5-1978

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Recommended Citation

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A DISCRIMINANT FUNCTION MODEL OF GRAY-HEADED JUNCO HABITAT

by

Andrew R. Grainger

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Wildlife Ecology

Approved:

Utah State University
Logan, Utah

1978

ACKNOWLEDGEMENTS

It is a pleasure to acknowledge the generous support of the Wildlife Management Institute and the American Petroleum Institute for this study. Utah State University provided a Graduate Summer Fellowship. The U. S. Forest Service SEAM-ECOSYM Project at Utah State supported the early phases of the study.

Dr. John Kadlec served as major professor for my masters work; his advice, understanding and policy of allowing graduate students to do their own work and make their own mistakes is sincerely appreciated. Dr. Mike Wolfe was instrumental in formulating the concept of wildlife habitat models which guided this study. Dr. Neil West has given me considerable insight into the conduct of science.

Drs. Gary White, Larry Ryel and David Anderson all provided help in the design and statistical analysis of the study. In addition, Jeff Laake worked many hours helping me figure out how to work computer programs, and I needed all the help I could get.

Many fellow graduate students assisted in this study in different ways. Glenn Gephart helped me find junco nests, rather monotonous work. Bill Clark provided lots of advice throughout the study; his insight in this study and in science in general have been a tremendous help to me.

Lastly, I want to thank my parents, who have given me much support and encouragement through what seems like a lot of schooling. Maybe now I can find a job!

Andrew R. Grainger

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ABSTRACT

A Discriminant Function Model of Gray-headed Junco Habitat

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This paper presents a description of gray-headed junco habitat in the form of a model based on discriminant function analysis. Junco nests were found by searching randomly located grids on a 7.8 km^2 study area in central Utah. Vegetation data was gathered on 500 m^2 circular plots surrounding nests and contrasted with similar data from searched grids where nests were not found. The model explains 28 percent of the between-groups variance and correctly classifies 68 percent of the plots.

Plant cover types are good predictors of areas where gray-headed juncos nest, while plant community type descriptions do not distinguish between utilized and unutilized areas.

The use of quantitative models of wildlife habitat with data derived from various kinds of information systems is discussed.

(52 pages)

INTRODUCTION

Since the origin of the biome concept and the early research of Lack (1933), much work has been done to describe the distribution of birds in relation to habitat variables. Pitelka (1941), in reviewing the subject, stated "Birds apparently do not respond to any specific differences among the dominant plants of a climax or any of its seral stages. Rather there are birds of deciduous forest, coniferous forest, grassland, etc. More importantly, then, life form as a differentiating feature of climax, seems to be a controlling factor of distribution."

To date, most of the research effort has been directed at explaining the mechanisms of habitat selection and patterns of species diversity and resource partitioning. Hilden (1965) stated that "birds are guided to their breeding stations by a primarily innate reaction released by certain stimuli, as in instinctive activities in general." Selection of a breeding territory is released by certain proximate characteristics of the territory, but the selection mechanisms are adaptations for selecting the area which will supply the most favorable array of resources for survival and reproduction (Lack 1954). Therefore, the features of the environment that are correlated with the presence of a given species may not be the features for which the bird is ultimately (evolutionarily) selecting (Orians 1971, Immelmann 1973). Researchers who find the presence of a particular species highly correlated with certain environmental variables can only speculate that those features are the ones for which the birds are selecting. Therefore, it is necessary to distinguish between studies of habitat selection in birds and work that attempts to correlate the presence or abundance of birds with particular environmental factors (Klopfer 1969). James (1971) has coined the term "niche-gestalt" to describe the environmental configuration within which a given species occurs, and points out that this configuration is not necessarily meaningful to the bird. For bird habitat management purposes all that is necessary are environmental features dependably correlated with the presence of acceptable habitat for the species.

Patterns of bird species diversity and the partitioning of resources among competing species have been studied in grasslands (Cody 1968, Weins 1969, 1974), temperate forests (Bond 1957, MacArthur and MacArthur 1961, MacArthur et al. 1962, Smith 1977), tropical forests (Orians 1969), deserts (Tomoff 1974, Whitmore 1975), and Mediterranean habitats (Cody 1974). MacArthur and MacArthur (1961) demonstrated that the number of species in eastern forests could be predicted by the foliage height diversity (FHD) of the habitat and that plant species diversity did not add significantly to this predictive ability. Cody (1975) has shown, using a somewhat different measure of FHD, that similar vegetation communities on different continents support similar numbers of bird species. In addition, by plotting the number of species gained and lost against the habitat gradient H (= vegetation height + vegetation half-height), he has shown that different species are associated with particular stages of the habitat gradient. Johnston and Odum (1956) stated that most species occur in specific seral stages, while some occur in many different successional stages. MacArthur (1964) and Tomoff (1974) presented data indicating that, at least in some situations, knowledge of the species composition of the plant community could be important in predicting which bird species are present. Data presented by Galli et al. (1976) indicate that size of habitat patches is important in predicting which bird species occupy deciduous forest islands in New Jersey. Balda (1975) provided a review of vegetation structure and bird species diversity and Schoener (1974) of the partitioning of resources.

Although these studies suggest that bird species select their habitat on the basis of vegetation structure, little work has been done to determine which habitat variables are correlated with the presence of particular bird species. Breckenridge (1956) found that the degree of openness just beneath the forest canopy was highly correlated with the presence of least flycatchers (*Empidonax minimus*), and termed the degree of openness a limiting factor to forest use by that species. Hagar (1960) investigated the response of bird populations to structural changes in habitat brought about by logging, and found that local populations of seed-eating birds increase as a result of clearcutting. Dow (1968) found that cardinal (*Cardinalis cardinalis*) home ranges contained similar proportions of woody cover in central and perhiperal parts of their range.

The concept of the ecological niche as an n-dimensional space (Hutchinson 1958) has led to the use of multivariate statistics to describe animal habitats (Dueser et al. 1976). Sturman (1968), using multiple regression, found that over 90 percent of the variation in abundance of chestnut-backed chickadees (*Parus rufescens*) could be explained by the average height and upper story canopy volume of conifers. Similarly, three variables accounted for over 90 percent of the variation in abundance of black-capped chickadees (*P. atricapillus*). Discriminant function analysis (Anderson and Shugart 1974) and principle component analysis (James 1971) have also been used to determine which features of vegetation structure explained the greatest amount of variance in abundance. Klebenow (1969) and Kaminski and Prince (1977) used discriminant function analysis to describe nesting habitat for sage grouse (*Centrocercus urophasianus*) and Canada geese (*Branta canadensis*) respectively. Hudson (1976) applied the same method to the study of habitat separation in a community of large herbivores in British Columbia.

Objectives

The objective of this study was to formulate a quantitative model of the nesting habitat of the gray-headed junco (*Junco caniceps caniceps*). The following hypotheses were tested:

H_1: gray-headed junco nests are located randomly with respect to the vegetation and topographic features of the landscape.

H_2: gray-headed junco nests are located randomly with respect to an independently determined classification of current vegetation.

Gray-headed Juncos

The northern subspecies of the gray-headed junco (*Junco caniceps caniceps*) is a common breeding bird of the mountaintop areas of the intermountain region. It breeds in forests above 2100 m from southern Idaho and Wyoming south through Nevada, Utah, and central Colorado to northern Arizona and New Mexico (A.O.U. 1957). Although it is known to interbreed with *J. hyemalis mearnsi* and probably with *J. h. thurberi* (Miller 1941), *J. caniceps* was retained as a separate species by the A.O.U. Checklist Committee (A.O.U. 1973).

Gray-headed juncos breed in forested areas dominated by almost any tree species, including pines (*Pinus contorta, P. ponderosa* and *P. flexilus*), firs (*Abies* spp.), spruces (*Picea* spp.), and aspen (*Populus tremuloides*) (Miller 1941, Thatcher 1968). Winternitz (1973) recorded 478 observations of juncos over four spring and summer seasons of field work in Colorado. Of the total number of sightings, 133 occurred in a subjectively defined apsen type, 115 in pine, 62 in mixed aspen and fir, 102 in fir, 53 in spruce and 13 in open areas. Haldeman (1975) found gray-headed junco territories in Nevada and New Mexico to be significantly different based on canonical variable analysis. Thatcher (1968) stated that gray-headed juncos can be found in forested mountain areas that are "well but not densely stocked, have numerous openings to provide edges, and are not too arid." Juncos are altitudinal and latitudinal migrants, wintering at lower elevations in the breeding area and south to northern Mexico (A.O.U. 1957).

Study Area

Field work was conducted from 26 May through 16 August 1977 on T 14 S, R 6 E, Salt Lake principle meridian, Sections 21, 22 and 23 of the Manti-LaSal National Forest on the Wasatch Plateau of central Utah. The area is mapped on U.S. Geological Survey Huntington Reservoir and Scofield Southwest quadrangles. Elevation ranges from 2560 to 2980 m on these three sections. Mean annual temperature is approximately -0.5°C, with July temperatures averaging 5°C (Zsiray and Wooldridge 1977).

The plant cover is a mosaic of forest, shrubland and herbland. Dominant tree species are aspen, occurring on slopes and ridges, with spruce (*Picea engelmanni*) and subalpine fir (*Abies lasiocarpa*) occurring primarily in drainages and on north-facing slopes. Sagebrush (*Artemisia tridentata*) and rabbitbrush (*Chrysothamnos* spp.) cover treeless meadows. Bromes (*Bromus* spp.) and bluegrasses (*Poa* spp.) are the dominant grasses. Wet meadows and seeps support elderberry (*Sambucus racemosa*) and false hellebore (*Veratrum californicum*). Plant species encountered during the course of the study are listed in Appendix A.

METHODS

Field Methods

Fifty-five randomly selected 100 x 200 m grids were searched during the period 18 June through 7 July 1977 to locate junco nests. Nests were chosen as the study unit in the belief that the location of an active nest is a more accurate reflection of the presence of suitable habitat than is the location of singing perches or mapped territories, as are often used in studies of bird habitat utilization. A numbered grid was overlaid on aerial photographs and line intersections were chosen from a table of random numbers. The chosen intersections were then pin-pricked on the photograph and the pin-pricked locations established on the ground as the northeast corner of the 100 x 200 m grid. Selection of grids to search was randomized to insure sampling of all habitats occurring on the study area. A total of 14 percent of the study area was searched.

Grids were searched by two observers walking on parallel compass lines 7 - 10 m apart until the entire plot was covered. Nests were located by seeing adults flush from the ground or by noting the scolding behavior of the adults when the observers came close to the nest. When nests were located the area was marked with plastic flagging. On grids where no nests were found the corner of the grid where the search began was designated as the center of a "non-nest" plot.

Vegetation and physical location data was gathered during the period 8 July through 16 August 1977. 500 m^2 circular plots were established using nests for the center of nest plots and the northeast corner of searched grids where no nests were found as the center of non-nest plots. Table 1 lists the variables measured and the method used. Tree, shrub, grass and herb coverage was estimated for each species over the entire 500 m^2 circle rather than by a series of small quadrats (Daubenmire 1959, Steele et al. 1975). Tree canopy volumes were calculated by considering each tree crown as a cone, hemisphere or cylinder. Canopy top height, canopy bottom height and outside diameter of the tree canopy were measured for each tree on each plot. Computations used were πr^2h for cylinder volume, $\pi/3\ r^2h$ for cone volume and $2\pi/3\ r^2h$ for hemisphere volume, where r is canopy radius and h is canopy top height minus canopy bottom height. Percent cover of downed woody material was occularly estimated and the method of Brown (1974) was used to estimate tons per ha. Tree heights and slope percentages were measured with a clinometer. Plot aspect was obtained with a compass and plot elevation taken from U. S. Geological Survey maps.

Community and cover types are classifications of current vegetation communities. Cover types are named on the basis of the dominant overstory species, while community types also consider the understory plants. One cover type may include several community types. Both types were described and mapped for the study area by Kerr and Henderson (1977). Field data were analyzed by the use of manual and computerized association tables, and by cluster analysis routines. Each method uses floristic differences to determine separation of plots into groups representing similar vegetation types.

Table 1. Mnemonics, variables, units of measurement and measurement methods.

Mnemonic	Variable	Unit of measurement	Method
COV1	canopy cover of aspen	%	occular estimate
COV2	canopy cover of fir	%	occular estimate
COV3	canopy cover of spruce	%	occular estimate
COVTR	total tree canopy cover	%	sum of COV1, COV2, COV3
COVS	total shrub cover	%	occular estimate
COVG	total grass cover	%	occular estimate
COVF	total forb cover	%	occular estimate
COVGF	total cover of grasses and forbs	%	Sum of COVG, COVF
COVALL	total vegetation cover	%	sum of COVTR, COVS, COVGF
BG	cover of bare ground	%	occular estimate
SHT	shrub height	cm	mean of five measurements
GFHT	height of grasses and forbs	cm	mean of five measurements
DBH1	diameter breast height of aspen	cm	diameter tape
DBH2	diameter breast height of fir	cm	diameter tape
DBH3	diameter breast height of spruce	cm	diameter tape
BA1	basal area of aspen	m^2	calculated from dbh

Table 1 Continued

Mnemonic	Variable	Unit of measurement	Method
BA2	basal area of fir	m^2	calculated from dbh
BA3	basal area of spruce	m^2	calculated from dbh
BALL	total basal area	m^2	sum of BA1, BA2, BA3
VOL1	canopy volume of aspen	m^3	geometric approximation
VOL2	canopy volume of fir	m^3	geometric approximation
VOL3	canopy volume of spruce	m^3	geometric approximation
VALL	total canopy volume	m^3	sum of VOL1, VOL2, VOL3
DWM1	downed woody material	%	occular estimate
DWM2	downed woody material	tons/ha	Brown (1974)
PSD	plant species diversity	$-\Sigma p_i \log p_i$	calculated from cover percentages
SLOP	slope	%	clinometer
ASPT	aspect	degrees	compass
ELEV	elevation	m	topographic map

Statistical Methods

All variables were tested for normality in order to meet the normality assumption for univariate comparisons and for discriminant function analysis. Although no practical method is available for testing the hypothesis of multivariate normality, certain necessary conditions for multivariate normality can be checked (Bock 1975). One of these is univariate normality. Normality was assessed using the chi-square goodness of fit test and the third moment (skewness) and the fourth moment (kurtosis) about the mean. Natural logarithm and square root transformations were used on variables found to be non-normally distributed, and the resulting transformed sample distributions were again tested for normality. Chi-square intervals were chosen so that the expected frequencies for each class was set equal to 10 (Mann and Walt 1942).

Univariate comparisons for each measured habitat variable were made to assess differences between group (i.e., nest, non-nest) means. The t-statistic was calculated for nest and non-nest plots for each variable. Homogeniety of variance was evaluated by an F-test for the two groups for each variable. The t-statistic was calculated using pooled variance estimates for variables with equal group variance, and separate variance with unequal group variance (Ostle and Mensing 1975).

The chi-square test was used to determine if the distribution of junco nests within the study area was random with respect to community and cover types.

Variables that had t-values significant at $p \leq 0.10$ in univariate comparisons and that were correlated with other such variables at <0.75 were used in a discriminant function analysis. This collection of a relatively small number of variables represents non-redundant variables with the power to discriminate among nest and non-nest plots (Deuser et al. 1976).

Discriminant function analysis computes an equation defining a linear axis which maximizes differences among the populations (James 1971). The set of discriminant function coefficients resulting from the procedure may be interpreted as the relative contribution to the discriminant function of the corresponding variables (Green 1971, Cooley and Lohnes 1971). In this case the average value of the function for a group of plots (i.e., nest or non-nest) may be expressed as $D = \Sigma w_i \bar{x}_i$ where w_i is the set of discriminant function coefficients for the habitat variables and $\bar{x}_i$ is the mean of that variable for the group (James 1971). For an individual plot

$$D = w_1(\mathrm{COV1}) \pm w_2(\mathrm{COV2}) \pm w_3(\mathrm{COV3}) \;\ldots.\; \pm w_i(\mathrm{ELEV})$$

Therefore, the discriminant function may be interpreted as a model of junco habitat, and values for other plots can be placed on the discriminant axis to evaluate their desirability as junco nesting habitat.

Statistical assumptions for discriminant function analysis are (Green 1971, Dueser et al. 1976):

1. The groups can be defined _a priori_, and each case can be assigned to the appropriate group without reference to the sample site or the variables measured.

2. Sampling is from a multivariate normal distribution.

3. The variance-covariance matrices for the groups are independent estimates of a common dispersion matrix.

4. The discriminant function is a linear function of the original variables.

Little is known about the consequences of violation of the statistical assumptions associated with discriminant function analysis. Therefore in this study an effort was made to meet those assumptions as closely as possible.

Discriminant function analysis and t-tests were performed with the DISCRIMINANT and T-TEST subprograms from the Statistical Package for the Social Sciences (Nie et al. 1975) on the Burroughs B6700 at Utah State University. The normality testing and transformation program was written by J. Laake, Utah Cooperative Wildlife Research Unit, using the chi-square routine from the International Mathematical and Statistical Libraries package (IMSL 1976). Chi-square tests for nests and plot distributions compared to community and cover types were done with a hand calculator.

RESULTS

Twenty-four junco nests were found during the course of nest searches. One nest was found on a grid in 17 cases, and in two cases two nests were found on a single grid. Three nests were found while moving from one grid to another. Therefore 24 nest plots and 36 non-nest plots were established. Four nests contained four or five eggs when first found while the remainder contained from three to five young. The nesting cycle was apparently very synchronous in the study area, because progressively older young were found during the period of time when nest searches were conducted.

Tables 2 and 3 show results of chi-square tests to determine if plots were distributed randomly with respect to the relative amounts of community and cover types (Kerr and Henderson 1977). Although the grids were placed randomly over the whole study area, they may not have fallen randomly with respect to the types. In addition, if the 60 plots are random with respect to the types and the 24 nest plots are not the argument that nests are non-randomly distributed can be made with confidence.

The alpha value of 0.043 for plots with community types indicates the null hypothesis should be rejected at the p = 0.05 level. However, the low expected value for the spruce-fir/*Berberis* type may result in an artificially large contribution to chi-square (Ostle and Mensing 1975). Therefore, the result may not be inconsistent with a random distribution of plots with respect to community types. The hypothesis that plots are distributed randomly with respect to cover types cannot be

Table 2. Chi-square test comparing total plot distribution with community type distribution.[1]

Type	Observed n of plots	Expected n of plots	Contribution to X^2
Spruce-fir/*Ribes*	10	10.08	.0006
Spruce-fir/*Berberis*	2	0.48	4.8132
Fir-aspen/*Ribes*	10	9.42	.0357
Fir-aspen/*Bromus*	3	1.08	3.4133
Aspen-*Bromus*	28	21.12	2.2412
Salix-Carex	0	1.08	1.0800
Sagebrush-rabbitbrush/ *Purshia*	0	1.32	1.3200
Sabebrush-rabbitbrush/ *Stipa*	6	13.02	3.7850
Sagebrush-rabbitbrush/ *Poa*	0	0.24	.2400
Carex	0	1.56	1.5600
Veratrum/Thalictrum	1	0.60	.2667
TOTAL	60	60.00	19.7558
			α = .043

---

[1] Expected values based on the proportions of the types occurring on the study area.

Table 3. Chi-square test comparing total plot distribution with cover type distribution[1].

Type	Observed n of plots	Expected n of plots	Contribution to X^2
Spruce-fir	12	10.56	.1964
Fir-aspen	13	10.50	.5952
Aspen-*Bromus*	28	21.12	2.2412
Salix-Carex	0	1.08	1.0800
Sagebrush-rabbitbrush	6	14.58	5.0491
Carex	0	1.56	1.5600
Veratrum/Thalictrum	1	0.60	.2667
Total	60	60.00	10.9886
			α = .09

---

[1] Expected values based on the proportions of the types occurring on the study area.

rejected (Table 3).

Tables 4 and 5 show results of chi-square tests to determine if junco nests were distributed randomly with respect to community and cover types, respectively. The alpha value of 0.052 for nests with respect to community types indicates the hypothesis of random distribution should be accepted. However, the alpha value of 0.006 for nests with respect to cover types allows a clear rejection of the hypothesis of random distribution. The birds show a preference for fir-aspen and aspen-brome types, while avoiding spruce-fir dominanted areas and areas with no tree cover. This result constitutes rejection of H_2.

Grand and group (i.e., nest, non-nest) means and standard deviations for the 29 habitat variables are shown in Table 6. The standard deviation exceeds the mean for eleven variables.

Skewness, kurtosis and chi-square tests showed that the hypothesis of normality could not be rejected at the 0.01 level on the basis of all three criteria for 10 variables (Appendix B). The remaining 19 variables were subjected to natural logarithm and square root transformations. Seven variables were transformed so that the hypothesis of normality could not be rejected at the 0.01 level (Appendix C). Therefore, subsequent analysis considered only the 17 normal or transformed variables.

Table 7 presents the results of t-tests to determine which variables show differences in means between nest and non-nest plots. Nine variables show such differences at the p = 0.10 level: COV1, COVF, COVALL, BG, SLOP, ELEV, GFHT, COVGF, and DWM2. These results suggest rejection of H_1 for some vegetation and landscape features. The total

Table 4. Chi-square test comparing nest distribution with community type distribution.[1]

Type	Observed n of nests	Expected n of nests	Contribution to X^2
Spruce-fir/*Ribes*	1	4.03	2.2781
Spruce-fir/*Berberis*	0	0.19	.1900
Fir-aspen/*Ribes*	7	3.77	2.7673
Fir-aspen/*Bromus*	1	0.43	.7556
Aspen-*Bromus*	15	8.45	5.0772
Salix-Carex	0	0.43	.4300
Sagebrush-rabbitbrush *Purshia*	0	0.53	.5300
Sagebrush-rabbitbrush/ *Stipa*	0	5.21	5.2100
Sagebrush-rabbitbrush/ *Poa*	0	0.10	.1000
Carex	0	0.62	.6200
Veratrum/Thalictrum	0	0.24	.2400
Total	24	24.00	18.1982
			α = .052

---

[1] Expected values based on the proportions of the types occurring on the study area.

Table 5. Chi-square test comparing nest distribution with cover type distribution.[1]

Type	Observed n of nests	Expected n of nests	Contribution to X^2
Spruce-fir	1	4.22	2.4570
Fir-aspen	8	4.20	3.4381
Aspen-*Bromus*	15	8.45	5.0772
Salix-Carex	0	0.43	.4300
Sagebrush-rabbitbrush	0	5.84	5.8400
Carex	0	0.62	.6200
Veratrum/Thalictrum	0	0.24	.2400
Total	24	24.00	18.1023
			$\alpha = .006$

---

[1] Expected values based on the proportions of the types occurring on the study area.

Table 6. Grand and group means and standard deviations.

Mnemonic	Grand mean[a]	Standard deviation	Nest mean[b]	Standard deviation	Non-nest mean[c]	Standard deviation
COV1	26.57	21.01	29.58	17.83	24.55	22.90
COV2	44.65	9.12	3.58	3.76	5.36	11.39
COV3	1.92	7.40	1.50	3.41	2.19	9.20
COVTR	32.88	23.97	34.67	16.02	31.70	28.22
COVS	8.87	14.48	5.33	6.31	11.22	12.70
COVG	37.58	16.41	40.37	12.27	35.72	18.60
COVF	39.48	19.88	45.00	18.69	35.81	20.05
COVGF	77.12	24.77	85.50	19.80	71.53	26.38
COVALL	119.12	21.82	125.50	18.57	114.86	23.02
BG	7.03	8.27	4.60	4.95	8.64	9.61
SHT	0.66	0.40	0.63	0.36	0.69	0.44
GFHT	0.72	0.22	0.79	0.21	0.68	0.22
DBH1	8.87	4.77	10.02	3.58	8.09	5.33
DBH2	4.88	6.71	7.55	7.87	3.11	5.20
DBH3	0.91	2.85	1.32	3.06	0.65	2.71
BA1	9.73	7.51	10.64	6.83	9.12	7.97

Table 6. Continued.

Mnemonic	Grand mean[a]	Standard deviation	Nest mean[b]	Standard deviation	Non-nest mean[c]	Standard deviation
BA2	1.64	3.08	1.72	2.49	1.59	3.46
BA3	0.92	4.48	0.24	0.64	1.37	5.75
BALL	12.29	8.95	12.60	6.34	12.09	10.43
VOL1	497.36	337.43	590.26	293.28	435.42	354.33
VOL2	57.20	104.21	59.00	86.48	56.02	115.71
VOL3	43.39	209.43	13.58	39.94	63.34	268.08
VALL	597.98	369.68	662.66	270.35	554.86	421.39
DWM1	3.05	4.30	2.37	2.38	3.50	5.19
DWM2	27.04	34.11	29.13	33.64	25.64	34.83
PSD	.88	.16	.93	0.13	0.85	0.17
ASPT	153.48	86.97	132.20	80.36	167.67	89.37
SLOP	15.93	9.00	18.96	8.65	13.91	8.78
ELEV	2791.56	77.03	2761.31	81.85	2811.74	67.47

[a] n = 60 [b] n = 24 [c] n = 36

Table 7. Results of t-tests for equality of group means, normal or normalized variables.

Mnemonic	F-value for equal variance	Two-tailed probability	t-value[a]	Two-tailed probability
COV1	2.72	0.014	2.06	0.043
COVTR	3.10	0.006	0.52	0.606
COVS	1.96	0.094	-0.89	0.377
COVG	2.30	0.040	1.17	0.248
COVF	1.15	0.735	1.79	0.079
COVGF	1.78	0.151	2.21	0.031
COVALL	1.54	0.282	1.89	0.064
BG	1.17	0.655	-2.16	0.035
SLOP	1.03	0.956	2.19	0.032
ELEV	1.47	0.295	-2.60	0.012
SHT	1.46	0.345	-0.49	0.625
GFHT	1.57	0.260	1.89	0.064
BA1	1.36	0.441	0.77	0.447
BALL	3.80	0.001	1.30	0.199
VALL	2.43	0.029	1.21	0.232
DWM1	1.33	0.475	-1.00	0.321
DWM2	2.72	0.014	1.82	0.074

[a] Pooled variance estimate if F-value probability is >0.05; separate variance estimate if F-value probability is <0.05.

correlation matrix for these nine variables is shown in Appendix D. Since these variables meet the criteria of t-test probabilities of <0.10 and have no bivariate correlations >0.75, they were used in the discriminant function analysis.

Table 8 summarizes the results of the stepwise discriminant function analysis and presents the standardized discriminant function coefficients. Variables that gave F-values of >1.0 when combined with other variables already in the equstion were allowed to enter the equation. The choice of this entry criterion is arbitrary. The remaining three variables (COVALL, BG, COVGF) gave F-value of 0.10 or less and would not contribute to the discrimination. Rao's V is a measure of distance between group centroids. The associated significance indicates the contribution of the variable to the discrimination.

The discriminant function equation derived from this analysis is

$$\bar{D} = 0.577(\mathrm{ELEV}) - 0.403(\mathrm{GFHT}) - 0.491(\mathrm{SLOP}) - 0.642(\mathrm{DWM2}) - 0.344(\mathrm{COVF}) + 0.452(\mathrm{COV1})$$

The canonical correlation for the discriminant function is 0.53. The square of the canonical correlation, 0.28, may be interpreted as the percentage of the variance explained by the groups. The value of the F-ratio based on Box's M, for testing equality of within-group variance-covariance matrices (Cooley and Lohnes 1971), is 1.20 with 45 and 3287 degrees of freedom. Thefore the assumption of equal within-group variance-covariance matrices cannot be rejected, allowing testing of the significance of the discriminant function (Green 1971). The chi-square statistic for testing significance is 17.807 with 6 degrees of freedom, significant at the p = 0.007 level.

The classification function coefficients, derived from the pooled within-group covariance matrix and the centroids for the discriminating variables (Nie et al. 1975) are presented in Table 8. These scores are multiplied by the raw variable values, summed, and added to a constant. Each case is assigned to the group with the highest score. Figure 1 shows a plot of each case along the discriminant axis. The discriminant function correctly classifies 68 percent of the plots into nest or non-nest groups.

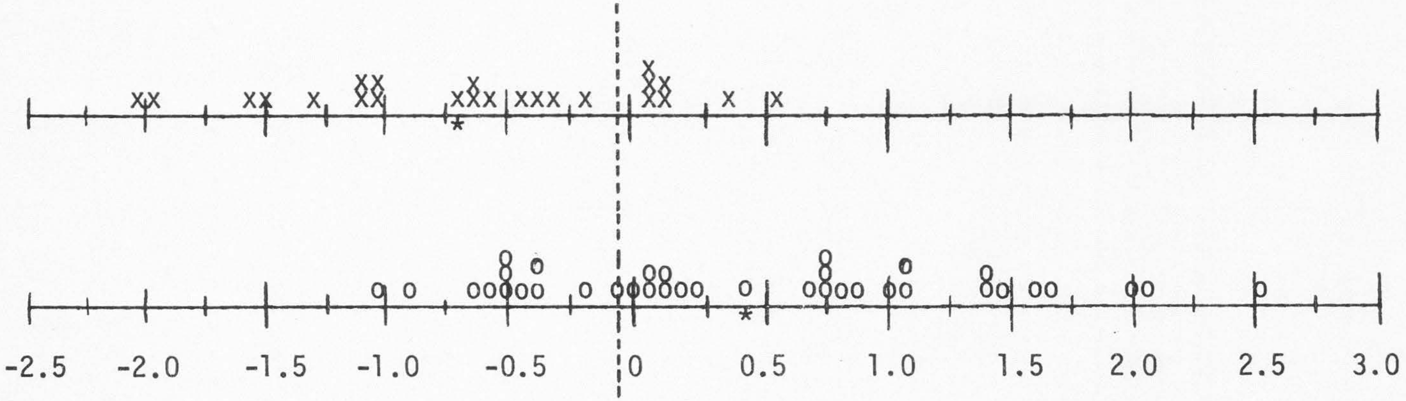
Table 8. Summary of stepwise discriminant function analysis, standardized coefficients and classification coefficients.

Step number	Variable entered	F-value to enter	Rao's V	Change in Rao's V	Significance	Standardized coefficients	Classification coefficient	
							Nest plot	Non-nest plot
1	ELEV	6.777	6.777	6.777	0.009	0.577	0.559	0.570
2	GFHT	4.668	12.082	5.305	0.021	-0.403	-10.484	-14.675
3	SLOP	2.373	15.052	2.970	0.085	-0.491	0.391	0.312
4	DWM2	2.133	17.884	2.833	0.092	-0.642	1.209	0.660
5	COVF	1.387	19.834	1.949	0.163	-0.344	-0.279	-0.304
6	COV1	1.594	22.175	2.341	0.126	0.452	7.691	8.174
							-778.902*	-803.260*

*constant.

Figure 1. Results of classification procedure.

Actual Group	n	Classified Group Nest	 Non-nest
nest	24	17 (71%)	7 (29%)
Non-nest	36	12 (33%)	24 (67%)



x = nest plot

o = non-nest plot

* = group centroid

DISCUSSION

Community and Cover Types

Plant community types used in this study do not appear to be a reliable variable for separating utilized from unutilized habitats. They may represent a division too fine to be of importance to the birds. The separation of the more inclusive cover type classification into community types is based primarily on taxonomic rather than physiognomic criteria. The fir-aspen, spruce-fir and aspen-*Bromus* cover type are structurally quite distinct, while the fir-aspen/*Ribes* and fir-aspen/*Bromus* community types are quite similar, especially in light of the relatively low cover percentages for shrubs on the study area (Table 6).

Cover types provide a reliable method for separating nesting areas from areas the juncos do not use for nesting. They provide a good indication of the gross structure of habitat which can support juncos. However, since it is known that juncos commonly nest in areas dominanted by conifers in other parts of their range, cover types must be defined on a fairly local basis, such as a single National Forest or B.L.M. District, to be applicable. On the Manti-LaSal study area, most spruce-fir stands are of large, old trees resulting in a very sparse grass-forb understory. This probably precludes junco nesting because of lack of substrate for adequate concealment of nests. In other areas conifer stands may be much more open and support significant shrub, grass and forb understories. For other species, of course, cover and community types may be of more or less value and broad geographic applicability in identifying suitable habitat than they are for gray-headed juncos.

Habitat Variables

Aspen cover, forb cover, grass-forb cover, total vegetation cover, bare ground, average grass-forb height and tons/ha of downed woody material are habitat variables showing significant t-test differences (Table 7) that generally indicate a relatively lush habitat particularly in the understory. I speculate that this is the kind of habitat the juncos select. Total tree cover and total tree canopy volume show no significant differences between nest and non-nest plots, suggesting no selection by the juncos for particular tree characteristics. In general these observations are consistent with what might be expected for a ground-nesting bird, and with the observation that many overstory tree species seem to provide acceptable junco habitat (Miller 1941, Thatcher 1968). The most important factor seems to be the presence of a lush understory of grasses and forbs. This allows concealment of the nest and young. The adults further utilize this protection by never flying directly to or taking off from the nest; rather they land several m from it and leave from several m away after feeding the young.

Elevation and slope were significantly different between nest and non-nest plots (Table 7). Elevation shows no significant correlations with other habitat variables (Appendix D) and seems to be an important variable. However, since juncos are known to nest at elevations above and below that of the study area, this statistical significance may not be important ecologically. In fact, used and unused cover types seem to be related to elevation on the study area. Forty-one plots fell in fir-aspen and aspen-*Bromus* cover types, which the birds used for nesting, while the 19 remaining plots fell in the other five types, which the birds did not use. A t-test comparing mean elevation for these two groups of plots yields $t = 2.81$, significant at $p<0.01$. The average elevation for the two used types (2772 m) is less than the average for the unused types (2834 m), consistent with the average elevations for nest and non-nest plots (Table 6). Therefore elevation _per se_ may not be important, but may incorporate other factors that are important to the birds.

Juncos used areas with steeper slopes for nest sites. Nest openings are always oriented downhill and are well concealed, providing cover from above and from three sides. The top of the nest was often almost flush with the ground. Building a nest on a steep slope, on the downhill side of a clump of vegetation provides effective nest concealment.

Discriminant Function

Discriminant function analysis has been used several times in connection with ecological problems, often with apparent disregard for the statistical assumptions. Dueser et al. (1976) and Green (1971) describe the assumptions and the problems of interpretation if they have not been met. Cover and community types were not used in this analysis because of difficulties with the use of categorical (non-continuous) data, especially in interpretation of the significance of the function when normality is violated (Waite 1971, Heyer 1977).

The standardized discriminant function coefficients represent the relative contribution of the associated variables to the discriminant function; the sign represents the relationship between the variable and the vector rather than the response of the birds to the variable. Response information is derived from the means of the nest and non-nest groups (Table 6)(Hudson 1976). Since the magnitude of all the coefficients (disregarding sign) is similar, each variable is considered to be roughly equal in its contribution to the discrimination. The discriminant function describes an area with a fairly steep slope, moderate stocking of aspens and a relatively dense understory of grasses and forbs. In addition there is a significant amount of downed woody material, consistent with the observations of Winn (1976) in the Uinta Mountains. As described in the previous section, elevation may incorporate some of the information provided by the description of cover type.

Some information may have been lost in eliminating variables because of non-normality. However, since little is known about the sensitivity of the discriminant procedure to violations of the assumptions, satisfying them as closely as possible allowed for a much more unambiguous interpretation of the results.

Green (1971) wrote that "If one wishes to classify environments in a manner that is both as efficient and as relevant to species distribution as possible, then a useful procedure is to base the classification on discriminant scores from an analysis such as this." Although his analysis included several discriminant functions, allowing mapping of species locations in discriminant space, species may also be placed along a single discriminant axis as in James (1971) and Smith (1977). In this analysis placing nest and non-nest plots on the discriminant axis resulted in considerable overlap, although 68 percent of the plots were correctly classified (Figure 1). This percentage of correct classification is another way of assessing the reliability of the discriminant function model, in addition to noting that the group explain 28 percent of the total between-group variance.

There are four possible explanations, not necessarily mutually exclusive, for the misclassified plots: 1) Misclassified nest plots represent utilization of marginal habitat by some members of the junco population. 2) Misclassified non-nest plots represent areas acceptable to the juncos, but not utilized because of low population densities on the study area. 3) Variables either not measured or eliminated from the analysis would provide greater discrimination and a higher percentage of correctly classified plots. 4) Misclassified non-nest plots represent plots where nests actually occurred but were not detected in the nest searches.

The first three possibilities each seem quite probable and would require much more extensive sampling, over a period of several nesting seasons, to resolve. I consider the last explanation unlikely.

Wildlife Habitat Models

The National Environmental Policy Act of 1969 and the Forest and Range Resources Planning Act of 1974 have created an immediate need for bird habitat information that can be used for resource evaluation and impact assessment purposes. Davis and Henderson (1976) have described the conceptual basis for the kind of land classification and information storage and retrieval system needed to answer questions pertaining to the resource base and the effects of alternative management programs on ecosystems. Except for endangered species and birds of some economic importance, management of birds will be in conjunction with management for other resources (Hamilton and Noble 1975, Buttery and Shields 1975). Therefore, an information system providing basic ecosystem information useful in evaluating land potential for the production of various renewable resources, including birds, is desirable. This information, coupled with an objectively formulated, quantitative model of bird habitat, would provide the land manager with a means of objectively determining the value of a given area for a particular species (Wolfe et al. 1977). Ideally, information from existing forest and range inventory systems could be used in constructing the habitat models, eliminating the need for information unique to particular species.

A habitat model is a quantitative description of a set of environmental variables that are dependably correlated with the presence of a given species. The variables may or may not represent factors important to the species in the selection of its habitat. The habitat model concept should be applicable to any animal species. Indeed, most people have at least a vague idea of the kinds of habitats where particular species are most likely to be found. However, in order to be useful to and defensible by wildlife managers, these models must be objectively formulated and at least partially quantified. Several types of analysis may be appropriate for the formulation of such models. Multiple regression would be particularly useful when measures of the level of habitat use were available. Using pellet group counts as an index of habitat utilization, Gephart (1978) has constructed such a model for mule deer. The discriminant function model of gray-headed junco habitat, as proposed here, has the property of allowing for the classification of areas on the basis of a predetermined description of acceptable habitat. By measuring field data on the discriminant function variables, aspen cover, forb cover, grass-forb height, downed woody material, slope and elevation, the manager can classify an area as nest or non-nest by multiplying each value by the appropriate classification function coefficient (Table 8).

The junco habitat model provides a quantitative description of acceptable nesting habitat based on six variables as described above. The mean values of these variables for nest and non-nest plots (Table 6) indicate juncos select fairly steep slopes (19 percent) that are moderately stocked with aspen (about 30 percent) and forbs (about 45 percent). There is also more downed woody material on nest plots (about 29 tons/ha) than on non-nest plots. Nest plots are located at somewhat lower elevations than non-nest plots, but this may not be ecologically important, as discussed previously.

Opportunities and Limitations

The availability of an information system providing baseline data on forest and range resources, combined with objectively constructed models of species habitats, would present several opportunities to the wildlife manager. First the potential of a given area to support a given species could be evaluated. Knowledge of the habitat variables reliably correlated with species presence could be applied to the determination of critical habitat for endangered species, and to evaluation of the potential for success in stocking and reintroduction programs. In addition, the presentation of a quantified description of habitat would put the designation of critical habitat on a more scientific basis and would therefore be more acceptable in the eyes of the public. Second, the use of habitat models with resource inventory data is potentially valuable in assessing the probable impact of alternative management practices on wildlife species. In the case of gray-headed juncos, a grazing system that would reduce forb cover and average grass-forb height would be expected to reduce the potential of the affected area for junco habitat.

The use of models as described here has several limitations. First, and probably most important, is the fact that the presence of all the key habitat characteristics does not guarantee the presence of the species. The actual occurrance and condition of the population would have to be determined independently. In addition no indication of the size of the population would be available. Second, many models may be limited in their geographic applicability. The seriousness of this limitation depends upon 1) the ecological lability of the species and 2) the habitat variables used to construct the model. The presence of winter cover is apparently very important in the suitability of habitat for snowshoe hares (*Lepus americanus*) (Wolfe et al. 1977). However, several different species of trees may provide effective cover, subalpine fir in the Rocky Mountain west and plantations of Norway spruce (*Picea abies*) in central New York. A model incorporating the presence of one of the tree species would probably fail in its predictions of acceptable habitat, while a model incorporating the structural feature of low overhanging branches might apply on a continent-wide basis.

The third limitation is the availability and cost of both resource base data and data on species habitat requirements. The base data provided by an integrated information storage and retrieval system like ECOSYM (Davis and Henderson 1976) would provide information on all the terms of the gray-headed junco model. The fact that extensive information systems such as ECOSYM and quantified models of species habitat are not readily available does not make the concept less useful. Information systems and maps providing data on many habitat variables are readily available, and information on habitat requirements of many species are much better known than for gray-headed juncos.

There are two strategies for formulating habitat models. One is to institute a study, such as this on gray-headed juncos, to find relevant habitat variables and construct a model accordingly. The other is to determine how well the information in an available data system can discriminate between utilized and unutilized habitat of a species of interest. The latter may in fact be a very cost-effective method in many cases. Obviously a manager wants a habitat model that will provide a high level of reliability. However, a model that requires a large number of variables, especially if several of them are unique to single species, may be quite useless because of excessive cost. A simple, easily obtained model providing a lower level of predictability may be more valuable.

This discussion has assumed that wildlife managers will continue to find the single-species approach to management the most effective. However, for non-game birds it is possible that a management philosophy aimed at maintaining species diversity could be most valuable. A first step toward such management could be a classification of bird communities as proposed by Bevanger (1977) for Norway.

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APPENDIX A

Plant species encountered on the study plots.[1]

Trees

Abies lasiocarpa
Picea engelmannii
Populus tremuloides

Graminoids

Carex spp.
Agropyron trachycaulum
Agropyron subsecundum
Arrhenatherum elatius
Bromus polyanthus
Calamagrostis sp.
Dactylis glomerata
Elymus glaucus
Melica bulbosa
Phleum alpinum
Poa nevadensis
Poa pratensis
Poa secunda
Poa reflexa

Thalictrum fendleri
Rosa nutkana
Collinsia parviflora
Penstemon spp.
Osmorhiza chilensis
Viola sp.
Erythronium grandiflorum
Smilacina stellata
Veratrum californicum

Shrubs

Sambucus racemosa
Symphoricarpos oreophilus
Artemisia tridentata
Chrysothamnus viscidiflorus
Salix sp.
Ribes cereum
Ribes montigenum

Berberis repens
Hackelia floribunda
Mertensia sp.
Stellaria jamesiana
Chenopodium album
Achillea millefolium
Artemisia frigida
Artemisia ludoviciana
Aster spp.
Cirsium sp.
Madia glomerata
Rudbeckia occidentalis
Solidago spp.
Tragopogon dubius
Capsella bursa-pastoris
Draba sp.
Geranium fremontii
Geranium richardsonii
Hydrophyllum capitatum
Astragalus spp.
Lathyrus lanzwertii
Collomia linearis
Delphinium nelsoni
Delphinium occidentale
Galium sp.

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[1] Taxonomy follows Welsh and Moore (1973).

APPENDIX B

Results of tests for univariate normality (untransformed)
*H_0 of normality cannot be rejected at p = .01.

Mnemonic	X^2	Skewness	Kurtosis
COV1	23.333	.591*	2.550*
COV2	166.333	3.023	12.461
COV3	410.666	4.583	23.573
COVTR	11.000*	0.487*	2.356*
COVS	83.667	3.020	13.779
COVG	5.000*	0.289*	3.068*
COVF	6.667*	0.046*	2.406*
COVGF	7.667*	-0.661*	3.311*
COVALL	7.000*	0.161*	2.713*
BG	48.000	2.030	7.438
ASPT	27.667	0.507*	2.177*
SLOP	13.667*	0.541*	2.304*
ELEV	6.333*	-0.215*	3.670*
SHT	8.000*	0.397*	4.211*
GFHT	28.000	-0.052*	2.876*
DBH1	19.333	-0.349*	3.272*
DBH2	156.000	1.314	4.614*
DBH3	432.000	2.947	10.231
BA1	6.667*	0.668*	3.386*
BA2	158.333	2.319	7.954
BA3	445.667	5.137	27.643
BALL	10.333*	0.758	3.507*
VOL1	24.333	-0.194*	1.785
VOL2	154.667	2.281	7.732
VOL3	463.667	5.273	29.843
VALL	13.000*	0.018*	2.545*
DWM1	62.000	2.903	13.424
DWM2	86.667	1.794	5.794
PSD	10.333*	-0.977	4.517*

APPENDIX C

Variables transformed to normal. H_0 of normality cannot be rejected at p = .01.

Mnemonic	Transformation	X^2	Skewness	Kurtosis
COV1	natural log	6.000	0.317	2.202
COVS[a]	natural log	13.200	0.343	2.349
BG	natural log	6.333	0.174	2.200
DWM1	natural log	13.667	0.554	3.116
DWM2	natural log	8.333	-0.332	2.040
BALL	square root	18.333	-0.622	2.913
GFHT[a]	square root	6.500	-0.719	4.674

[a] Seven intervals (4df) for X^2 test; ten intervals for all other variables.

Appendix D

Matrix of bivariate correlations for variables included in discriminant function analysis.

	COV1	COVF	COVGF	COVALL	BG	SLOP	ELEV	GFHT	DWM2
COV1	1.000								
COVF	0.181	1.000							
COVGF	0.066	0.734*	1.000						
COVALL	0.593*	0.414*	0.554*	1.000					
BG	-0.349**	-0.294	-0.450*	-0.610*	1.000				
SLOP	0.235	0.215	0.215	0.261	-0.111	1.000			
ELEV	-0.206	0.142	0.018	-0.046	-0.016	-0.044	1.000		
GFHT	0.284	0.299	0.475*	0.403*	-0.504*	0.156	0.149	1.000	
DWM2	0.611*	-0.117	-0.179	0.248	-0.233	-0.207	-0.159	-0.028	1.000

* significant correlation at p = .01.

** significant correlation at p = .05.