirement for plot numbers to equal or exceed the number of independent variables, we did not feel we could deal with layers of less than 5 feet.

Different bird species are significantly correlated with different coniferous and deciduous vegetation layers (table 12). There was little difference in the pattern of correlations for deciduous shrubs and trees combined, or for coniferous trees and shrubs combined. No species except the song sparrow differentiated between tree and shrub forms. Song sparrows were significantly and negatively correlated with coniferous shrubs and with deciduous overstory layers up to 45 feet, and with no other vegetation variables.

Bird Species Compatibility

The densities of several of the bird species studied were significantly correlated with each other:

Species correlated	*r* [a]
Robin—gray catbird	0.340**
Robin—black-capped chickadee	.380**
Gray catbird—northern oriole	.457**
Gray catbird—house sparrow	.267*
Northern oriole—black-capped chickadee	.395**

[a] *p<.05;**p>.01.

All significant correlations were positive, which perhaps indicates that these bird species had similar habitat associations. The converse would be true with negative correlations. In making management decisions, it could be assumed that significant routine correlations mean that management for one species would have a similar effect on another. In fact, examination of the habitat associations of positively correlated species reveals a similarity of associations.

Comments on Study Design

Our design specified 10 species in the belief that observers could not accurately census more without confusion. We found this to be incorrect; in future similar studies we intend to include all species encountered. This should increase the efficiency of studies, because information on more species is gathered from the same amount of field work.

Unless an inventory of vegetation by species is needed for other purposes, we suggest recording vegetation data only as deciduous or coniferous. Time would be saved, and botanically expert field personnel would not be needed.

Our census plots were of variable size, while 0.5-acre plots were used for sampling vegetation. Such an arrangement adds a source of variability that can be avoided by having a standard plot size for the measurement of all variables. Unless the vegetation plot is representative of the surrounding habitat, birds could be counted in a different habitat than that on the 1/2-acre circular vegetation plot. Thus, a standard plot for all field measurements is recommended.

Our bird-population estimates are, actually, measures of bird use of plots or are indices to bird numbers. The correlations with habitat features were no less valid—but care should be taken when utilizing such data for other purposes, such as measuring bird-population trends.

Many of the independent variables proved of little value in describing habitat. The variables (which were expensive to measure) concerning human populations, dogs and cats, and auto and pedestrian traffic, accounted for little in the results. Careful consideration of these variables led to a reduced list for use in continuing studies.

This study was a pilot for the development and testing of a habitat-evaluation technique for birds in urban-suburban situations. The approach is flexible and could be altered to fit different circumstances, because independent and dependent variables, sampling schemes, plot sizes and shapes, and statistical levels of significance can be manipulated.

The study area was chosen to provide the complexity present in man-dominated environments. We visualize suburban areas, ecologically, as essentially extended variable "edge". While ecologists have long recognized "edge effect" *(Dice 1931, Leopold 1933:131)*, those who have made habitat analyses have generally avoided studying such complex habitats. We believe our technique and its results show that meaningful results can be obtained in such circumstances, and this approach should be even more effective in less complex situations.

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