UNIVERSITY OF MANITOBA

AN ANALYSIS OF USE OF NEST BOXES BY MOUNTAIN BLUEBIRDS IN SOUTHWESTERN MANITOBA

by

Hugh L. Munro

A Thesis Submitted to the Faculty of Graduate Studies in Partial Fulfillment of the Requirements for the Degree of Master of Arts

Department of Geography

Winnipeg, Manitoba

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ABSTRACT

Surface cover types and nest box properties characteristic of nest sites used and not used by mountain bluebirds nesting in southwestern Manitoba were investigated. Twenty-six variables considered pertinent to secondary cavity nesting passerines were evaluated at 1169 nest boxes on 28 nest box lines in 1980. Stepwise discriminant function analysis was used to determine which variables were important in discriminating between nest sites used and not used in 1) the first nesting period and 2) both nesting periods of mountain bluebirds. Variables unsuitable for inclusion in discriminant analysis were analyzed by chi-square criteria.

Nest sites were used in a variety of habitats, but were associated positively with grass and wooded pasture and negatively with shrub pasture, long grass, and fallow field. When surface cover characteristics were analyzed as a separate set of variables, wooded pasture was the most important variable separating nest sites used or not used in the first nesting period, and long grass was predominant in separating sites used or unused in both nesting periods.

Distance to the nearest building, entrance hole diameter, box depth, and line age were the important discriminating variables when nest box properties were analyzed separately. Nest box properties were superior to surface cover characteristics in separating used and unused sites. When surface cover and nest box variables were

analyzed together distance to nearest building, entrance hole diameter, and box depth were the important discriminating variables.

Entrance hole orientation, directional location of the nest box from the road, type of supporting structure, box condition, and land use and disturbance in the vicinity of the nest box had no impact on use by mountain bluebirds. Position of the entrance hole with respect to the road, road type, nest box color, and presence of utility lines and livestock did affect use.

My analyses reveal that mountain bluebirds are euryvalent in their use of breeding sites, but appear to prefer grass and wooded pasture and avoid shrub pasture and heavily cultivated areas. Characteristics of the nest box are more operative than surface cover characteristics in determining use by this species.

FOR DONITA

My Wife and Friend

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CHAPTER ONE

INTRODUCTION

1.1 Objectives

Many observers believe that mountain bluebirds (*Sialia currucoides*) have been declining in numbers over much of their range during the past several decades (Power 1966, Zeleny 1976). A similar trend in populations of eastern bluebirds (*Sialia sialis*) prompted speculation that elimination of natural nest cavities was a major factor in the decline (Wallace 1959). Bluebirds are secondary (non-excavating) cavity nesters. Availability of nest cavities is often the most important limiting factor for such species (Haartman 1957).

The perceived bluebird population decline and its suspected cause stimulated naturalists throughout North America to establish nest box lines by placing nest boxes along fence and utility lines (Zeleny 1976). Although thousands of man-made nest boxes are currently in place, few quantitative studies have been attempted on their use by nesting passerines.

The purpose of this study is to investigate habitat characteristics and nest box properties that separate nest sites used and not used by mountain bluebirds nesting in southwestern Manitoba. Specific objectives include:
1) identifying factors that may affect use of nest sites,
2) determining which habitat characteristics and nest box properties are most operative in discriminating between

used and unused sites, and 3) discussing the biological significance of discerned differences.

1.2 Background

In Manitoba, mountain bluebirds were common in the Spruce Woods Forest Reserve in 1890 (Criddle 1904). By the turn of the century nest boxes were being installed to attract bluebirds into more settled areas (Criddle 1927).

In 1959, the late Dr. John Lane initiated a project designed to increase populations of both bluebird species in southwestern Manitoba. Lane's efforts produced the largest nest line complex in North America (Zeleny 1976). Since Lane's death in 1975 this project has been continued by the Brandon-based "Friends of the Bluebird" coordinated by Norah Lane.

Approximately 5000 nest boxes have been erected along hundreds of miles of fence and utility lines in southwestern Manitoba, but many are either no longer in place or are unuseable because of the effects of time, weather, and human interference (Lane et al. 1980). Between 800 and 1500 nest boxes are monitored each year.

Data compiled from annual reports indicate that the percentage of nest boxes used by mountain bluebirds increased steadily between 1963 and 1970 in Manitoba (Fig. 1). The population remained relatively stable during the next four breeding seasons. In 1975 and 1976, 277 bluebirds were not identified to species (see Lane and Black 1975, Lane et al. 1976), and calculation of percent occupancy for these years would be unreliable. Data from 1977 to 1980 have been adjusted because in these years reports included the number of nestings rather than the number of boxes used. Use of nest boxes by mountain bluebirds peaked in 1978 at 38.2% of all monitored boxes. A population decline occurred in 1979 and was attributed to a late cold spring followed by a hot dry summer that resulted in heavy mortality and nest failure (Lane et al. 1980). The population subsequently increased in 1980.

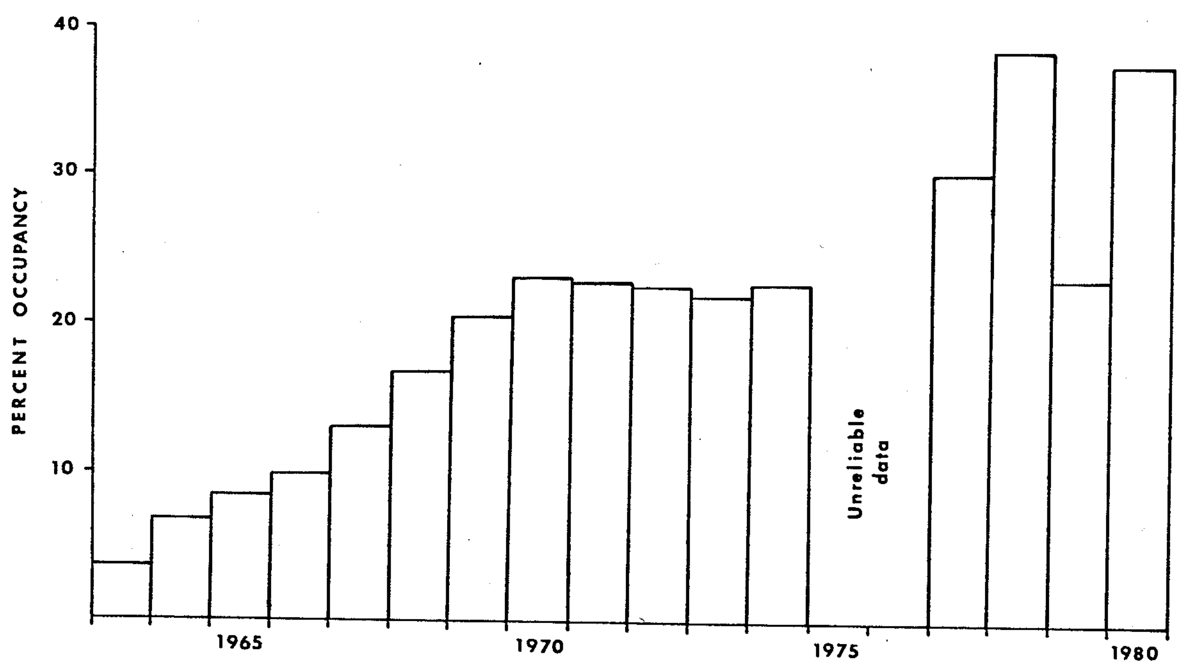

Fig. 1. Percentage of nest boxes occupied by nesting mountain bluebirds in southwestern Manitoba, 1963-1980 (compiled from annual reports from Brandon to the Blue Jay, Vols. 21-39).

Miller (1970) interpreted the increase in nest box use by mountain bluebirds between 1963 and 1968 as evidence that nest sites were limiting in Manitoba. Some species, however, appear to prefer nest boxes to natural cavities (wood ducks (<u>Aix sponsa</u>), Strange et al. 1971; eastern bluebirds, Pinkowski 1976). Caution must be exercised, therefore, in interpreting increased occupancy of nest boxes in absence of data on birds nesting in natural cavities.

1.3 Study Area

The study area (Fig. 2), which lies within a 140km radius of Brandon, Manitoba (49°50'N, 100°00'W), is near the eastern periphery of mountain bluebird breeding range (see Bent 1964). Elevation ranges from 350m to 550m and topography is generally flat. River valleys and fluvio-glacial deposits provide variation in the landscape.

Surface cover is dominated by cultivated grain and hay, fallow fields, and pastureland. Native grassland, marshes, and mature stands of trembling aspen (*Populus tremuloides*) or bur oak (*Quercus macrocarpa*) occur in areas unsuitable for agriculture. White spruce (*Picea glauca*), black spruce (*P. mariana*), and jack pine (*Pinus banksiana*) grow in scattered shelter belts and forest reserves.

1.4 Literature Review

1.4.1 Factors Affecting Distribution of a Species Within its Breeding Range

Distribution of an avian species within its breeding range may be affected by a number of factors. In an ecologically isolated situation individuals are expected to settle in the most suitable habitat available (Orians 1971). Birds are guided in the choice of a breeding site by instinctive responses to stimuli from the physical

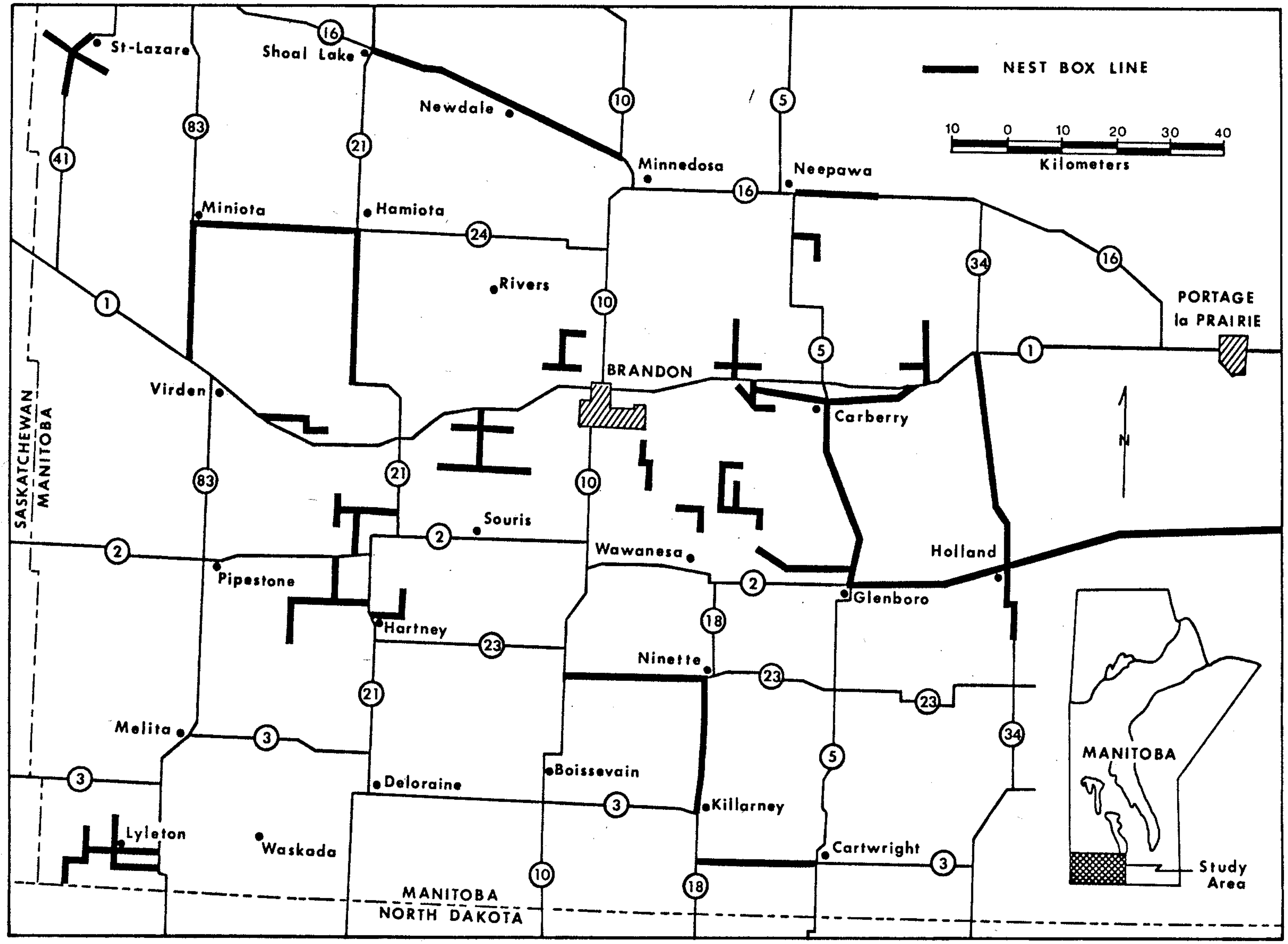

Fig. 2. Location of nest box lines within the study area.

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environment (Hildén 1965).

Partridge (1974) demonstrated that habitat preference of blue tits (Parus caeculeus) and coal tits (P. ater) was predominantly under genetic control. Berndt and Winkel (in Brewer 1979) found similar results while working with the pied flycatcher (Ficedula hypoleuca). Genetic influence on habitat preference, however, may be modified by learning. For example, site tenacity and imprinting on the rearing environment are known to affect the distribution of some species (Hildén 1965).

Some birds exhibit breeding site tenacity regardless of habitat changes that occur over time (Hildén 1965). Limited data suggest that once a mountain bluebird has nested in an area, it returns to the same general area for subsequent nesting seasons (Scott 1974, Pinel 1980, Stiles 1980). The impact of habitat change on this trend has not been studied.

Site tenacity by double-brooded mountain bluebirds during a breeding season is not well documented. Miller (1970) states that this species generally renests in the same nest box used for first broods. Power (1966) found that of five pairs of double-brooded mountain bluebirds in Montana, two used the same nest site to raise both broods, while three did not. In the latter three cases Power had removed the nest from the nest box after first broods had fledged. Eastern bluebirds remain at the same site to renest unless the first nesting attempt was unsuccessful or the nest site was disturbed (Laskey 1939,1940; Thomas 1946). Low (1934) found that eastern bluebirds raised two broods in nest boxes located in suitable habitat more often than in nest boxes placed where habitat was not as favorable. Since eastern and mountain bluebirds are similar in behavior (Bent 1964, Pinkowski 1975), it is likely that mountain bluebirds will remain at the same nest box to raise both broods provided that the nest site is suitable.

Imprinting on the rearing environment by young birds may at least temporarily modify habitat preference in some species (Klopfer 1963). Imprinting studies have not been done on mountain bluebirds, but neither imprinting nor postfledging experience are important influences on nest site selection by other secondary cavity nesting passerines (house sparrows (Passer domesticus), Cink 1976; eastern bluebirds, Pinkowski 1979a).

Birds seldom are able to choose breeding sites in ecological isolation. Topographic distribution of a species, therefore, is influenced by additional factors. Disease or depredation can selectively remove individuals from certain areas (Partridge 1978). For example, in 1974 many first broods of mountain bluebirds to the south and west of Brandon, Manitoba suffered heavy mortality from an infestation of black flies (Simulium venustum) (Lane and Burton 1974).

Intraspecific competition during periods of high population density may force individuals into less preferred habitat (Kluyver and Tinbergen 1953, Hildén 1965). In Manitoba, the practice of placing nest boxes 400m apart allows sufficient space for the territorial requirements of mountain bluebirds (see Power 1966). Individuals, however, do compete for possession of either territories or mates or both (pers. observ.).

An animal also can be restricted to certain areas by interspecific competition (Grinnel 1904, Caccamise 1974). In Manitoba, the most common competitors of mountain bluebirds for nest sites are tree swallows (Iridoprocne bicolor), house sparrows, house wrens (Troglodytes aedon), eastern bluebirds, mice (Peromyscus spp.), and red squirrels (Tamiasciurus hudsonicus). Nest boxes occasionally are occupied by starlings (Sturnus vulgaris), black-capped chickadees (Parus atricapillus), flying squirrels (Glaucomys volans), and eastern chipmunks (Tamias striatus) (Lane 1971, Lane and Bauman 1972, Lane et al. 1981).

On the Canadian prairies, early spring arrival and nesting give mountain bluebirds an advantage over tree swallows in obtaining nest sites (Miller 1970, Pinel 1980). If inclement weather delays first nesting attempts by mountain bluebirds, however, competition with tree swallows may become significant (Pinel and Robinson 1975). Tree swallows also may become a factor in second nesting attempts by mountain bluebirds.

Analysis of reports from areas where the two species are sympatric reveals that the number of mountain bluebirds using nest boxes increases relative to the number of tree swallows over time (see Scott 1969, Miller 1970, Burns et al. 1973, Houston 1974, Carter 1979, Pinel 1980). This supports the belief by Bent (1964) that mountain bluebirds are competitively superior to tree swallows.

Opinions differ on the competitive superiority between mountain bluebirds, house sparrows, and house wrens. Criddle (1927:43)states:

> Male mountain bluebirds are able to defend their nest against all intruders of their own size, this includes the house sparrow which has somewhat of a reputation for ousting other species. The sparrow, however, is no match for the bluebird..., it has never been observed to get possession of a nesting box occupied by the latter.

Criddle (op. cit.) also stated that he had never observed house wrens interfering with nesting mountain bluebirds. Others, however, regard these two species as serious threats to bluebirds (Miller 1970, Lane 1971, Zeleny 1976, Case 1979).

Early reports suggest that eastern bluebirds expanded their range westward into areas occupied by mountain bluebirds (Thompson 1893). This might indicate that *Sialia sialis* competes successfully with *S. currucoides*. The westward dispersal by *S. sialis*, however, has been erratic and without definite pattern or persistence (Belcher 1966). In fact, evidence suggests that *S. currucoides* is dominant over *S. sialis* in interspecific contests (Miller 1970). For example, Criddle (1927:40) states that "the two species continued as neighbours... for several years but as the western birds increased the eastern ones diminished."

Mice and squirrels use nest boxes to rear young in early spring and boxes occupied by these rodents are not available to mountain bluebirds (Lane 1971). Starlings, although formidable competitors of secondary cavity nesters elsewhere (Bent 1964, Erskine and McLaren 1976), are not a serious competitor for nest boxes in Manitoba (Lane and Bauman 1972). Competition with other occasional nest box occupants is insignificant.

Since suitability of a breeding site is affected by competition and predation pressures as well as its intrinsic qualities, an optimal area with regard to survival requirements of the individual may not be one where breeding success is greatest (Hildén 1965). Individuals whose distribution is affected by the foregoing constraints are under selective pressures to choose nest sites where the probability of successfully rearing offspring is maximized (Smith 1974, Gibo et al. 1976).

1.4.2 Habitat Utilization by Mountain Bluebirds

No quantitative studies have been completed concerning habitat utilization by mountain bluebirds. Power (1980) hypothesized that nest site limited species can be expected to be euryvalent because individuals will be under selective pressures to use almost any available nest site. Even nest site limited species, however, should evolve to be more persistent in attempts to enter and more vigorous in defense of habitats in which their fitness is greater (Orians 1971).

Descriptive accounts suggest that mountain bluebirds prefer relatively open areas with scattered bushes or trees (Criddle 1927, Bent 1964, Zeleny 1976). Along nest box lines near Calgary, Alberta mountain bluebirds are restricted to aspen parkland and are not found juxtaposed with cultivated hay or native grassland (Pinel 1980). Power (1980) found that foraging mountain bluebirds prefer to exploit areas where ground cover is sparse or kept short by cutting or grazing. Mountain bluebirds have the widest habitat tolerance within the genus Sialia, possibly because the ability to hover-forage permits utilization of areas with low perch density (Pinkowski 1979b).

Several reports suggest that mountain bluebirds are not fastidious about selecting a nest cavity. For example, Bent (1964) states that almost any cavity will suit them including deserted woodpecker holes, crevaces in cliffs, and holes in river banks. On rare occasions S. currucoides has been known to depart from its customary habit of nesting in cavities (Murie 1934).

1.4.3 Multivariate Studies of Habitat Utilization

Several studies have employed multivariate statistical methods to describe animal distributions in relation to environmental characteristics. James (1971), Anderson and Shugart (1974), and Whitmore (1975) used this approach to describe habitat relationships among avian species in Arkansas, Tennessee, and Utah respectively. Conner and Adkisson (1977) used principal component analysis to compare nesting habitat of five species of woodpeckers. Titus and Mosher (1981) successfully differentiated between nesting habitat of four species of raptors in Maryland using discriminant analysis. These studies identified habitat differences among species within a particular community.

Other researchers have attempted to quantify differences between habitat used and not used by a single species. Klebenow (1969) used discriminant function analysis in an unsuccessful attempt to distinguish between habitat used and not used by nesting sage grouse (*Centrocercus urophasianus*). Kaminski and Prince (1977) used the same technique to provide information for predicting potential nest sites of Canada geese (*Branta canadensis*). Titus and Mosher (1981) were able to define the factors that separate nest sites used and not used in three of the four species of raptors in their study.

CHAPTER TWO

METHODS

2.1 Data Collection

Data were collected between 20 April and 10 August, 1980 from 28 nest box lines that provided a cross section of the study area. I visited each line at least once to obtain data on nest sites. Additional information on nest box occupants and their progress during the breeding season was obtained from individuals who regularly monitor the lines.

Data were collected at 1169 nest boxes. Twenty-six parameters that were considered pertinent to cavity nesting species were evaluated. Measured parameters were divided into three groups: 1) surface cover types, 2) properties of the nest box, and 3) other characteristics of the nest site.

Six classes of surface cover were recorded: 1) forested areas (nongrazed deciduous, coniferous, or mixed forest), 2) wooded pasture, 3) shrub pasture, 4) grass pasture, 5) long grass areas (cropped field, native hay, and native grass), and 6) fallow field. Percent cover was estimated for each class within a 100m radius from the nest box. Power (1980) states that mountain bluebirds usually forage within this distance from the nest. Percentages were converted to m^2 for analysis.

Fourteen characteristics were measured for each nest box: 1) interior box area, 2) box depth from entrance hole to floor, 3) box height from ground to entrance hole,

4) box condition, 5) box color, 6) box age, 7) nest line age, 8) entrance hole diameter, 9) aspect of entrance hole, 10) position of entrance hole with respect to the road, 11) directional location of box from the road, 12) distance to nearest tree or shrub greater than 2m in height, 13) distance to nearest road, and 14) distance to nearest occupied building. Dimensions of the nest box were measured with a tape, and distances were measured with a tape, a 300mm telephoto lens, or an odometer. Box and nest line ages were obtained from Lane's records. Box condition was recorded as good or fair, and box color was categorized as weathered wood, new wood, or painted. Aspect of the entrance hole was determined with a compass and recorded as an azimuth. Entrance holes faced towards, away from, or parallel to the road. Directional location of the nest box from the road was recorded as a cardinal direction.

Other variables recorded at nest sites included: 1) presence of overhead utility lines, 2) presence of livestock, 3) presence of disturbance, 4) type of road near nest box, 5) type of supporting structure for nest box, and 6) general land use in the area. Burning, land clearing, construction, feedlots, and human activity were considered disturbances. Road types were classified as paved, all-weather, internal, rail, or no road (if roads were absent within a 100m radius of a nest box). Nest boxes were mounted on fence posts, non-fence posts, and utility poles. Land use was categorized as farmland or forest reserve.

2.2 Methods of Analysis

Median clutch initiation dates for all avian species were calculated from 1980 field notes. Since a nest box may be used more than once in a breeding season, two nesting periods were calculated: 1) 20 April to 6 June and 2) 7 June to 24 July. The 48 day nesting periods were calculated from the following information on mountain bluebirds: 4 days nest building (Scott 1967), 6 days egg laying (Munro et al. 1981), 14 day incubation period, 20 day nestling stage (Power 1966), and 4 days between fledging a first brood and initiating a second clutch (Scott 1967).

Nesting period dates were derived from data on mountain bluebirds for two reasons. First, they usually began nesting before other passerines. Second, they are double-brooded in Manitoba (Criddle 1927), and can be expected to compete for nest boxes after first broods have fledged.

Stepwise discriminant function analysis (in Nie et al. 1975) was used to define differences between nest sites used and not used by mountain bluebirds during 1) the first nesting period and 2) both nesting periods. The stepwise selection criteria was Wilks' lambda and all default criteria were used.

The 15 variables analyzed by the discriminant method were divided into two sets (Table 1). Surface cover types comprised one set of variables while the other set included variables describing properties of the nest box that were suitable for inclusion in discriminant analysis. Since several discriminant analyses were performed on the data,

Table 1. Description of variables included in stepwise discriminant analyses of nest sites used and not used by nesting mountain bluebirds in southwestern Manitoba.

Mnemonic	Description
1) Surface cover types	
FOREST	Percent cover by deciduous, coniferous, and mixed forest
WPAS	Percent cover by wooded pasture
SPAS	Percent cover by shrub pasture
GPAS	Percent cover by grass pasture
LGRAS	Percent cover by cropped field, native hay, and native grass
FALLO	Percent cover by fallow field
2) Nest box properties	
AREA	Interior area of nest box
HDIAM	Entrance hole diameter
DPTH	Depth from entrance hole to floor
HGHT	Height of entrance hole above ground
BOXAG	Age of nest box
LINAG	Age of nest box line
DSTREE	Distance to nearest tree or shrub greater than 2m in height
DSRD	Distance to nearest road
DSBLDG	Distance to nearest occupied building

detail of specific analyses will be presented with the results.

Variables collected at a level of measurement unsuitable for analysis by parametric statistics were analyzed by chi-square criteria. The chi-square test's sensitivity to small cell frequencies was satisfied (see Taylor 1977).

2.3 Discriminatory Analysis and Data Preparation

Discriminatory analysis distinguishes statistically between two or more groups based on a set of variables that measure characteristics on which the groups are expected to differ (Nie et al. 1975). Original variables are reduced to linear functions consisting of one or more variables by maximizing among-group variation (Tatsuoka 1971). Since there are two groups in this study, one discriminant function that accounts for 100% of the among-group variance will be derived (see Cooley and Lohnes 1971).

In the stepwise procedure, variables are selected for inclusion in analysis on the basis of their discriminating power. The process of sequentially selecting the next best discriminator at each step produces a set of variables that best describe group separation. The stepwise process stops when addition of new variables does not improve group separation (Johnston 1978). A previously selected variable that loses its discriminating power in combination with other variables is removed (Nie et al. 1975).

Statistical assumptions underlying use of discriminant analysis are:

1) Groups can be defined prior to analysis and all observations belong to one of the groups (King 1969). In this study, the two groups are nest sites used and nest sites not used by mountain bluebirds.
2) The variables are samples from a multivariate normal distribution (Tatsuoka 1971). Skewness and kurtosis are measures of departure from normality (Snedecor 1956). If these moments deviated from zero, data were transformed using power transformations for negatively skewed data and a logarithmic transformation for positively skewed data (Appendix 1). This procedure improves normality (Green 1971). Green (op. cit.) states that even if the variables deviate from normality, the discriminant function is likely to be normally distributed as a consequence of the Central Limit Theorem.
3) The discriminant function is, in fact, a linear function of the variables. Data transformations minimize nonlinearity (Green 1971).
4) The groups have homogeneous covariance matrices. A test for equality of group covariance matrices (Nie et al. 1975: 460) performed on all discriminant analyses revealed that my data often did not satisfy this assumption. Green (1971) states that this assumption is unlikely to be satisfied with most ecological data, but if the overall chi-square test is highly significant and the discriminating variables can be interpreted

ecologically it is reasonable to conclude that group differences are greater than would be expected by chance.

5) The variables are independent (Green 1979). Variables with extreme intercorrelations (0.8-1.0) should not be included in the analysis (Nie et al. 1975). The within-group correlation matrix revealed no extreme intercorrelations between variables (Appendix 2). The strongest intercorrelation (0.5) was between box and line age, indicating that these variables may measure similar features (Titus and Mosher 1981).

The following terms are necessary for interpretation of discriminant function analysis. Wilks' Lambda is the ratio of within-group to total variance along the discriminant function. A large lambda is indicative of relatively weak discriminating power. Lambda is converted to a chi-square statistic to test the significance of the discriminant function. This statistic describes the probability that a Wilks' lambda of any given value occurred due to chance. The ratio of between-group to total variance is measured by the canonical correlation (Johnston 1978). The squared canonical correlation indicates the proportion of variance in the function explained by the groups (Nie et al. 1975).

Group centroids are group means, calculated by averaging discriminant scores for all cases within a group (Nie et al. 1975). Greater differences between group centroids indicate greater group separation in discriminant function space. Another measure of group separation is the number of cases that are correctly classified into each group. The ability to correctly classify cases indicates that the groups are distinct.

The eigenvalue measures the relative importance of the discriminant function. This measure assumes greater importance when more than one function is derived. A standardized discriminant function coefficient, with sign ignored, indicates the relative contribution of its associated variable to the function. The sign signifies whether the contribution is positive or negative (Nie et al. 1975).

CHAPTER THREE

RESULTS

3.1 Use of Nest Boxes

Tree swallows (44.7%) and mountain bluebirds (33.0%) occupied most of the nest boxes in the first nesting period (Table 2). House sparrows occupied 9.3%, eastern bluebirds 1.5%, and house wrens 1.2% of available sites. Eighteen (1.5%) boxes were utilized by rodents and 96 (8.2%) boxes were empty during the first nesting period.

The median date of first clutch initiation by mountain bluebirds was 29 April. House sparrows began laying on 3 May. Tree swallows and eastern bluebirds usually initiated clutches during the third week of May. House wrens were the latest nesters.

Lack of information on use of 242 of the original 1169 nest boxes did not allow classification of these boxes during the second nesting period. Among 927 nest boxes with known occupants, the pattern of use was similar to that of the first nesting period. Mountain bluebirds initiated 188 new nests in the second nesting period. The number of empty nest boxes decreased to 24 (2.6%).

3.2 Description of Nest Sites

Nest sites used by mountain bluebirds in the first nesting period were located in areas characterized by a high mean percent cover of grass pasture (31.4%), and sites not used were found in areas with a high average percent cover

Table 2. Occupants of nest boxes during first and second nesting periods of mountain bluebirds in southwestern Manitoba, 1980.

Occupant	First nesting cycle (20 April-6 June)			Second nesting cycle[a] (7 June-26 July)	
	Absolute freq.	Relative freq.	Median clutch initiation date	Absolute freq.[b]	Relative freq.
Tree swallow	523	44.7	25 May	527 (73)	56.9
Mountain bluebird	386	33.0	29 April	239 (188)	25.8
House sparrow	109	9.3	3 May	81 (33)	8.7
Eastern bluebird	18	1.5	24 May	24 (13)	2.6
House wren	14	1.2	1 June	29 (15)	3.1
Mouse	11	0.9	-	1 (1)	0.1
Squirrel	7	0.6	-	0 (0)	0.0
Starling	3	0.3	2 May	1 (0)	0.1
Black-capped chickadee	1	0.1	7 May	0 (0)	0.0
Crossbred bluebird	1	0.1	18 April	1 (1)	0.1
Empty	96	8.2	-	24	2.6
Total	1169	100.0		927	100.0

[a] Excludes 242 of the original 1169 boxes because of insufficient information on use.
[b] Numbers in brackets indicate the number of new nestings.

of long grass (35.2%) (Table 3). Average percent cover of forest and wooded pasture was greater at used sites, while percent cover of shrub pasture and fallow field was greater at unused sites. All surface cover types had high variances and wide ranges in amount present.

Average percent cover by grass pasture was more predominant (37.5%) at nest sites used by mountain bluebirds in both nesting periods. Nest sites used twice by mountain bluebirds also were characterized by increases in mean percent cover of wooded and shrub pasture and decreases in percent cover of long grass, fallow field, and forest.

Sites used and not used in the first nesting period also were differentiated by nest box properties. Means for entrance hole diameter, box depth, box height, box age, line age, and distance to nearest building were larger for nest boxes used than for those not used (Table 3). Means for box area and distances to nearest tree and road were smaller for used than unused sites. Mountain bluebirds were not found on nest box lines that were less than two years old. They did, however, utilize one year old boxes when these boxes were present on older lines.

Nest boxes used by mountain bluebirds in both periods were characterized by decreases in mean internal area and height above ground. Average entrance hole diameter and box age remained constant for boxes used in both breeding periods, while means of other box properties increased. Ranges of most variables decreased for nest boxes used in

Table 3. Descriptive statistics for variables of nest sites used and not used by mountain bluebirds in the first, and both nesting periods in southwestern Manitoba, 1980.

				Nest sites used by mountain bluebirds						Nest sites not used by mountain bluebirds					
	Complete sample			First nesting cycle			Both nesting cycles			First nesting cycle			Both nesting cycles		
Variable	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
FOREST(%)	12.9	18.7	0-100	13.2	18.6	0-100	12.0	18.0	0-90	12.7	18.8	0-100	13.0	19.2	0-100
WPAS(%)	12.2	20.0	0-100	15.8	21.4	0-90	18.6	23.3	0-85	10.5	19.1	0-100	10.5	19.2	0-100
SPAS(%)	5.1	10.4	0-90	3.9	8.6	0-60	4.9	10.2	0-60	5.7	11.1	0-90	5.9	11.4	0-90
GPAS(%)	26.7	28.0	0-100	31.4	28.3	0-100	37.5	30.1	0-100	24.3	27.6	0-100	24.7	28.1	0-100
LGRAS(%)	31.9	30.5	0-100	25:3	27.9	0-100	20.5	26.4	0-100	35.2	31.2	0-100	35.9	31.6	0-100
FALLO(%)	11.2	20.6	0-100	10.4	20.5	0-100	6.5	16.3	0-85	11.6	20.8	0-100	11.8	20.9	0-100
AREA(cm^2)	117.3	26.0	81-305	113.9	24.4	81-285	112.0	22.7	90-285	119.0	26.6	81-305	119.2	26.8	81-305
HDIAM(mm)	41.5	5.7	30-80	43.2	5.4	33-70	42.7	5.0	35-58	40.7	5.6	30-80	41.3	5.0	30-80
DPTH(cm)	17.1	2.5	6-24	17.5	2.1	7-24	17.8	1.7	11-24	16.9	2.7	6-22	17.0	2.6	6-22
HGHT(cm)	130.9	25.7	42-244	133.6	24.9	42-244	132.0	25.2	50-182	129.6	26.1	48-187	129.7	26.2	48-187
BOXAG(yrs)	7.4	3.7	1-17	7.9	3.6	1-17	7.9	3.7	1-17	7.1	3.7	1-17	7.0	3.7	1-17
LINAG(yrs)	9.9	4.4	1-17	10.7	4.2	2-17	11.7	4.5	2-17	9.6	4.4	1-17	9.5	4.4	1-17
DSTREE(m)	58.4	105.0	1-1000	55.0	88.5	1-1000	60.3	108.1	1-1000	60.1	112.3	1-1000	60.4	113.2	1-1000
DSRD(m)	26.1	50.9	1-640	25.9	54.4	2-640	26.3	45.4	2-400	26.2	49.1	1-640	24.9	43.3	1-560
DSBLDG(m)	985.3	839.8	41-5000	1189.6	965.5	50-5000	1461.7	1064.5	100-5000	884.6	750.8	41-4600	876.0	741.5	41-4600

both nesting periods.

3.3 Discriminant Analyses of the First Nesting Period

To identify factors that separate nest sites used and not used by mountain bluebirds in the first nesting period, three sets of variables were included in separate discriminant analyses: 1) surface cover types, 2) properties of the nest box, and 3) all variables combined (Table 4). When analyzed separately, five of six surface cover variables contributed significantly to the separation between used and unused sites. The standardized discriminant function coefficient with the heaviest weighting indicates that wooded pasture was the most important variable contributing to the function. Nest sites used also were affiliated positively with forest and grass pasture, and negatively with long grass and shrub pasture. The function was highly significant ($X^2 = 58.76$, $P < 0.001$), and 59.5% of the sites were correctly classified using only surface cover characteristics.

When analyzed as a separate set of variables, all measured nest box attributes entered into the discriminant analysis were significant in defining used and unused sites. Heavy weightings were evident on entrance hole diameter, distance to building, and box depth. Mountain bluebirds nested in boxes that had larger entrance hole diameters, were farther from buildings, and were deeper than would be expected by chance. The lower Wilks' lambda, higher eigenvalue and canonical correlation, and wider range in

Table 4. Summary of stepwise discriminant function analyses of nest sites used and not used by mountain bluebirds in the first nesting period. Variables in each set are ordered according to entry into the stepwise procedure.

	F to enter	Standardized coefficients	Discriminant function parameters
1) Surface cover types			
WPAS	28.26**	0.608	Wilks' lambda = 0.951
SPAS	17.98**	-0.499	Chi-square statistic = 58.76
LGRAS	7.59**	-0.318	Significance = P< 0.001
FOREST	2.96*	0.314	Eigenvalue = 0.052
GPAS	2.55*	0.258	Canonical correlation = 0.222
			Group centroids = -0.324, 0.160
			Cases correctly classified = 59.5%
2) Nest box properties			
HDIAM	57.20**	0.651	Wilks' lambda = 0.886
DSBLDG	34.56**	0.468	Chi-square statistic = 140.48
DPTH	26.07**	0.465	Significance = P< 0.001
LINAG	7.76**	0.165	Eigenvalue = 0.129
DSRD	4.77**	-0.244	Canonical correlation = 0.338
HGHT	3.91**	0.181	Group centroids = -0.511, 0.252
AREA	3.76**	-0.208	Cases correctly classified = 66.0%
BOXAG	2.83**	0.197	
DSTREE	2.48*	-0.139	
3) All variables			
HDIAM	57.20**	0.538	Wilks' lambda = 0.875
DSBLDG	34.56**	0.417	Chi-square statistic = 178.51
DPTH	26.07**	0.387	Significance = P< 0.001
GPAS	20.47**	0.254	Eigenvalue = 0.166
SPAS	8.66**	-0.178	Canonical correlation = 0.378
WPAS	7.36**	0.400	Group centroids = -0.580, 0.286
BOXAG	6.75**	0.265	Cases correctly classified = 67.5%
DSRD	6.09**	-0.211	
HGHT	4.02**	0.166	
DSTREE	2.78**	-0.213	
FOREST	3.63**	0.204	
AREA	2.47**	-0.141	
FALLO	1.50	-0.108	

* P< 0.05; ** P< 0.01

group centroids illustrates that nest box characteristics discriminated between groups better than did surface cover characteristics. This is evident in that significance of the function increased (X^2 = 140.48, $P < 0.001$), and 66.0% of the sites were correctly classified.

When all variables were combined, 13 of the 15 variables entered the stepwise procedure and 12 made a significant contribution to the separation between groups (Table 4). Three of the four most powerful discriminating variables were nest box characteristics. Entrance hole diameter made the greatest contribution to group separation. Distance to the nearest building, presence of wooded pasture, and box depth were next in importance. Sites used by mountain bluebirds also were separated from unused sites by higher percent cover of grass pasture and forest, lower percent cover of shrub pasture, and nest boxes that were older, higher, smaller, and closer to the nearest tree and road. Fallow field was included in the function but its contribution to the discrimination was not significant. The function was highly significant (X^2 = 178.51, $P < 0.001$). and 67.5% of the cases were correctly classified.

Since nest boxes used by mice and squirrels are not available to mountain bluebirds in the first nesting period, the 18 boxes occupied by these rodents were removed from an analysis of all variables to determine if there would be changes in the discriminating variables. No major changes were evident (Appendix 3).

In another analysis of all variables, nest boxes used by mice, squirrels, and house sparrows were removed. Nest boxes used by house sparrows were removed because the sparrows initiated clutches at approximately the same time as mountain bluebirds and occupied 9.3% of the available nest boxes (Table 2). No substantive changes occurred in the discriminant function, but the relative contribution of distance to the nearest building decreased (Appendix 4).

3.4 Discriminant Analyses of Both Nesting Periods

Nest boxes used twice by mountain bluebirds during 1980 were compared to those not used twice. Only the 927 nest boxes with known occupants were included in analyses of both nesting periods. Discriminant analyses were performed on variable sets in the same manner as for the first nesting period (Table 5). In all three analyses fewer variables made significant contributions to the functions but overall group separation was superior to that achieved by analyzing only the first nesting period.

The discriminant function derived from analysis of surface cover variables as a separate set had a heavy negative weighting on long grass. Fallow field, shrub pasture, and forest also were negatively associated with used sites. Positive weights were evident for grass and wooded pasture. Grass pasture, wooded pasture, and forest did not contribute significantly to the function.

When analyzed separately, nest box properties adding to group partitioning were similar to those contributing

Table 5. Summary of stepwise discriminant function analyses of nest sites used and not used by mountain bluebirds in both nesting periods. Variables in each set are ordered according to entry into the stepwise procedure.

	F to enter	Standardized coefficients	Discriminant function parameters
1) Surface cover types			
LGRAS	30.66**	-0.570	Wilks' lambda = 0.946
FALLO	11.89**	-0.348	Chi-square statistic = 51.13
SPAS	4.29**	-0.240	Significance = P< 0.001
WPAS	2.13	0.296	Eigenvalue = 0.057
GPAS	1.12	0.250	Canonical correlation = 0.232
FOREST	1.76	-0.217	Group centroids = -0.500, 0.114
			Cases correctly classified = 62.2%
2) Nest box properties			
DSBLDG	59.00**	0.683	Wilks' lambda = 0.869
HDIAM	31.14**	0.548	Chi-square statistic = 129.26
DPTH	22.57**	0.390	Significance = P< 0.001
LINAG	11.42**	0.324	Eigenvalue = 0.150
AREA	5.48**	-0.241	Canonical correlation = 0.362
HGHT	1.39	0.113	Group centroids = -0.812, 0.185
DSRD	1.28	0.105	Cases correctly classified = 69.2%
3) All variables			
DSBLDG	59.00**	0.575	Wilks' lambda = 0.845
HDIAM	31.14**	0.535	Chi-square statistic = 155.11
DPTH	22.57**	0.358	Significance = P< 0.001
GPAS	25.23**	0.261	Eigenvalue = 0.184
LINAG	10.07**	0.276	Canonical correlation = 0.394
LGRAS	4.08**	-0.147	Group centroids = -0.897, 0.204
AREA	3.22**	-0.161	Cases correctly classified = 70.2%
WPAS	1.90	0.135	
HGHT	1.38	0.100	

** P< 0.01

to the first nesting period function. Distance to nearest building and entrance hole diameter were the most important discriminating variables. Depth and area of the nest box remained in the same relative position on the function. Line age became more important to group separation, while distance to road and tree, box height and box age lost discriminating power.

When all variables were analyzed together, nine of 15 variables were included in the stepwise procedure, seven of which contributed significantly to the function (Table 5). The four variables with the heaviest weightings were the following properties of the nest box: distance to building, entrance hole diameter, box depth, and line age. Nest boxes used twice by mountain bluebirds also were associated positively with grass pasture and negatively with long grass and box area. The function is highly significant ($X^2 = 155.11$, $P < 0.001$), but a large Wilks' lambda and a small canonical correlation indicate that the ratio of within-group to total variance is higher than the ratio of between-group to total variance. The widest separation between groups, however, was achieved with this function (group centroids = -0.897, 0.204), and 70.2% of the cases were correctly classified.

3.5 Chi-square Tests

Variables unsuitable for inclusion in discriminant analysis were analyzed by chi-square criteria. All chi-square tests were performed on data from nest boxes used by mountain bluebirds during the first nesting period.

Entrance holes in nest boxes used apparently were oriented at random ($X^2 = 0.92$, $P > 0.05$) (Table 6). Position of the entrance hole with respect to the road, however, was important. Mountain bluebirds used nest boxes with entrance holes facing away from the road more often, and those with entrance holes facing towards or parallel with the road less often than expected by chance ($X^2 = 10.42$, $P < 0.01$). Differences in use of nest boxes located north or south of east-west roads, and east or west of north-south roads were not apparent.

Table 6. Orientation of entrance hole, position of entrance hole with respect to road, directional location of nest box from road, and use of nest boxes by mountain bluebirds.

	Available	Observed	Expected
Orientation of entrance hole			
NW-NE	390	125	128.8
NE-SE	267	83	88.2
SE-SW	190	67	62.7
SW-NW	322	111	106.3
	$X^2 = 0.92$, $P > 0.05$		
Position of entrance hole			
Facing toward road	267	85	88.2
Facing away from road	198	89	65.4
Facing parallel with road	704	212	232.4
	$X^2 = 10.42$, $P < 0.01$		
Directional box location			
East-west roads			
N of road	318	88	95.6
S of road	314	102	94.4
	$X^2 = 1.22$, $P > 0.05$		
North-south roads			
E of road	290	114	105.8
W of road	247	82	90.2
	$X^2 = 1.38$, $P > 0.05$		

Mountain bluebirds used nest boxes constructed of weathered wood more often than nest boxes that were either painted or non-weathered ($X^2 = 22.79$, $P < 0.01$) (Table 7). Condition of the nest box ($X^2 = 2.63$, $P > 0.05$) and type of supporting structure ($X^2 = 2.18$, $P > 0.05$) had no impact on use.

Table 7. Color, condition, and supporting structure of nest boxes used by mountain bluebirds.

	Available	Observed	Expected
Color of nest box			
Weathered wood	888	333	293.2
Non-weathered wood	68	10	22.5
Painted	213	43	70.3
	$X^2 = 22.79$, $P < 0.01$		
Condition of nest box			
Good	1074	346	354.7
Fair	95	40	31.3
	$X^2 = 2.63$, $P > 0.05$		
Supporting structure			
Fence post	1025	348	338.5
Non-fence post	62	16	20.5
Utility pole	82	22	27.0
	$X^2 = 2.18$, $P > 0.05$		

Nest sites without utility lines were utilized more often than expected ($X^2 = 16.14$, $P < 0.01$) (Table 8). Nest box use was related to presence of livestock ($X^2 = 8.34$, $P < 0.01$), but not to disturbance within the nesting area ($X^2 = 0.25$, $P > 0.05$). There were more bluebirds than expected in nest boxes located along all-weather and internal roads and less than expected in nest boxes positioned along paved roads ($X^2 = 15.66$, $P < 0.01$). Land use in the vicinity of the nest box did not affect use ($X^2 = 0.25$, $P > 0.05$).

Table 8. Utility lines, livestock, distubance, road type, and land use at nest sites used by mountain bluebirds.

	Available	Observed	Expected
Utility line			
Present	713	197	235.5
Absent	456	189	150.5
	$X^2 = 16.14$, $P < 0.01$		
Livestock			
Present	728	268	240.5
Absent	441	118	145.5
	$X^2 = 8.34$, $P < 0.01$		
Disturbance			
Present	63	23	20.8
Absent	1106	363	365.2
	$X^2 = 0.25$, $P > 0.05$		
Road type			
Paved	494	127	163.2
All-weather	514	198	169.7
Internal	120	47	39.7
Rail	8	1	2.7
No road	33	13	10.7
	$X^2 = 15.66$, $P < 0.01$		
Land use			
Farmland	1112	365	367.1
Forest reserve	57	21	18.9
	$X^2 = 0.25$, $P > 0.05$		

CHAPTER FOUR

DISCUSSION

Nest box use in the study area in 1980 was similar to that reported in recent years (Lane et al. 1978, 1979, 1980). Percent occupancy by mountain bluebirds was close to the peak occupancy reached in 1978 (Fig. 1). Use by all species except eastern bluebirds, which rarely breed in Alberta (Butot 1978), was comparable to occupancy of nest boxes near Calgary in 1980 (Stiles 1981). The ratio of tree swallows to mountain bluebirds, however, was lower in Manitoba than in Alberta. Empty boxes accounted for 8.2% of all available nest boxes in Manitoba, indicating that availability of nest cavities was not a limiting factor in the first nesting period. In Alberta 2.2% of available sites were unused.

Tree swallows were the most numerous competitors of mountain bluebirds for nest boxes in the first nesting period. Mountain bluebirds had a competitive advantage over tree swallows early in the breeding season because they arrived earlier (pers. observ.) and began nesting before tree swallows (Table 2). Some tree swallows, however, were observed defending nest sites as early as the first week in May.

House sparrows not only were present in sufficient numbers to affect the distribution of mountain bluebirds, but also initiated first clutches at approximately the same time (Table 2). Similar breeding chronology and a reputation for outcompeting other species (Miller 1970, Lane 1971, Case 1979) probably make house sparrows the most serious rivals of mountain bluebirds for nest sites in Manitoba. Other nest box occupants were not abundant enough to seriously affect use of nest sites by mountain bluebirds.

Power (1966) found that 50% of mountain bluebirds in his study area in Montana were double-brooded. Randall and Lane (1969) estimated that more than 50% of this species raised two broods in Manitoba. Comparison of the number of new nestlings by mountain bluebirds in the second nesting period with the number of nests in the first nesting period (Table 2) reveals that my data are consistent with that of these two studies. It is, therefore, reasonable to conclude that most of the new nests in the second period are second broods of previously nesting pairs rather than first broods of late nesters. However, there was no way of proving that a mountain bluebird pair initiating a new nest in the second nesting period was same pair that utilized the nest box in the first nesting period because birds in the study area were not banded.

Use of nest boxes in the second nesting period was dominated by tree swallows. Swallows usually began nesting in the first nesting period but did not fledge their young until halfway through the second nesting period. A mountain bluebird that remains at the same nest box to raise a second brood, therefore, will not be affected by tree swallows, provided that the bluebird is able to defend the nest site during the interval between fledging of the first brood and completion of the second clutch. It is during this interval that double-brooded mountain bluebirds are most vulnerable to competition from other species (Burns et al. 1973, pers. observ.). This also is evident from numerous reports of two species laying eggs in the same nest box at the same time (Murray 1972, Houston 1974, Scott 1974, Lane et al. 1979, Stiles 1981).

House sparrows are double- or triple-brooded (Anderson 1978, Case 1979), and their influence on the local distribution of nesting mountain bluebirds probably continues throughout the summer. The number of boxes used by all other occupants combined remained relatively constant from first to second nesting periods. Although competitive pressure on nest sites increased in the second nesting period, 24 boxes remained empty.

Mountain bluebirds used nest boxes located in a variety of habitats. Percent cover of all measured surface cover types except shrub pasture ranged from zero to 100% at sites used (Table 3). This supports the hypothesis that mountain bluebirds are euryvalent (Power 1980) and are found in a great variety of habitats over their breeding range (Pinkowski 1979b). Bluebirds nesting in natural cavities commonly use old nest holes of the common flicker (*Colaptes auratus*) (Conner and Adkisson 1974, Pinkowski 1976). Several reports depict the nesting habitat of the common flicker as being diverse (Dennis 1969, Conner and Adkisson 1977). One might expect a secondary cavity nester that commonly uses nest holes excavated by a euryvalent species to be under strong selective pressures to be euryvalent itself.

Mountain bluebirds are found in areas characterized by low density trembling aspen and grass pasture, and are not found in areas that are heavily cultivated or devoid of trees near Calgary (Pinel 1980, Stiles 1980). The combined mean percent cover of grass and wooded pasture at sites used indicates a similar trend in Manitoba.

Since nest sites used by mountain bluebirds to raise two broods were successfully defended throughout the breeding season, they should be indicative of sites at which the bluebirds' fitness is greater (see Orians 1971). The fact that mean percent cover of grass and wooded pasture increased, and mean percent cover of long grass decreased at sites used twice (Table 3), suggests that mountain bluebirds prefer the former and avoid the latter. Several descriptive reports support this observation (Criddle 1927, Bent 1964, Zeleny 1976).

Stepwise discriminant function analysis provides an optimum procedure for mathmatically separating habitats used from those not used by maximizing separation between groups (James 1971). In all discriminant analyses of variable sets in this study, the function was significant ($P < 0.001$), and separation between sites used and not used by mountain bluebirds was achieved (Tables 4, 5). In all analyses, however, Wilkes' lambda was larger than the canonical correlation, indicating that within-group compared to between-group variation was high. This, combined with the fact that the highest number of cases correctly classified was 70.2%, suggests that separation is not complete.

When surface cover types were analyzed separately, wooded pasture was the most important variable distinguishing between nest sites used and not used in the first nesting period (Table 4). The importance of wooded pasture to mountain bluebirds probably relates to their foraging behavior. Mountain bluebirds are opportunistic in foraging habits, and adopt a variety of hunting techniques depending on prey availability, time of year, and habitat characteristics (Pinkowski 1979b, Power 1980). Perch-foraging, a method of sitting on an elevated perch to locate, and dropping to the ground to seize prey, is the most calorically inexpensive foraging pattern (Power 1980). Power (op. cit.) also states that bluebirds prefer to hunt in areas where ground cover is short even though availability of their preferred prey is greater in long grass areas. He cites possible advantages of this strategy as achieving a higher rate of harvest because of prey visibility and ease of movement, and increasing the opportunity to monitor nest, mate, and territory while foraging. Among available habitats, wooded pasture best provides these advantages.

A strong negative weighting on shrub pasture also was important in separating used and unused nest sites (Table 4). Mean percent cover by shrub pasture was low at used sites, and mountain bluebirds did not nest in areas with more than 60% cover by shrubs (Table 3). A shrub habitat has many perches from which to hunt, but height of perches is low. As foraging height decreases the perceptual field of a bird trying to locate food items on the ground also decreases (Pinkowski 1979b). Furthermore, the common shrubs on pastures in southwestern Manitoba, silver berry (*Elaeagnus commutata*) and snowberry (*Symphoricarpos occidentalis*), usually grow in thick clumps and reduce ground visibility. These factors reduce the suitability of shrub pasture to foraging mountain bluebirds. Pinkowski (1979b) states that reduction or removal of the herbaceous understory in forests is beneficial to mountain bluebirds. Closely related members of the thrush family are known to prefer areas where shrub growth is limited (e.g. robins (*Turdus migratorius*), James 1971; eastern bluebirds, Pinkowski 1979b).

When surface cover variables of sites used and not used twice by mountain bluebirds were analyzed, the positive association of wooded pasture with sites used decreased, and the negative association of long grass increased in importance (Table 5). As the breeding season progresses in Manitoba, vegetation height in long grass areas increases, while ground cover in grass and wooded pastures remains short because of grazing. Power (1980) presented experimental evidence that mountain bluebirds will employ an energetically more costly foraging strategy in order to forage in short grass areas, rather than forage in tall vegetation with a less costly method. Caloric expenditure is an important factor during the breeding season (Pyke et al. 1977), and this behavior indicates that mountain bluebirds are under selective pressures to utilize short grass areas and avoid long grass areas. Other researchers also have found that vegetation physiognomy is more important than either geographic location or floristic composition in constraining the distribution and abundance of bird species foraging in grasslands (Cody 1968, Wiens 1973).

Sites used twice by mountain bluebirds also were separated from unused sites by a heavy negative weighting on fallow field. There are two possible reasons why mountain bluebirds do not use nest sites associated with high percent cover by fallow fields. First, fallowing is more likely to occur in areas where cropped fields dominate surface cover. Furthermore, it is unlikely that mountain bluebirds are able to differentiate between fallow and cropped fields when they initially choose nest sites because both cover types look the same in early spring. The negative relationship between sites used and fallow field, therefore, may be related to the negative association with long grass cover. Other species that prefer to nest in short grass areas, but are unable to distinguish short from long grass in spring, choose nest sites on the basis of color of the landscape (Brewer 1979). Second, prey availability is probably lower on fallow fields. Arthropods (mainly grasshoppers and caterpillars) account for the bulk of a bluebird's diet during the breeding season (Zeleny 1976, Power 1980). Since these insects feed on vegetation, their abundance on fallow fields is likely limited.

When analyzed as a separate set, all measured nest box properties contributed significantly to the discriminant function of the first nesting cycle (Table 4), and were superior to surface cover characteristics in discriminating between used and unused sites. Haartman (1957) and Hildén (1965) emphasize the importance of the nest cavity to secondary cavity nesting species. Haartman (1957) states that, compared to an appropriate nest hole, the surrounding terrain is of relatively slight importance in territorial selection by pied flycatchers and great tits (Parus major).

Entrance hole diameter was the most important discriminating variable among nest box properties. Entrance hole diameters in boxes used ranged from 33mm to 70mm. Mean entrance hole diameter of boxes used ($\bar{x}$ = 43mm) was larger than in boxes not used ($\bar{x}$ = 41mm). The recommended hole diameter designed to attract bluebirds (and exclude starlings) is 38mm (Kibler 1969, Zeleny 1976, Burtt 1979). Mountain bluebirds sometimes have difficulty entering this size of hole (pers. observ.). My data support Brinkerhoff and Brinkerhoff (1980), who believe that mountain bluebirds prefer to use nest boxes with entrance holes larger than the recommended size. Other secondary cavity nesting species, common goldeneyes (Bucephala clangula) and hooded mergansers (Lophodytes cucullatus), also prefer entrance hole diameters larger than necessary (Lumsden et al. 1980).

Entrance hole diameters of woodpecker cavities used by eastern bluebirds in Virginia ranged from 40mm to 120mm (Conner and Adkisson 1974). Pinkowski (1976) found entrance hole diameters of natural cavities and woodpecker holes used by eastern bluebirds in Michigan to be smaller ($\bar{x}$ = 46mm) than those not used ($\bar{x}$ = 60mm), but suggests that starlings limited the distribution of eastern bluebirds in cavities with larger entrance holes. These data indicate that natural cavities available to bluebirds generally have larger entrance hole diameters than man-made nest boxes.

Distance to the nearest occupied building was the second most important discriminating variable among nest box properties (Table 4). Sites used by mountain bluebirds were farther from buildings than sites not used (Table 3). Laskey (1939, 1940) found that nest boxes placed farther from buildings were more successful in attracting eastern bluebirds than sites near houses or barns. She stated that eastern bluebirds do not adapt well to continuous human activity in the nesting area. Mountain bluebirds do not appear to be as diffident as eastern bluebirds about disturbance in the nesting area (pers. observ.).

House sparrows often occupy nest boxes placed in proximity to human habitation (Laskey 1940, Stiles 1980, Reid 1981). When boxes used by house sparrows were removed from analysis, distance to the nearest building became less important in discriminating between sites used and not used by mountain bluebirds (Appendix 4). This suggests that house sparrows are more operative than a possible preference for more remote areas in limiting the distribution of mountain bluebirds near buildings.

Nest box depth was associated positively with nest sites used (Table 4). Mountain bluebirds did not utilize nest boxes less than 7cm in depth, and generally were located in deeper boxes (Table 3). Miller (1970) states that both bluebird species in Manitoba prefer to nest in deeper boxes. Pinkowski (1976) found eastern bluebirds in natural cavities that ranged in depth from 7.6cm to 48.3cm ($\bar{x}$ = 19.8cm), and stated that shallower cavities were ignored. Wood ducks (Bellrose et al. 1964) and common goldeneyes (Lumsden et al. 1980) also reject shallow nest boxes.

Selection of deep cavities for nesting is likely an adaption to predation pressures. Black-billed magpies (<u>Pica pica</u>) have been reported to prey upon bluebird nests in shallow boxes (Lane et al. 1976). Depredation by mammalian predators such as raccoons (<u>Procyon lotor</u>) also will be reduced by use of deeper cavities (Kibler 1969). Kibler (op. cit.) recommends that bluebird nest boxes be

20cm deep to prevent premature fledging of nestlings.

Mean distance to the nearest road was greater for sites not used by mountain bluebirds than for those used in the first nesting period. The reverse was true for sites used and unused in both nesting periods (Table 3). Contribution of this variable was significant in the discriminant function describing the first nesting period, but was not significant in the function derived from analysis of both nesting periods. The fact that sites used twice by mountain bluebirds were typically farther from roads might be related to preference for remote areas.

Nest boxes used by mountain bluebirds had a smaller mean internal area ($\bar{x}$ = 113.9cm^2) than boxes not used ($\bar{x}$ = 119.0cm^2). Diameters of natural cavities used ($\bar{x}$ = 45.4cm^2) by eastern bluebirds in Michigan were significantly smaller than those not used ($\bar{x}$ = 63.6cm^2) (Pinkowski 1976). Research has shown that ectoparasitism is more predominant in nest boxes than natural cavities, possibly because bluebirds place more nesting material in flat-bottomed boxes than in round-bottomed tree cavities (Pinkowski 1977a, 1980). Utilization of large nest cavities also requires more energy expenditure in nest building.

Mountain bluebirds nested in older nest boxes and along older nest lines. The tendency to utilize older boxes probably relates to color of the nest box (see discussion later). As age of a nest box increases it more closely resembles a tree cavity because of weathering.

Nest lines less than two years old were not used by mountain bluebirds (Table 3). Scott (1969) and Lane et al. (1981) report that new nest lines usually attract tree swallows rather than bluebirds. The intercorrelation between box and line age (Appendix 2) indicates that these two variables might be measuring the same thing, in which case avoidance of new nest lines may actually be avoidance of new nest boxes.

Site tenacity also may affect use of new nest lines. The fact that bluebirds do not occur on new nest lines may be simply because they do not find them. Strange et al. (1971), however, point out that newer boxes are more readily visible than older, weathered ones and will probably be inspected first by species searching for a nest cavity.

Height of the nest cavity was associated positively with nest sites used (Table 4), but a wide range of heights was acceptable to mountain bluebirds (Table 3). Eastern bluebirds will utilize nest cavities at a variety of heights (Conner and Adkisson 1974, Pinkowski 1976). Nest boxes are generally lower than tree cavities that would normally be used by bluebirds and utilization of higher nest boxes may reflect this difference.

Distance to the nearest tree was only weakly weighted in the first nesting period function, indicating that this variable was relatively unimportant in separating used and unused sites. Presence of nearby perches from which to hunt and monitor the nest is important to eastern bluebirds (Burtt 1979). Perch availability is less important to mountain bluebirds because they have the ability to hover (Pinkowski 1979b, Power 1980).

When nests used and not used in both nesting periods were analyzed using only nest box properties, box age and distance to the nearest tree were excluded from the discriminant function (Table 5). Box height and distance to the road contributed to discrimination between groups, but were not significant factors. The remaining nest box characteristics include distance to the nearest building, entrance hole diameter, box depth, line age, and box area and appear to be most critical in determining use by mountain bluebirds.

These five nest box properties were among the seven significant discriminating variables when all variables were combined for analysis of both nesting periods (Table 5). This emphasizes the importance of nest box properties compared to surface cover characteristics in affecting use. The two surface cover types that contributed significantly to this function were grass pasture and long grass. Besides the availability of a suitable nest box, presence of grass pasture and absence of long grass areas are important factors affecting use by mountain bluebirds.

Chi-square analysis revealed that compass orientation of entrance holes in nest boxes used by mountain bluebirds was random (Table 6). Pinkowski (1976) found that more tree cavities used by eastern bluebirds opened at 135°N and 150°N than expected by chance, but attributed it to random selection of available cavities, most of which were woodpecker holes that faced in a southeastern direction (see Dennis 1969). Cavity nesting ducks show no preference for entrance holes facing in any compass direction (Lumsden et al. 1980).

Mountain bluebirds used nest boxes with entrance holes that faced away from the road significantly more often than those either facing or parallel with the road (Table 6). Erskine (1972) found that buffleheads preferred cavities that offered a relatively unobstructed flight path to the entrance hole. Bluebirds may view a road as an "obstruction" because of the disturbance of traffic. Nest boxes with entrance holes facing away from gravel and dirt roads also will be less affected by dust from passing vehicles.

Weathered nest boxes were used significantly more often than non-weathered or painted boxes (Table 7). Weathered nest boxes most closely approximate natural cavities. Opinions differ on whether or not nest boxes should be painted (Kibler 1969). My data suggests that they should not.

The fact that mountain bluebirds used sites without utility lines more often, and sites with utility lines less often than expected is puzzling (Table 8). Bluebirds are known to use utility lines as perches for hunting (Preston and McCormick 1948). In fact, Burtt (1979) stated that utility lines and fences are adequate substitutes for treeless areas. Hunting perches of eastern bluebirds in Ohio averaged 2.3m above ground for males and 1.8m for females (Goldman 1975). Pinkowski (1977b) found that this species generally hunts from a height of 2.0m in spring and 3.8m in summer. Since most utility lines in my study area were 6m in height, they are probably too high for optimum foraging by bluebirds. This does not, however, explain why bluebirds might avoid nest sites with utility lines. One possible explanation is that kestrels (Falco sparverius) have been implicated as predators of the mountain bluebird (Power 1966, Lane 1971, Carter 1979), and regularly hunt from utility lines in Manitoba (pers. observ.). Presence of a utility line above the nest box may increase the liklihood of being attacked while entering or leaving the nest.

The significant difference in use of boxes along various road types may indicate a preference for nest sites along roads with less traffic. Use of boxes along paved roads, where traffic is heaviest was less than expected. Disturbance in the nesting area, however, had no impact on use (Table 8). This suggests that mountain bluebirds may adapt to disturbance more readily than eastern bluebirds (see Laskey 1940).

The difference in use of sites where livestock was present or absent probably relates to the fact that grazing keeps ground cover short, rather than any direct relationship between livestock and bluebirds. Power (1980) emphasized the importance of livestock to mountain bluebird management. He stated that grazing is important to bluebird habitat because it keeps vegetation short and speeds succession of woody plants that provide perches and potential sites for excavation of woodpecker nest holes.

CHAPTER FIVE

SUMMARY AND CONCLUSIONS

5.1 Summary

The purpose of this thesis has been to identify and discuss habitat and nest box characteristics that affect use of nest sites by mountain bluebirds in southwestern Manitoba. Several stepwise discriminant function analyses were performed on data collected from 1169 nest boxes. All analyses provided separation between nest sites used and not used by mountain bluebirds, but separation was not complete.

Measured surface cover types included wooded, shrub, and grass pasture, long grass, fallow field, and forest. All except fallow field contributed significantly to separation between sites used and unused in the first nesting period of mountain bluebirds. Wooded pasture was the heaviest weighted variable. Heavy negative weights on long grass, fallow field, and shrub pasture were predominant in the function derived from analysis of sites used and not used twice.

All nest box characteristics included in analysis of the first nesting period contributed significantly to group separation. Entrance hole diameter, distance to the nearest building, and box depth were the most important discriminating variables. These three variables also were prevalent when sites used and not used twice were compared.

Nest box properties provided better separation between groups than did surface cover characteristics. Similarly, when all variables were analyzed together, nest box properties dominated the discriminant function.

Other measured nest site characteristics included 1) directional location of nest box from road, 2) type of structure supporting the box, 3) land use in the area, 4) disturbance in the vicinity of the nest, 5) box condition, 6) orientation of entrance hole, 7) position of entrance hole with respect to road, 8) type of road near nest, 9) presence of utility line, 10) presence of livestock, and 11) box color. The former six variables appeared to have no effect on use by mountain bluebirds, while use of nest boxes in relation to the latter five was out of proportion to availability.

5.2 Conclusions

Availability of nest boxes was not likely a factor limiting the distribution of mountain bluebirds on nest box lines in southwestern Manitoba in 1980. The effect of tree swallows on mountain bluebirds was probably minimal because mountain bluebirds generally began nesting three weeks prior to tree swallows. House sparrows, however, appeared to limit the mountain bluebird distribution in proximity to buildings. The impact of interspecific competition on nest box use requires further study.

Mountain bluebirds used nest boxes in a variety of habitats but appeared to favor grass and wooded pasture and avoid shrub pasture, long grass, and fallow field. Nature of the surrounding terrain seemed relatively unimportant compared to nest box characteristics in affecting use. Distance to the nearest building, entrance hole diameter, and box depth are the most critical nest box properties with respect to use by mountain bluebirds.

My analysis supports the hypothesis that mountain bluebirds are euryvalent, but suggests that when nest sites are not limiting this species will discriminate between suitable and unsuitable nest sites. Since discriminant analysis is best suited to generating probable inter-relationships rather than testing specific hypotheses (Johnston 1978), the suggested associations between mountain bluebirds and their environment should be subjected to further scrutiny.

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APPENDICES

Appendix 1. Skewness and kurtosis values of variables included in discriminant function analyses.

Variable	Original data		Transformation	Transformed data	
	Skewness	Kurtosis		Skewness	Kurtosis
FOREST	1.940	- 3.923	logarithmic	0.329	-1.596
WPAS	2.003	3.662	logarithmic	0.511	-1.534
SPAS	3.394	14.843	logarithmic	0.957	-0.776
GPAS	0.778	- 0.406	logarithmic	-0.304	-1.775
LGRAS	0.539	- 0.845	logarithmic	-0.406	-1.702
FALLO	1.970	3.333	logarithmic	1.082	-0.753
DSTREE	4.840	28.516	logarithmic	-0.195	0.935
DSBLDG	1.804	3.797	logarithmic	-0.224	-0.132
DSRD	7.956	75.264	logarithmic	1.202	4.611
AREA	2.403	9.530	logarithmic	1.410	2.507
HDIAM	1.074	2.426	logarithmic	0.624	0.244
DPTH	-1.656	2.658	4th power	-0.415	0.993
HGHT	-0.525	0.608	2nd power	0.195	0.953
BOXAG[a]	-0.269	-0.605	2nd power	0.928	1.478
LINAG[a]	-0.145	-0.292	2nd power	0.825	-0.373

[a] Variable was analyzed in original form because transformation did not improve skewness or kurtosis.

Appendix 2. Within-group correlation matrix of variables included in discriminant function analyses.

	FOREST	WPAS	SPAS	GPAS	LGRAS	FALLO	DSTREE	DSBLDG	DSRD
FOREST	1.000								
WPAS	-0.408	1.000							
SPAS	-0.246	0.077	1.000						
GPAS	-0.359	0.439	0.024	1.000					
LGRAS	0.199	-0.436	-0.067	-0.474	1.000				
FALLO	0.125	-0.330	-0.094	-0.352	0.017	1.000			
DSTREE	-0.249	-0.225	-0.126	0.106	0.143	0.020	1.000		
DSBLDG	-0.070	0.035	0.001	0.122	-0.147	-0.166	0.076	1.000	
DSRD	0.054	-0.054	-0.066	-0.012	0.060	-0.016	-0.013	-0.002	1.000
AREA	0.012	-0.105	0.058	-0.074	0.093	0.037	0.059	-0.051	-0.133
HDIAM	0.100	0.030	-0.104	-0.095	-0.018	0.065	-0.041	-0.082	-0.042
DPTH	0.054	0.102	-0.023	-0.043	-0.091	0.053	-0.125	0.022	0.103
HGHT	0.063	0.017	0.004	-0.027	0.006	-0.009	-0.080	-0.122	0.052
BOXAG	0.104	-0.095	-0.072	-0.045	0.022	0.024	0.048	-0.046	0.128
LINAG	0.077	-0.005	-0.143	0.047	-0.008	-0.148	0.078	0.125	0.066

	AREA	HDIAM	DPTH	HGHT	BOXAG	LINAG
AREA	1.000					
HDIAM	0.056	1.000				
DPTH	-0.430	-0.185	1.000			
HGHT	-0.015	0.108	0.060	1.000		
BOXAG	0.209	0.393	-0.332	0.071	1.000	
LINAG	0.091	0.153	-0.191	0.032	0.548	1.000

Appendix 3. Summary of stepwise discriminant function analysis of nest sites used and not used by mountain bluebirds in the first nesting period excluding nest boxes used by mice and squirrels. All variables were included in the analysis and are ordered according to entry into the stepwise procedure.

	F to enter	Standardized coefficients	Discriminant function parameters
HDIAM	56.89**	0.516	Wilks' lambda = 0.851
DSBLDG	36.43**	0.428	Chi-square statistic = 184.49
DPTH	26.42**	0.398	Significance = P< 0.001
GPAS	20.91**	0.259	Eigenvalue = 0.175
SPAS	8.87**	-0.177	Canonical correlation = 0.386
BOXAG	7.50**	0.301	Group centroids = -0.589, 0.297
WPAS	8.75**	0.394	Cases correctly classified = 67.4%
DSRD	6.88**	-0.222	
HGHT	4.59**	0.173	
DSTREE	2.66**	-0.207	
FOREST	4.06**	0.210	
AREA	2.35**	-0.136	
FALLO	1.33	-0.100	

** P< 0.01

Appendix 4. Summary of stepwise discriminant function analysis of nest sites used and not used by mountain bluebirds in the first nesting period excluding nest boxes used by mice, squirrels, and house sparrows. All variables were included in the analysis and are ordered according to entry into the stepwise procedure.

	F to enter	Standardized coefficients	Discriminant function parameters
HDIAM	44.86**	0.476	Wilks' lambda = 0.859
GPAS	25.49**	0.303	Chi-square statistic = 157.25
DPTH	26.79**	0.419	Significance = $P < 0.001$
DSBLDG	8.57**	0.302	Eigenvalue = 0.164
SPAS	7.38**	-0.205	Canonical correlation = 0.376
HGHT	6.48**	0.229	Group centroids = -0.528, 0.311
DSRD	6.45**	-0.242	Cases correctly classified = 66.7%
WPAS	5.15**	0.394	
BOXAG	5.92**	0.270	
DSTREE	3.10**	-0.223	
FOREST	2.48**	0.182	
AREA	1.76*	-0.124	
FALLO	1.64	0.136	
LINAG	1.13	0.110	

* $P < 0.05$; ** $P < 0.01$