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Effects of Army Training Activities on Bird Communities at the Piñon Canyon Maneuver Site, Colorado

by
David J. Tazik

This report describes a study conducted at the Piñon Canyon Maneuver Site, Colorado, a subinstallation of Fort Carson, which investigated species habitat relationships of, and impacts of Army training activities on, avian communities in shortgrass prairie and pinyon-juniper woodlands. This study also identified wildlife indicators of habitat change using both species and guild approaches. Principal Components Analysis (PCA) of vegetation data was used to quantify habitat gradients. Multivariate correlation analysis was employed to relate density and variety of bird species to derived PCA factors. Effects of Army training activities were evaluated by documenting density and richness of breeding bird populations over 2 years, during breeding season, once before and once after training.

Disturbance caused little response in either habitat. In prairie habitat, only grasshopper sparrows, and in woodlands only species richness exhibited any marked response to 1 year's training-related disturbance. The response was negative in each case. In both habitats, species richness is a good general indicator of changing conditions. While wildlife guilds may be useful indicators of major habitat changes, they were unresponsive to the levels of disturbance observed here.

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This report describes a study conducted at the Piñon Canyon Maneuver Site, Colorado, a subinstallation of Fort Carson, which investigated species habitat relationships of and impacts of Army training activities on avian communities in shortgrass prairie and piñyon-juniper woodlands. The study also identified wildlife indicators of habitat change using both species and guild approaches. Principal Components Analysis (PCA) of vegetation data was used to quantity habitat gradients. Multivariate correlation analysis was employed to relate density and richness of breeding bird populations over 2 years, during breeding seasons, once before and once after training.

Disturbance caused little response in either habitat. In prairie habitat only grasshopper sparrow, and in woodlands only species richness exhibited any marked response to 1 year's training-related disturbance. The response was negative in each case. In both habitats, species richness is a good general indicator of changing conditions. While wildlife guilds may be useful indicators of major habitat changes, they were unresponsive to the levels of disturbance observed here.

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1 INTRODUCTION

Background

The Department of the Army acquired the Piñon Canyon Maneuver Site (PCMS) in 1983 fo rthe 4th Infantry Division (Mechanized) at Fort Carson, CO. The 104,000 hectare site is large enough to permit brigade level tactical maneuvers accompanied by air and artillery support. These activities involve the use of a variety of tracked vehicles that can inflict considerable damage on soils, vegetation, and wildlife. Such damage can seriously impair long term of the land for training by loss of concealment cover, by soil erosion, and by the creation of environmental hazards. Direct impacts on wildlife populations result from noise and physical disruptions, while secondary impacts arise from damage to vegetation. The latter alter or diminish food resources, foraging and nesting substrates, and cover.

Numerous studies have been carried out on Army lands to measure the effects of training activity on wildlife (Ref 17, 18, 32, 56, 58, 59, 60, 61, 68).* These studies have helped to identify species and species groups (guilds) affected by activity, to mitigate those impacts, and to identify useful indicators of wildlife habitat conditions.

Birds are considered useful indicator species for their sensitivity to changing habitat and environmental conditions, and because they are easily censused (Ref 26,66). A wildlife guild is a group of species that use the same resources in a similar way (Ref 52). The guild concept has been applied in environmental assessment studies that emphasize avian communities (Ref 9, 16, 31, 34, 39, 55, 58, 62, 65, 73). The guild approach is applied here in addition to the species approach in order to measure the effects of Army training maneuvers on communities of interrelated species on isolated species.

Objective

The objectives of this work are:

1. To determine species habitat relationships of birds occupying training areas on PCMS

2. To document responses of these species and resource-based wildlife guilds to 1 year of training activity

3. To identify which species are useful indicators of habitat conditions.

This information will help natural resource managers to better manage the PCMS avifauna and associated ecological communities, and will serve as a basis for predicting the effects of subsequent training activities.

*The reference list begins on page 36.

Approach

Extensive field studies were conducted during the breeding seasons prior to and following initiation of training on PCMS in 1985. Study sites were selected to represent a broad range of habitat conditions in prairie, scrub, and woodland. Data were collected on bird species abundance, and vegetation structure and composition.

Mode of Technology Transfer

The study design employed here should be considered as a possible supplement to existing Land Condition-Trend Analysis (LCTA) standardized inventory procedures. The indicator species identified should be employed in the analysis of LCTA wildlife data collected in pinyon-juniper and shortgrass prairie habitats.

2 GENERAL DESCRIPTION

Piñon Canyon is located in Las Animas county, 40 km north-northeast of Trinidad, in the high plains of south central Colorado (Figure 1).* Elevation ranges from 1311 to 1737 m, generally sloping east and southeast to a low point in the Purgatoire River Valley which bounds the parcel (Ref 79). The climate is semiarid, with annual precipitation of 33.5 cm, two-thirds of it falling from April through August. Diurnal temperature ranges are large. Mean minimum and maximum temperatures vary by 17 °C in January (-9 °C to 8 °C) and July (14 °C to 31 °C), respectively the coldest and warmest months.

Landscape Types

Four major landscape types have been delineated based on soil characteristics (Ref 70) (Figure 1). Silty Level Plains consist of silty, calcareous soils with occasional limestone outcrops. Tolling Silty and Shaley Plains soils range from silty on flats to clayey on broad elevated areas. Limestone Hills and Ridges soils vary from silty to stone covered. Sandstone Canyon and Breaks are a series of steep, rocky cliffs and rolling mesa tops formed along the Purgatoire River canyon; noncalcareous soils range from silty on rolling hillslopes to stony on the steepest portions.

Vegetation

Shortgrass prairie and pinyon-juniper woodland are the two major habitat types (Ref 50, 70). Prairie vegetation dominates the Silty Level Plains and the Rolling Silty and Shaley Plains landscape types. Blue grama *(Bouteloua gracilis)*, galleta grass *(Hilaria jamesii)*, and western wheatgrass *(Agropyron smithii)* are the most commonly encountered grasses. Squirreltail *(Sitanion hystrix)* and six weeks grass *(Volpia octoflora)* are common on disturbed sites. Yucca *(Yucca glauca)*, cholla cactus *(Opuntia arborescens)*, prickly pear *(O. polycantha)* and a variety of low shrubs (winterfat, *Ceratoides lanata*, bigelow sage, *Artemisia bigelovii*, and snakeweed, *Gutierrizia sarothrae)* are present to varying degrees.

Pinyon pine (*Pinus edulis*) and one-seed juniper *(Juniperus monosperma)* occur in varying proportions in woodlands within the Limestone Ridges and Hills and the Sandstone Canyons and Breaks landscape types. Woodland associated shrubs include mountain mahogany *(Cercocarpus montanus)*, bigelow sage, greasebush *(Forsellisia spinescens)*, and skunkbush *(Rhus trilobata)*. Herbaceous vegetation is dominated by blue grama, galleta, snakeweed, needle-and-thread *(Stipa comata)*, and New Mexican feathergrass *(S. neomexicana)*. A large portion of woodland in these areas is off limits to tactical vehicles (Figure 2).

A shrub habitat characterized by four-winged saltbush *(Atriplex canescens)* and greasewood *(Sarcobatus vermiculants)* occurs along flats bordering streams.

Land Use

PCMS was used as grazing land prior to Department of the Army acquisition. The parcel is divided into five land management units to facilitate a rest-and-rotation scheme (Ref 70) (Figure 1) that uses only three units in any 1 year. In a 5-year period, each unit would be rested for 2 years and used for 3.

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*All figures and tables included at end of text.

Military exercises began in August 1985. Three major training cycles were completed prior to April 1986 in management units A, B, and C. These exercises involved the use of 143 to 149 tank and tank-like vehicles, 289 to 302 armored personnel carriers (APC) and APC-like vehicles, 818 to 870 wheeled vehicles, and 3180 to 3351 personnel over 25 to 29 day periods. A fourth training cycle of 3 days involved 152 tanks, 50 APC, and 956 wheeled vehicles and was accompanied by 2520 personnel.*

* Mr. Chuck Markel, Range Control Officer, and Mr. Thomas Warren, Director, Environment and Natural Resources, Directorate of Engineering and Housing, Fort Carson, CO.

3 METHODS

Site Selection

Since units A, B, and C were scheduled for use in 1985, most of the 29 sites selected for study were in those units. There were also several study sites in areas less likely to receive vehicle use during the first year of training.

Selected sites included a wide range of soil and vegetation types. Selection was based on examination of soil survey and topographic maps, and upon on-site observations. Seventeen prairie and prairie/shrub sites (henceforth referred to as prairie sites) and 12 pinyon-juniper sites were included (Figure 2).

Birds

Bird censuses were completed between 23 May and June in both 1985 and 1986. Each site was censused four times; all observations were made within 4 hours after sunrise. On prairie sites, the Emlen transect method (Ref 23, 24) was employed using two 500 m long transects, 200 m to 250 m apart, on each site. Observations were made by moving slowly along each transect (15 to 20 minutes each), while recording the location of all birds seen or heard within 100 m. For each species, data were tabulated separately for singing males, all other observations, and total observations. Coefficients of detectability (Ref 23) were calculated for each and densities were estimated by multiplying the raw count by the corresponding coefficient. Reported densities are the greater of: singing male data x 2, all other observations, or total observations (Ref 25).

The variable circular plot (VCP) method as described by Reynolds and coworkers (Ref 49) was used on woodland sites because it is better suited than the transect method to the insular nature and rough terrain of this habitat. The plot size is variable in accordance with the detectability of each species. Species usually observed at close range (e.g., less than 30 m) will have a relatively small effective plot size as compared to more conspicuous species frequently detected at greater distances (e.g., more than 75 m). At each visit to a given VCP, observations were made during two consecutive 5-minute periods. Locations of all birds seen or heard within 100 m of the center point were recorded. Three plots per site were censused in 1985, four per site in 1986. Minimum distance between center points of any two VCP's was 180 m.

Bird Guilds

Two guild classifications were used. First, as suggested by De Graaf and coworkers (Ref 16), species were grouped according to their foraging habits. In this way, species were categorized by the substrates from which they obtain food, by their foraging techniques, and by their major food resources. Then species were categorized by habitat zone used for feeding and nesting (Ref 62, 73) (Appendix A). Guild assignments were based on literature sources and direct field observations.

In several instances it was difficult to assign a species to a single guild. In the cases of Bewick's wren and the ash-throated flycatcher in the woodland foraging guilds, single species were split equally into two different guilds. Bewick's wren was split between the foliage gleaning insectivore guild and the ground gleaning insectivore guild. The ash-throated flycatcher was split between the air sallying insectivore guild and the foliage gleaning insectivore guild. In each case the two guilds represent about half the species foraging habits; neither guild predominates. In instances where overlap into another guild is important but where one guild does predominate, the species is assigned to the most representative guild. These species are listed in parentheses in Figures 5, 8, 25, and 28 but are ignored in the analysis.

Vegetation

Prairie Habitat

Vegetation data were collected between 3 and 19 June 1985 on all bird census plots. On prairie sites, eight randomly oriented vegetation transects per site were located with starting points 100 m apart along each 500 m bird transect. Ground cover was estimated by recording species present at each meter mark. At each even meter mark (200 points total per site), a vertical profile of vegetation was obtained using a 5 mm diameter, 5 dm long rod divided into five 1.0 dm intervals. Species contacting the rod within each vertical decimeter interval were recorded.

Ground cover was classified as percent bare ground (no cover under 5 dm), percent grass cover, and percent forb cover. Grass cover was further subdivided into percent short grasses (e.g., grama grasses and ring muhly, *Muhlenbergia torreyi*) and medium grasses (e.g., galleta grass and wheatgrass). The latter exhibited a taller growth which might affect grassland birds.

Several variables were derived from vertical profile data:

1. Average number of hits per transect per site (AVHIT), an index of vegetation volume, was calculated by taking the average over the eight transects of the number of times a decimeter interval contacted any vegetation. Five decimeter intervals along the rod and 200 recording points give a possible total of 1000 dm interval hits and a maximum average of 125 hits per site (1000/8).

2. Average height of hits (AVHGT) was calculated by the frequency of vegetation contact in each decimeter interval. The first decimeter interval was assigned a value of one, the second a value of two, up to five.

3. Average maximum (AVMAX) was derived by averaging the highest measured hit in each of the eight transects.

4. The number of points with one or more vegetation contacts within a given decimeter interval were summed to yield H1, H2, H3, and H4, corresponding to intervals one, two, three, and four and greater, respectively.

Small shrub coverage (m^2/ha), including half-shrubs, broad-leaved shrubs, cacti, and yucca between 2 and 5 dm tall, was estimated using the line intercept method (Ref 12, 22, 38). Coverage was calculated as:

$$\text{Coverage} = 10^4/nL \times \sum_{i=1}^{m} y_i \qquad \text{[Eq 1]}$$

where n = number of transects
m = number of individual plants encountered
L = vegetation transect length
y = distance along the line to the nearest cm covered by a vertical projection of the ith plant.

Coverage (m^2/ha) of broadleaved shrubs, cholla cactus, and yucca taller than 5 dm, as well as the sum of these (large shrub cover) was estimated using a 5 m wide belt centered on the line transect. The diameter of each individual whose center fell within the belt was measured to the nearest centimeter along the broadest axis of the plant (d1) and along an axis perpendicular to the first (d2). Aerial coverage was then estimated using the formula for the area of an ellipse:

$$\text{Coverage} = \pi/4 \times (d1 \times d2) \qquad \text{[Eq 2]}$$

Cholla cactus density (no./ha) was also obtained using the belt transect.

Pinyon-Juniper Habitat

On pinyon-juniper sites, two 50 m vegetation transects were randomly located within each bird census plot as follows:

1. The center point of one was established in a random direction 25 m from the center point of the plot.

2. The center point of the second was placed 25 m from the plot center in the diametrically opposing direction.

3. Each 50 m transect was laid out in a random direction.

Tree density and coverage of shrubs, yucca, and cholla taller than 2 dm were estimated using the line intercept method. Ground cover below 5 dm was recorded by species at each meter mark along each transect.

Disturbance

At each site in 1986, the percentage of ground disturbed by vehicle tracking was estimated using several 100 step, randomly oriented foot-transects (approximately 100 m long). At each step, the observer noted whether a vehicle track was present at the tip of the toe and totaled the number of such points where tracks were present. On prairie sites, 10 foot-transects were employed, one originating at each 100 m mark of the bird transects. On pinyon-juniper sites, seven such transects were employed; one originated at the center point of each of the four circular bird plots, and three others began at midpoints between each of the four plots.

4 DATA ANALYSIS

Species Habitat Relationships

Species habitat relationships were analyzed using 1985 bird and vegetation data. Species observed on three or more sites within one habitat type were included. Species were grouped by cluster analysis by their similar distribution among plots. The unweighted group averaging cluster procedure, a hierarchical clustering method used in ecological studies, was used (Ref 32, 47). Density estimates were standardized before clustering to equalize the relative influence of abundant and rare species.

Many environmental factors influence the distribution and abundance of wildlife. Delineating the factors most important to a species is a major challenge in the field of wildlife ecology. In this case, stepwise multiple correlation analysis was used to assess species habitat association. This procedure attempts to identify a set of variables (vegetation variables in the present case) that best account for spatial variability in abundance of a particular bird species.

A primary assumption of multiple correlation analysis is that the vegetation variables to which bird densities are to be correlated are mutually independent. Since the vegetation variables are intercorrelated this assumption does not hold. To address this problem, vegetation data were first analyzed using principal components analysis (PCA).

PCA takes a large, complex set of variables and consolidates them into a smaller set of uncorrelated principal components (PC) that do meet the assumption of independence (Ref 15, 27, 33, 47). PCA also helps to define important habitat gradients across the study sites. Ecological relevance is retained to the extent that each PC is correlated with a distinct subset of the original variables. For example, a PC that is positively correlated with tree cover, tree density, woody foliage volume, and leaf litter, and negatively correlated with grass cover, clearly represents a gradient in abundance of woody vegetation. PCA generates factor scores for each study site that are then plotted in two dimensions to illustrate such gradients. An assumption in using PCA here is that bird species respond to these major habitat gradients (Ref 77). For stepwise multiple correlation analysis the F-to-enter criterion used was $p \leq 0.15$ (Ref 3).

Disturbance Impacts

Sites within each habitat type were grouped according to level of tracked vehicle disturbance as measured by the foot-transects. Sites were subjectively categorized from least disturbed (DL1) to most disturbed (DL2, in pinyon-juniper sites, or DL3, in prairie sites) based on obvious discontinuities among sites in levels of disturbance (Tables 2 and 4). Although this approach is somewhat arbitrary, an *a priori* grouping was impossible given our inability to control use of areas by the military. Means for species, guild, total density, and species richness were plotted to show trends for each disturbance level over the 2-year period. A fixed factor analysis of variance on the difference between years in these parameters was employed to test for differences in response between levels.

Statistical Analyses

All statistical analyses were performed using SYSTAT Version 3 (Ref 80). When appropriate, data were transformed using natural logarithms to meet the statistical requirement of normal distribution (Ref 27). The arcsine transformation was used for percentage data (Ref 64).

5 RESULTS

Prairie Birds

Data were sufficient to estimate densities for 26 bird species, 23 in 1985 and 19 in 1986 (Appendix C, Tables C1 and C2). Over the 2 years average total density remained nearly the same (168.8/100 ha in 1985 vs. 180.8/100 ha in 1986), but species richness declined from 7.4 to 6.1 species per site ($p \leq 0.05$).

Figures 3 and 4 summarize total and relative density, and frequency of occurrence of species on prairie sites. Western meadowlarks, horned larks, and lark buntings dominated in 1985, accounting for 64 percent of total. While lark buntings disappeared in 1986, meadowlarks and horned larks increased substantially, accounting for 69 percent of the later total. Lark and Cassin's sparrows ranked next followed by grasshopper sparrows and mourning doves. Lark sparrows increased markedly over the 2 years, while the latter three declined. Mockingbirds, western kingbirds, and Brewer's sparrows were not common to most prairie sites. Water pipits and loggerhead shrikes also occurred on three or more sites in both years but in small numbers.

The four habitat zone guilds boxed in Figure 5 account for 19 of the 26 species and over 99 percent of total density in each year (Appendix C, Tables C3 and C4). The ground-ground (feeding zone-nesting zone) guild cell contains birds typical of grassland situations, although lark sparrows are also associated with open woodland. Ground-shrub species are associated with shrub and prairie shrub habitat. Species in the other two cells did not nest on prairie sites except for kingbirds, on site 37, and mockingbirds and northern orioles, on site 3. (Both of these sites contained trees.)

Total and relative density, and frequency of occurrence of habitat zone guilds are plotted in Figures 6 and 7. Ground-ground and ground-shrub guilds accounted for over 93 percent of yearly totals. Ground-ground guild density increased markedly between the 2 years, while ground-shrub density decreased. These changes are consistent with patterns shown by the dominant members of these guilds. In the ground-ground guild, meadowlarks, horned larks, and lark sparrows increased between years, while in the ground-shrub guild, lark buntings and Cassin's sparrows declined (Figures 3 and 4).

Classification of species by foraging guild is presented in Figure 8. Twenty of the 26 species fall into four guild categories that account for approximately 99 percent of total density in each year (Appendix C, Tables C3 and C4). Ground foraging omnivores and ground gleaning insectivores clearly dominated overall (Figures 9 and 10).

Total and relative density of foraging guilds remained remarkably similar in each year despite marked changes in some constituent species (Figures 9 and 10). Among ground foraging omnivores, the increase in numbers of horned larks in 1986 appears to have compensated for disappearance of lark buntings (Figure 10) overall, as well as on a site-by-site basis ($r=-0.60$, $p \leq 0.01$). Among ground gleaning insectivores, an overall increase in meadowlarks compensated for an overall decline in numbers of Cassin's sparrow. Although on a site-by-site basis this compensation effect was irregular, there was a positive correlation between the changes in these two species ($r=0.50$, $p \leq 0.05$).

Prairie Habitat Analysis

Prairie vegetation data presented in Appendix D (Table D1). PCA resulted in five PC factors that account for 86.9 percent of variance in the original vegetation variables. Correlation coefficients in Table 1 indicate relationships between each factor subsets of the original variables. Figures 11A-C illustrate the position of each prairie site relative to these habitat factors.

Factor I, the primary habitat gradient, is related to abundance of medium grasses and shrubs and accounts for 28 percent of variation in the vegetation variables (Table 1). Sites 15, PC1, PC2, and 19 scored high on this axis (Figure 11A). Factor II represents a gradient of areas of mostly grass cover to those with more bare ground and broadleaved shrub cover. This factor largely distinguishes site 19 from the others (Figures 11A and 11B). Factor III is associated with large shrub abundance, cholla cactus, and various other tall vegetation (Figure 11B). Factor IV relates to tree and forb cover, the distinguishing characteristics of sites 3 and 37 (Figure 11C). Juniper were present in near equal numbers on these two sites. Factor V is associated with yucca and small shrub cover. For clarity of discussion, the following labels are used:

Factor	Label
I	VEG VOL
II	BROADLEAVED/SPARSE GRASS
III	LARGE SHRUB/CHOLLA
IV	TREE/FORB
V	YUCCA/SMALL SHRUB

Prairie Birds: Species Habitat Relationships

Results of cluster analysis are shown in Figure 12. The first major division is between bird species that were associated with woody vegetation (further split into Woodland species and Shrub species) and those associated with grassland. Although typical of grassland habitats, here the western meadowlark is associated with species that prefer shrub habitat.

Figures 13 through 16 show results of multiple correlation analysis. The statistically significant amount of variance in bird species density or richness accounted for by each PCA factor is indicated. Solid bars represent a positive relationship, open bars a negative one.

The amount of variance explained by PC factors ranged widely from zero in the case of Cassin's sparrow to nearly 95 percent in mockingbirds. The average among the eleven species with significant multiple correlations (excluding Cassin's sparrow) was 66.8 percent. Species below the average included the western kingbird, the water pipit, the lark bunting, and Cassin's sparrow. Species with particularly high values (>70 percent) included the mockingbird, Brewer's sparrow, the shrike, and the horned lark. PC factors accounted for only 41.6 percent of variance in total density but over 64 percent of variance in species richness. VEG VOL, LARGE SHRUB/CHOLLA, and TREE/FORB were the most important PC factors, showing significance in eight, seven, and six of the twelve species respectively, as well as in total density and/or species richness.

Each Woodland species was strongly associated with TREE/FORB (Figure 13). All but the kingbird (especially the lark sparrow) were also associated with LARGE SHRUB/CHOLLA. Mourning doves and, to a lesser extent, mockingbirds were associated with VEG VOL. BROADLEAVED/SPARSE GRASS associate only with mockingbirds. Brewer's sparrow and loggerhead shrike (Figure 14) were most strongly associated with BROADLEAVED/SPARSE GRASS followed by LARGE SHRUB/CHOLLA and VEG VOL.

Western meadowlarks and the Shrub species were positively related to both LARGE SHRUB/CHOLLA and VEG VOL (Figure 15). Meadowlarks differed from the Shrub species in not being associated with BROADLEAVED/SPARSE GRASS, and by showing a strong negative association with YUCCA/SMALL SHRUB.

Patterns among Grassland species were inconsistent (Figure 15). Horned larks were unique in their negative response to each of the first four factors. Grasshopper sparrows associated negatively with BROADLEAVED/SPARSE GRASS, but were strongly and positively associated with VEG VOL. Water pipits showed a negative association with VEG VOL. Both water pipit and grasshopper sparrow densities were inversely related to YUCCA/SMALL SHRUB. Lark buntings were negatively associated with TREE/FORB. Cassin's sparrow showed no significant relationships.

Total density and species richness were both most strongly associated with LARGE SHRUB/CHOLLA (Figure 16). Total density associated with VEG VOL, species richness with TREE/FORB.

Prairie Birds: Response to Tactical Vehicle Disturbance

Classification of prairie sites by disturbance level (DL) and percent disturbance is presented in Table 2. Three DLs were recognized. Changes in bird densities between years within each DL are illustrated in Figures 17 to 22.

Differences among DLs were significant in only two species ($p \leq 0.05$)--mourning doves and grasshopper sparrows. Numbers of doves increased in DL2 but declined at a similar rate in both DL1 and DL3 (Figure 17). Since DL1 sites were the least and DL3 sites the most disturbed, this pattern of change appears unrelated to disturbance. In contrast, numbers of grasshopper sparrow increased in DL1 and declined in DL3 (Figure 19); this pattern indicates a disturbance effect. None of the Shrub species exhibited a response to disturbance (Figure 18).

Change in total density between years differed markedly among disturbance levels (Figure 20). Density increased similarly in DL1 and DL2, but declined substantially in DL3. This effect was due primarily to disappearance of lark buntings in 1986; note the effect of excluding lark bunting numbers from total density in Figure 20.

Although there was a marked overall decline in average species richness, declines were similar in DL1 and DL3 (Figure 20). Species number increased only slighdy in DL2. After excluding lark buntings, differences between DLs while nearly significant ($p=0.06$), are not consistent with a disturbance effect.

No marked response to disturbance was found among the foraging guilds (Figure 21). Ground foraging omnivores exhibited a nearly significant trend ($p=0.09$) prior to removal of lark buntings from yearly totals (an increase in DL1 nd DL2 and a decrease in DL3). After removal of lark buntings the three DLs exhibited similar increases. Ground gleaning insectivores showed a suggestive but insignificant pattern. Air sallying insectivores were too few on most sites for a meaningful analysis. Mourning doves were the sole representatives of the ground gleaning granivores, and are treated above.

Habitat zone guilds also appeared unresponsive to disturbance (Figure 22). The disproportionately sharp decline in ground feeding-shrub nesters in DL3 was statistically insignificant ($p=0.11$) and heavily influenced by the decline in numbers of lark buntings.

Pinyon-Juniper Birds

Excluding swallows, 41 species were recorded (Appendix C, Tables C5 and C6). Although total species count across all sites declined from 39 to 34 between years, average species richness per site increased from 15.3 to 17.8 ($p=\leq0.05$). Total density increased from 256.6 to 332.6 per 100 ha ($p\leq0.01$).

Sixteen species contributed 1 percent or more to total density (Figures 23 and 24), and together accounted for 94 to 95 percent of the total each year. Mockingbirds, lark sparrows, mourning doves, Bewick's wrens, and meadowlarks were observed on all woodland sites each year, and constituted over 70 percent of yearly totals. Others contributed less than 5 percent to total numbers. Only four species increased markedly between years: the lark sparrow, the meadowlark, the cowbird, and the titmouse (Figure 23). None declined substantially.

The 26 species in seven guilds boxed in Figure 25 accounted for over 95 percent of total density each year (Appendix C, Tables C7 and C8). The ground-lower canopy guild, dominated by doves and mockingbirds, and the ground-ground guild, dominated by meadowlarks and lark sparrows, were most abundant overall (Figures 26 and 27). The ground-ground and lower canopy-bole guilds increased markedly in 1986. A few species tended to dominate individuals guild (Figure 30).

Thirty-five species included in seven foraging guild blocks accounted for 99 percent of total density each year (Figure 28, and Appendix C, Tables C7 and C8). Ground foraging omnivores with 10 species constituted nearly 50 percent of yearly totals, and were substantially more abundant in 1986 (Figures 29 and 30). Ground gleaning insectivores and foliage foraging omnivores were more abundant in 1986. Again, relatively few species tended to dominate individual guilds (Figure 30).

Pinyon-Juniper Habitat Analysis

Vegetation data for pinyon-juniper sites are presented in Appendix D (Table D2). PCA results are illustrated in Table 3 and Figures 31A and 31B.

Four PC factors were derived which accounted for 81 percent of variance in the original 10 variables. Factor I represents a tree density gradient accounting for over 35 percent of variance in vegetation measures. Tree density tended to be inversely related to small shrub and grass cover. Sites in the limestone hills, excepting sites 6 and 11, scored highest on this PC, while sandstone sites scored low (Figure 31A). Factor II is positively associated with large shrub cover, but negatively related to dead tree density. Limestone hills sites ranged widely along this axis, while sandstone sites scored above average. Factor III is correlated with increasing bare ground and decreasing grass cover. Factor IV correlates with forb cover. There is fairly wide scatter along each of these latter two axes (Figure 31B) without any clear regional pattern. Each factor will be referred to as:

Factor	Label
I	TREE
II	LARGE SHRUB
III	BARE GROUND
IV	FORB

Pinyon-Juniper Birds: Species Habitat Relationships

Woodland bird species clustered into seven groups (Figure 32). The lark sparrow, a species of sparse woodland and edge, clustered alone. Three other groups were labeled as Woodland I, II, and III for reference below. Three other clusters exhibited little or no relationship to habitat variables and were left unlabeled.

PC factors accounted for an average of 62.6 percent of density variation among the 17 species exhibiting a significant multiple correlation. Species substantially below this average (<50 percent) include the mountain bluebird, the rufous-sided towhee, the common nighthawk, and the house finch. Those well above average (>70 percent) include the lark sparrow, Bewick's wren, the brown-headed cowbird, the ash-throated flycatcher, and the western meadowlark. PC factors accounted for 62.1 percent and 73.6 percent of variance in total density and species richness respectively. TREE and LARGE SHRUB were most important overall, entering multiple correlations in 11 and 12 cases respectively, as well as in the cases of total density and species richness.

Lark sparrows exhibited a strong negative association with TREE (Figure 33), while Woodland I species demonstrated a consistent positive relationship (Figure 34). The positive response of lark sparrows to LARGE SHRUB and negative association with BARE GROUND also contrast with trends among Woodland I species. Three species among the latter group exhibited a negative response to LARGE SHRUB, while the mourning dove exhibited a positive response to BARE GROUND. Pinyon jays exhibited a small negative association with BARE GROUND. Forb cover accounted for a small portion of variation in numbers of Bewick's wren.

Woodland II species were consistent in their negative association with BARE GROUND (Figure 35). LARGE SHRUB accounted for some portion of variability in density of all but western kingbirds. TREE was positively related to density of brown-headed cowbirds, ash-throated flycatchers, and western kingbirds.

Woodland III species appeared unaffected by tree density (Figure 36), and were consistent in their negative association with LARGE SHRUB. FORB cover accounted for substantial portions of density variation in both meadowlarks and mockingbirds. Meadowlarks exhibited a small positive response to BARE GROUND.

LARGE SHRUB and FORB each accounted for a significant portion of variation in total density and species richness of pinyon-juniper birds* (Figure 37). Species richness was also strongly associated with TREE.

Pinyon-Juniper Birds: Response to Tactical Vehicle Disturbance

The percentage of terrain showing vehicle disturbance ranged from near zero to over 60 percent, which included categories DL1 and DL2 (Table 4). Little of the observed disturbance resulted in loss of trees or tree cover.

None of the species examined exhibited a marked response to disturbance, although responses of mountain bluebirds and house finches were nearly significant ($0.05<p<0.10$). Many species showed

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remarkably similar trends over the 2 years (Figures 38-42), but densities of some of those species were too low for meaningful analysis.

Species richness did show a significant disturbance response (Figure 43) but total density did not. Responses were not significant among any of the foraging or habitat zone guilds (Figures 44 and 45).

6 DISCUSSION

Prairie Birds

Twenty-six bird species were observed over 2 years on 17 prairie and prairie/shrub sites. Species richness ranged from 3 to 15 species per plot with yearly averages of 6.1 and 7.4. This is considerably higher than the range of 2 to 6.2 and the average of 4.3 reported for 19 shortgrass prairie sites by Wiens and Dyer (Ref 76). Trees (sites 3 and 37) or shrubs (especially site 19) present on several of our sites substantially enhanced species richness.

Total species count declined from 23 to 19 between 1985 and 1986 due to the absence in 1986 of several woodland or scrub species uncommon in prairie habitat that were present in 1985. Decline in average species richness from 7.4 to 6.1 on the other hand was related to losses from several sites of three grassland species: the grasshopper sparrow, Cassin's sparrow, and especially the lark bunting.

Total density ranged from 80 to 259.5/100 ha, with yearly means of 168.8 and 180.8. These figures fall within the range of 74.7 to 526.3 reported by Wiens and Dyer (Ref 76), although their average was higher at 282.3. Cody (Ref 14) reported an average of 200 birds per 100 ha. Shortgrass prairie sites at Fort Carson, CO had bird densities of 60 to 80 birds/100 ha (Ref 18, 68). The PC and PT prairie sites at PCMS were reported to have densities of 75 and 137 birds/100 ha respectively in 1983 (Ref 17), considerably lower than the 133 to 171.3 and 180.8 to 234.5 birds/100 ha observed here. Variation in habitat, methodology, and annual weather conditions, as well as differences among observers contribute to variability in reported density estimates.

Prairie Bird Guilds

Foraging guilds represent a functional view of the community that relate species to available food resources (Ref 16). Prairie sites were dominated by ground feeding and ground nesting species (Figures 6, 7, 9, 10), typical for this structurally simple habitat type. Shrub nesters were more important in 1985 when lark buntings were present.

If food resources and associated substrate do not change, one would not anticipate major changes in associated foraging guilds. We observed little change in absolute and relative numbers among foraging guilds between years despite marked changes in density of several species (Figure 10). Thus, one year of military training activity appears to have had little impact on foraging guilds and underlying foraging resources.

The habitat zone guilds used here are similar to the guild blocks proposed by Short and Burnham (Ref 62), and the management guilds defined by Verner as, ". . . a group of species that respond similarly to a variety of changes likely to affect their environment." (Ref 73, p 3). Over time, changes in habitat zone guilds should reflect structural alteration in habitats inventoried. While the observed increase in the ground-ground guild accompanied by declines in the ground-shrub guild (Figure 6) suggests a substantial change in shrub cover between years, it was attributable largely to shifts in abundance of lark buntings and horned larks, and was probably not related to habitat alteration. Local abundance of lark buntings can vary considerably from year to year for reasons that are still not entirely clear (Ref 30). Horned larks, on the other hand, increased similarly in each disturbance level (Figure 19), as did the habitat and foraging guilds of which it is a member (Figure 22); horned larks may have expanded in response to a decline in lark buntings. Overall variation at the level of management guilds in this case is misleading.

Species Habitat Relationships

Species richness was most strongly correlated with vertical habitat complexity. Addition of trees and large shrubs had a marked positive effect by providing additional foraging and nesting opportunities. However, small shrub and yucca cover had no apparent impact on species richness.

Total density was positively influenced by large shrub cover and vegetation volume. This is not surprising given that these had positive impacts on several individual species. The relatively low total variance explained by LARGE SHRUB/CHOLLA and VEG VOL (41.6 percent) was due to a negative trend exhibited by the abundant horned lark that offset a positive trend among several other species.

Woodland Species. Presence of woodland and woodland edge birds on prairie sites reflects the added structural complexity of trees, shrubs, and arborescent cacti. Sites 3 and 37, with trees, and site 19, abundant in tall broadleaved shrubs, harbored most of these species.

Lark sparrows were the most numerous and frequently encountered species in this group. Densities were higher than on many woodland sites, consistent with their preference for savannah-like conditions (Ref 30). Scattered trees, cholla cactus, and other large shrubs appear to increase their numbers (Ref 77).

Although mourning doves are not common on shortgrass prairie (Ref 75), they do occur and have been known to nest in open grassland far from tree cover (Ref 1,30). Doves were present on many sites but were sparse (Figure 4) and probably did not nest except possibly on sites 3 and 19. Laurion (Ref 36) observed dove nests on only 2 of 10 prairie sites studied at PCMS--a cholla-sand prairie and a yucca-juniper prairie.

Mockingbirds are even more restricted to woodlands than doves (Ref 30). Here they were abundant only on sites with tree or broadleaved shrub cover--3,19, and 37. Most observations were of individuals singing from the top of junipers or tall shrubs.

Trees were the most important factor influencing western kingbirds, although they are also known to nest in tall shrubs and yuccas (Ref 30). Nonetheless, both the western and Cassin's kingbird were abundant on site 17, which lacked trees and had little large shrub cover. This site appears to have been a productive foraging location as evidenced by frequent kingbird sightings there. Kingbirds are known to fly some distance from their nesting areas to feed (Ref 28), and commonly use a wide variety of perches (Ref 69).

Shrub Species. Brewer's sparrow and loggerhead shrike were most abundant on site 19, with its abundant broadleaved shrub cover. Both were also present each year on site 8, one of two other sites to have a substantial cover of broad-leaved shrubs (Table D1). Both species probably nested on site 19.

Others have reported a negative relationship between numbers of loggerhead shrikes and Brewer's sparrows (Ref 77). Reynolds (Ref 48) has suggested that shrikes may negatively influence populations of Brewer's and other sparrows by direct predation. The clustering of these two species suggests that habitat rather than predation was most limiting to Brewer's sparrow.

Brewer's sparrow is commonly associated with shrub-steppe habitat of the Great Basin (Ref 53,76). In the shortgrass prairie region it is a good indicator of broadleaved shrub cover. At PCMS there are several areas similar to site 19 that probably harbor this species. Although many of these sites occur near drainage areas, the species is not dependent upon free water (Ref 46). Laurion (Ref 36) reported that loggerhead shrikes are common residents in all habitat types on PCMS.

Western meadowlarks also fell into the Shrub group (Figure 12) owing to their high density on site 19 with its abundant shrub cover. However, meadowlarks are much more broadly distributed than the other Shrub group species and are for convenience treated along with the Grassland Species.

Grassland Species. This is a diverse group in terms of individual responses to habitat (Figure 15). Western meadowlarks and grasshopper sparrows were similar in their positive association with VEG VOL and negative response to YUCCA/SMALL SHRUB. Horned larks and water pipits, on the other hand, were both negatively related to VEG VOL. Horned larks were also unique in their negative association with tall vegetation. Lark buntings and Cassin's sparrow were similar in that neither exhibited particularly strong associations with the habitat variables.

Dense grass cover generally is considered to be a critical factor influencing meadowlark numbers (Ref 19, 30, 77). High density of meadowlarks in shrub habitat at site 19, where grass cover was at its lowest (33 percent) contradicts this notion. Although some minimum grass cover is required for nesting and foraging, data suggest that meadowlark numbers may be more strongly related to total volume of vegetation rather than grass cover alone. Bivariate correlation analysis revealed a correlation with AVHIT ($r=0.50$, $0.01<p\leq 0.05$), but not grass cover, and VEG VOL had a small but significant influence on meadowlark numbers. Also, taller vegetation, which adds to vegetation volume and is often used as a singing perch by meadowlarks, probably is important. Judging from their negative association with YUCCA/SMALL SHRUB, this cover appears unattractive to meadowlarks. Reasons for this are unclear.

Water pipits also showed a negative response to YUCCA/SMALL SHRUB. They avoided deep grass cover, preferring areas dominated by blue grama. Water pipits do not breed on PCMS, and occur as migrants in low numbers. They more commonly breed in montane grassland to the west (Ref 13, 72, 76).

Horned larks are common in short grasslands (Ref 30) and tolerate various disturbances (Ref 10, 36) including tactical vehicle impacts (Ref 19, 32, 56). At PCMS they avoided deep dense grass and shrub and tree cover, and preferred areas dominated by short grasses; other studies agree (Ref 10, 21, 32, 53, 75). In contrast to meadowlarks, horned larks place their nests in small grass clumps surrounded by bare areas (Ref 71); they do not require substantial ground cover, nor do they use elevated perches for singing.

Grasshopper sparrows clearly are associated with deep grass cover (see also Ref 10, 53, 75). When they did occur on sites dominated by short grasses (7, 38, PT1, PT2), they were recorded within isolated patches of medium grasses such as wheatgrass and galleta grass. The grasshopper sparrow responds to changes in grass cover (Ref 74), indicates low grazing pressure (Ref 10), and is negatively correlated with bare ground (Ref 53).

Although no PC factors explained variation in Cassin's sparrow densities at least some emergent vegetation such as cholla, yucca, or broadleaved shrub cover appears to be important (Ref 29). This species consistently used large shrubs as takeoff points for flight songs, a critical aspect of territorial advertisement (Ref 82). Also, in both years, this species was rare on sites with little or no such cover (sites 7, 13, and 29). A preference for moderate shrub cover may explain the lack of significant correlations. Multiple correlation analysis assumes that there will be a linear response to habitat variables. When a species exhibits preferences for intermediate values, a curvilinear response that goes undetected appears (Ref 44). That is, a species may increase in density in response to an increasing variable, but only up to a certain point where density levels off or declines. The linear correlation model used here does not detect such a response.

Lark buntings appear to tolerate a range of habitats, but avoid grassland with trees. While buntings often are abundant on shortgrass prairie, local abundance varies considerably from year to year (Ref 30).

Response to Disturbance

Species richness was not significantly affected by disturbance (Figure 10=9). Although, after disregarding lark buntings, there was a tendency toward marked variability among DLs (p=0.06), the pattern was not indicative of a negative response to disturbance: DL2 increased in richness, while both DL1 and DL3 declined. Of these two, the decrease in DL1 was related primarily to net loss of several woodland species not typically associated with prairies, while in DL3 the decrease was mainly in the grasshopper and Cassin's sparrows (see below) which appear to be sensitive to disturbance.

After lark buntings were removed from site totals, total density appeared unaffected by disturbance. Studies in prairie habitat at Fort Carson, CO and Fort Lewis, WA also revealed little difference in total density of grassland bird species between disturbed and undisturbed sites (Ref 18, 56).

Foraging and habitat zone guilds showed no marked response to disturbance (Figures 21 and 22). A possible negative response to disturbance among ground foraging omnivores and the ground-shrub guild was due to the influence of lark buntings. A similar tendency among ground gleaning insectivores, dominated by meadowlarks and Cassin's sparrows, was suggestive but not statistically significant.

The Woodland cluster of species occupying prairie sites showed no detectable response to disturbance (Figure 17). Significant loss of woody cover will have a negative impact on the use of prairie sites by these species in the future, but none of these represent a critical habitat for them. Each species is commonly associated with woodland habitat, and appears to be tolerant of a wide range of habitat conditions. Among these, lark sparrows may respond positively to a certain degree of disturbance (Ref 10,18).

Neither Brewer's sparrow nor loggerhead shrike were abundant enough to identify their response to disturbance. However, substantial loss of broadleaved shrub cover within the riparian shrub habitat type occupied by these species will likely be detrimental. Limits of tolerance of each to disturbance remain to be established.

Brewer's sparrow is sensitive to alterations in shrub cover (Ref 32, 78). In central Montana, Best (Ref 8) found that these sparrows tolerated a 50 percent reduction in foliage cover one year after herbicide application, but Brewer's sparrow declined appreciably on an area in which foliage cover was totally eliminated. Individuals shifted food resources to compensate for loss for foraging substrate, and nested deeper in larger shrubs to compensate for loss of foliar cover.

After 1 year of training activity, meadowlarks did not exhibit a marked response to disturbance. However, this species may respond negatively in the long run if habitat conditions are significantly degraded (Ref 19, 32). Given its widespread distribution and abundance on PCMS, meadowlarks should prove useful as an indicator of changing range conditions.

Horned larks appeared unaffected by vehicular damage. Other data agree with this (Ref 32) or suggest a positive response (Ref 19).

Only the grasshopper sparrow showed a clear negative response to disturbance, apparently as a result of tracked vehicles matting down its preferred cover of medium grasses. Although this makes the grasshopper sparrow a useful damage indicator, its restricted distribution and abundance, and potentially large annual fluctuations in breeding densities (Ref 1,30,63) limit its utility.

Overall, Cassin's sparrow did not show a clear disturbance response. However, a closer examination of six sites with substantial shrub cover suggests that this species may be responsive to tactical vehicle disturbance. Density increased an average of 2.7/20 ha on three relatively undisturbed shrub sites (3, 19, and 12) but declined 3.3/20 ha on three highly disturbed shrub sites (8, 10, and 15). Nonetheless, its utility as an indicator species is hampered by its normally large annual variation in numbers.

Pinyon-Juniper Birds

Species richness of pinyon-juniper birds ranged from 9 to 19 in 1985 and 12 to 24 in 1986, well within the range reported in other studies (Ref 2,17,18,36,68). The 16 percent increase in mean richness between years (15.3 to 17.8) is not abnormal (Ref 68), and is related to increased sampling effort in 1986.

Sites in the main portion of the Limestone Ridges and Hills (2,26,28,PJS, and PJN) tended to have the highest species numbers in each year (means of 18 and 22 in 1985 and 1986). Sites in the Sandstone Canyon and Breaks (36,39,and 45) tended to have fewer species (means of 10.7 and 13.7). Isolated stands of pinyon-juniper woodland in the limestone hills (6,11,and 21) exhibited intermediate numbers (means of 17 and 15.3). Laurion (Ref 36) reported similar species richness (17 to 19) on sites in the main portion of the limestone hills but observed 18 species in each of two sites in the sandstone region, which suggests that this area is not species-poor throughout.

Total density in pinyon-juniper woodlands may vary greatly both annually and geographically, due to variation in habitat, annual precipitation, winter weather, and pinyon pine cone production (Ref 2,18,43,68). Different observers and methodologies also contribute. The 30 percent increase in mean total density between years may result from one or more of these factors, and the larger 1986 sampling effort.

Total density on the 12 woodland sites ranged from 191 to 323/100 ha in 1985, and from 190 to 404 in 1986. This compares with a range of 433 to 605/100 ha on five PCMS sites reported on by Laurion (Ref 36), and a range of 124 to 177/100 ha on two PCMS sites reported on by Diersing and Severinghaus (Ref 17). The latter figures were obtained in the same area as our PJS and PJN sites, where an overall average of 274 birds/100 ha was observed.

Woodland Bird Guilds

As expected, guild structure in woodland sites was more complex than on prairie sites. Nonetheless, ground feeding species dominated in woodland sites as well as in prairie (Figures 26,27,29, and 30).

Increase in abundance of three of the foraging guilds was proportionate to the increase in total density, so that relative densities were similar through both years. This suggests little shift in the underlying food resource base between years. Two habitat zone guilds increased significantly between years--ground-ground and lower canopy-bole guilds. However, there were no dramatic overall changes in relative density of habitat zone guilds.

Species Habitat Relationships

Tree density was found to be an important factor influencing avian species richness in pinyon-juniper woodland. Masters (ref 41) reported a correlation between total bird density and pinyon pine density (in Ref 2) that was also nearly significant here as well ($r=0.55, p=0.07$).

It appears that LARGE SHRUB and species richness are negatively associated due to a strong correlation between richness and dead tree density ($r=0.87 p \leq 0.001$) which loaded negatively on this factor (Table 3). Richness showed no correlation with large shrub measures, which loaded positively on this factor.

Total avian density was unrelated to TREE. Although 10 to 22 species were positively related to this factor, there was a strong negative association between abundant lark sparrows and TREE. In contrast, Masters (Ref 41) found total bird density to be correlated with pinyon pine density in a year following a large cone crop (in Ref 2).

A negative association with LARGE SHRUB accounted for over 50 percent of variation in total density among sites in 1985. Eleven of 22 species exhibited a similar negative association, and only the lark sparrow exhibited a positive, though relatively weak, response.

Sparse Woodland. Lark sparrows were the sole member of this group. They were unique in their strong negative association with tree density, in agreement with known habitat preferences of the species (Ref 30) and with results of other studies (Ref 17). They were most abundant on the three sandstone sites with densities similar to those reported by Laurion (Ref 36) (98 to 139/100 ha vs. 92.5 to 105/100 ha). Lark sparrows clearly tolerate a wide range of habitat conditions, and generally increase in numbers with a decline in tree density. This species tolerates bare ground if there is some ground cover available for nesting.

Woodland I. Although they did not respond entirely alike, these seven species were most strongly associated with TREE. Nesting requirements seem to underlie this relationship. Two species are cavity nesters, while all the rest (except rufous-sided towhees) typically nest in foliage. Bewick's wren is sometimes a foliage gleaning insectivore which may further attract it to more wooded sites. LARGE SHRUB had a small but significant negative impact on the density of several of these species--scrub jay, Bewick's wren, and the mourning dove.

A strong relationship between pinyon jays and pinyon pine is expected, as this bird is behaviorally and physiologically dependent upon this tree species (Ref 37). The extent and timing of reproductive activity in pinyon jays is linked with periodically abundant cone supply. In years of low cone production these jays wander widely in search of food, and are attracted to individual pinyon trees.

Mourning doves associated positively with TREE in pinyon-juniper woodland and the TREE/FORB in prairie habitat. However, while doves respond negatively to LARGE SHRUB in woodlands, they respond positively to LARGE SHRUB/CHOLLA in the prairie. On the prairie, doves were probably limited by availability of woody cover, and responded positively to the presence of large shrubs.

Scrub jays and rufous-sided towhees prefer areas with dense cover (Ref 4, 7). Abundance of low growth in dense pinyon-juniper woodlands apparently satisfies this need at PCMS. Diersing and Severinghaus (Ref 17, 18) observed scrub jays only on two of the four sites with the greater tree density at both Fort Carson and PCMS. A similar trend was observed in towhees at PCMS but not at Fort Carson.

Chipping sparrows typically are associated with areas of scattered trees with open herbaceous ground cover that is good for foraging (Ref 7,30). This would not suggest a positive relationship with TREE. Nonetheless, in both years this sparrow was restricted to sites in the main portion of the limestone hills, characterized by high densities of pinyons and junipers. It was absent from both the sandstone and pinyon-juniper island sites (6,11, and 21). While Laurion (Ref 36) did find them abundant on his two sandstone sites, he did not provide tree density data.

Woodland II. The consistent negative response to bare ground among the five species of this group is not easily explained. Although ash-throated flycatchers sometimes glean insects from the ground (Ref 35), cowbirds were the only other important ground feeder. None are ground nesters, and all these species show a negative response to large shrub cover. Three of the species exhibit a positive response to TREE, especially the ash-throated flycatcher.

Cassin's and western kingbirds were observed on most study sites over the 2 years, and were similarly distributed among sites. This was not anticipated given the likelihood of competitive interaction between these two species. In the Trans-Pecos of Texas, Ohlendorf (Ref 45) found them segregated by elevation, based on different habitat preferences. Western kingbirds were more common in desert scrub and farmland below 4000 feet, while Cassin's dominated in grassland and riparian situations above this elevation. Hespenheide (Ref 28) found Cassin's to prefer nesting in riparian habitat and other areas with tall trees. The western also used tall trees, but exhibited a greater tolerance for shrubs and yuccas. In contrast, here we found that western kingbirds were more strongly associated with tree density than Cassin's. A better understanding of the relationships among kingbirds at PCMS will require more study.

The ash-throated flycatcher was similar to members of the Woodland I group in its strong positive relationship with TREE and negative association with LARGE SHRUB. This is related to its use of tree cavities for nesting and lower canopy foliage for foraging.

The broad-tailed hummingbird rarely appeared on the sites. It is more characteristic of the higher elevation ponderosa pine forest (Ref 1).

Woodland III. Each of the four species in this group responded negatively to LARGE SHRUB. Each was more abundant on the pinyon-juniper island sites (6, 11, and 21) than on other pinyon-juniper sites, and each appeared to be indifferent to tree density. Laurion (Ref 36) also found nighthawks and house finches to be most common at a pinyon-juniper island site.

Mockingbirds were the most uniformly abundant species encountered. Laurion (Ref 36) found them to be relatively common on his sandstone break sites. A large portion of variation in density of this species also was accounted for by FORB for unknown reasons.

Western meadowlarks typically are associated with prairie and prairie/shrub habitat. Among the woodland sites in this study, they were least abundant in areas with uniformly dense tree cover (PJS and PJN) and on the sandstone sites, and frequently were observed singing from conspicuous tree perches near large, treeless, grass covered openings. A negative association with LARGE SHRUB contrasts with its positive response to LARGE SHRUB/CHOLLA in the prairie. Apparently, the presence of tall vegetation enhances the suitability of shortgrass prairie for this species. Trees adjacent to grassy patches within woodland accomplish the same end; large shrubs are not critical. The unexpected large portion of variation in meadowlark density explained by FORB is inexplicable.

House finches are a highly adaptable species usually not found far from water (Ref 7). However, water does not appear to be a critical factor in its selection of nesting areas at PCMS. Most cattle tanks were more than a mile from the three pinyon-juniper island sites where these finches were most abundant.

Common nighthawks nest on the ground in a variety of locations. This species prefers barren areas of rock, gravel, or soil unobstructed by shrubbery (Ref 5). Avoidance of shrubby areas may explain a negative response to large shrub cover. In 1985, nighthawks were most abundant on sites 6 and 11, neither of which were gravelly. In 1986, the nighthawk was even more abundant on site 39, a site with sandstone outcrops.

Response to Disturbance

Results from several woodland types (Ref 18, 59, 61) show that tactical vehicle disturbance does cause a reduction in species richness in pinyon-juniper woodland as was observed here. However, individual species, guilds, and total density showed no negative response to disturbance. This was probably related to the fact that the considerable ground damage at many sites had little effect on tree cover. Nearly significant negative responses in mountain bluebirds and house finches, however, are noteworthy. Total biomass, another measure of abundance, often declines in response to training activity in woodland habitat (Ref 18, 57). Woodland species that appear to respond positively to tactical vehicle disturbance elsewhere include mourning dove, rufous-sided towhee, northern mockingbird, and chipping sparrow (Ref 57). Longer term data and a larger sample size are needed to further document training impacts on the pinyon-juniper avifauna at PCMS.

Special Interest Species

Among the species observed in the present stud, , the following have been identified as species of special concern in Colorado: Lewis' woodpecker, the solitary vireo, the brown-headed cowbird, the loggerhead shrike, the common nighthawk, the mountain bluebird (Ref 81), and the grasshopper sparrow.*

Based on known habitat preferences, PCMS training areas do not provide important habitat for Lewis' woodpecker or the solitary vireo. Neither was observed on more than one site each over the two years.

Cowbirds, on the other hand, were observed on all twelve woodland sites over the course of the study. They are brood parasites that lay their eggs in the nests of other species, sometimes substantially reducing the nesting success of host species (Ref 42). Most importantly, the species has increased in recent years, especially in the central United States (Ref 11,51,54), and has responded positively to cattle grazing (Ref 6) and forest fragmentation. Initiating a grazing program at PCMS along with fragmenting the woodlands by training activity will increase this species with possible negative impacts on the reproductive success of host species. Warblers and vireos, many of which breed in canyon areas on PCMS (Ref 36), are of particular concern in this regard.

The loggerhead shrike has declined throughout its range (Ref 51). Although inconsistent in its site occupation from year to year in this study, Laurion (Ref 36) reported it as a common year-round resident in all habitats on PCMS. It is currently listed as a Category 2 species by the U.S. Fish and Wildlife Service, and is on the Audubon Blue List (Ref 67); there is a need for further study and evaluation for listing as threatened or endangered.

Although populations of common nighthawks appear to have been stable during the past decade (Ref 51), recent trends have caused it to be included on the Audubon Blue List (Ref 67).

Mountain bluebirds are reportedly a common winter resident and likely breeder in all woodland habitats on PCMS (Ref 13, 36). Although the breeding bird census (Ref 51) indicates a significant increase in the Colorado population between 1965 and 1979, the Colorado Nongame Advisory Council has noted a population decline atttributable to loss of cavity nesting sites (Ref 81).

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Grasshopper sparrows are considered unusual breeders in this region (Ref 13). They have registered significant declines throughout their range in recent years (Ref 51) and are currently on the Audubon Blue List (Ref 67). Range improvement techniques that encourage growth of either wheatgrass or galleta grass on PCMS areas will be of benefit.

7 CONCLUSIONS AND RECOMMENDATIONS

Species Habitat Relationships

The 29 PCMS sites inventoried range widely in locality and habitat conditions, and exhibit a varied abundance and diversity of bird species. Principal component analysis is an effective technique for describing the gradient in habitat conditions among these sites, and the resulting PC factors meet the statistical assumption of independence critical to subsequent multiple correlation analysis. Although a direct causal relationship between bird species abundance and richness, and specific habitat features cannot be assumed, multiple correlation analysis between bird species and PC factors helps to delineate the relationships between species and their habitat, and provides useful insight into the habitat features most important to prairie and pinyon-juniper bird species.

Prairie Birds

The presence of trees, shrubs, arborescent cacti, and medium grass cover provide foraging and nesting opportunities that enhance species richness in an otherwise species-poor shortgrass prairie bird community. Declines in emergent woody vegetation and cover of medium grass from tactical vehicle training activity likely will lead to a reduction in species richness.

Abundance of the Woodland species on prairie sites also is enhanced by the presence of trees, shrubs, and cholla cactus. Although scattered woodv vegetation on the prairie is not critical to the populations of these species, trees, at least, may be an important resource for raptors.

The saltbush-greasewood habitat at site 19 was unique in its high bird species richness and total density, and presence of Brewer's sparrows. The loggerhead shrike also was attracted to this site. This riparian habitat with its abundant broadleaved shrub cover harbors a unique wildlife and floristic community that warrants further study and special consideration for protective measures.

Among the Grassland species, the western meadowlark and the grasshopper sparrow are positively, and the horned lark is negatively influenced by the volume of vegetation on prairie sites. Grass cover does affect the grasshopper sparrow and the horned lark, and grass cover and shrub cover are important to the meadowlark. While the lark bunting avoids savannah-like areas, Cassin's sparrow appears unresponsive to measured habitat features. Both may require shrub cover.

Training activity is likely to have a considerable impact on cholla grassland bird communities. Cholla grassland covers a substantial portion of PCMS, particularly in Management Unit B; species richness, total density, and several individual species were associated with LARGE SHRUB/CHOLLA. Meadowlarks and lark sparrows are the species most likely to be negatively affected by loss of cholla. Horned larks will either benefit or remain indifferent to such disturbance.

Pinyon-Juniper Birds

Woodlands provide a greater diversity of feeding and nesting opportunities than do prairie sites. As a consequence, pinyon-juniper woodlands have higher species richness and total density, and a more complex guild structure than prairie sites.

Tree density is a critical factor affecting the pinyon-juniper woodland bird community. Species richness and the abundance of 11 bird species in pinyon-juniper woodlands are related to tree density.

Total bird density, however, is not related to tree density because of the opposing responses of several abundant species; the lark sparrow responded negatively, while the 10 other species responded positively to tree density. A large decline in tree cover and density due to tactical vehicle training will significantly alter the PCMS pinyon-juniper bird community. As individual species densities showed different sensitivities to gradients in tree density among the study sites, it is expected that each will exhibit a similar range in sensitivity to changes in tree density and cover resulting from tactical vehicle damage.

Several woodland species showed no correlation with the habitat features measured: the brown towhee, the plain titmouse, the black-headed grosbeak, the loggerhead shrike, and the gray flycatcher. A larger sample of sites and measurement of additional habitat features may be necessary to shed additional light on the habitat relationships of these species.

Response to Disturbance

Among the 12 prairie and 23 pinyon-juniper bird species analyzed, only the grasshopper sparrow in prairie habitat showed a clear negative response to tracked vehicle disturbance. Neither guilds nor total density appeared to respond to disturbance in either habitat. Species richness did decline with disturbance in the woodlands, but did not clearly do so in the prairie.

Most prairie and woodland species showed little response to disturbance for several reasons. First, in woodlands, there was little obvious loss of trees or tree cover among the sites studied. Most tracks were confined to the interspaces between trees. Second, extent of vehicle tracking is only a rough indicator of the extent of damage in any particular area. Actual damage to soils and vegetation will vary depending upon soils, vegetation type, weather conditions, and vehicle maneuvers. Third, there can be a lag time in the response of wildlife to disturbance. Individuals that have bred successfully in the past on a given site may return to the same or nearby sites in future years despite changes in habitat conditions. Therefore, it may be several years before clear trends are seen. Finally, species vary in their ability to adapt to changes in their accustomed habitat. Regular monitoring will be required to detect responses of PCMS bird populations to disturbance from military training.

Wildlife-Based Indicators of Habitat Conditions

Prairie Birds

Extent and quality of ground cover is an important feature affecting the prairie bird community and has an important bearing on the trafficability of training lands; loss of perennial cover may reduce the ability of lands to support tactical vehicle maneuvers. Three grassland species may be useful indicators of changing ground cover conditions. Although restricted in distribution, grasshopper sparrows are a good indicator of deep grass conditions provided by galleta and wheatgrass, since they are sensitive to loss of these vegetation components. The more common western meadowlark is less sensitive but should also respond negatively to declining range conditions in the long run. Horned larks, on the other hand, are expected to increase with or remain indifferent to loss of ground cover. Brewer's sparrow is a good indicator of shrub-prairie habitat at PCMS.

The lark bunting and Cassin's sparrow are poor choices as indicator species. Neither species is closely tied to specific habitat features although presence of some shrub cover may be important. Lark bunting numbers vary annually regardless of habitat conditions, and Cassin's sparrow numbers vary from year to year on individual sites.

Species richness can be a useful gross indicator of site conditions in the prairie. Although species richness did not respond to 1 year of training activity, the association between species richness and emergent woody vegetation suggests that loss of shrub and cholla cactus cover over time will lead to a decline in bird species richness. Also, the grasshopper sparrow and Cassin's sparrow tended to disappear from heavily disturbed prairie sites.

Total density is not a good indicator of range conditions because of differing responses of individual species that tend to offset one another.

Pinyon-Juniper Woodland Birds

Loss of tree cover will negatively affect the training mission in the long run by reducing tactical concealment resources, especially in the semi-arid west where trees recover and grow slowly, requiring 60 to 100 years to reach a height (3 m) sufficient to provide substantial concealment cover (Ref 20).

Species that rely most heavily on trees for foraging and nesting are most likely to respond to alterations in tree density, composition and cover. Among species that did respond positively to tree density, Bewick's wren and the ash-throated flycatcher are cavity nesters that glean insects from tree foliage much of the time. Both appear to be good indicator species as each is abundant and widely distributed in the limestone hills area, and each is positively related to tree density. Cavity nesters and foliage gleaners may also prove to be useful indicators. Lark sparrows, on the other hand, increase in numbers with decreasing tree density.

Two other potential disturbance indicators are mountain bluebirds and house finches, each of which demonstrated a nearly significant negative response to disturbance. Bluebirds appear suited due to their cavity nesting and insectivorous habits, but are of limited usefulness due to restricted distribution and abundance. House finches, on the other hand, exhibit a broad pattern of habitat use that diminishes their value as an indicator species.

Mockingbirds and mourning doves are abundant, but their numbers are insensitive to all but dramatic habitat changes. These two species, along with the rufous-sided towhee, often respond positively to tactical vehicle disturbance.

Pinyon jay populations are indicative of the state of the pinyon pine cone production, and are expected to respond negatively to extensive loss of pinyon trees. However, monitoring populations of this species will require a strategy different from that commonly employed in such studies. Because they are colonial nesters and forage over a large area in flocks, their population should be monitored on an installation-wide rather than site specific basis. Scrub jays also may respond to loss of pinyon mast as they make considerable use of this resource as well.

Species richness is a good general indicator of disturbance in pinyon-juniper woodlands. Total density is not a good indicator because differing responses of individual species do offset one another.

Guilds

As constructed here, guilds are not a good disturbance indicator. Guilds are less sensitive than species to minor disturbances when responses among species within individual guilds differ. However, in the long run, the guild approach may prove useful in determining the underlying causes of dramatic changes in wildlife community patterns resulting from major disturbances.

Recommendations

1. Future work in assessing the impacts of tactical vehicle maneuvers on nongame birds at PCMS should emphasize rapid assessment methods that broadly cover the installation on a regular basis to show whether changing range conditions caused by patterns of disturbance over time correlate with changes in wildlife distribution, abundance, and diversity.

2. The wildlife-based indicators of habitat conditions identified above should be monitored to assess the impact of training activities on the environment and on the PCMS bird community.

3. Selection of study sites must provide for an adequate number of control sites in areas least likely to be impacted by training activity to provide points of reference for assessment of training impacts.

4. Habitat degradation should be mitigated to the extent compatible with the Army's mission by managing species and habitats of special concern (e.g., by providing nest boxes for mountain bluebirds). Other taxa in addition to birds should be similarly considered.

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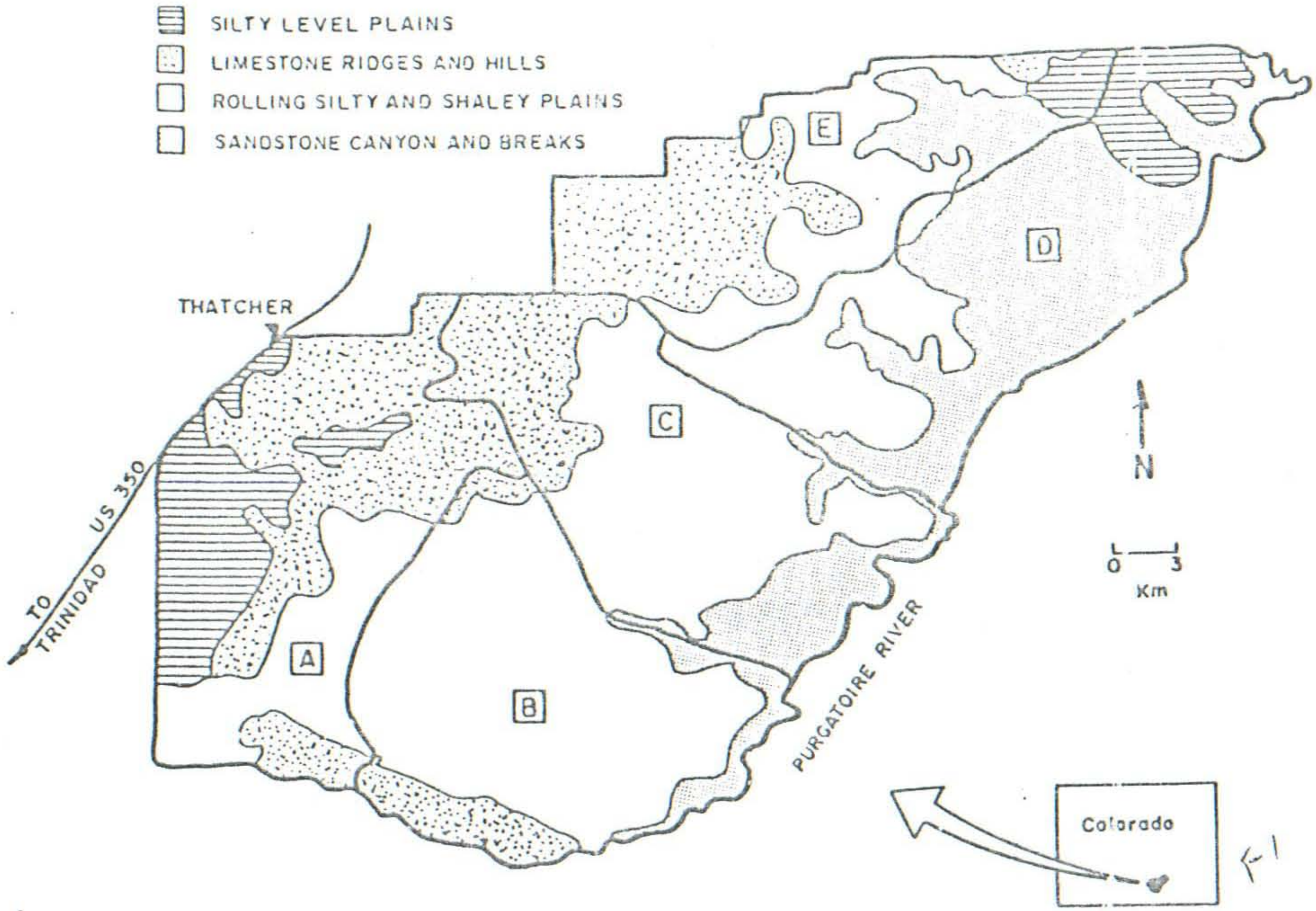


Figure 1. Landscape types of the Piñon Canyon maneuver site.

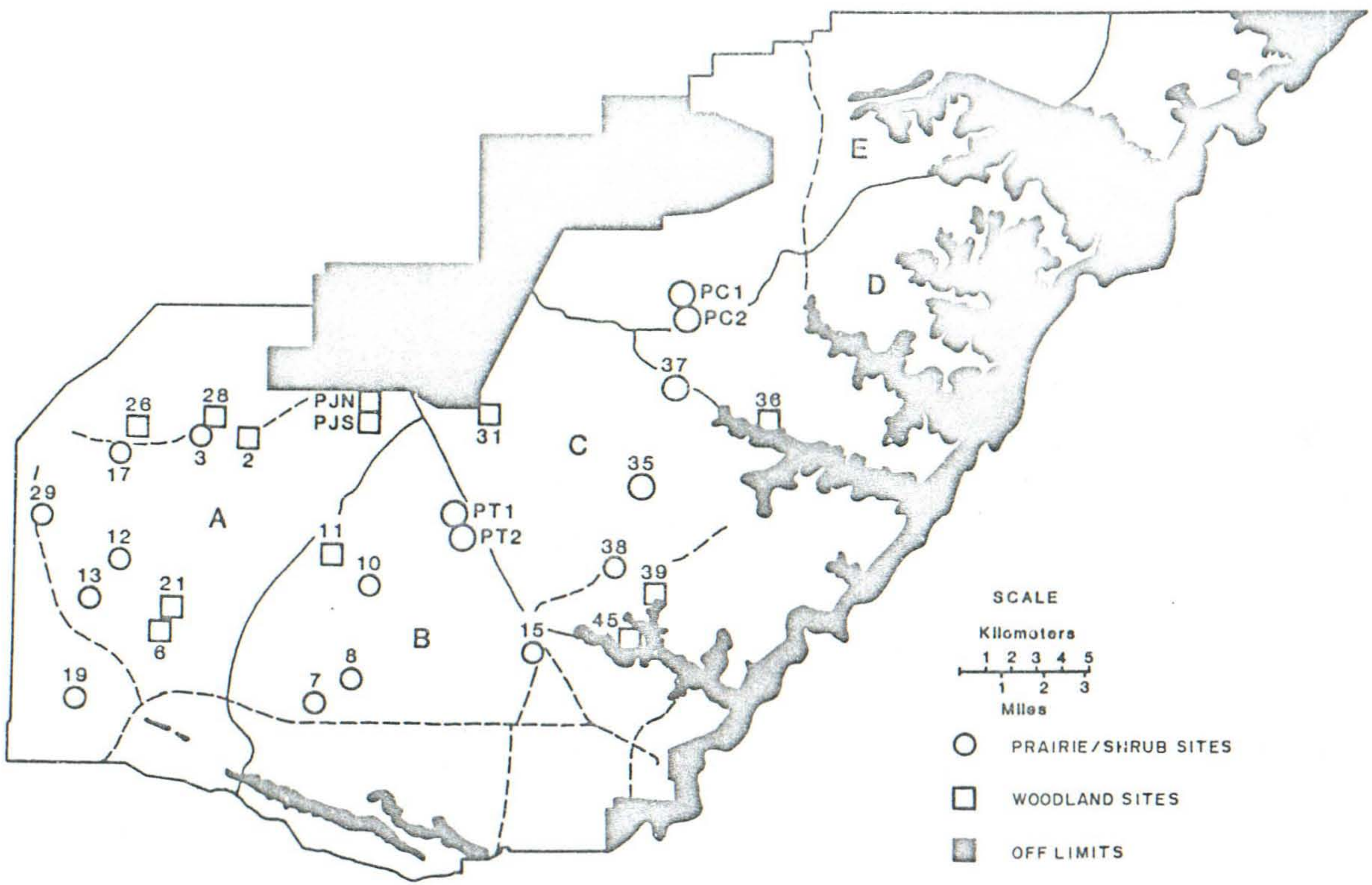


Figure 2. Location of study sites on the Piñon Canyon maneuver site.

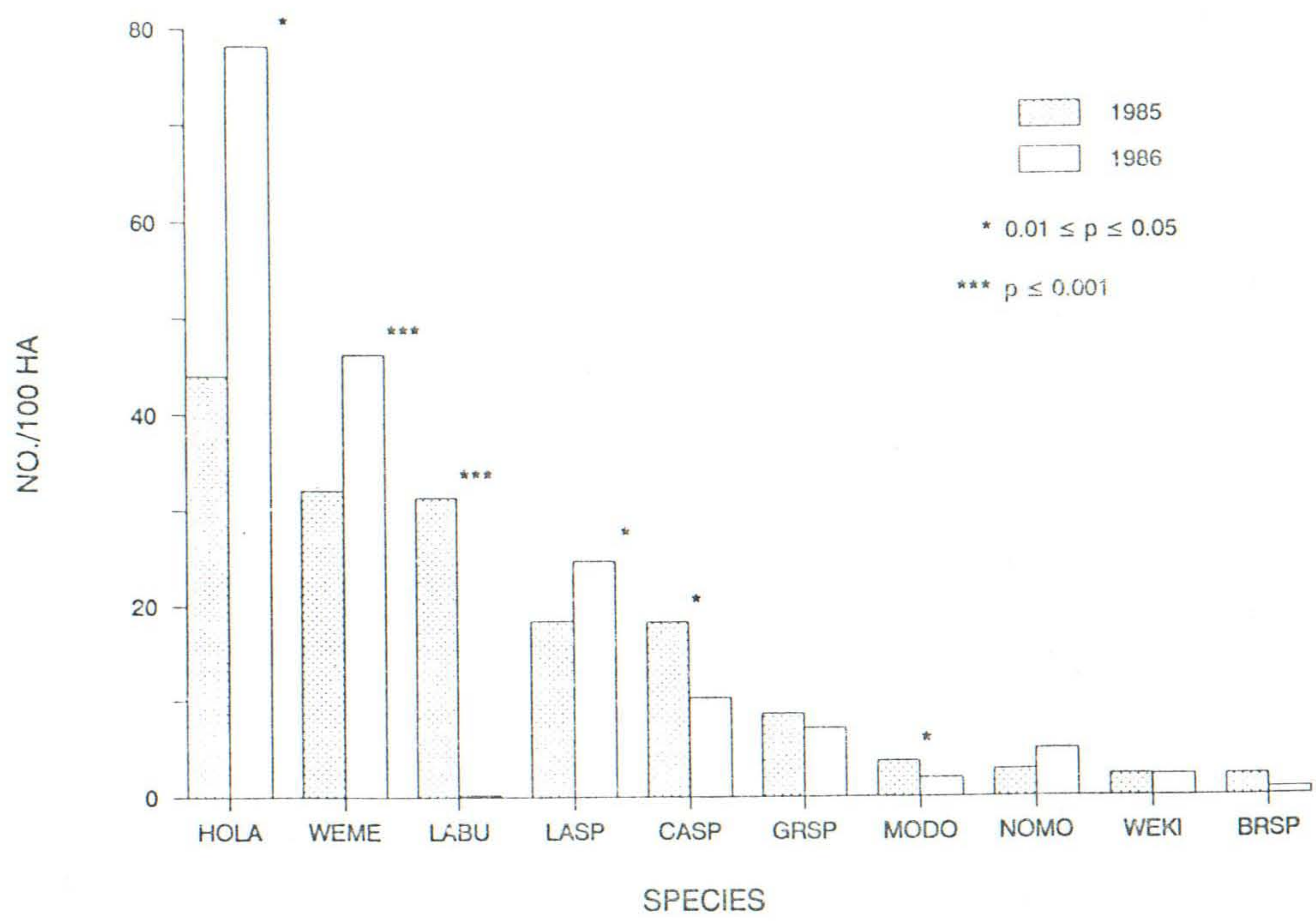


Figure 3. Mean density of selected bird species among 17 prairie sites.

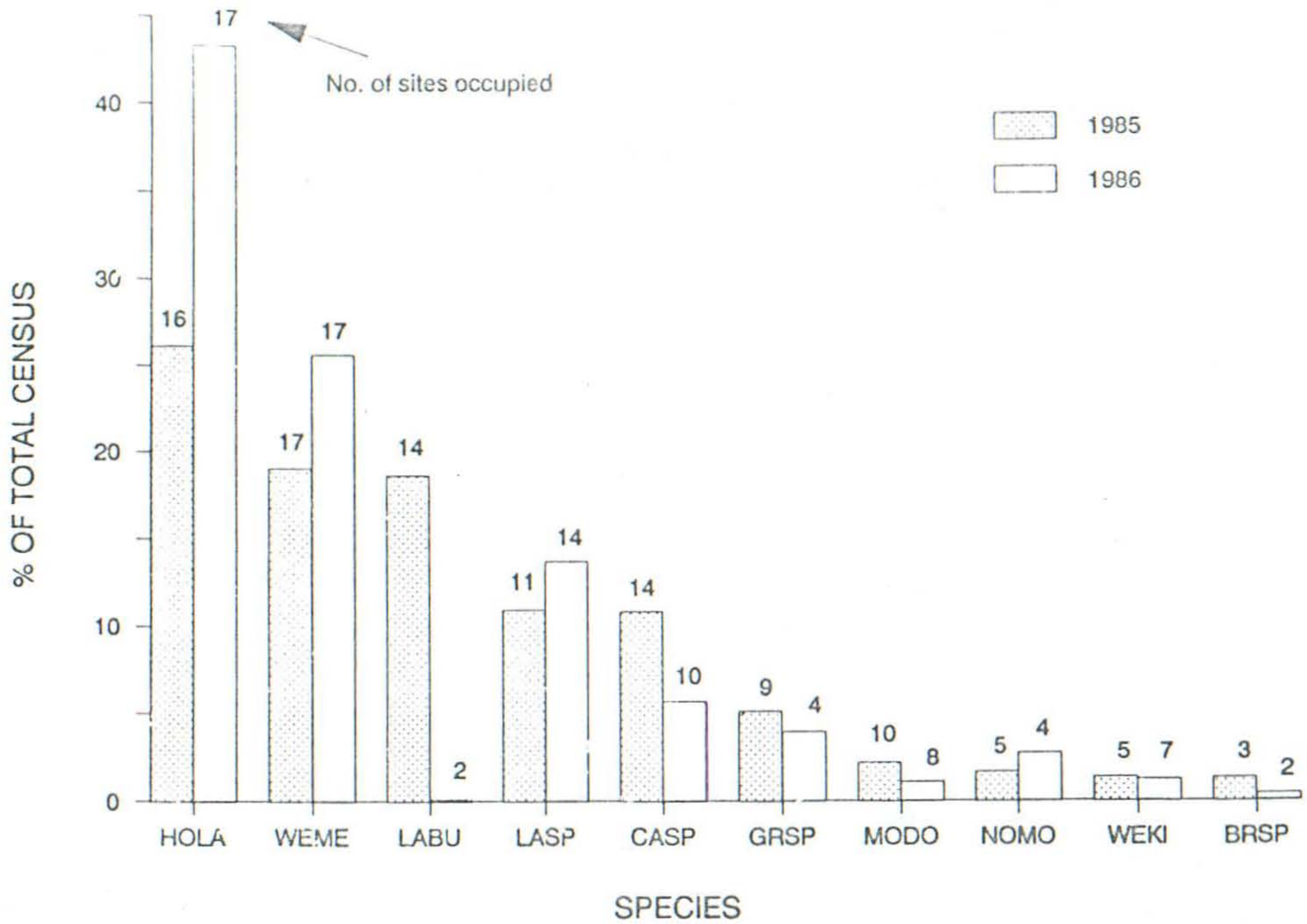


Figure 4. Relative density of selected bird species and number of sites occupied among 17 prairie sites.

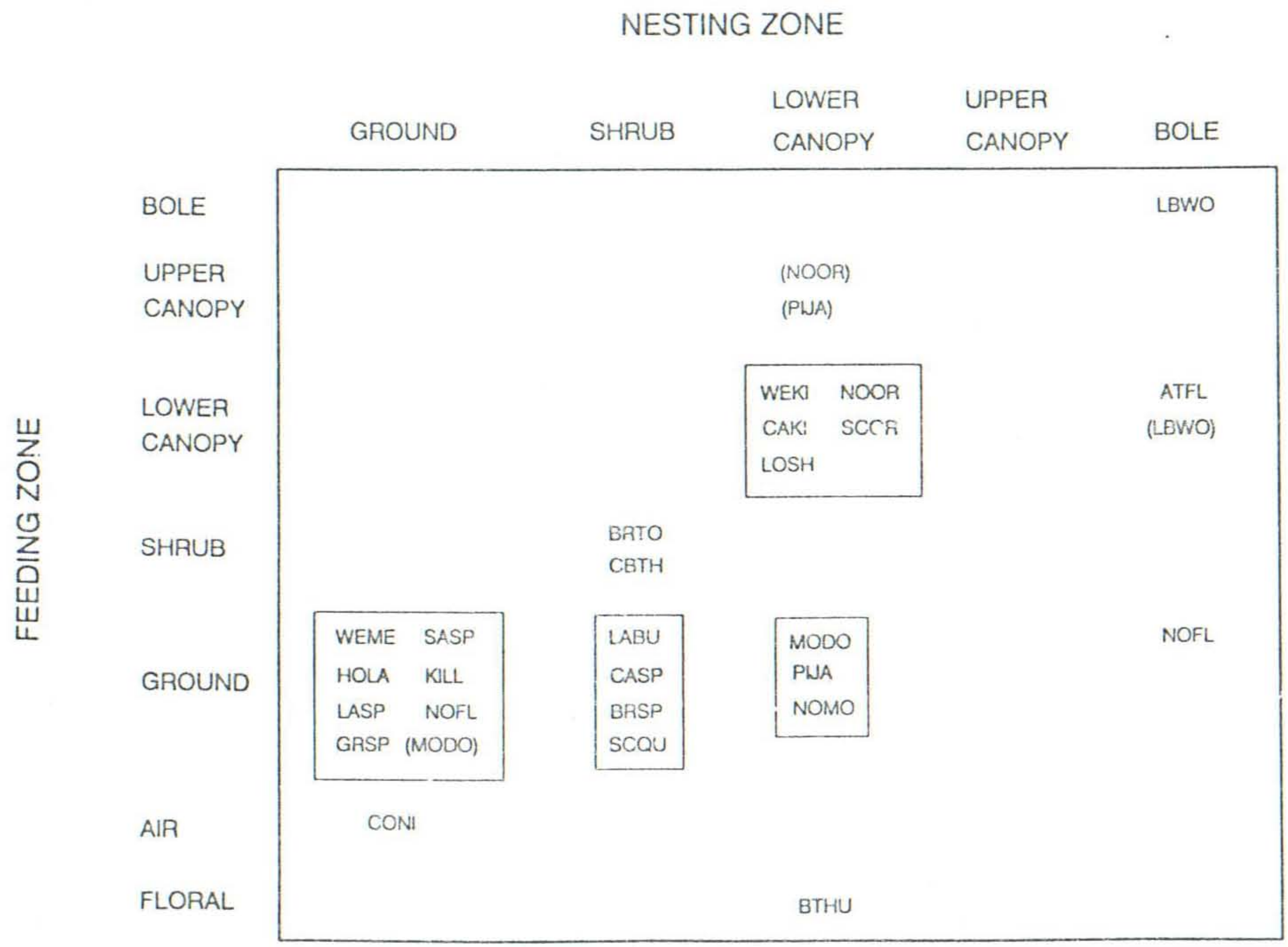


Figure 5. Prairie birds by feeding and nesting zone.

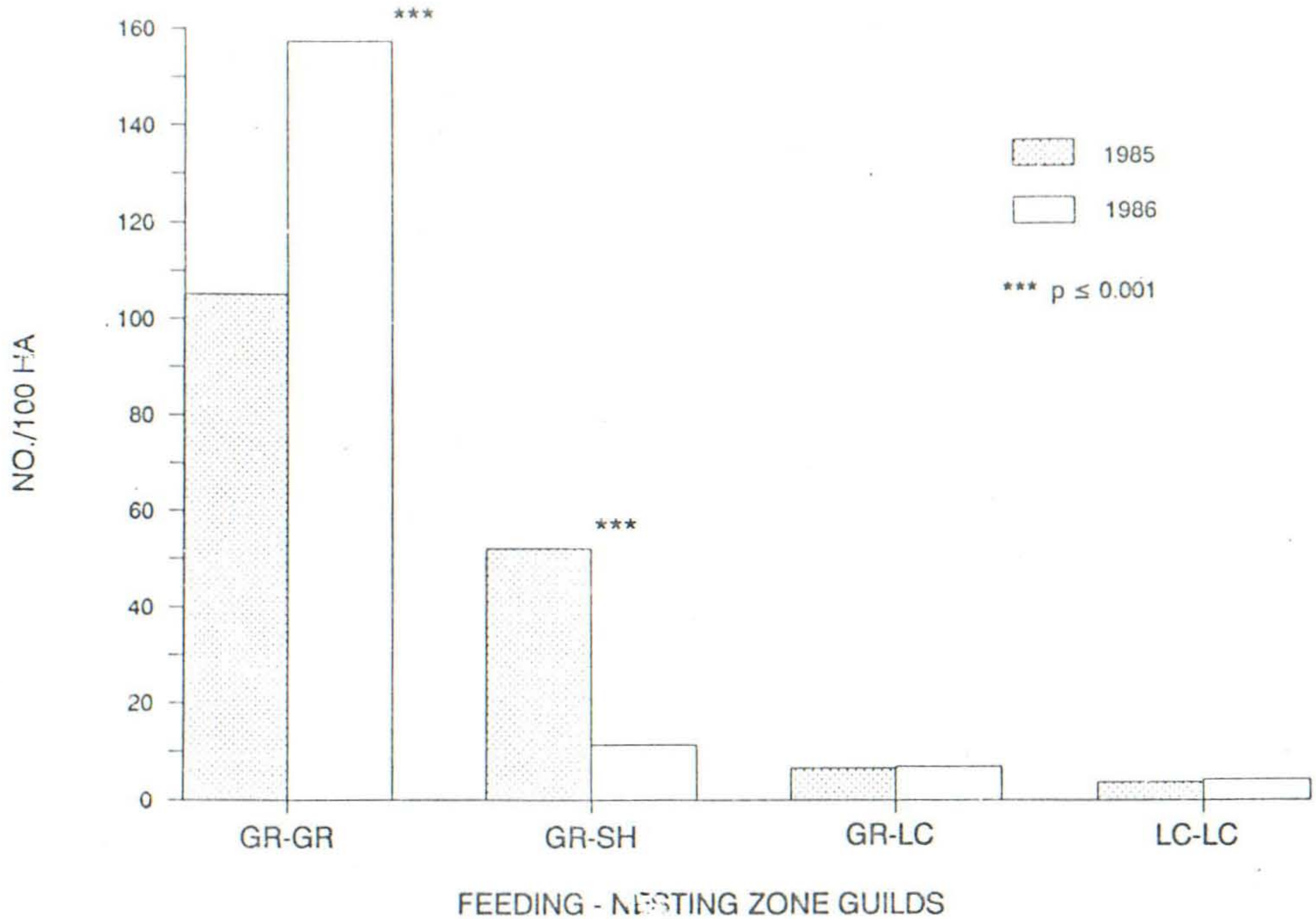


Figure 6. Mean density of selected avian habitat zone guilds among 17 prairie sites.

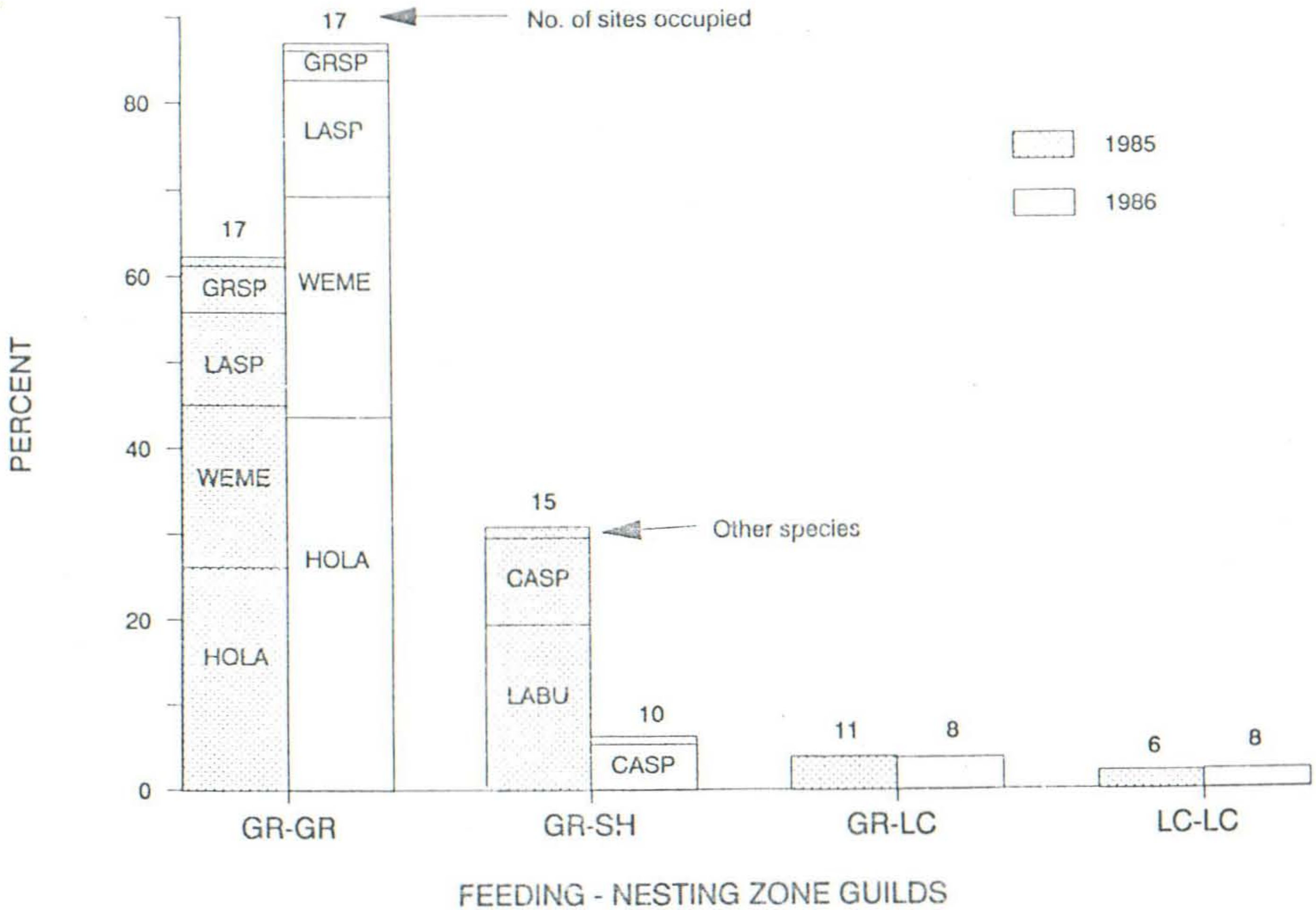


Figure 7. Relative density of selected avian habitat zone guilds and number of sites occupied among 17 prairie sites.

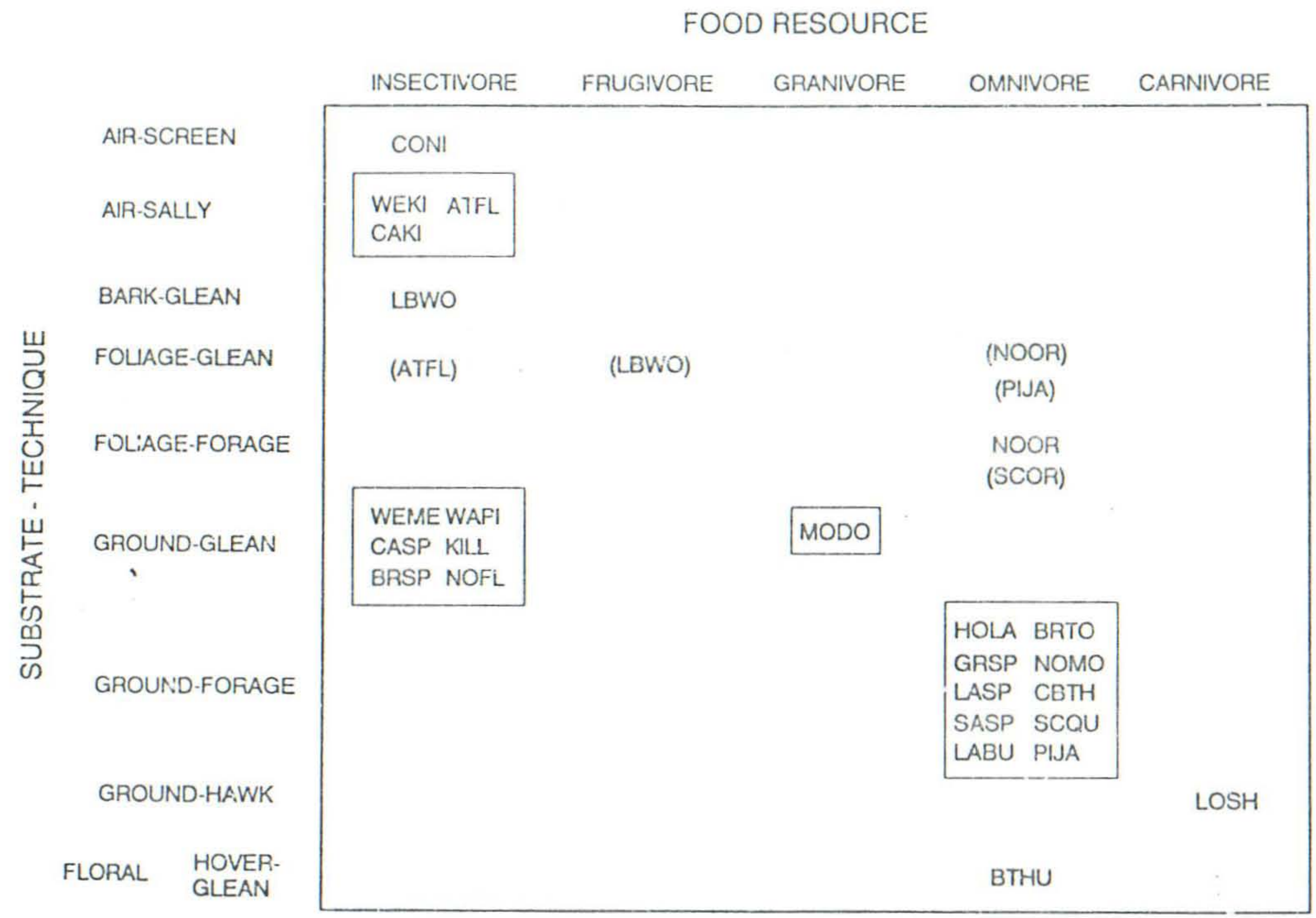


Figure 8. Prairie birds by food resource and substrate-technique.

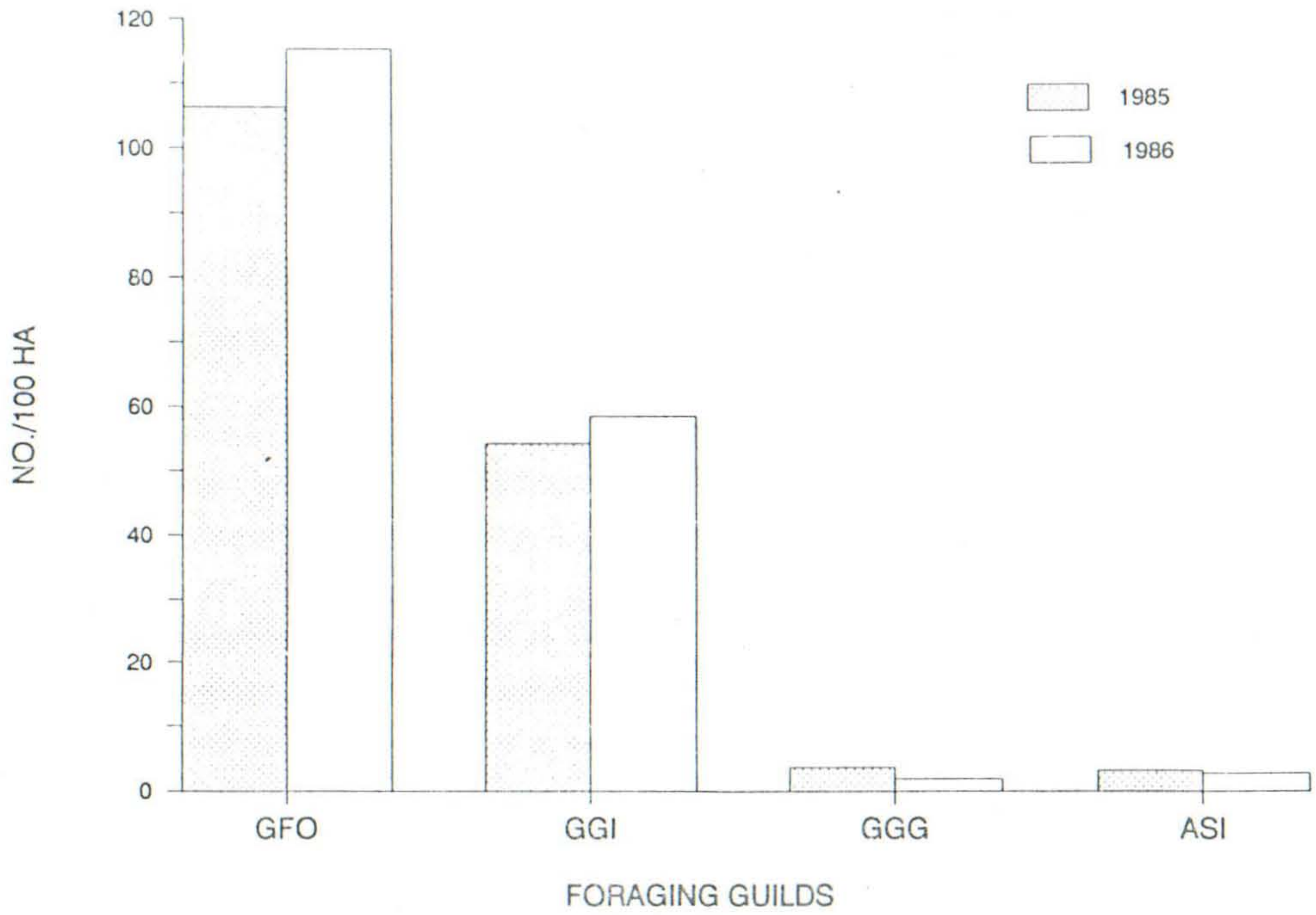


Figure 9. Mean density of selected avian foraging guilds among 17 prairie sites.

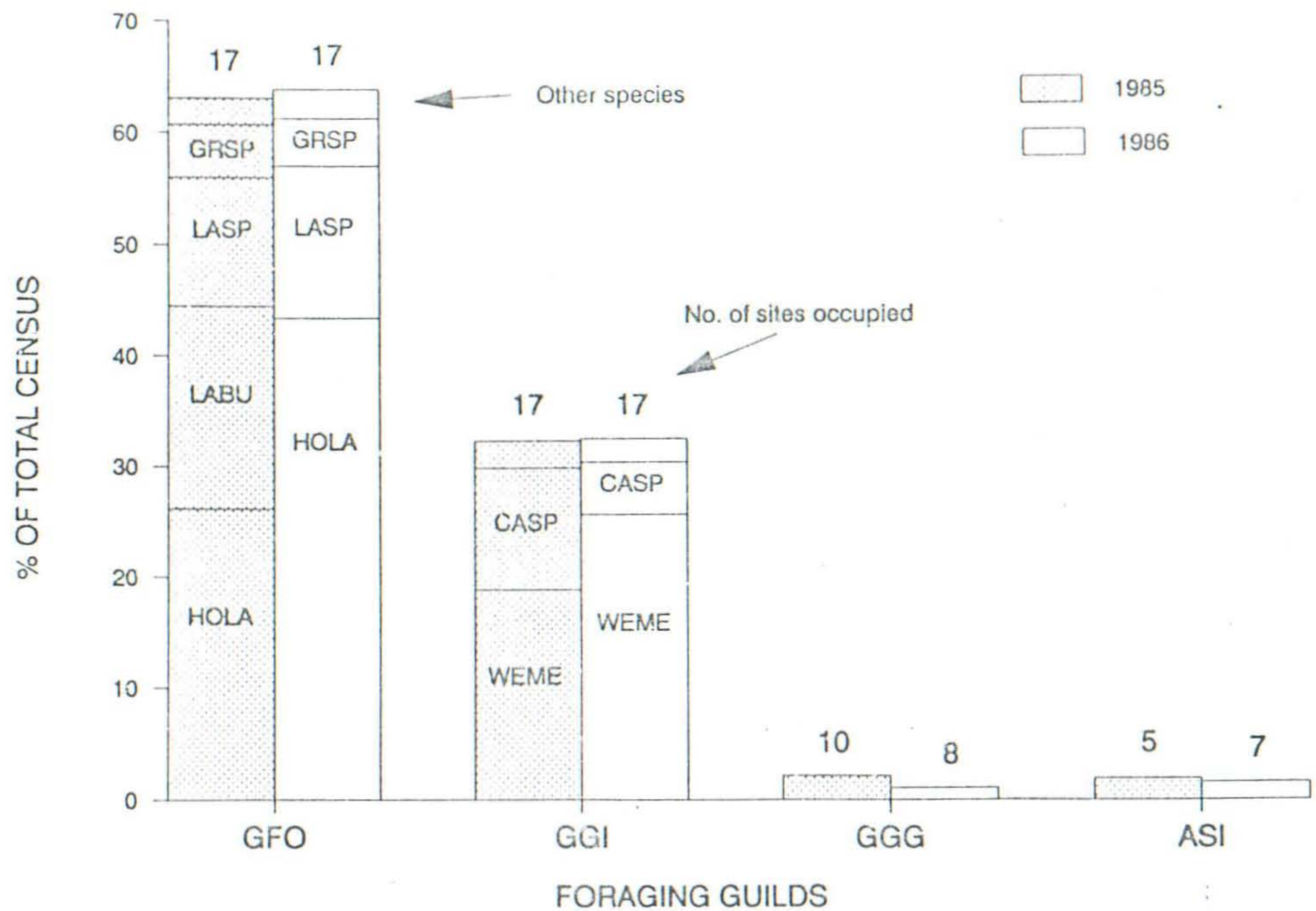


Figure 10. Relative density of selected avian foraging guilds and number of sites occupied among 17 prairie sites.

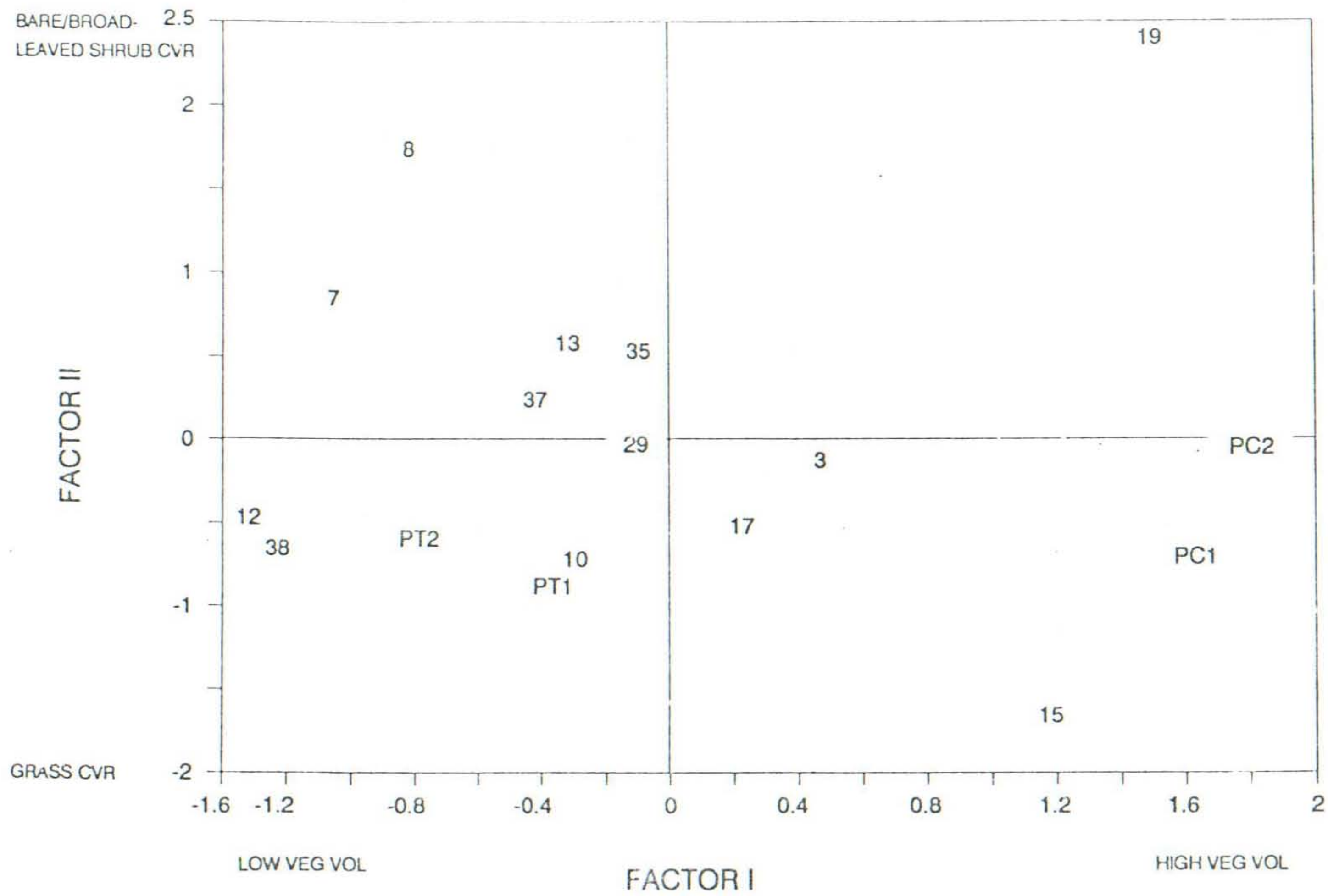
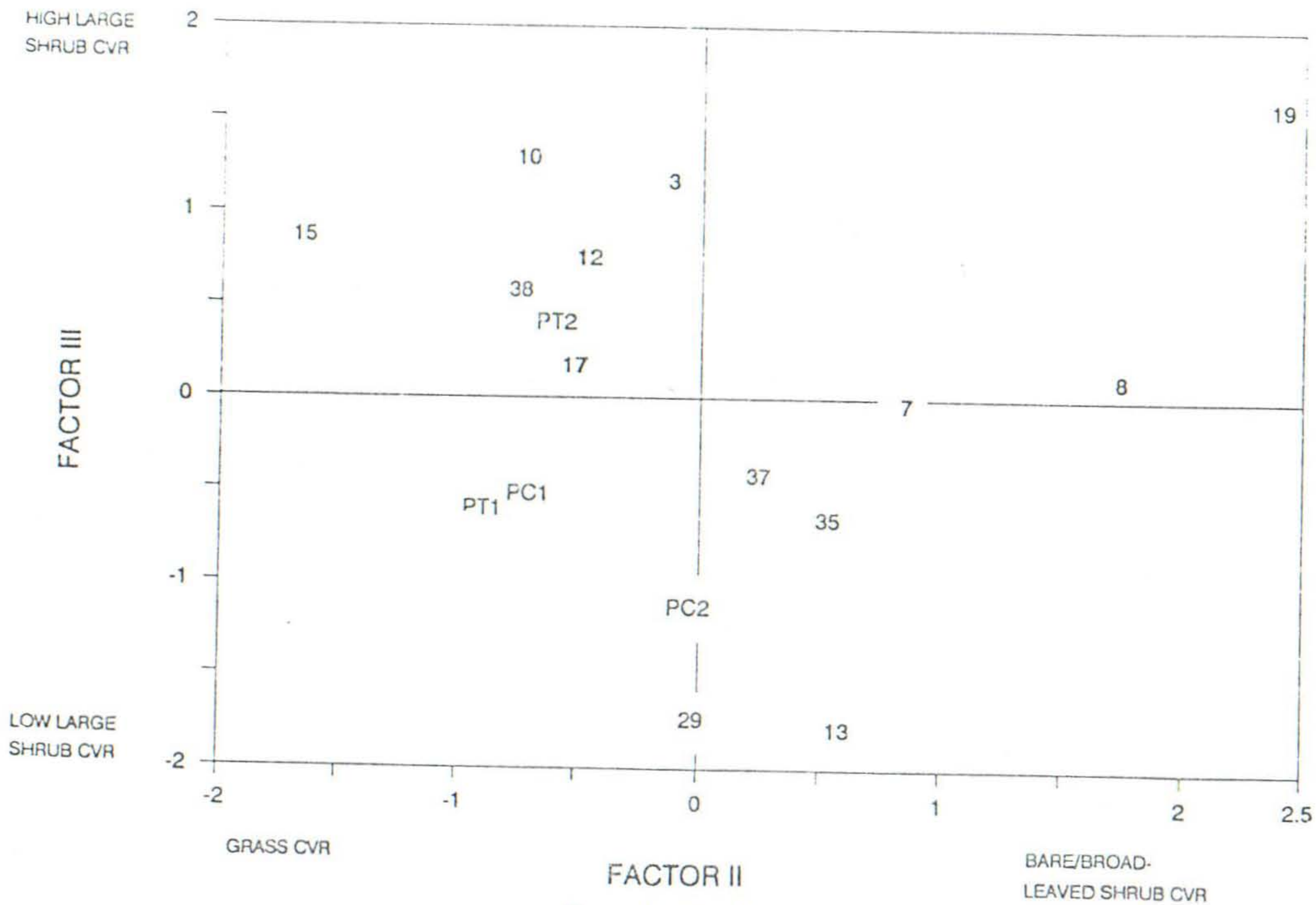


Figure 11. PCA by site number of 17 prairie sites based on vegetation data.



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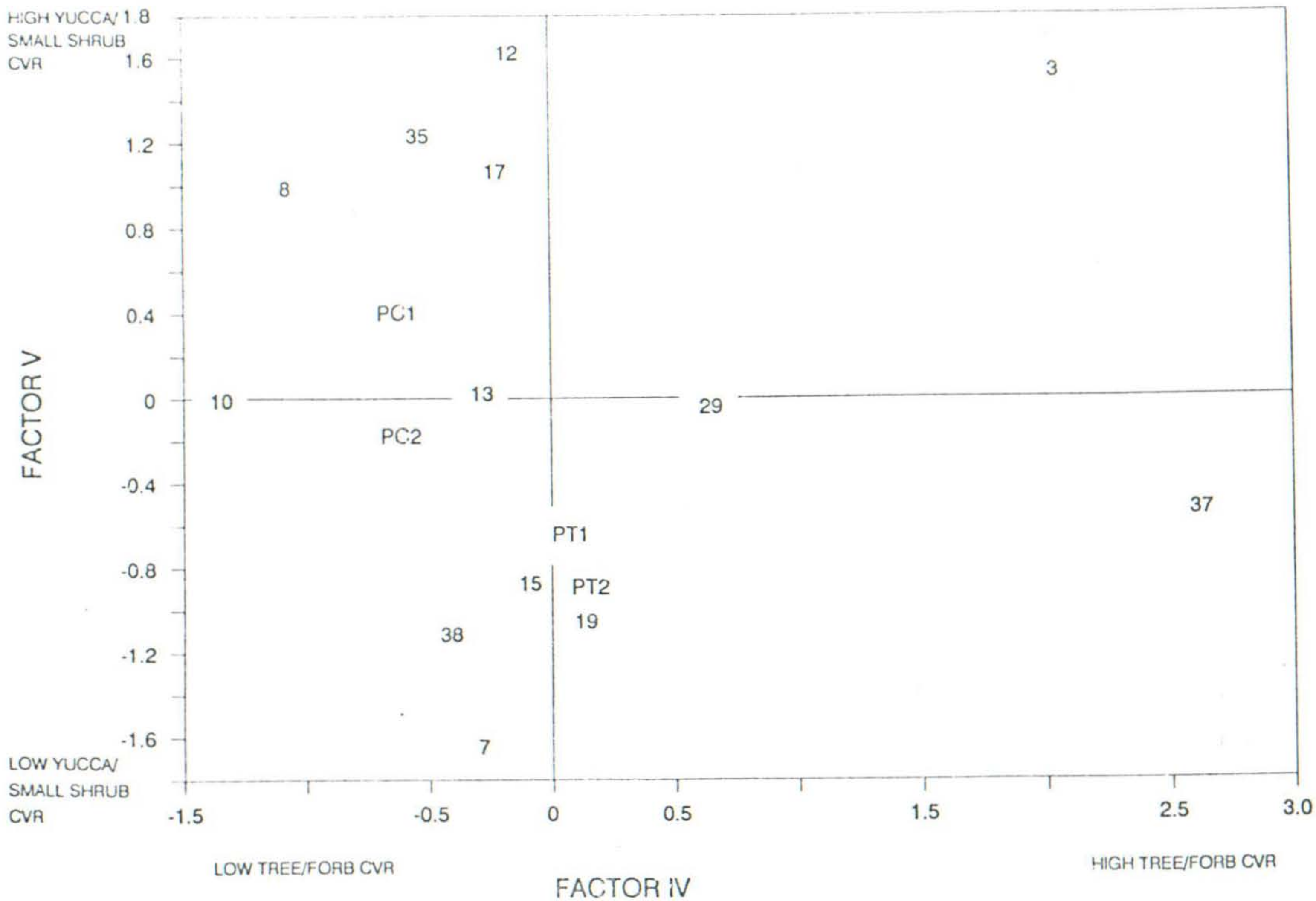

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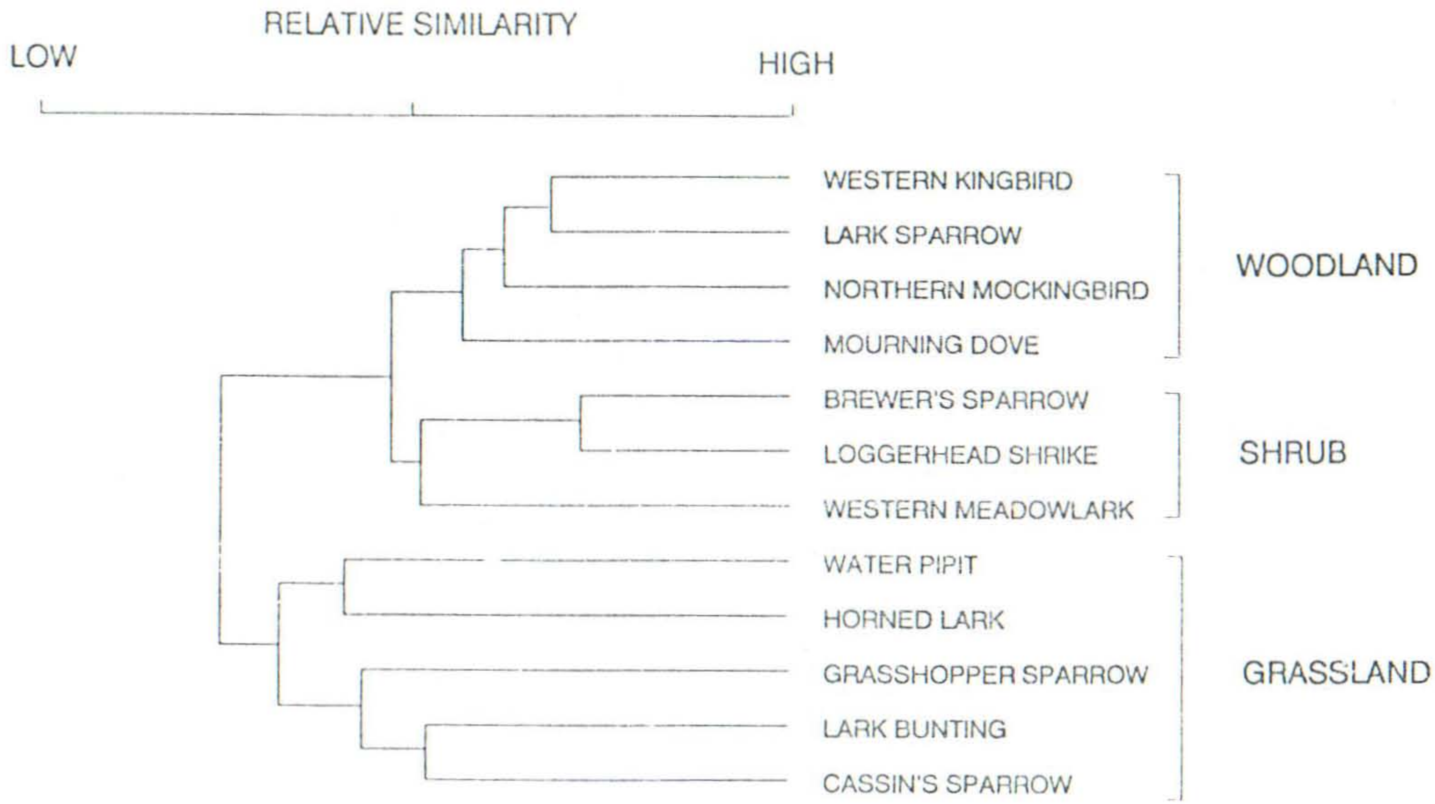

Figure 12. Cluster analysis of the prairie bird community

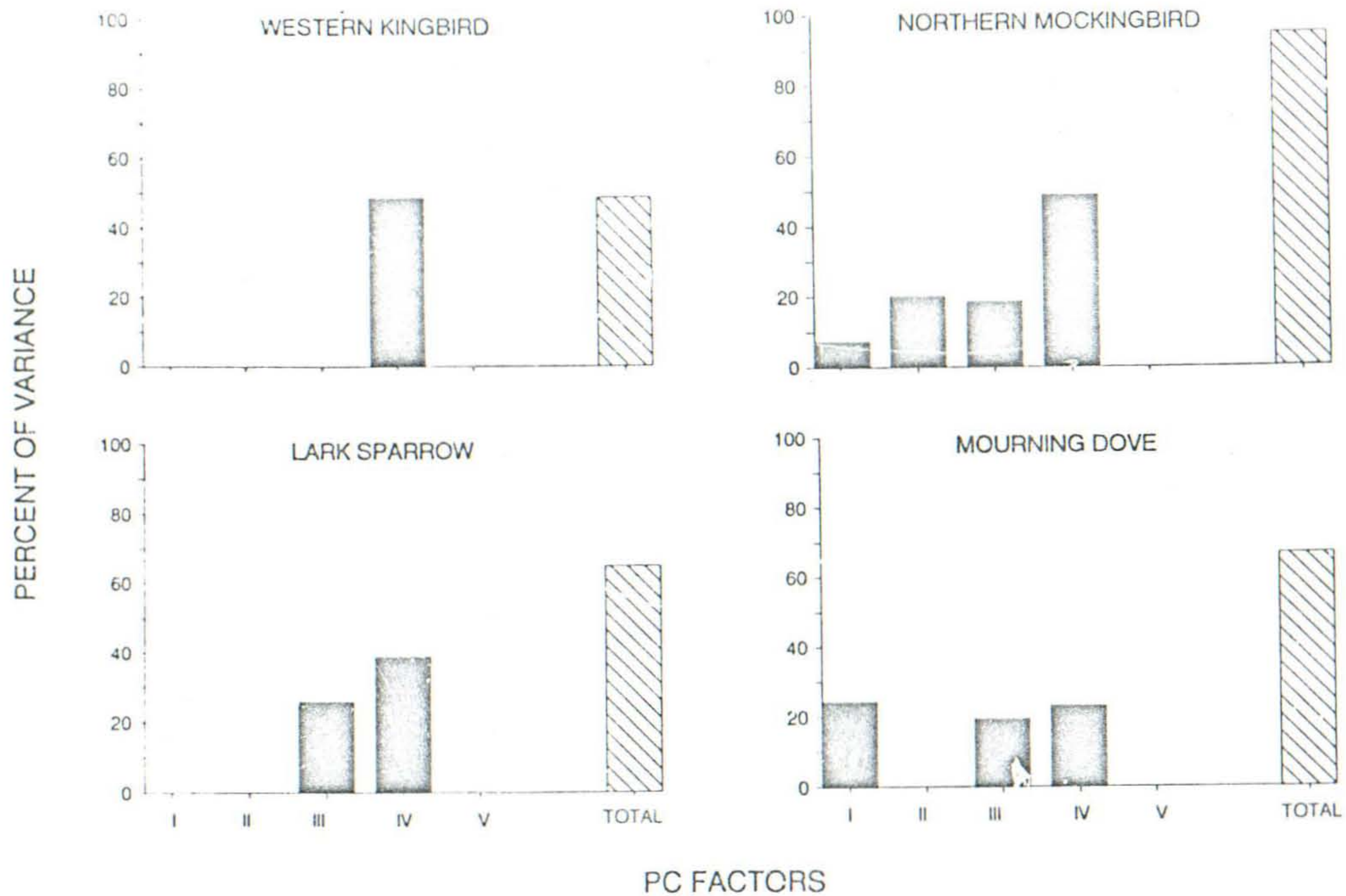

Figure 13. Multiple correlation analysis between PC habitat factors and the woodland cluster of prairie birds.

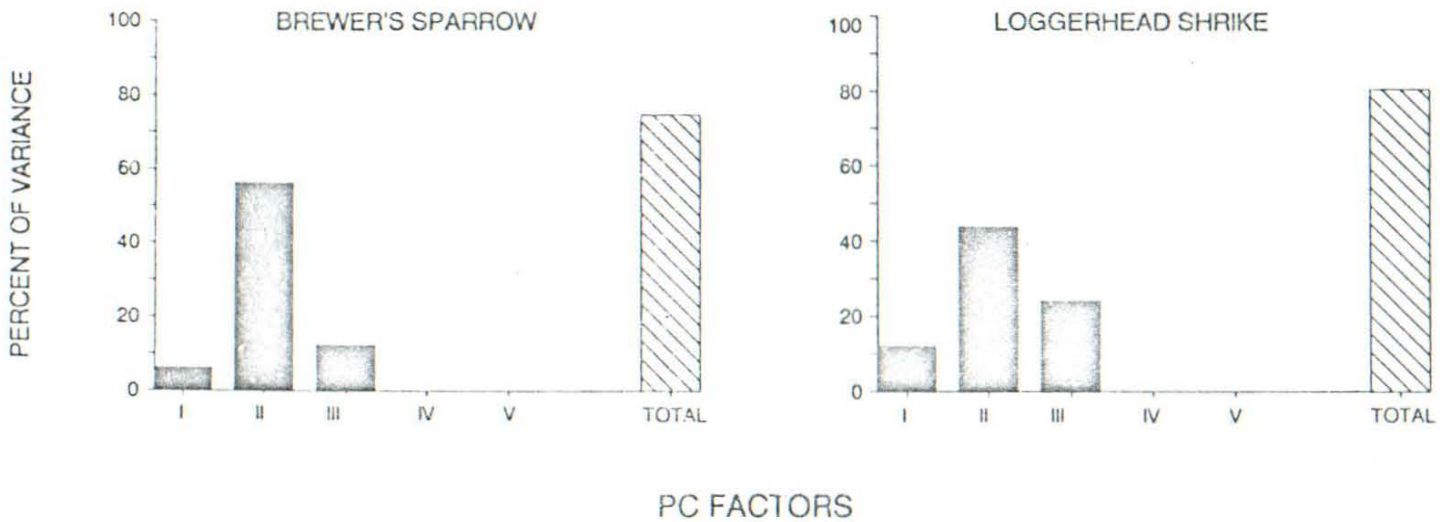

Figure 14. Multiple correlation analysis between PC habitat factors and the shrub cluster of prairie birds.

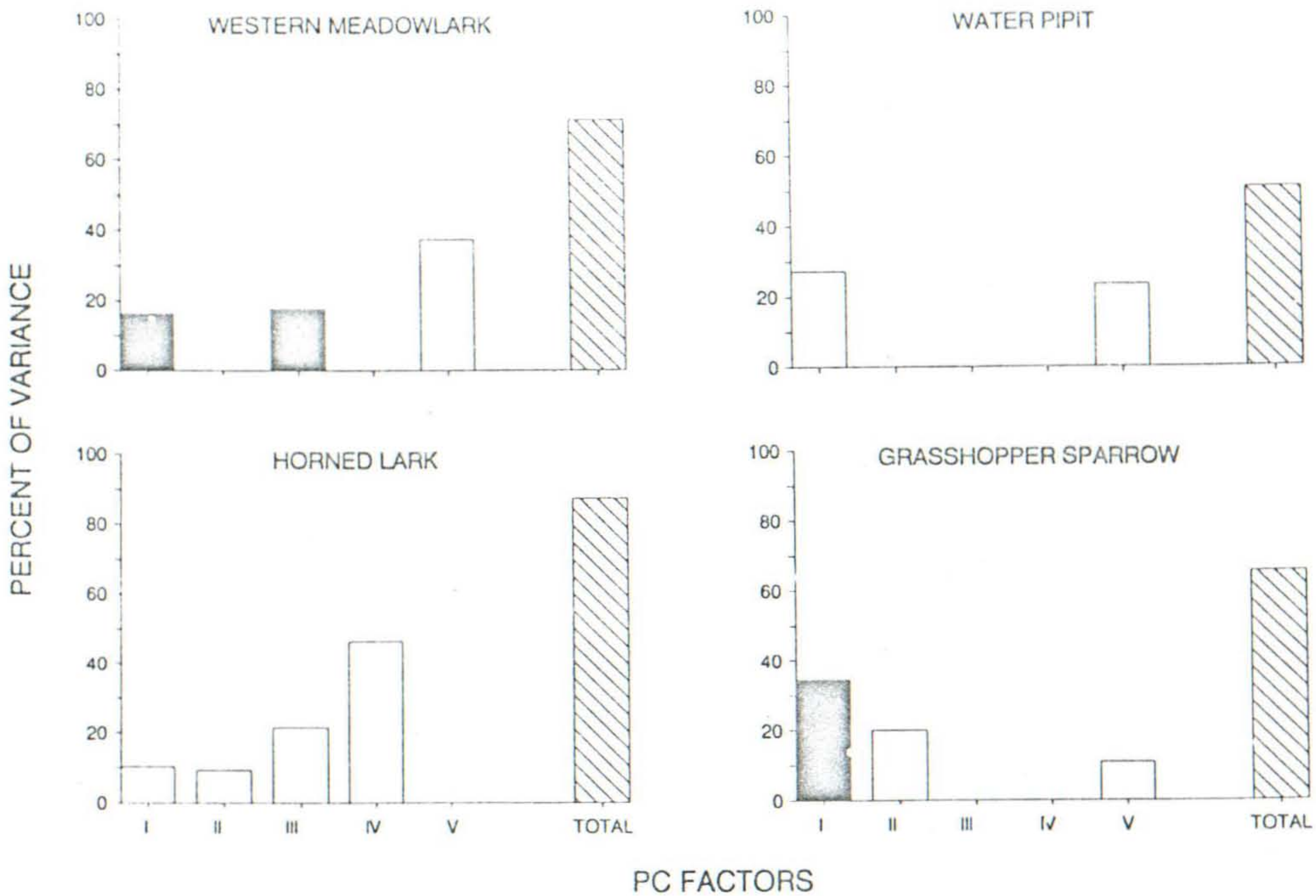

Figure 15. Multiple Correlation analysis between PC habitat factors and the grassland cluster of prairie birds.

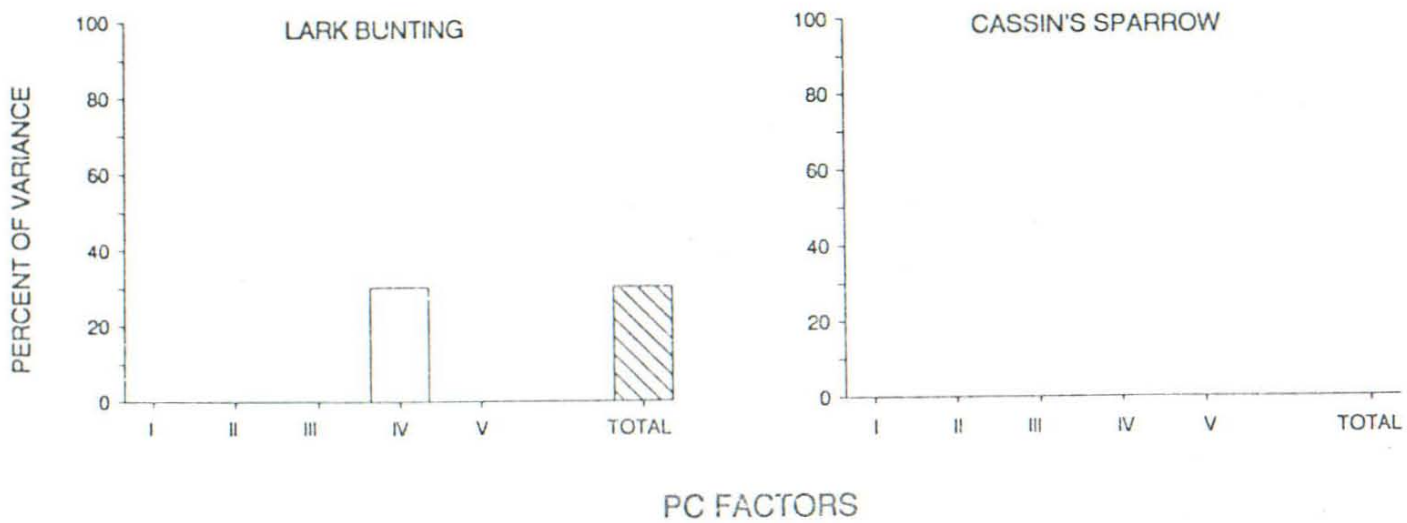

Figure 15. Cont'd.

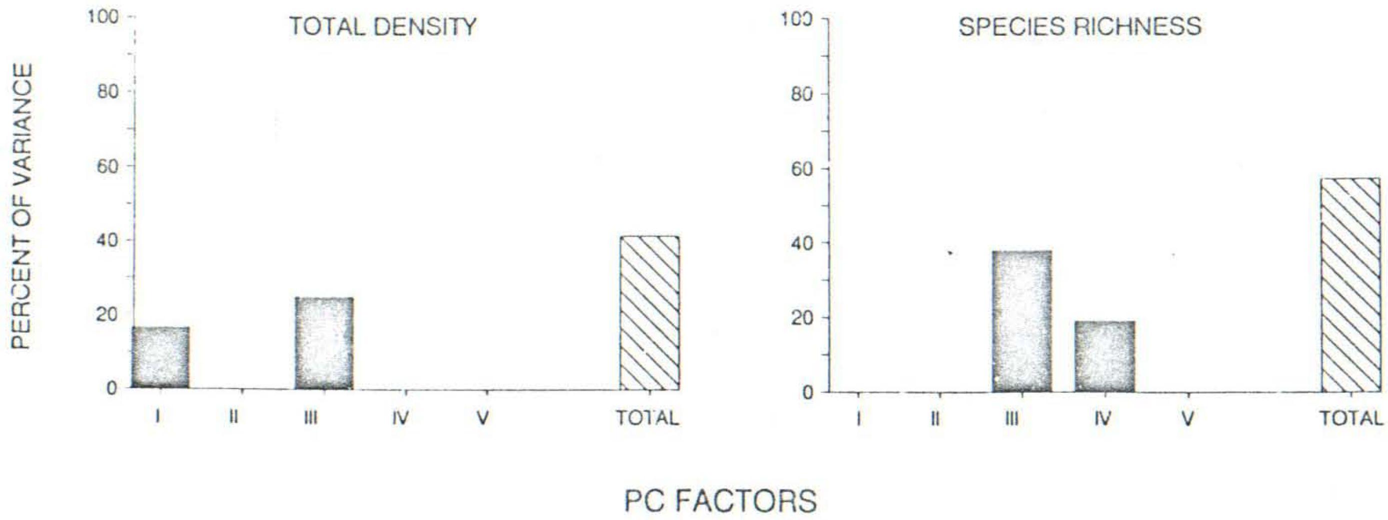

Figure 16. Multiple correlation analysis between PC habitat factors and total density and species richness of prairie birds.

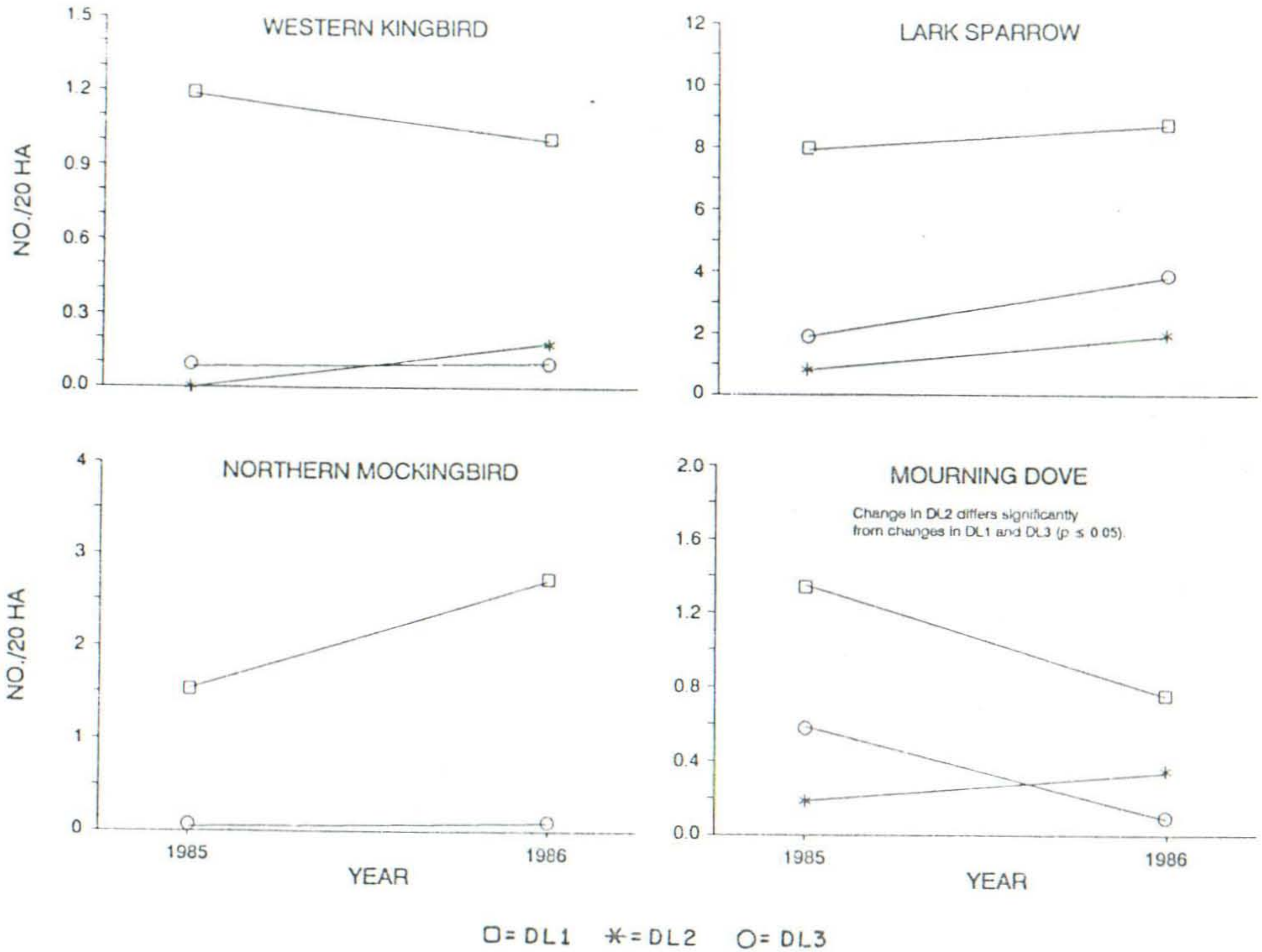

Figure 17. Population trends among woodland birds on prairie sites by disturbance level.

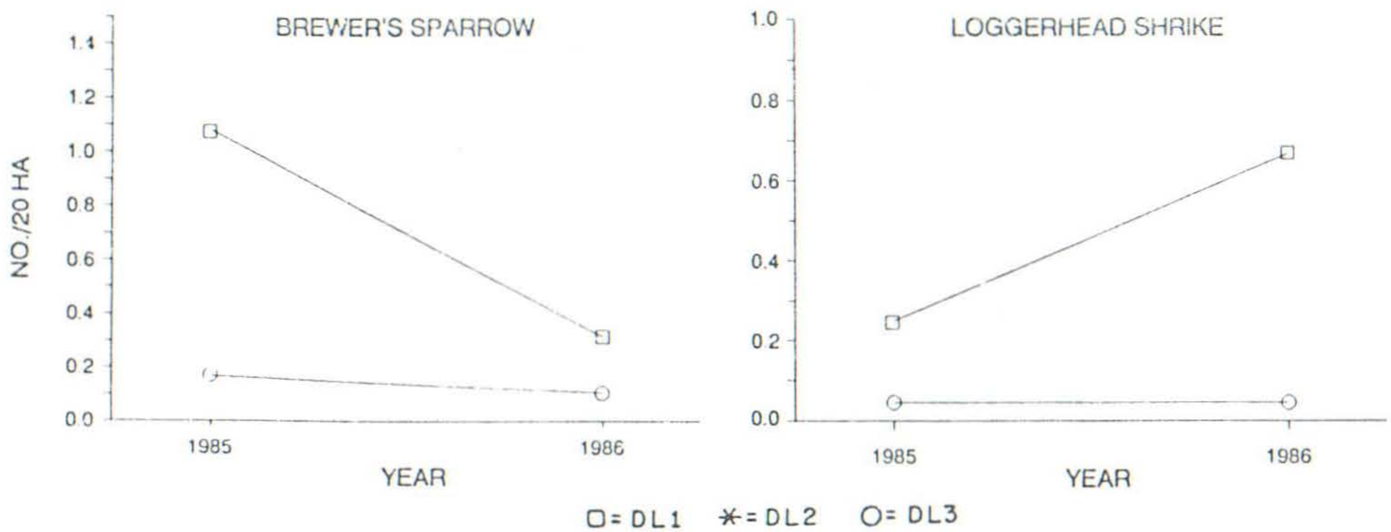

Figure 18. Population trends among shrub birds on prairie sites by disturbance level.

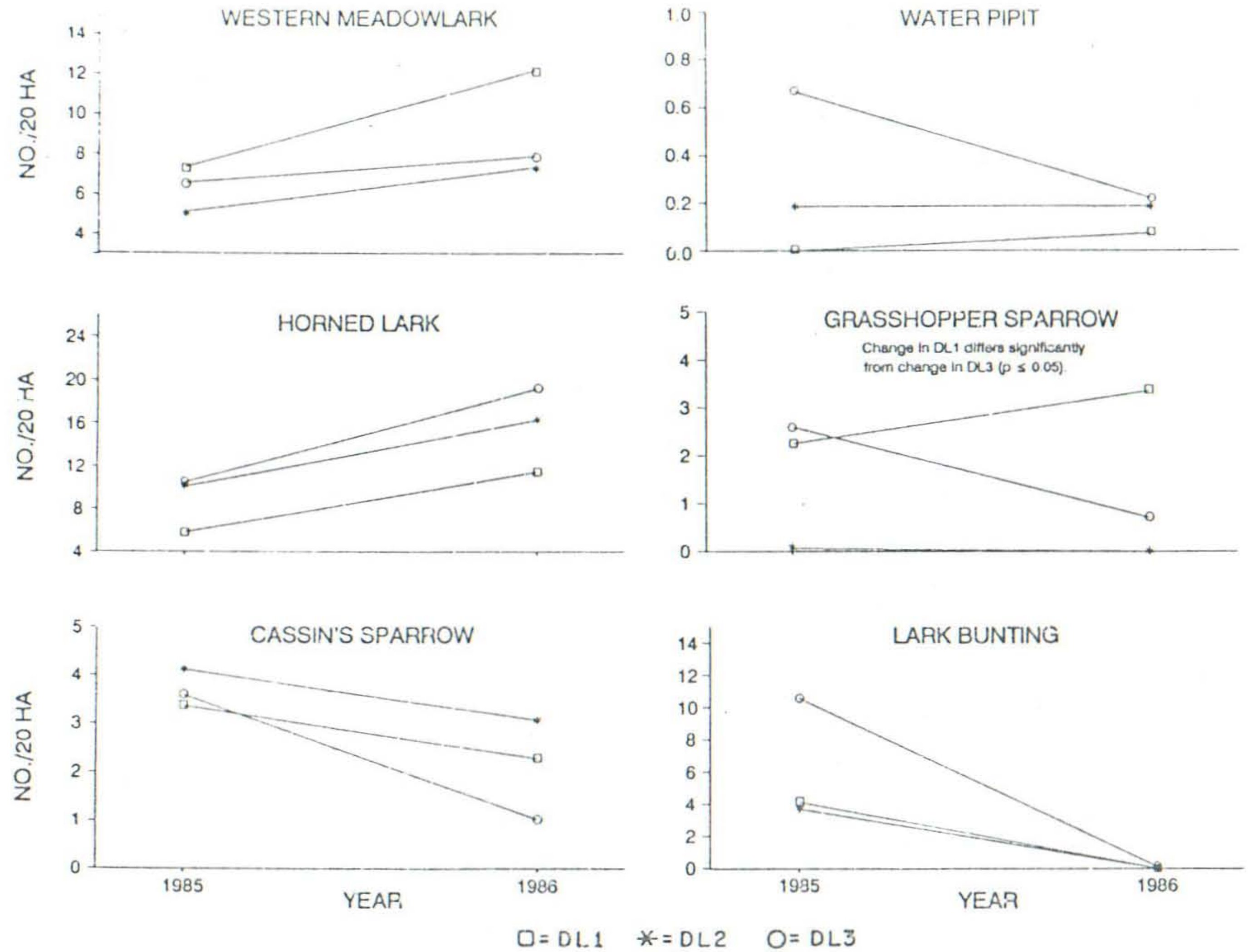

Figure 19. Population trends among grassland birds on prairie sites by disturbance level.

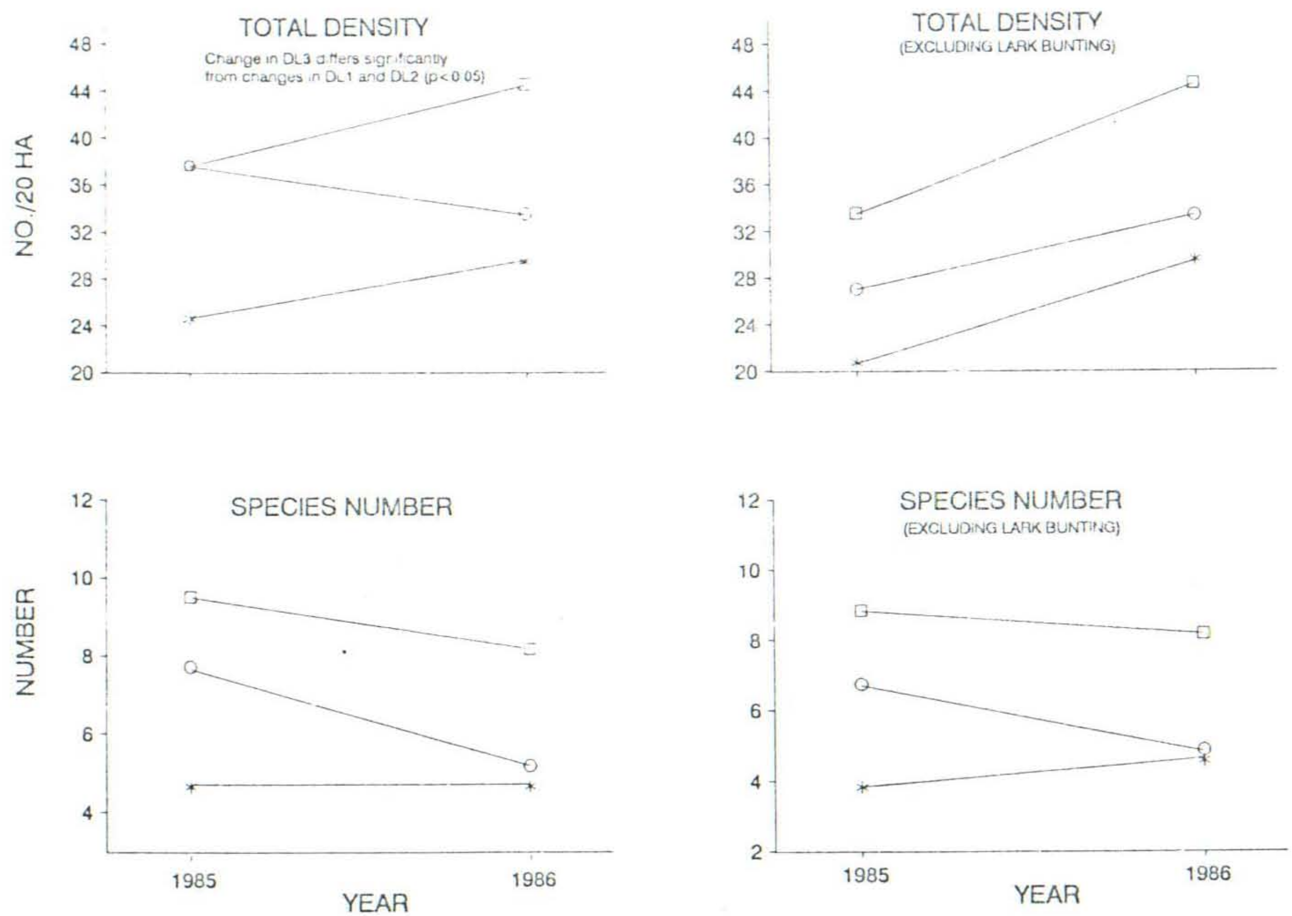

Figure 20. Trends in total avian density and species richness on prairie sites by disturbance level.

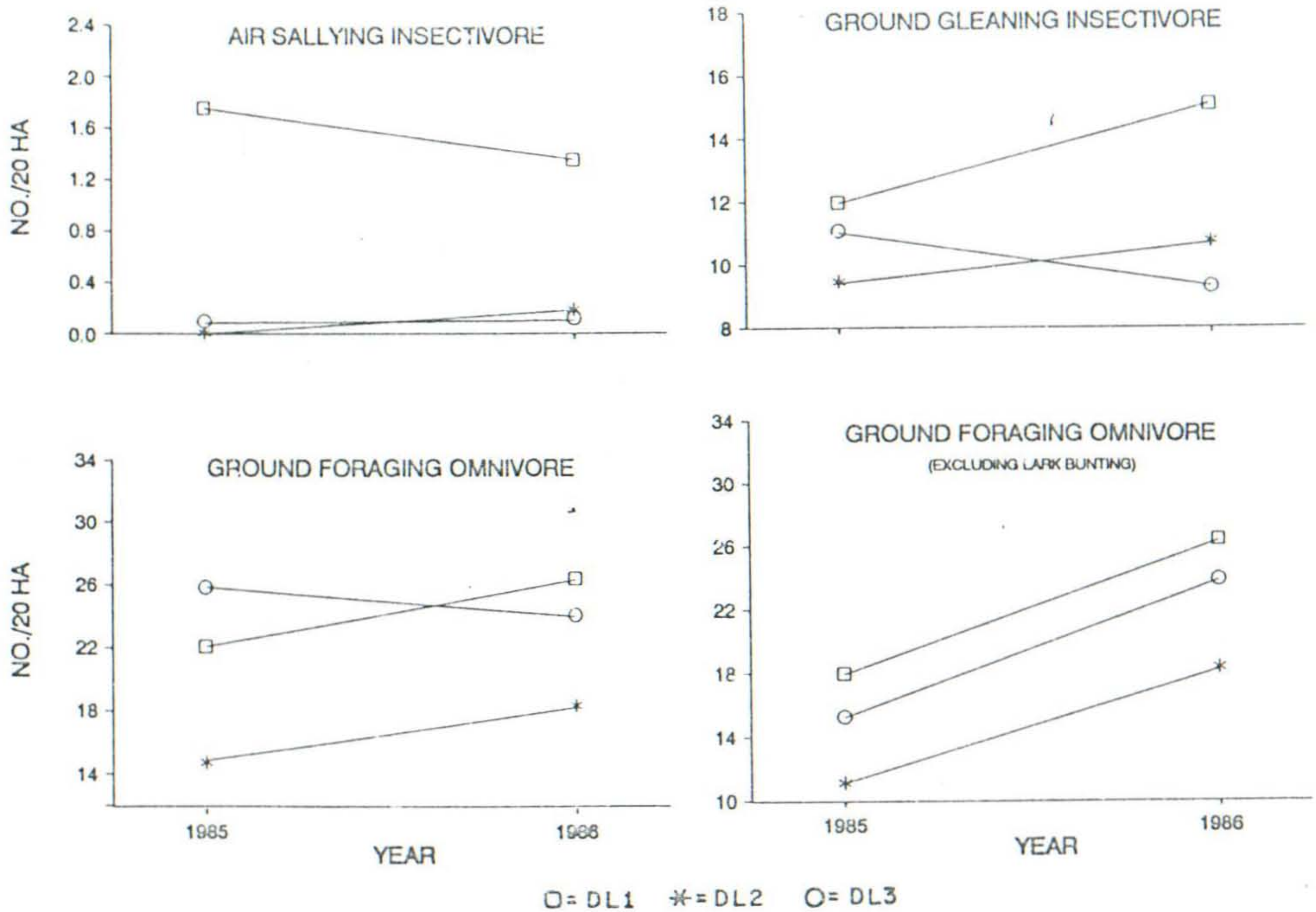

Figure 21. Trends in avian foraging guilds on prairie sites by disturbance level.

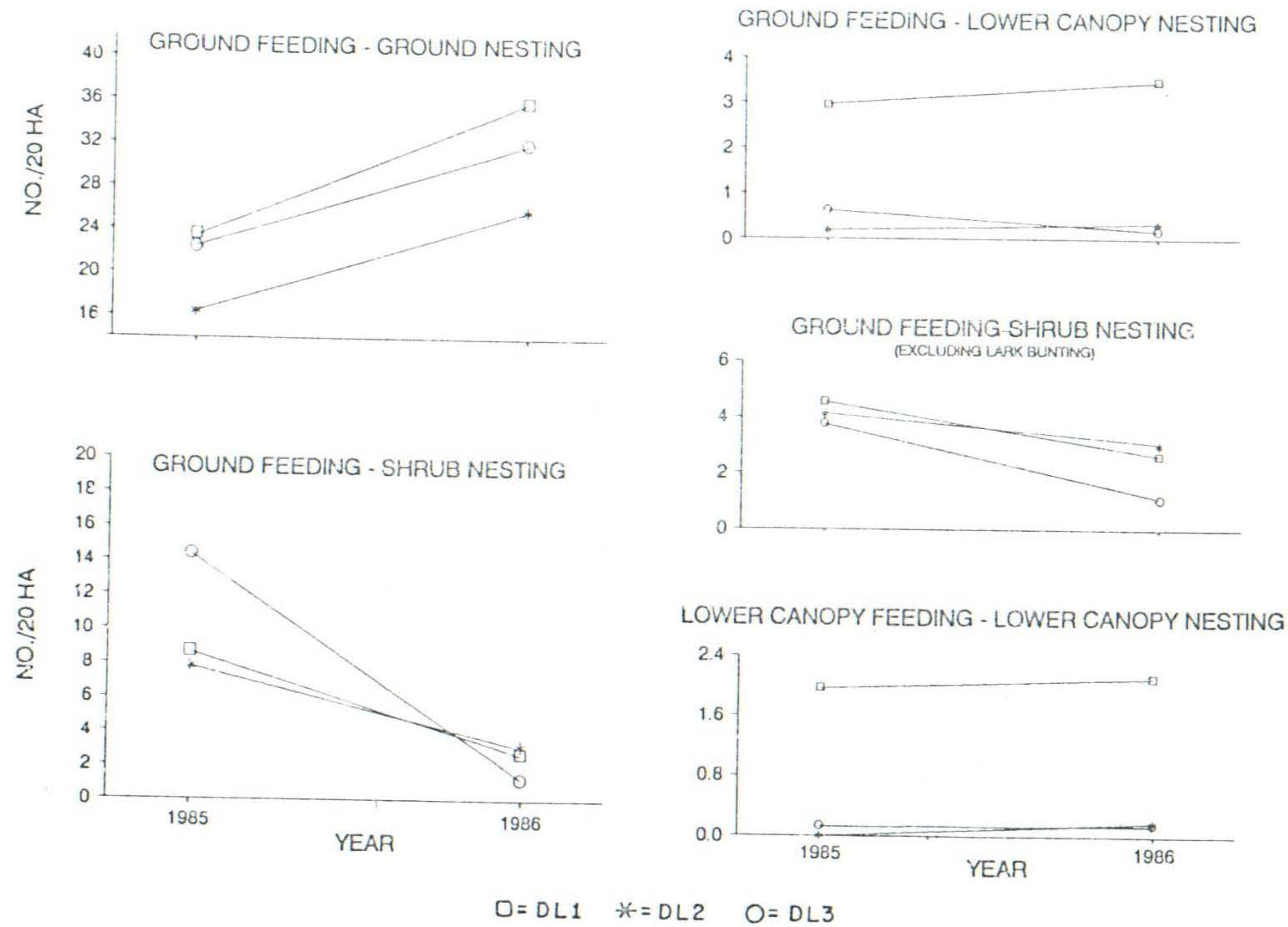

Figure 22. Trends in avian habitat zone guilds on prairie sites by disturbance level.

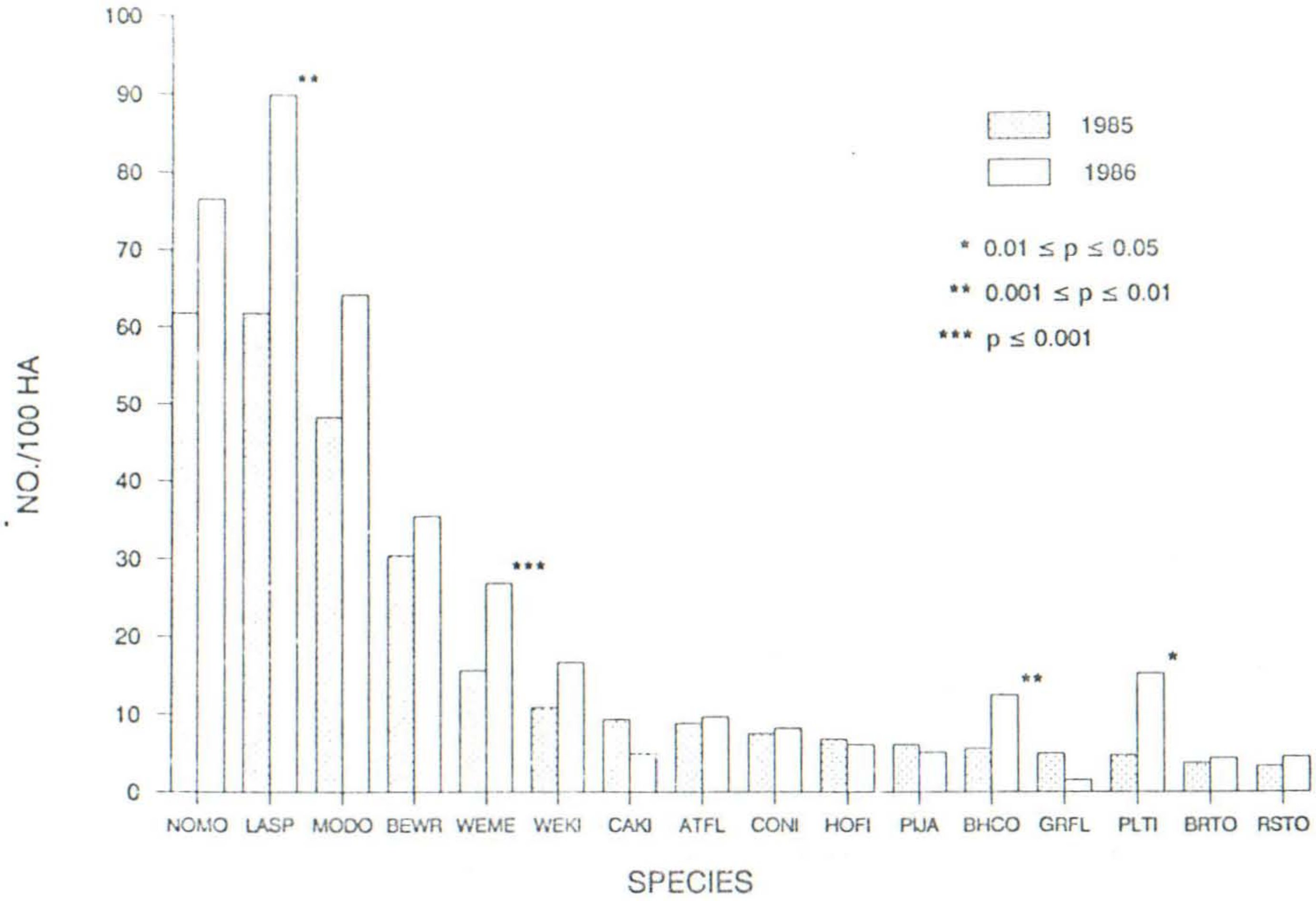

Figure 23. Mean density of selected bird species among 12 pinyon-juniper sites.

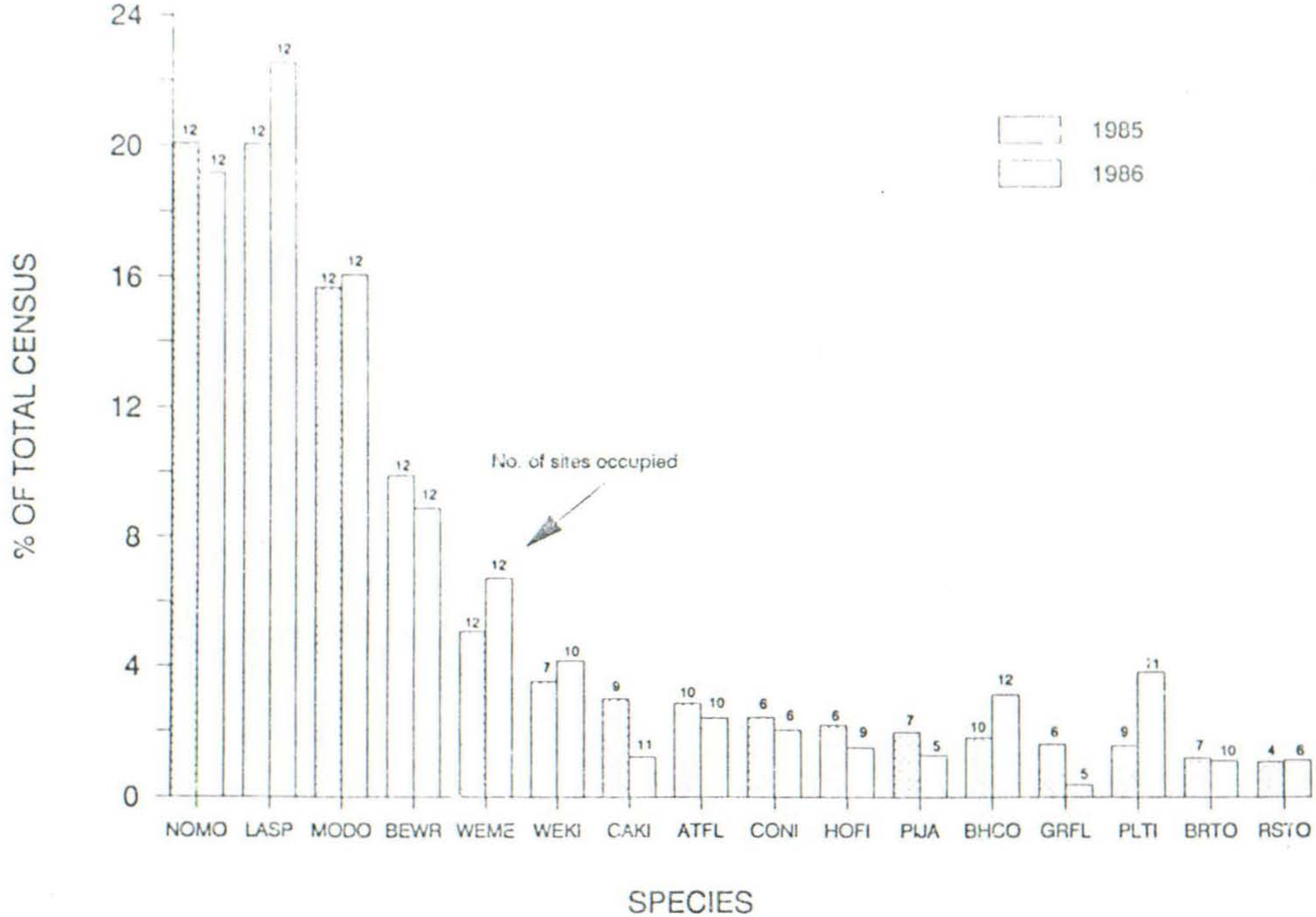

Figure 24. Relative density of selected bird species and number of sites occupied among 12 pinyon-juniper sites.

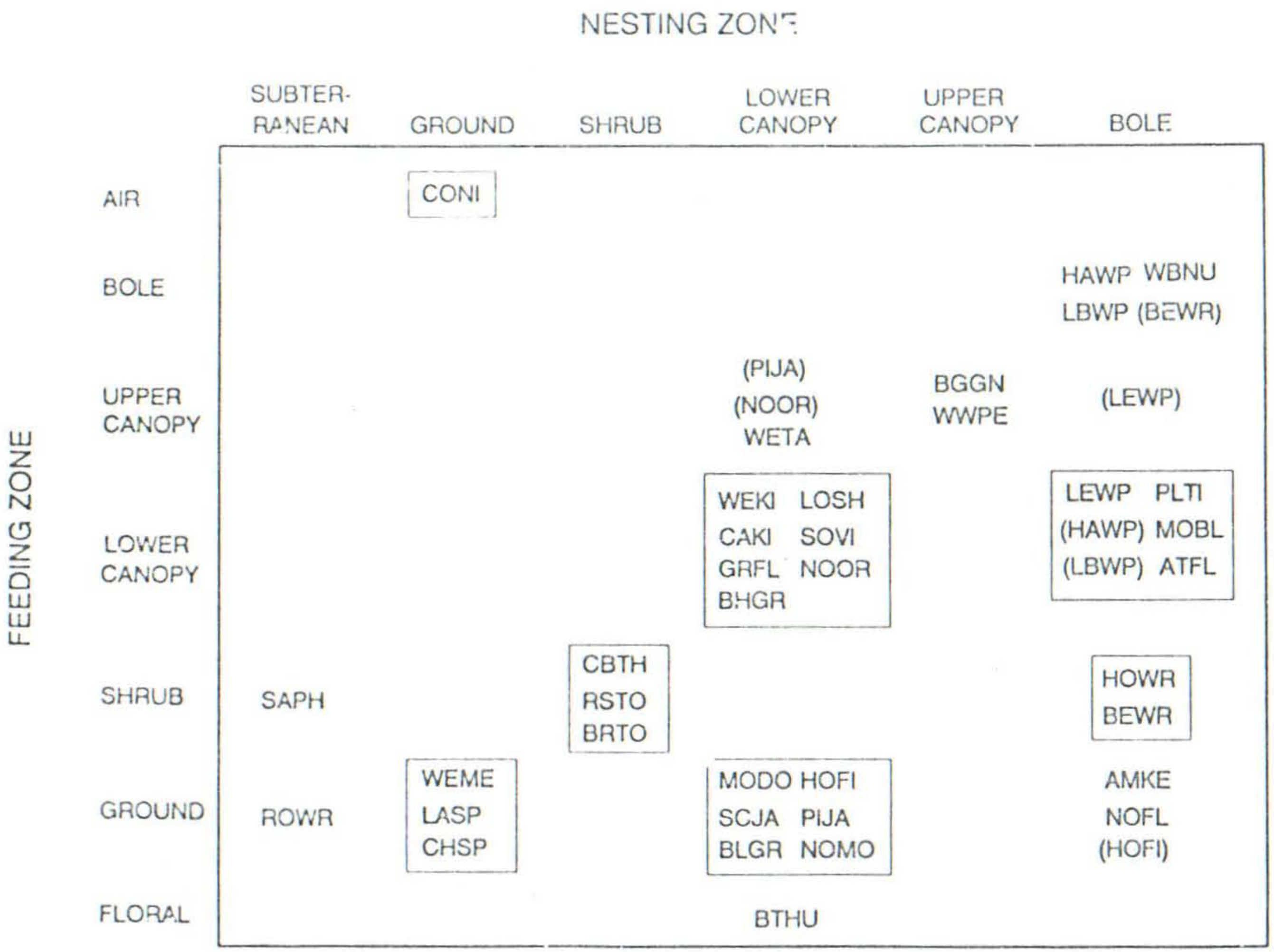

Figure 25. Pinyon-juniper birds by feeding and nesting zone.

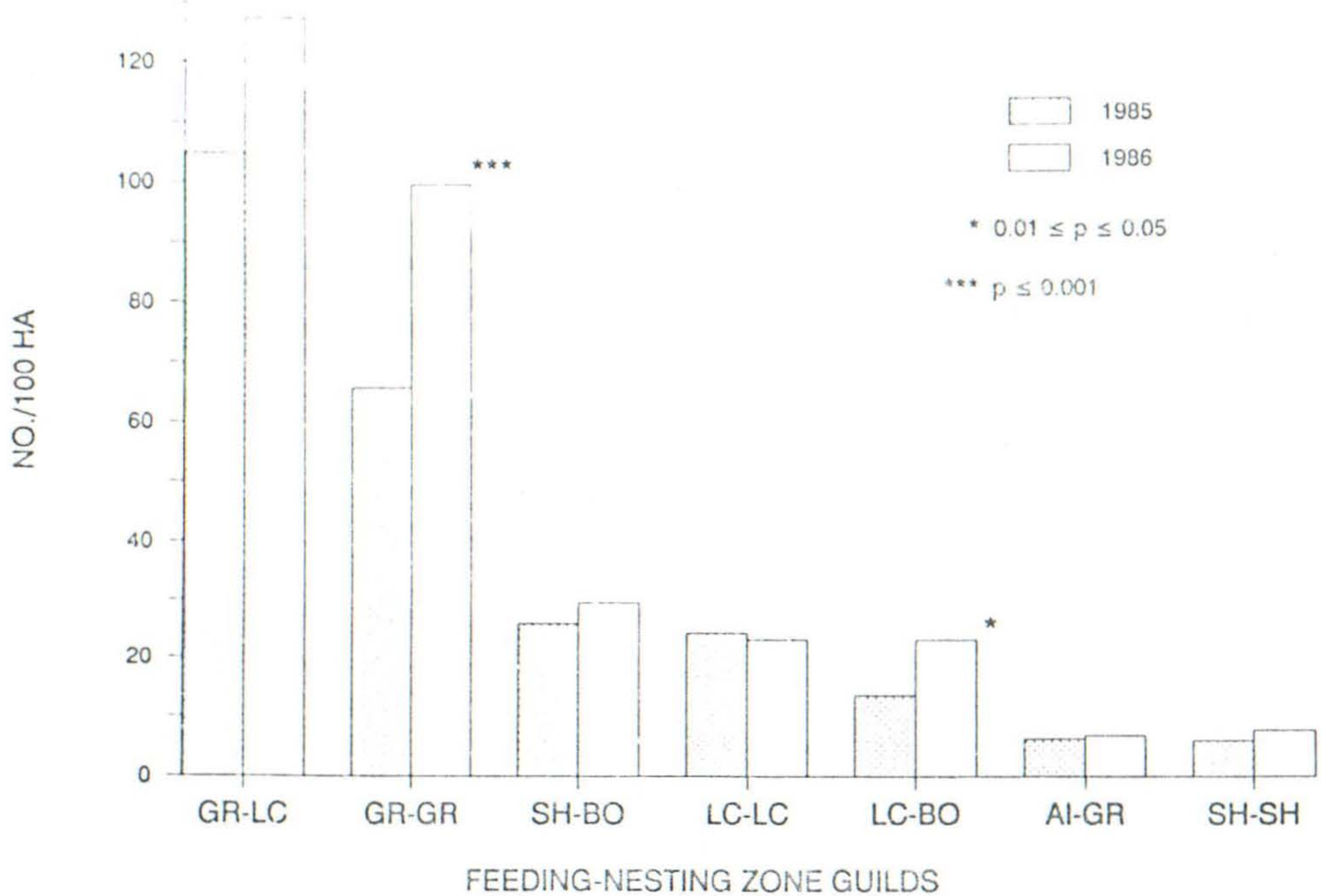

Figure 26. Mean density of selected avian habitat zone guilds among 12 pinyon-juniper sites.

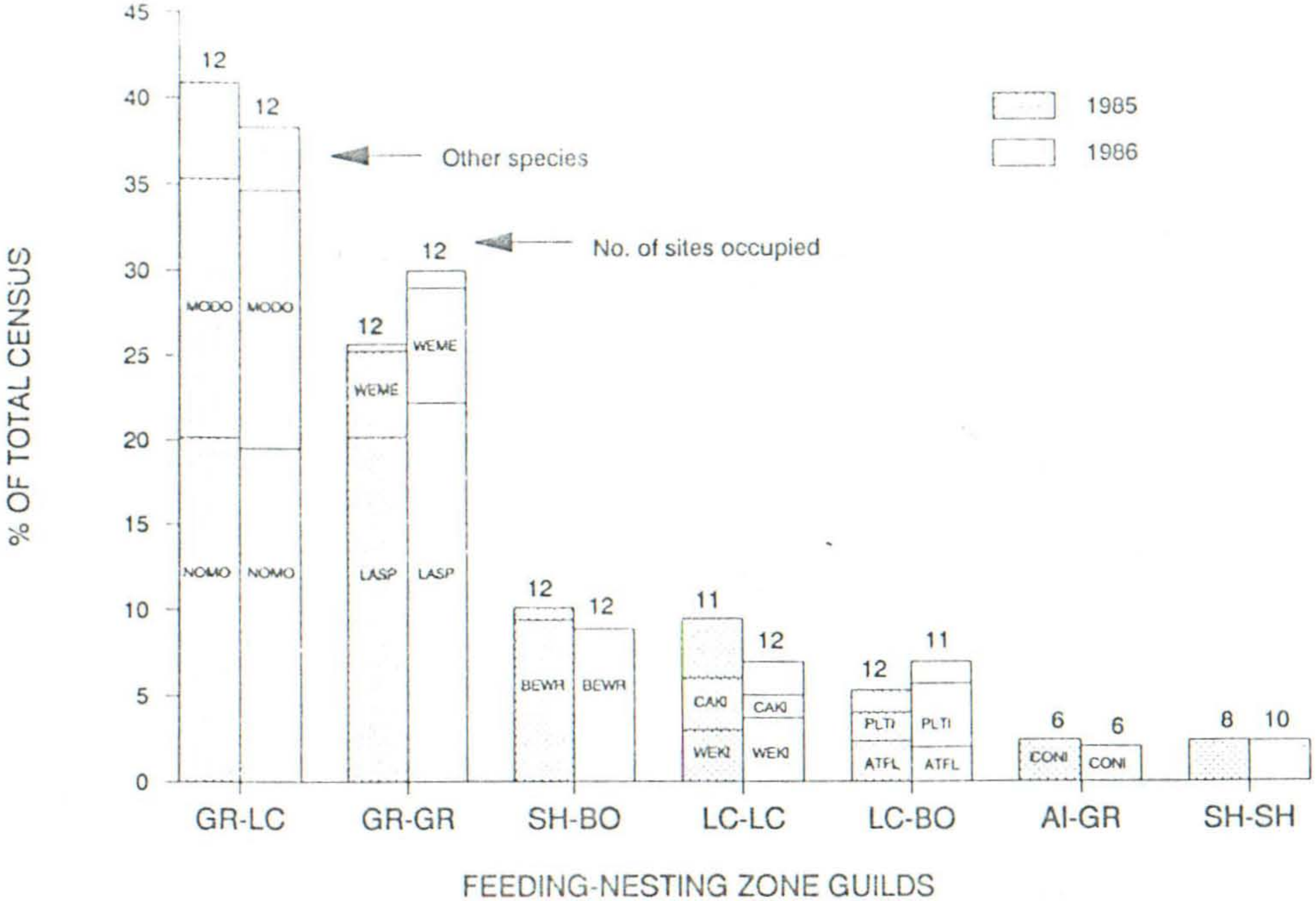

Figure 27. Relative density of avian habitat zone guilds and number of sites occupied among 12 pinyon-juniper sites.

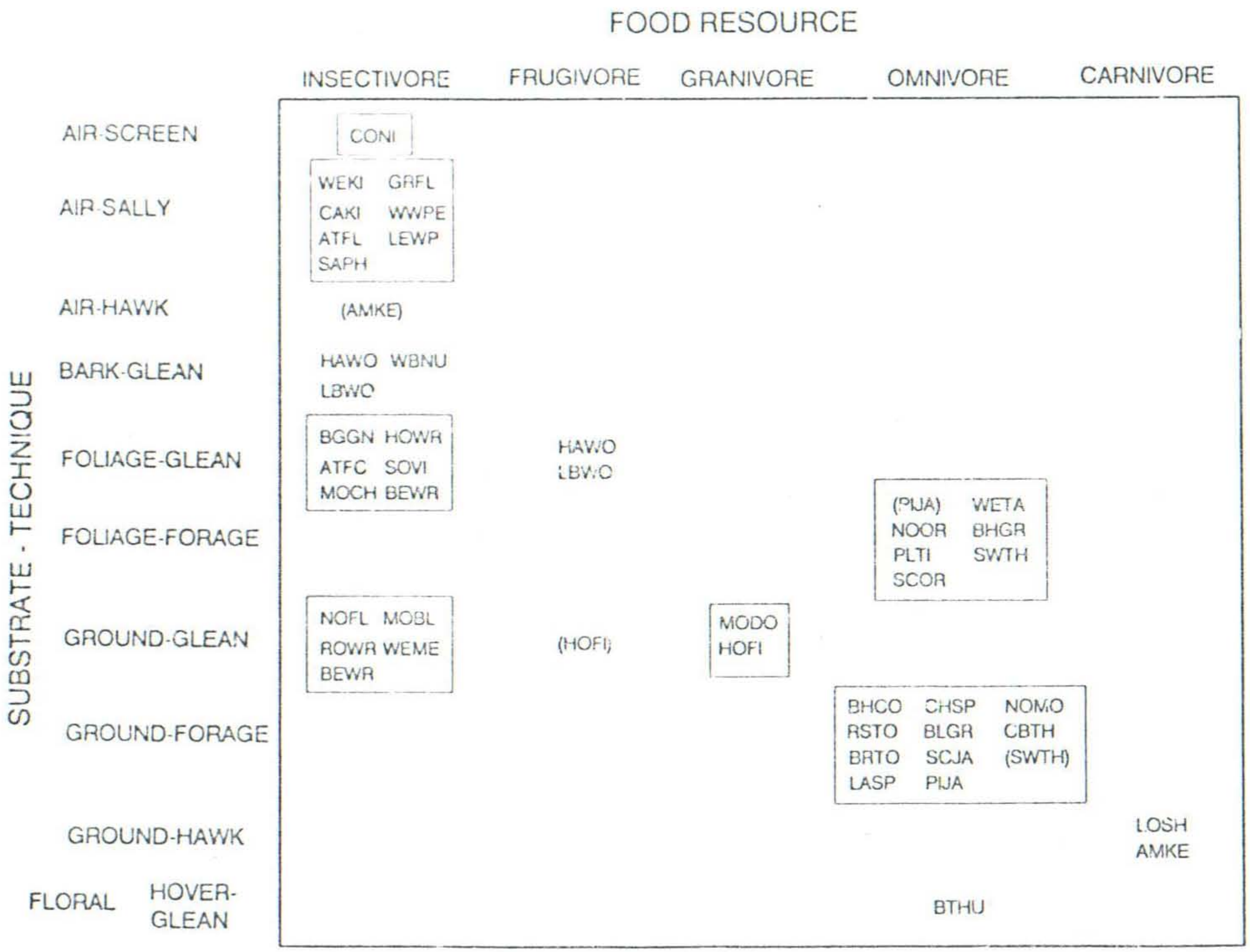

Figure 28. Pinyon-juniper birds by food resource and substrate-technique.

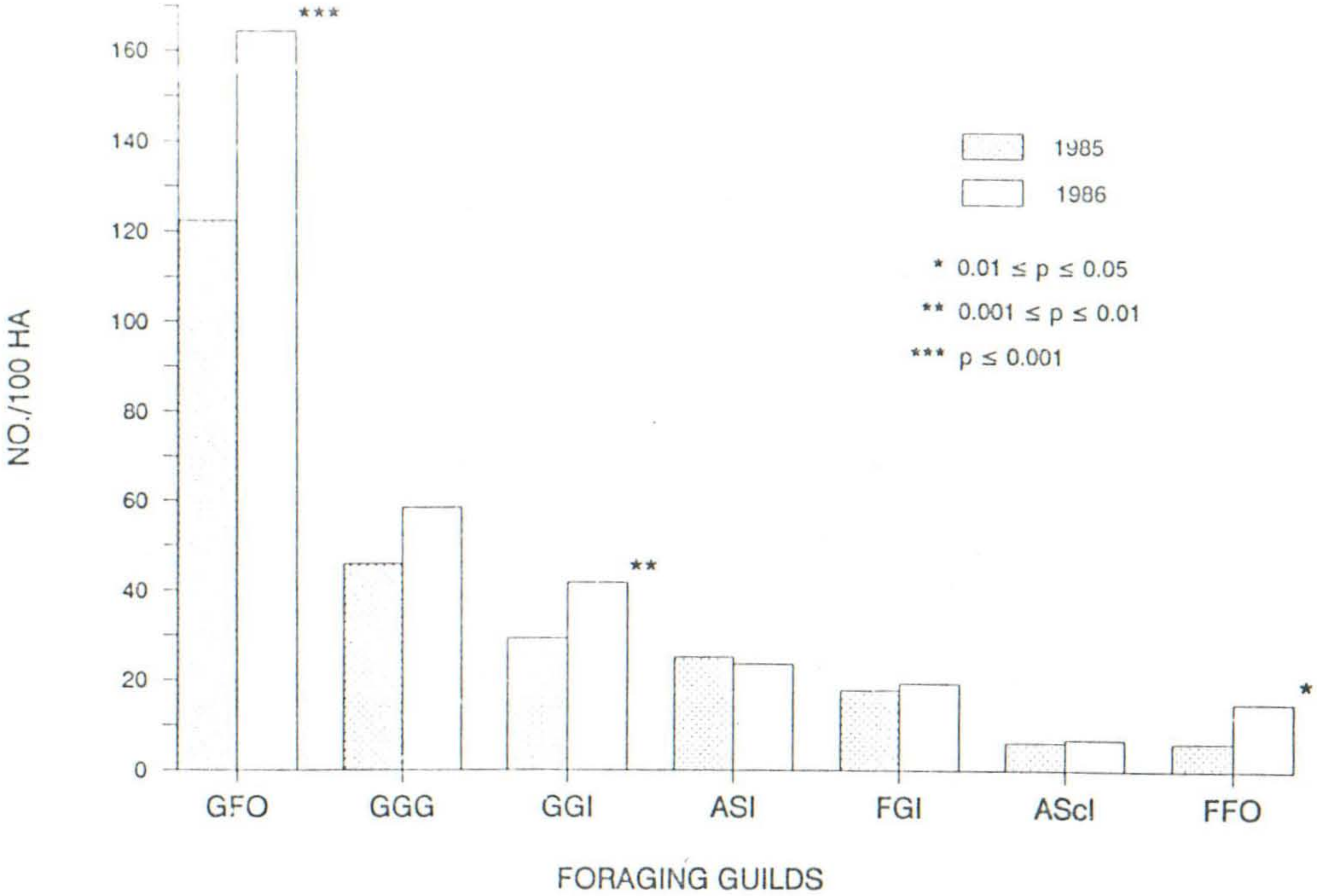

Figure 29. Mean density of avian foraging guilds among 12 pinyon-juniper sites.

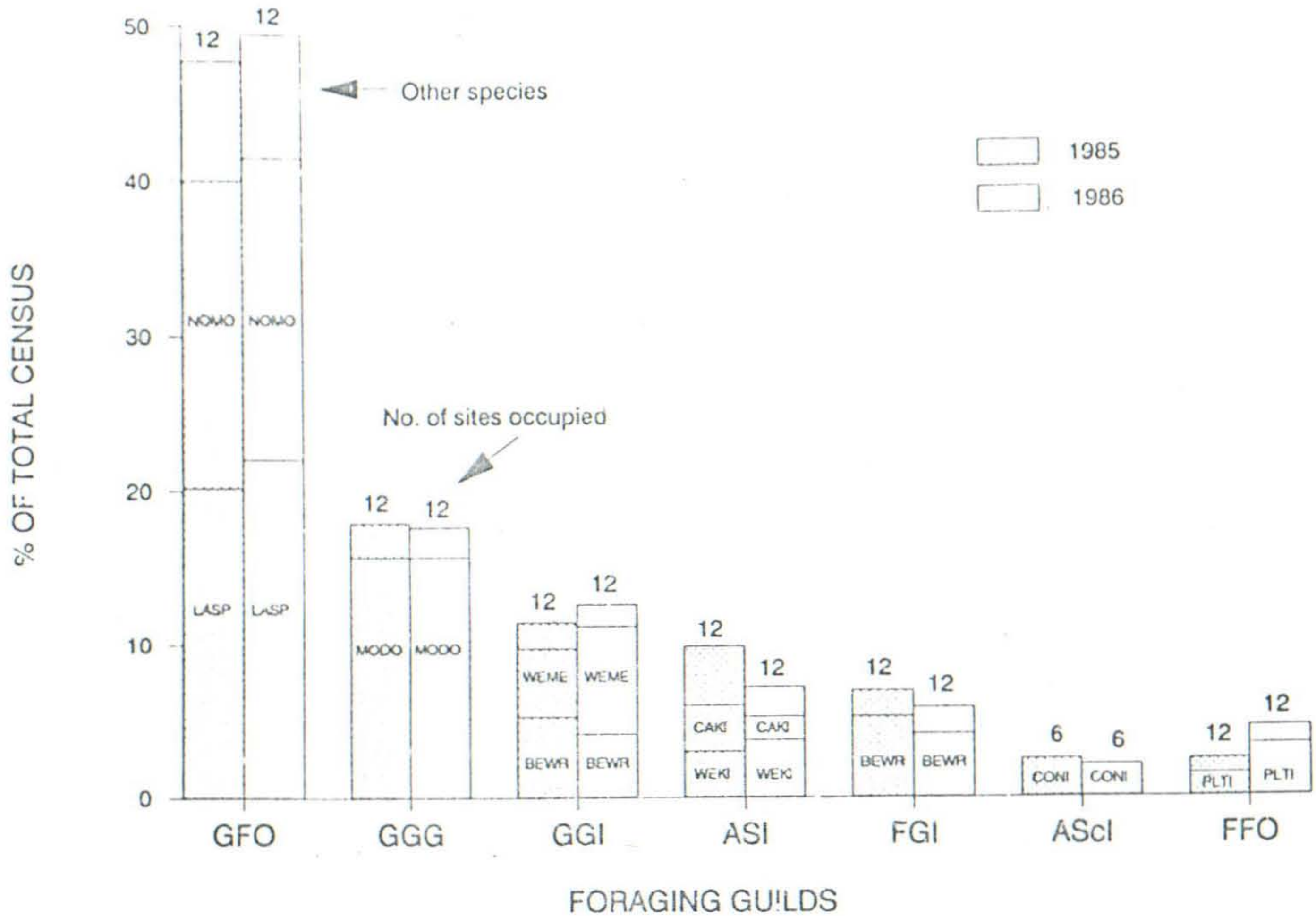

Figure 30. Relative density of avian foraging guilds and number of sites occupied among 12 pinyon-juniper sites.

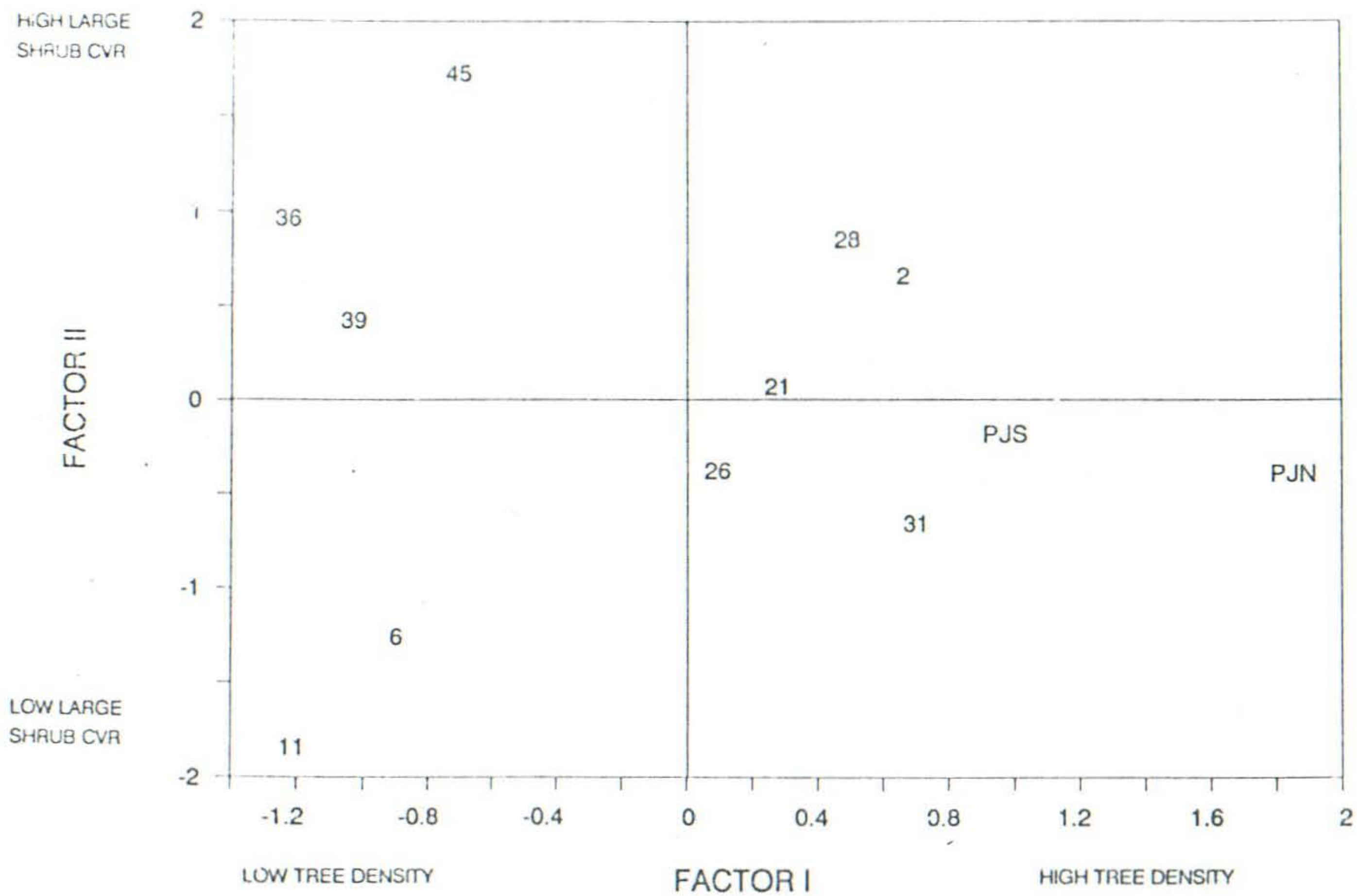

Figure 31. PCA by site number of 12 pinyon-juniper sites based on vegetation data.

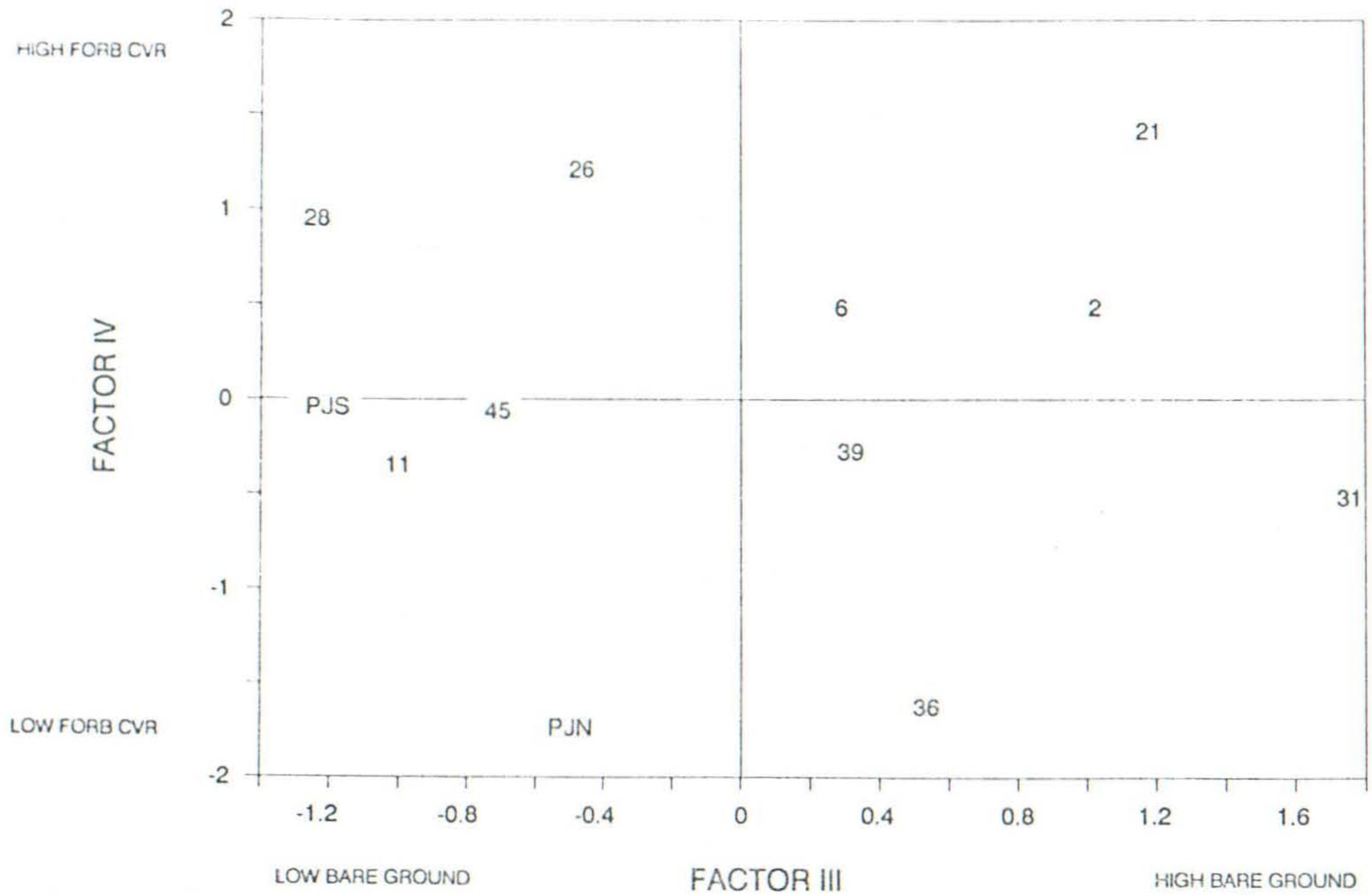

Figure 31. Cont'd.

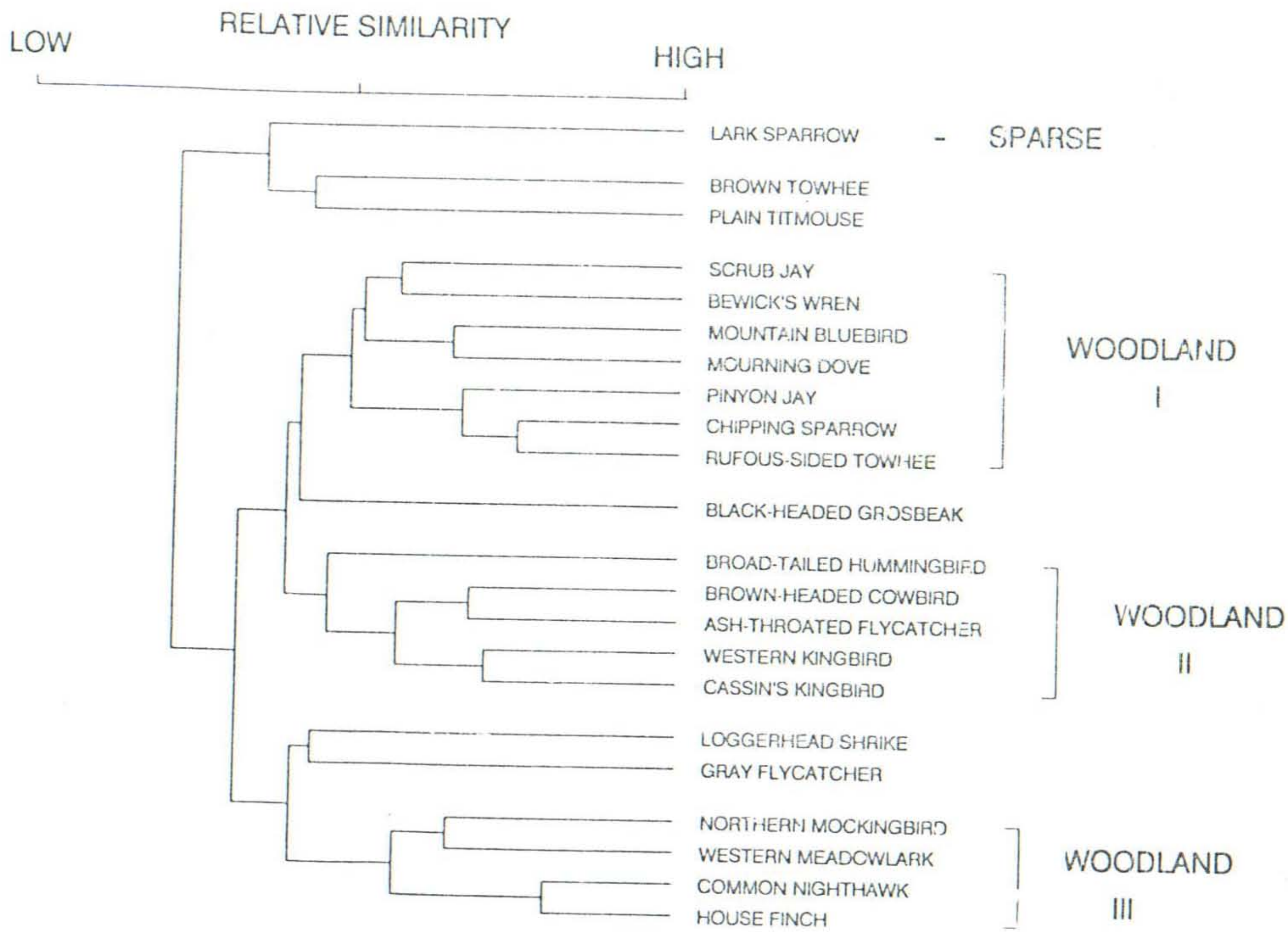

Figure 32. Cluster analysis of the pinyon-juniper sites based on vegetation data.

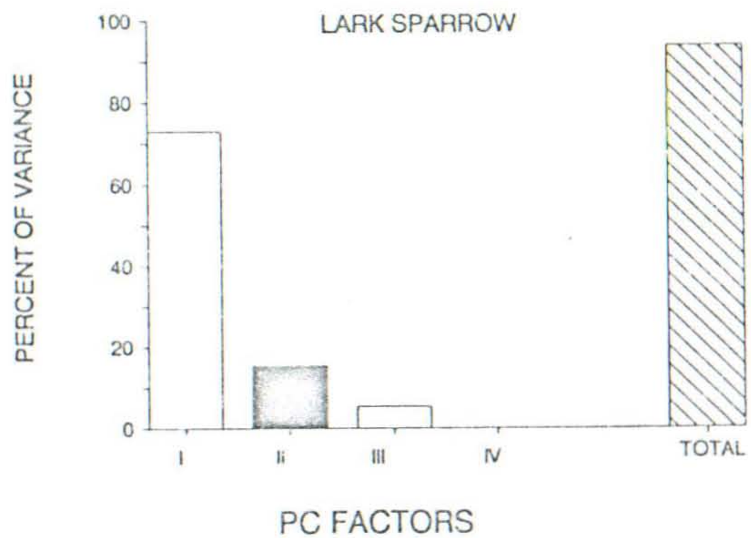

Figure 33. Multiple correlation analysis between PC habitat factors and the sparse cluster of pinyon-juniper birds.

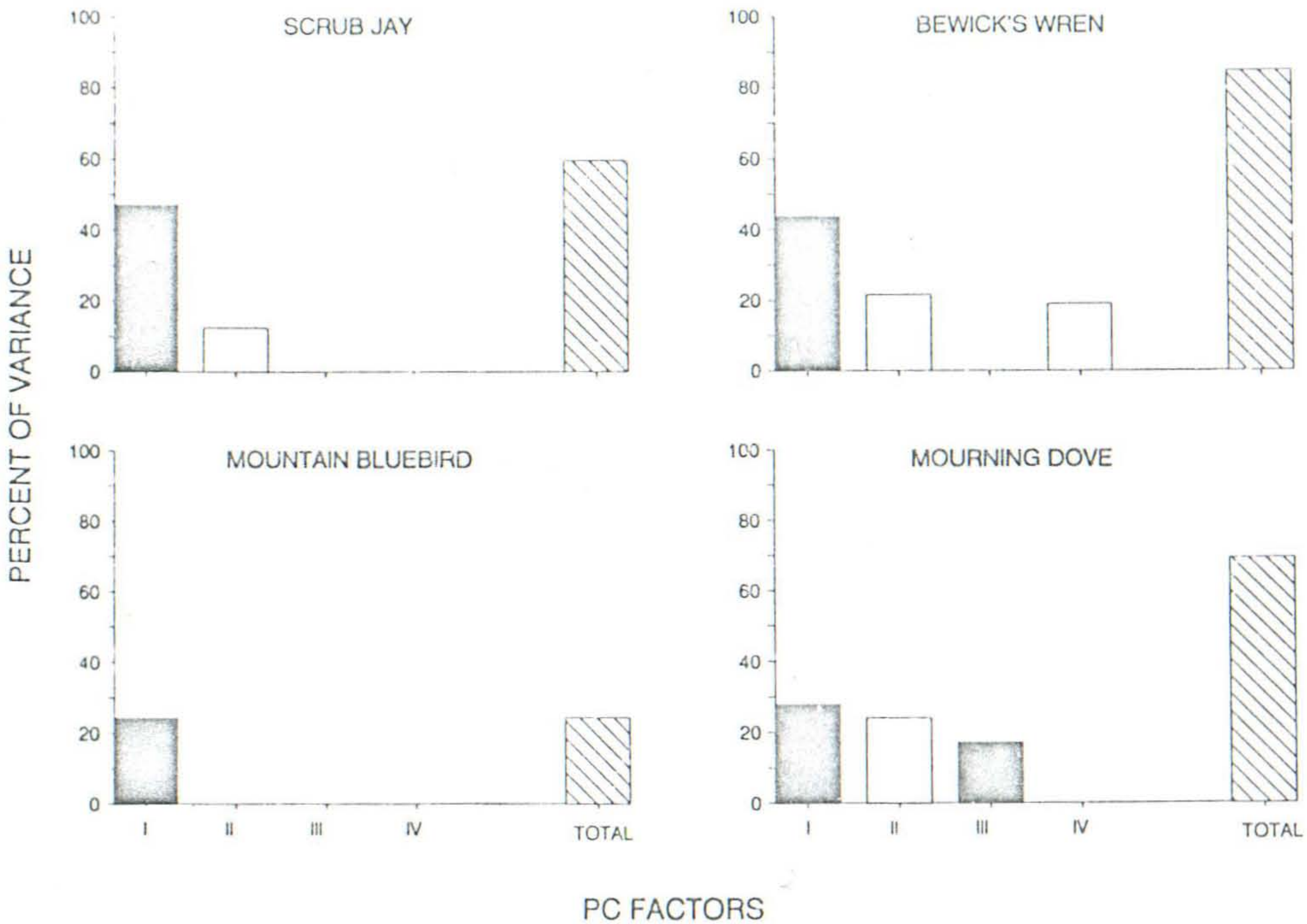

Figure 34. Multiple correlation analysis between PC habitat factors and the woodland I cluster of pinyon-juniper birds.

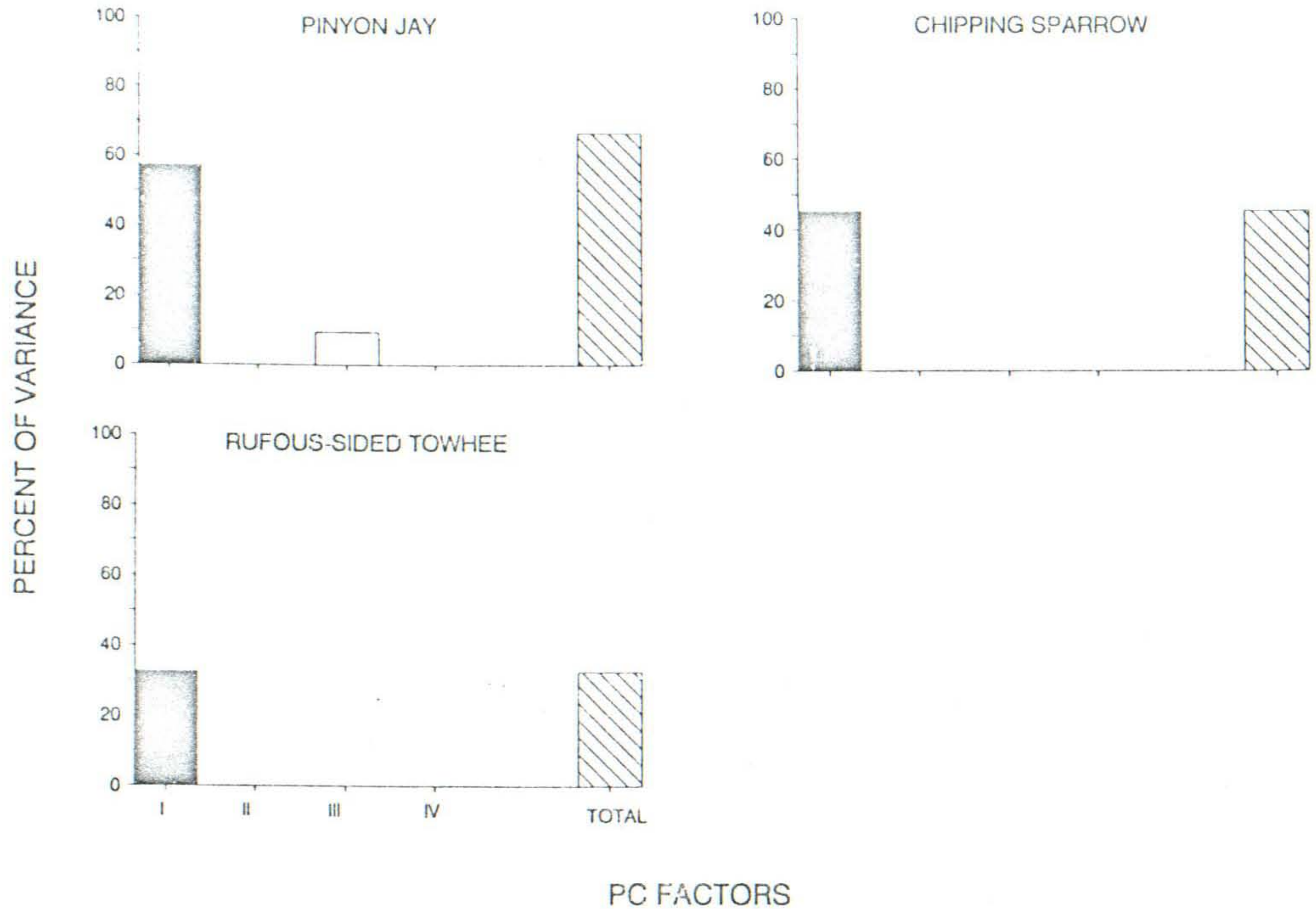

Figure 34. Cont'd.

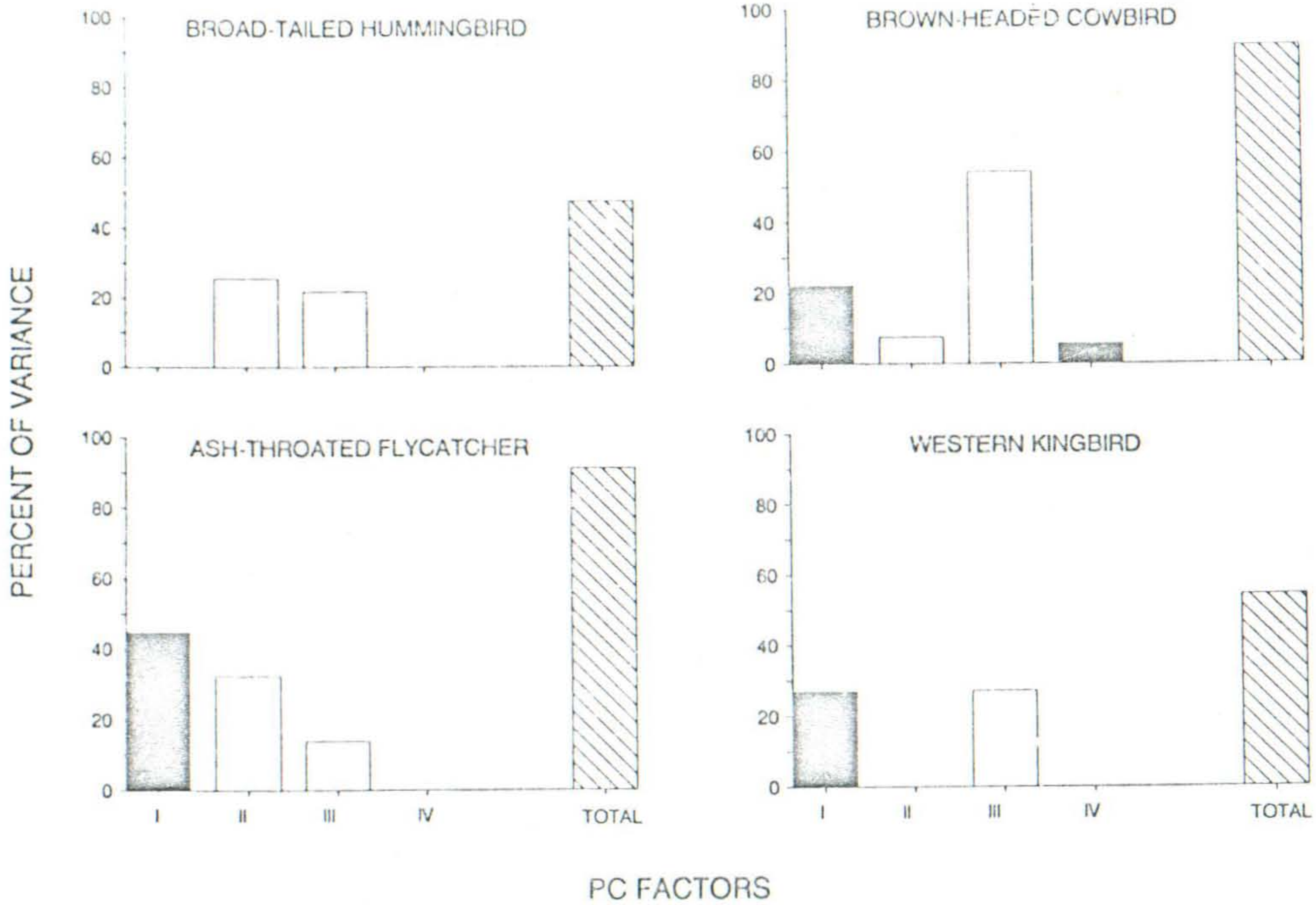

Figure 35. Multiple correlation analysis between PC habitat factors and the woodland II cluster of pinyon-juniper birds.

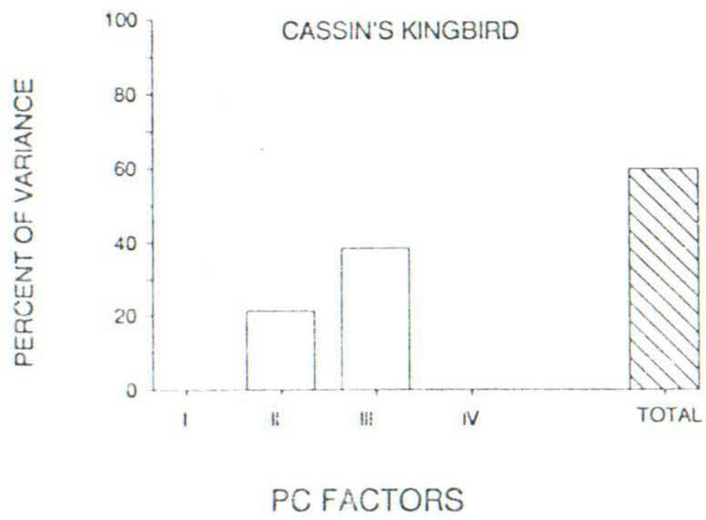

Figure 35. Cont'd.

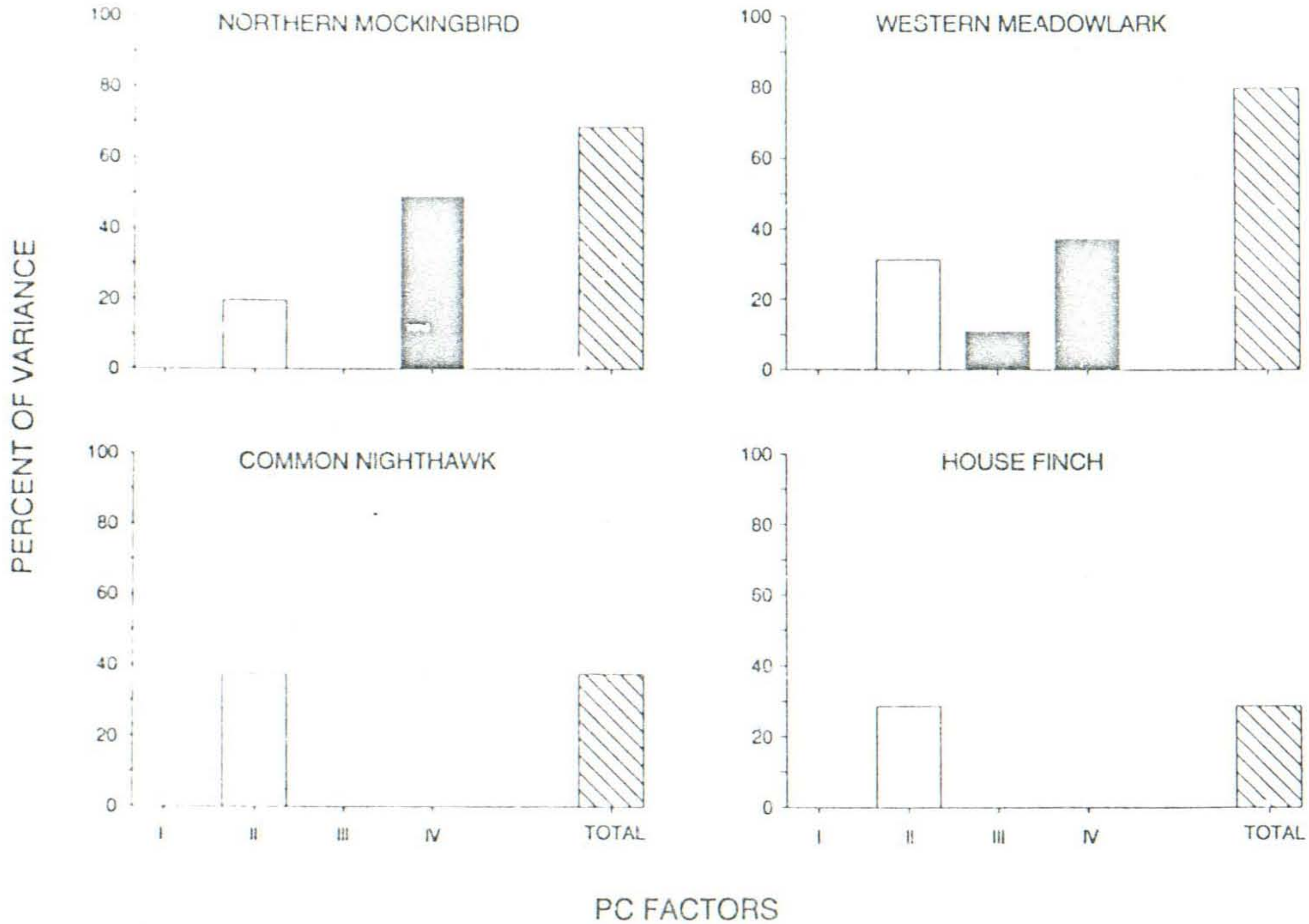

Figure 36. Multiple correlation analysis between PC habitat factors and the woodland III cluster of pinyon-juniper birds.

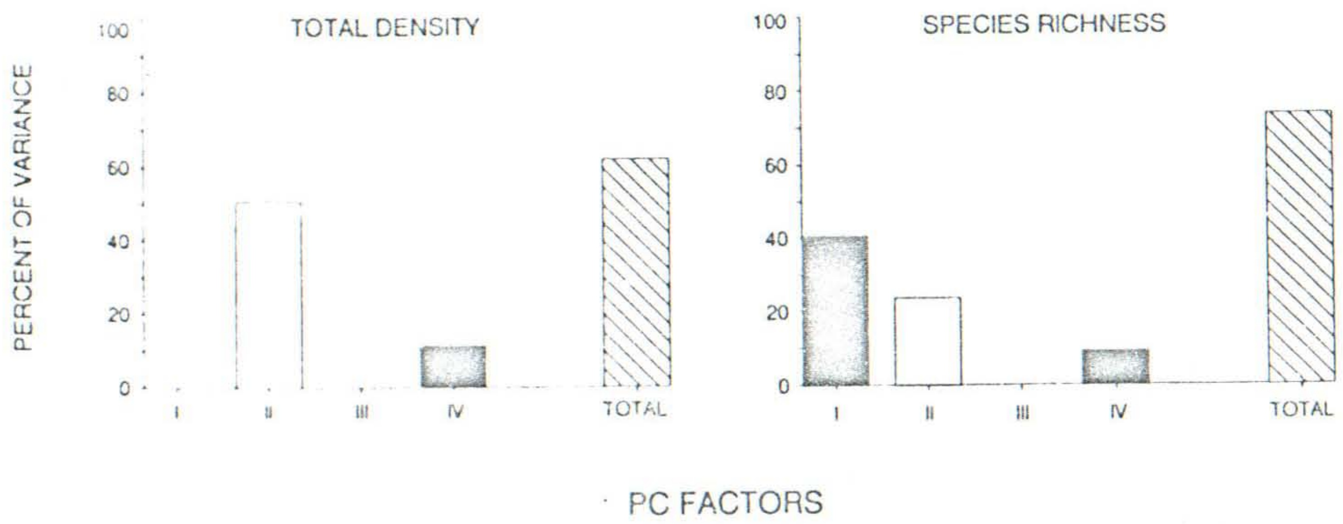

Figure 37. Multiple correlation analysis between PC habitat factors and total density and species richness of pinyon-juniper birds.

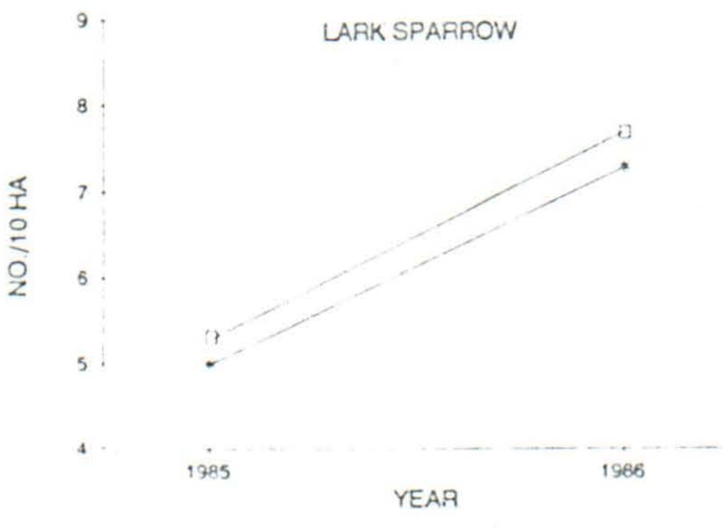

Figure 38. Population trends among lark sparrows by disturbance level.

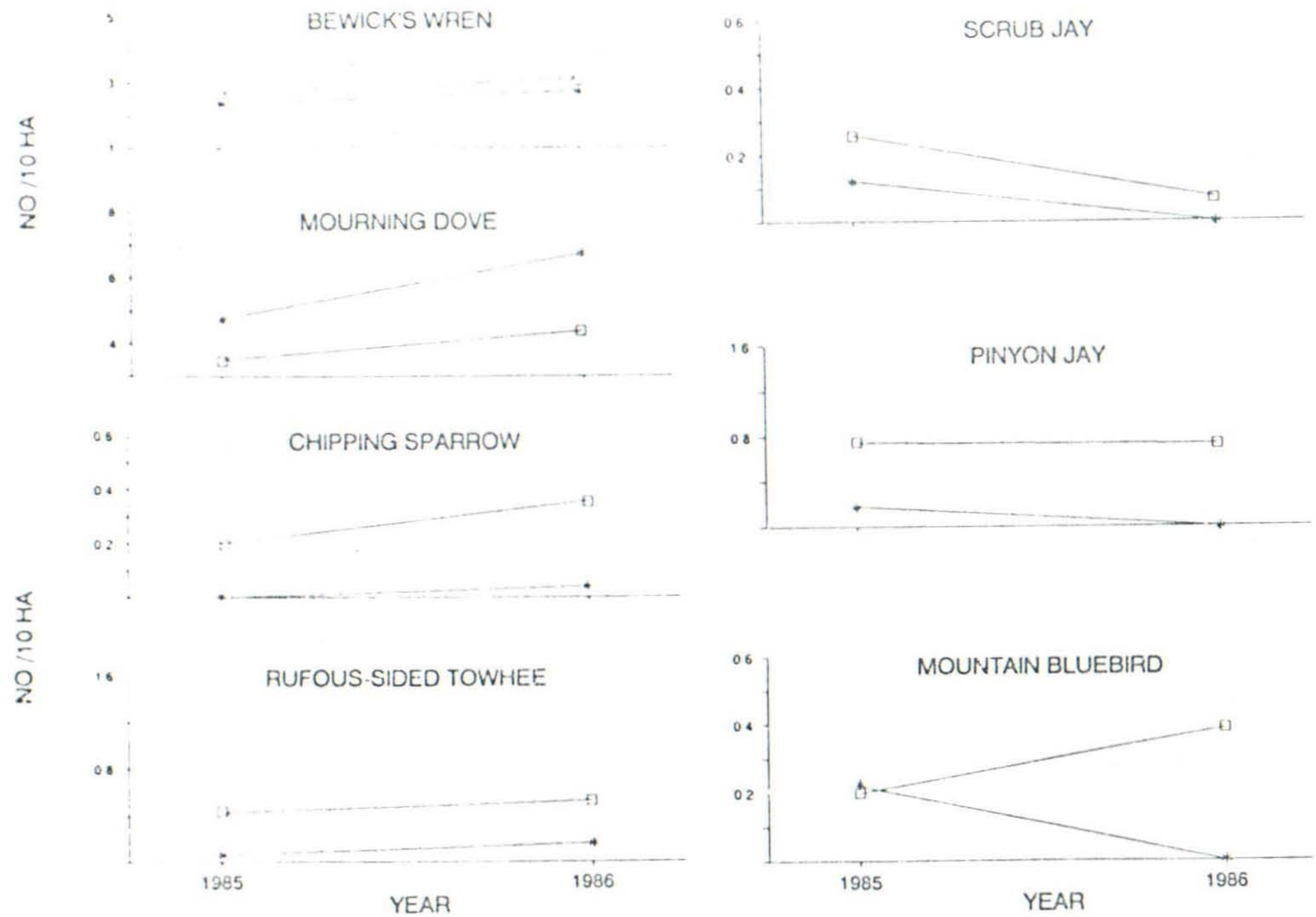

Figure 39. Population trends among woodland I birds on pinyon-juniper sites by disturbance level.

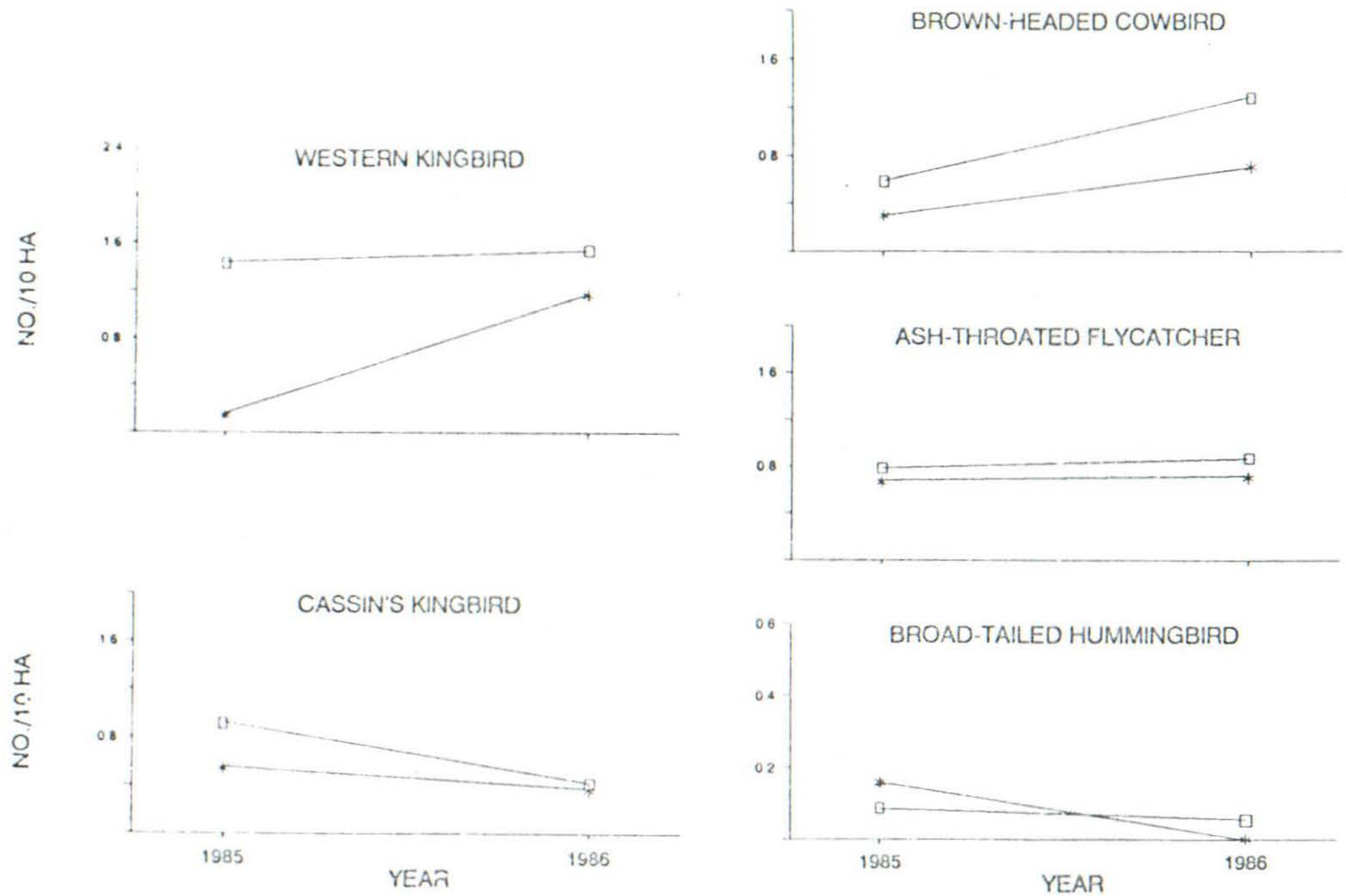

Figure 40. Population trends among woodland II birds on pinyon-juniper sites by disturbance level.

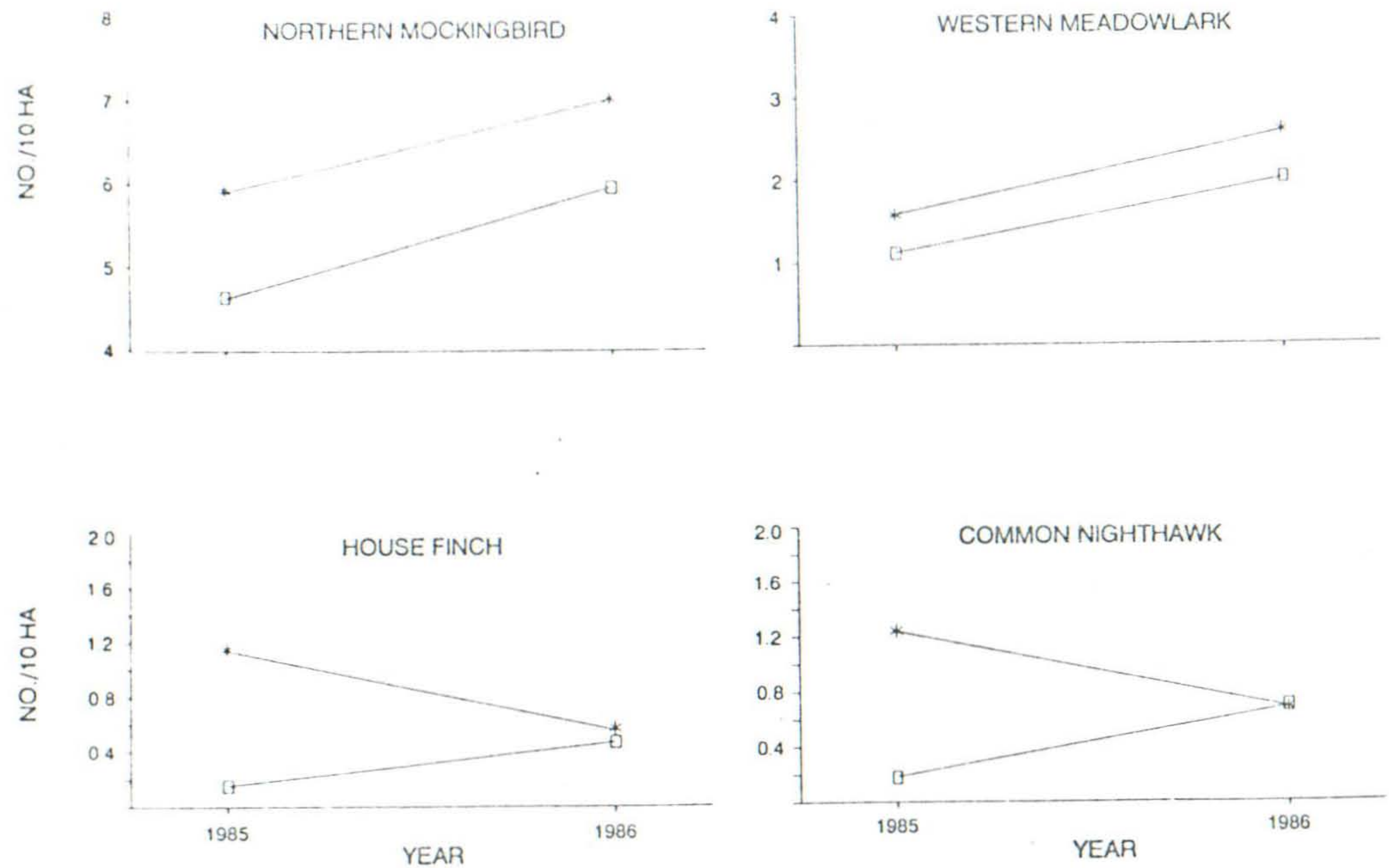

Figure 41. Population trends among woodland III birds on pinyon-juniper sites by disturbance level.

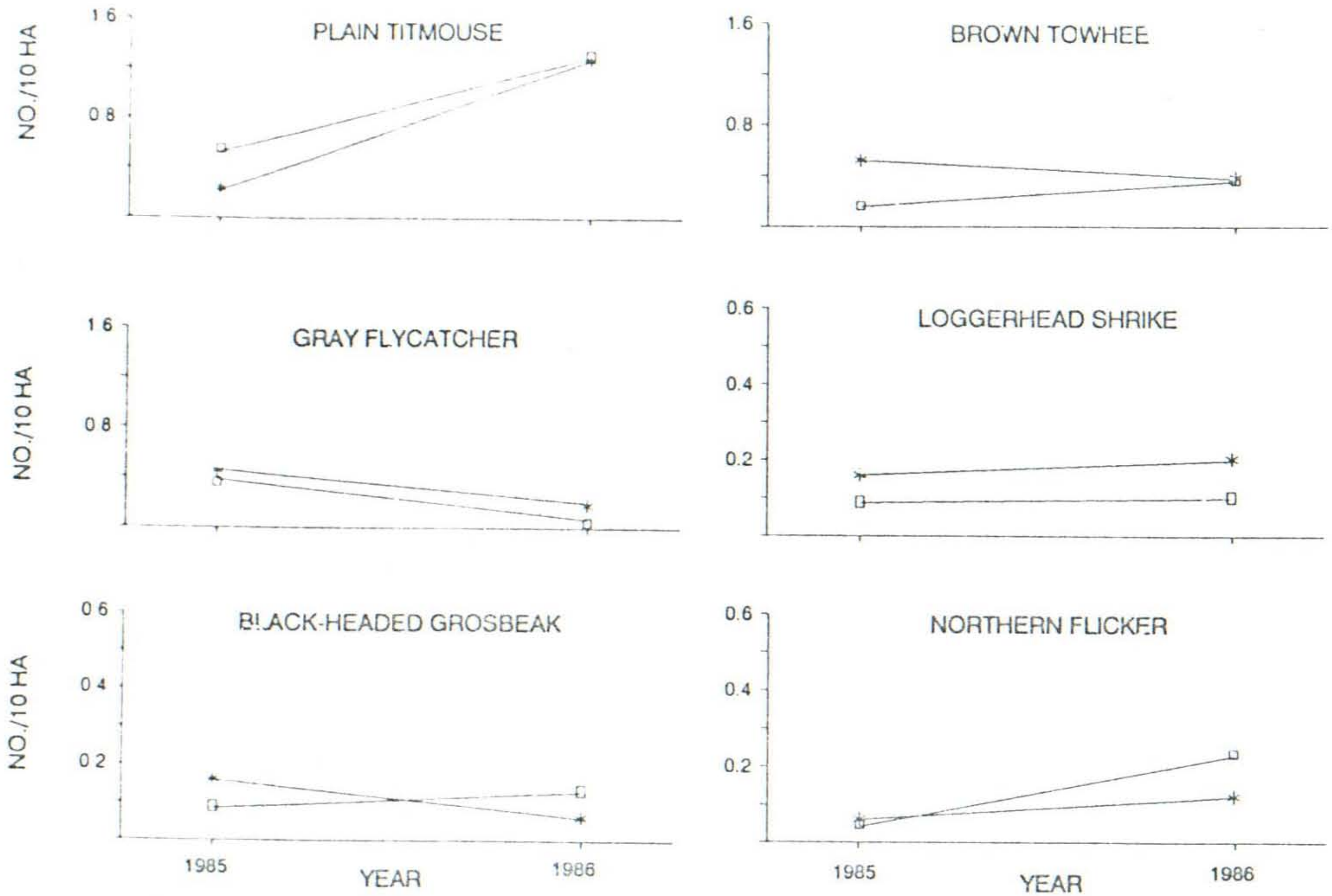

Figure 42. Population trends among other pinyon-juniper birds by disturbance level.

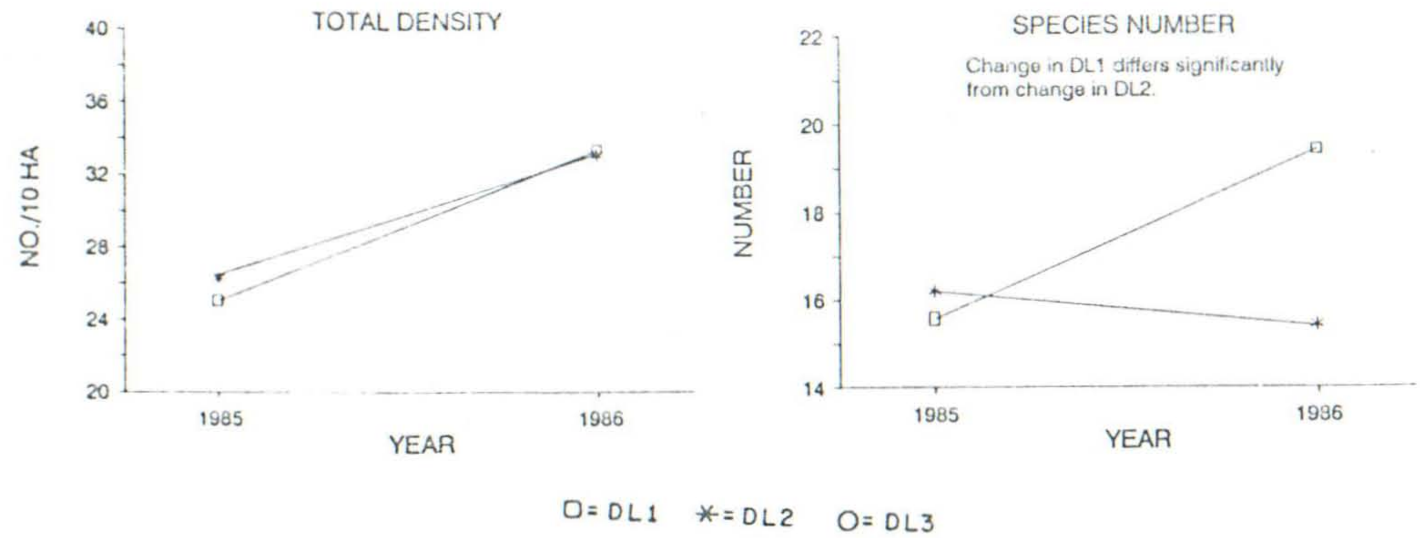

Figure 43. Trends in total avian density and species richness on pinyon-juniper sites by disturbance level.

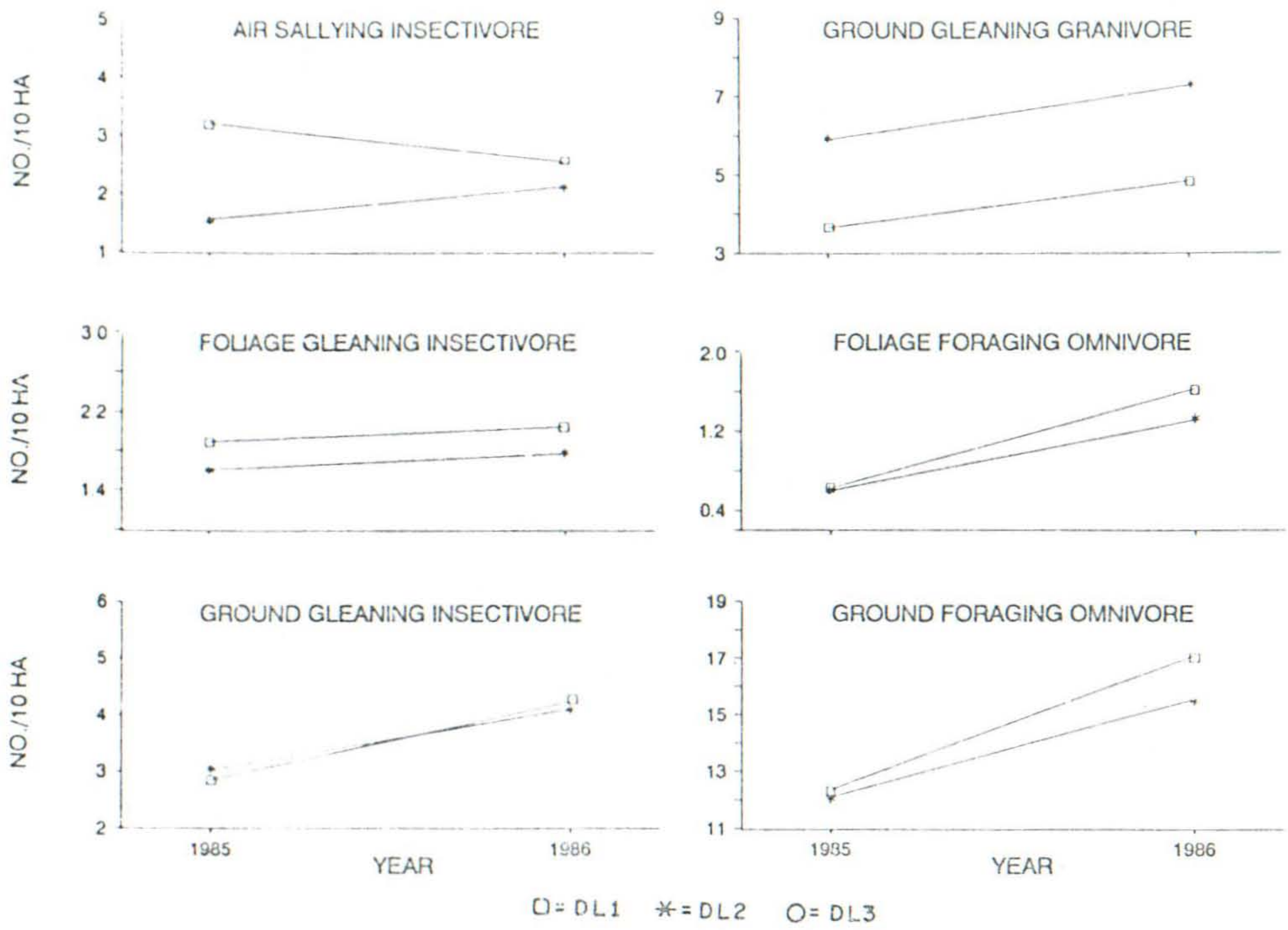

Figure 44. Trends in avian foraging guilds on pinyon-juniper sites by disturbance level.

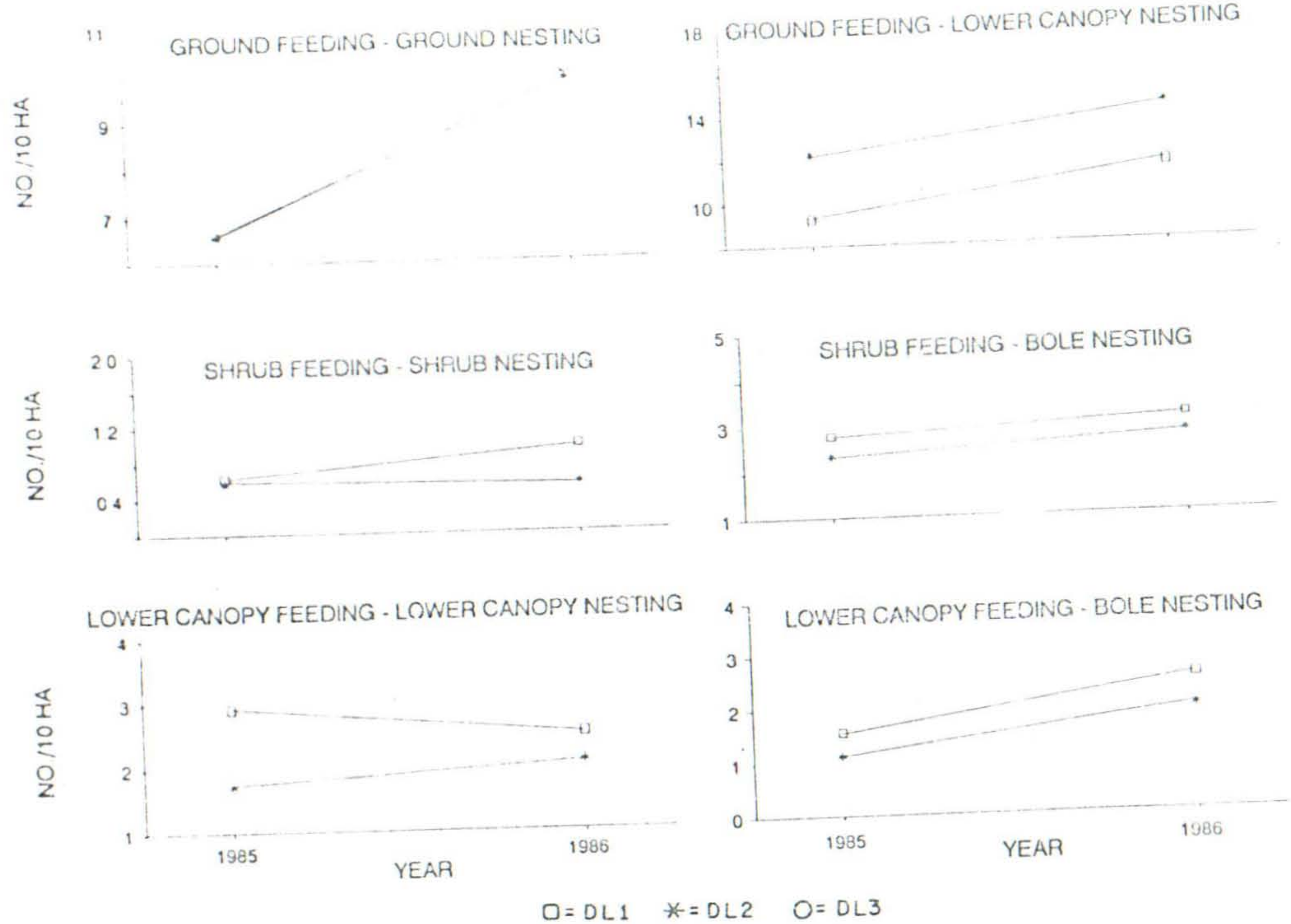

Figure 45. Trends in avian habitat zone guilds on pinyon-juniper sites by disturbance level.

Table 1

PCA of Prairie Study Sites Based on Habitat Variables

	PC Habitat Factors				
	I	II	III	IV	V
Eigenvalue	4.78	3.05	3.47	1.88	1.60
% Variance	28.10	17.90	20.40	11.10	9.40
Cumulative %	28.10	46.00	66.40	77.50	86.90
H2	0.94				
AVHGT	0.89				
AVHIT	0.85				
H3	0.85				
Medium grass	0.77				
AVMAX	0.54		0.76		
Short grass	-0.83				
Bare ground	-0.57	0.71			
H1		-0.90			
Grass		-0.86			
Broadleaved		0.65			
Large shrub			0.94		
H4			0.84		
Cholla			0.78		
Tree				0.87	
Forb				0.70	
Yucca					0.85
Small shrub					0.78

Only significant factor loadings are shown (p≤0.05).

Table 2

Disturbance Due to Tracked Vehicle Activity on 17 Prairie Sites in 1986

Disturbance Level					
DL1		DL2		DL3	
Site	Percent	Site	Percent	Site	Percent
3	6.2	12	19.2	7	42.8
7	5.6	13	28.4	8	55.8
19	9.2	29	22.9	10	35.6
37	6.4	35	21.2	15	40.5
PC1	0.5	38	27.6	PT1	46.1
PC2	0.0			PT2	30.3
Mean	4.7		23.8		41.9

Table 3

PCA of Pinyon-Juniper Study Sites Based on Habitat Variables

	PC Habitat Factors			
	I	II	III	IV
Eigenvalue	3.54	1.73	1.50	1.33
% Variance	35.40	17.30	15.00	13.30
Cumulative %	35.40	52.70	67.70	81.00
Juniper	0.91			
Pinyon	0.88			
Dead trees	0.75	-0.55		
Small shrubs	-0.84			
Broadleaved	0.44	0.78		
Choila		0.65		
Yucca		0.57		
Bare ground			0.88	
Grass	-0.50		-0.70	
Forb				0.95

Only significant factor loadings are shown: ($p \leq 0.05$).

Table 4

Disturbance Due to Tracked Vehicle Activity
on 12 Pinyon-Juniper Sites in 1986

Disturbance Level			
DL1		DL2	
Site	Percent	Site	Percent
2	8.3	6	24.6
26	10.9	11	61.1
28	14.6	21	34.6
36	0.1	31	25.1
39	2.9	45	24.7
PJS	4.4		
PJN	1.0		
Mean	6.0		34.0

APPENDIX A:

GUILD CLASSIFICATION TERMINOLOGY

Foraging Guilds (modified from Ref 16)

Substrates (place from which food items are taken)

Air	Caught in the air
Bark	On, in, or under bark of trees
Foliage	On foliage
Ground	On the ground or on very low vegetation

Technique (the way in which food is obtained)

Forager	Takes most food items encountered upon substrate
Gleaner	Selects particular food items from substrate
Hawker	Flies after and captures prey in air or on ground
Hover-glean	Secures prey while hovering in air
Sallier	Sits and waits for insects to fly by, then pursues and captures insects in the air
Screener	Screens prey from air with bill open

Food Resource

Carnivore	Vertebrates
Frugivore	Fruits
Granivore	Seeds and nuts
Insectivore	Primarily insects but includes other invertebrate as well
Omnivore	A variety of foods including animal and plant material

Feeding-Nesting Zones

Air	In the air
Bole	Tree boles
Floral	Flowers
Ground	On the ground in the open or under herbacesous cover, typically away from woody cover
Lower Canopy	Branches of saplings and lower crowns of trees, but may extend into shrub layer
Upper Canopy	In the main canopy of trees
Shrub	In, on, or under shrubs; may be on the ground but not typically extending into lower canopy

APPENDIX B:

ACRONYM DEFINITIONS

Species

AMKE	American kestrel	LEWO	Lewis' woodpecker
ATFL	Ash-throated flycatcher	LOSH	Loggerhead shrike
BEWR	Bewick's wren	MOBL	Mountain bluebird
BGGN	Blue-gray gnatcatcher	MOCH	Mountain chickadee
BHCO	Brown-headed cowbird	MODO	Mourning dove
BHGR	Black-headed grosbeak	NOFL	Northern flicker
BLGR	Blue grosbeak	NOMO	Northern mockingbird
BRSP	Brewer's sparrow	NOOR	Northern oriole
BRTO	Brown towhee	PIJA	Pinyon jay
BTHU	Broad-tailed hummingbird	PLTI	Plain titmouse
CAKI	Cassin's kingbird	ROWR	Rock wren
CASP	Cassin's sparrow	RSTO	Rufous-sided towhee
CBTH	Curve-billed thrasher	SAPH	Say's phoebe
CHSP	Shipping sparrow	SCJA	Scrub jay
CONI	Common nighthawk	SCOR	Scott's oriole
GRFL	Gray flycatcher	SCOU	Scailed quail
GRSP	Grasshopper sparrow	SOVI	Solitary vireo
HAWO	Hairy woodpecker	SASP	Savannah sparrow
HOFI	House finch	SWTH	Swainson's thrush
HOLA	Horned lark	WAPI	Water pipit
HOWR	House wren	WBNH	White-breasted nuthatch
KILL	Killdeer	WEKI	Western kingbird
LABU	Lark bunting	WEME	Western meadowlark
LASP	Lark sparrow	WETA	Western tanager
LBWO	Ladder-backed woodpecker	WWPE	Western wood-pewee

Guilds

Foraging Guilds		**Habitat Zone Guilds**	
ASCI	Air screening insectivore	AI-GR	Air-ground
ASI	Air sallying insectivore	BO-BO	Bole-bole
BGI/F	Bark gleaning insectivore Frugivore	LC-LC	Lower canopy-Lower canopy
FFO	Foliage foraging omnivore	LC-BO	Lower canopy-bole
GFO	Ground foraging omnivore	SH-BO	Shrub-bole
GGG	Ground gleaning granivore	GR-GR	Ground-ground
GGI	Ground gleaning insectivore	GR-LC	Ground-lower canopy
GHC	Ground hawking carnivore	GR-BO	Ground-bole

Habitat Variables (see text for further details)

AVHIT	Average number of decimeter interval contacts among eight transects at each prairie site.
AVHGT	Average height of decimeter interval hits.
AVMAX	Average among eight transects of the maximum decimeter interval hit.
H1	Frequency of vegetation hits in the first decimeter interval.
H2	Frequency of vegetation hits in the third decimeter interval.
H3	Frequency of vegetation hits in the third decimeter interval.
H4	Frequency of vegetation hits in the fourth and higher decimeter intervals.

APPENDIX C: BIRD SPECIES AND GUILD DENSITIES

Table C1

Density (No./20 Ha) of Bird Species on 17 Prairie Sites in 1985

	Sites																
Species	3	7	8	10	12	13	15	17	19	29	35	37	38	PT1	PT2	PC1	PC2
Scailed quril	0.5																
Killdeer																	
Mourning dove	2.7			0.8			1.2	1.0	2.9	0.9		0.8		1.2	0.4	0.7	
Common nighthawk			0.3						0.5								
Broad-tailed hummingbird	0.5																
Northern flicker	0.8																
Ladder-backed woodpecker																	
Western kingbird	1.6							2.6	0.3			2.6		0.5			
Cassin's kingbird								2.9									
Ash-throated flycatcher	0.5																
Horned lark	0.6	13.5	14.6	11.6	4.8	8.5	4.7	9.3		10.2	13.2	1.4	14.4	9.2	9.8	14.0	9.9
Pinyon jay	0.5																
Northern mockingbird	3.6		0.3					0.3	3.3			2.1					
Curve-billed thrasher	0.5																
Water pipit		1.8			0.4								0.4	1.3	0.9		
Loggerhead shrike	0.3		0.3					0.3	1.0								
Western meadowlark	7.3	6.3	4.0	5.5	3.8	6.3	10.3	5.3	14.2	4.8	3.5	5.9	7.2	5.3	8.1	4.0	7.6
Scott's oriole	0.3																
Northern oriole																	
Brown towhee												0.5					
Lark bunting		7.5	15.5	11.3	0.5	2.5	15.2		8.3		15.3	0.8	0.3	2.4	11.8	7.4	8.3
Savannah sparrow						0.3								1.0			
Grasshopper sparrow		0.8					10.4	0.6	0.3				0.3	0.5	3.8	5.9	6.6
Lark sparrow	11.7		2.4	1.8	4.0		1.5	6.8	8.2			20.6		3.8	1.9		0.3
Cassin's sparrow	1.0	0.5	3.2	5.1	7.5		6.2		4.2		11.1	7.5	2.0	2.5	4.0	2.5	5.0
Brewer's sparrow			1.0						5.5			1.0					
Total density	32.3	30.4	41.5	36.2	21.1	17.5	49.5	29.1	48.7	16.0	43.1	43.2	24.6	27.8	40.7	34.6	37.7
Number of species	15	6	9	6	6	4	7	9	11	3	4	10	6	10	8	6	6

Table C2

Density (No./20 Ha) of Bird Species on 17 Prairie Sites in 1986

	Sites																
Species	3	7	8	10	12	13	15	17	19	29	35	37	38	PT1	PT2	PC1	PC2
Scaled quail												0.3					
Killdeer		0.3											0.3				
Mourning dove	1.0			0.3		0.6	0.3		3.1	0.6		0.4	0.6				
Common nighthawk									0.8								
Broad-tailed hummingbird																	
Northern flicker	1.0																
Ladder-backed woodpecker	0.8																
Western kingbird	0.3			0.6	0.6			4.7	0.4			0.7	0.4				
Cassin's kingbird	0.5							0.8				0.8					
Ash-throated flycatcher																	
Horned lark	2.9	23.2	19.1	16.0	3.1	17.5	22.5	9.9	0.9	13.1	28.4	6.8	19.5	16.0	18.6	24.0	24.5
Pinyon jay																	
Northern mockingbird	4.1			0.5					6.9			5.3					
Curve-billed thrasher																	
Water pipit		1.3								0.4	0.4	0.4					
Loggerhead shrike			0.3						3.0			1.0					
Western meadowlark	10.6	7.2	6.5	10.1	12.9	6.7	13.4	11.4	20.3	9.0	2.0	6.5	6.3	4.0	6.3	12.6	12.0
Scott's oriole																	
Northern oriole	0.3											0.3					
Brown towhee																	
Lark bunting							0.5								0.3		
Savannah sparrow																	
Grasshopper sparrow							4.2		0.5							8.8	10.9
Lark sparrow	10.9		3.5	5.6	7.8	0.8	7.3	8.8	5.7		0.9	26.0		1.4	5.0	0.5	0.3
Cassin's sparrow	3.5		1.0		12.9		3.6	2.0	4.3		2.5	3.5			1.5	0.4	
Brewer's sparrow			0.6						1.9								
Total density	35.8	32.0	31.0	33.1	37.2	25.5	51.7	37.6	47.6	23.1	34.3	51.9	27.0	21.4	31.8	46.2	47.6
Number of species	11	4	6	6	5	4	7	6	11	4	5	12	5	3	5	5	4

Table C3

Density (No./20 Ha) of Bird Guilds on 17 Prairie Sites in 1985

Foraging Guilds (Substrate Technique Food)	3	7	8	10	12	13	15	17	19	29	35	37	38	PT1	PT2	PC1	PC2
	Sites																
Air sallying insectivore	2.1							5.5	0.3			2.6		0.5			
Ground foraging omnivore	17.4	21.8	32.8	24.7	9.4	11.2	31.8	17.0	20.1	10.2	28.5	25.4	15.0	16.9	27.3	27.4	25.1
Ground gleaning granivore	2.7			0.8			1.2	1.0	2.9	0.9		0.8		1.2	0.4	0.7	
Ground gleaning insectivore	9.0	8.6	8.1	10.7	11.8	6.3	16.6	5.3	24.0	4.8	14.6	14.4	9.6	9.2	13.0	6.5	12.6
Other	1.0		0.5	0.0				0.3		1.5		0.0					
Habitat Zone Guilds (Feeding - Nesting)																	
Ground-Ground	19.6	22.4	21.0	19.0	13.1	15.0	26.9	22.0	22.8	15.0	16.7	27.9	22.4	21.2	24.5	24.0	24.4
Ground-Shrub	1.5	8.0	19.7	16.4	8.0	2.5	21.4		18.0		26.4	9.3	2.3	4.9	15.8	9.9	13.3
Ground-lower canopy	6.8		0.3	0.8			1.2	1.3	6.1	0.9		2.9		1.2	0.4	0.7	
Low. canopy-low. canopy	2.2		0.3					5.7	1.3			2.6		0.5			
Other	2.3		0.3	0.0			0.0	0.0	0.5	0.0		0.5		0.0	0.0		

Table C4

Density (No./20 Ha) of Bird Guilds on 17 Prairie Sites in 1986

Foraging Guilds (Substrate Technique-Food)	Sites 3	7	8	10	12	13	15	17	19	29	35	37	38	PT1	PT2	PC1	PC2
Air sallying insectivore	0.8			0.6	0.6			5.5	0.4			1.5	0.4				
Ground foraging omnivore	17.9	23.2	22.6	22.2	10.9	18.3	34.5	18.8	13.9	13.1	29.4	38.4	19.5	17.4	23.9	33.2	35.7
Ground gleaning granivore	1.0			0.3		0.6	0.3		3.1	0.6		0.4	0.6				
Ground gleaning insectivore	15.1	8.8	8.1	10.1	25.7	6.7	17.0	13.4	26.4	9.4	4.9	10.4	6.6	4.0	7.8	13.0	12.0
Other	1.0		0.3					0.0	3.8			1.3					
Habitat Zone Guilds (Feeding - Nesting)																	
Ground-ground	24.4	32.0	29.1	31.7	23.7	24.9	47.4	30.1	27.3	22.5	31.8	39.7	26.1	21.4	30.0	45.9	47.6
Ground-shrub	3.5		1.6		12.9		4.1	2.0	6.2		2.5	3.8			1.8	0.4	
Ground-lower canopy	5.1			0.8		0.6	0.3		10.0	0.6		5.7	0.6				
Low.-canopy-low. canopy	1.1		0.3	0.6	0.6			5.5	3.4			2.7	0.4				
Other	1.8							0.0	0.8						0.0		

Table C5

Density (No./10 Ha) of Bird Species on Each of 12 Pinyon-Juniper Sites in 1985

Species	Sites: 2	6	11	21	26	28	31	36	39	45	PJS	PJN
American kestrel					10.3					0.2		
Mourning dove	4.3	6.0	2.4	8.7	2.8	2.3	5.8	1.9	2.1	0.9	6.6	4.5
Common nighthawk	1.0	2.6	2.3	1.0		0.3	0.3					
Broad-tailed hummingbird			0.8		0.3	0.3						
Northern flicker					0.3					0.3		
Lewis' woodpecker								0.2				
Hairy woodpecker	0.3											0.2
Ladder-backed woodpecker		0.4										
Western kingbird		0.4	0.2		1.8	4.8	0.2				0.4	3.1
Cassin's kingbird		1.4	1.1		0.8	2.1	0.3	0.2	0.3		1.0	2.1
Ash-throated flycatcher	0.8	0.6	1.3	0.6	0.8	0.8	0.7			0.2	1.5	1.6
Say's phoebe										0.2		
Gray flycatcher		0.2	0.5	1.6	1.8						0.2	0.7
Western wood-pewee								0.2				
Scrub jay		0.2		0.2	0.5		0.2				0.5	0.8
Pinyon jay	1.3		0.5	0.2		0.9	0.2				1.3	1.7
Mountain chickadee	0.5											
Plain titmouse	0.7		0.2		0.8		0.2	0.9	0.2	0.7	0.9	0.2
White-breasted nuthatch												
House wren						0.3						0.3
Bewick's wren	2.6	1.7	2.6	1.3	2.0	1.7	5.5	2.2	0.6	0.6	3.9	5.8
Rock wren									1.1			
Northern mockingbird	6.6	8.5	6.1	6.2	6.0	4.4	5.0	2.4	6.3	3.7	4.0	2.6
Curve-billed thrasher					0.3							
Swainson's thrush				0.1								
Mountain bluebird	0.2	0.6		0.5							0.5	0.7
Blue-gray gnatcatcher												
Loggerhead shrike			0.1	0.7		0.1			0.5			
Solitary vireo							0.5					
Western meadowlark	1.8	1.9	1.8	2.0	2.0	1.8	2.1	0.3	0.8	0.1	0.5	0.6
Brown-headed cowbird	0.2	0.2	0.7	0.2	0.9	1.0	0.2			0.2	1.4	0.6
Scott's oriole		0.2										
Northern oriole			0.7									
Western tanager				0.1		0.1						
Black-headed grosbeak	0.1	0.3				0.2	0.5				0.3	
Blue grosbeak								0.3		0.2		
House finch	0.5	2.6	1.3	1.8		0.3						0.3
Rufous-sided towhee	0.8						0.3				1.9	0.3
Brown towhee	0.5		0.5		0.2	0.2	0.5			1.6	0.2	
Lark sparrow	2.3	4.5	6.5	2.3	2.6	5.4	0.6	10.5	13.9	11.0	1.4	0.8
Chipping sparrow	0.5										0.5	0.4
Total density	25.0	32.3	29.6	27.5	24.2	27.0	23.1	19.1	25.8	19.9	27.0	27.3
Species number	18	17	18	16	17	18	17	10	9	13	18	19

Table C6

Density (No./10 Ha) of Bird Species on Each of 12 Pinyon-Juniper Sites in 1986

Species	Sites 2	6	11	21	26	28	31	36	39	45	PJS	PJN
American kestrel					0.5					0.1		
Mourning dove	9.6	9.2	8.4	8.8	7.8	1.9	7.0	1.3	0.8	0.2	2.8	6.4
Common nighthawk		1.2	1.0		0.7	0.2	1.2		3.9			
Broad-tailed hummingbird	0.2					0.2						
Northern flicker	0.2	0.4	0.1		1.0	0.1				0.1	0.1	0.2
Lewis' woodpecker												
Hairy woodpecker	0.1						0.1				0.1	
Ladder-backed woodpecker			0.1	0.2						0.1		
Western kingbird	2.3	1.9	3.1	0.4	2.1	3.1		0.5	0.7	0.5		2.1
Cassin's kingbird	0.3	0.8	0.1	0.8	0.6	0.3	0.2	0.5	0.5		0.1	0.7
Ash-throated flycatcher	1.6	1.0	0.3	0.4	0.3	0.9	1.6			0.3	1.6	1.7
Say's phoebe												
Gray flycatcher		0.2	0.1	0.7							0.2	0.3
Western wood-pewee	0.1				0.3	0.1						
Scrub jay	0.1										0.4	
Pinyon jay	0.3				0.5	3.3					0.7	0.3
Mountain chickadee												
Plain titmouse	1.4	1.4	0.7	0.8	1.3	1.3	3.1	1.8		0.3	0.3	2.9
White-breasted nuthatch												
House wren												
Bewick's wren	5.3	0.8	1.1	2.8	3.2	3.3	8.0	2.4	1.5	1.0	4.1	2.0
Rock wren	0.3				0.2					0.2		
Northern mockingbird	7.1	9.3	6.9	8.8	6.3	5.4	7.1	8.7	8.0	2.9	3.0	3.1
Curve-billed thrasher					0.3				0.2			
Swainson's thrush						0.1						
Mountain bluebird	0.4				0.4	0.4					1.3	0.2
Blue-gray gnatcatcher						0.2						
Loggerhead shrike		0.1		0.9				0.6				0.1
Solitary vireo							0.2				0.2	
Western meadowlark	2.2	3.5	5.2	2.6	3.0	2.4	2.7	1.4	1.2	0.9	1.9	1.9
Brown-headed cowbird	0.7	0.7	0.9	0.6	1.7	0.6	0.1	0.3	1.3	1.2	3.8	0.6
Scott's oriole												
Northern oriole	0.2				0.1	0.6			0.5			
Western tanager												
Black-headed grosbeak	0.4						0.3				0.2	0.3
Blue grosbeak								0.2	0.2			0.1
House finch	1.0	0.7	1.5	0.6		0.4		0.2	0.7		0.4	0.6
Rufous-sided towhee	1.5				0.4		0.4			0.4	1.0	0.8
Brown towhee	0.5	0.2	0.3		0.2	0.2	0.4		1.0	1.0	0.4	0.2
Lark sparrow	2.5	6.2	10.3	5.1	9.3	8.7	4.9	12.2	13.9	9.8	3.7	3.4
Chipping sparrow	0.8				0.2	0.6	0.2				0.3	0.6
Total density	39.1	37.6	38.1	33.5	40.4	34.3	37.5	30.1	34.4	19.0	26.6	28.5
Species number	24	16	16	14	22	22	16	12	14	15	21	21

Table C7

Density (No./10 Ha) of Bird Guilds on Each of 12 Pinyon-Juniper Sites in 1985

Foraging Guilds (Substrate Technique Food)	Sites 2	6	11	21	26	28	31	36	39	45	PJS	PJN
Air sallying insectivore	0.4	2.3	2.5	1.9	4.8	7.3	0.9	0.6	0.3	0.3	2.4	6.7
Air screening insectivore	1.0	2.6	2.3	1.0		0.3	0.3					
Foliage gleaning insectivore	2.2	1.2	2.0	1.0	1.4	1.6	3.6	1.1	0.3	0.4	2.7	4.0
Foliage foraging insectivore	0.8	0.5	0.9	0.2	0.8	0.3	0.7	0.9	0.2	0.7	1.2	0.2
Bark gleaning insect/frugivore	0.3	0.4										0.2
Ground gleaning insectivore	3.3	3.4	3.1	3.2	3.3	2.7	4.9	1.4	2.2	0.7	3.0	4.2
Ground gleaning granivore	4.8	8.6	3.7	10.5	2.8	2.6	5.8	1.9	2.1	0.9	6.6	4.8
Ground foraging omnivore	12.2	13.4	14.3	9.1	10.5	11.9	7.0	13.2	20.2	16.7	11.2	7.2
Ground hawking carnivore			0.1	0.7	0.3	0.1			0.5	0.2		
Other			0.8		0.3	0.3						

Habitat Zone Guilds (Feeding - Nesting)	2	6	11	21	26	28	31	36	39	45	PJS	PJN
Air-ground	1.0	2.6	2.3	1.0		0.3	0.3					
Bole-bole	0.3	0.4										0.2
Lower canopy-lower canopy	0.1	2.3	2.6	2.3	4.4	7.2	1.5	0.2	0.8		1.9	5.9
Lower canopy-bole	1.7	1.2	1.5	1.1	1.6	0.8	0.9	1.1	0.2	0.9	2.9	2.5
Shrub-shrub	1.3		0.5		0.5	0.2	0.8			1.6	2.1	0.3
Shrub-bole	2.6	1.7	2.6	1.3	2.0	2.0	5.5	2.2	0.6	0.6	3.9	6.1
Ground-ground	4.6	6.4	8.3	4.3	4.6	7.2	2.7	10.8	14.7	11.1	2.4	1.8
Ground-lower canopy	12.7	17.3	10.3	17.1	9.3	7.9	11.2	4.6	8.4	4.8	12.4	9.9
Ground-bole					0.6					0.5		
Other	0.7	0.4	1.5	0.4	1.2	1.4	0.2	0.2	1.1	0.4	1.4	0.6

Table C8

Density (No./10 Ha) of Bird Guilds on Each of 12 Pinyon-Juniper Sites in 1986

Foraging Guilds (Substrate Technique Food)	Sites 2	6	11	21	26	28	31	36	39	45	PJS	PJN
Air sallying insectivore	3.5	3.4	3.5	2.1	3.2	4.0	1.0	1.0	1.2	0.7	1.1	4.0
Air screening insectivore		1.2	1.0		0.7	0.2	1.2		3.9			
Foliage gleaning insectivore	3.5	0.9	0.7	1.6	1.8	2.3	5.0	1.2	0.8	0.7	3.1	1.9
Foliage foraging insectivore	2.0	1.4	0.7	0.8	1.4	2.0	3.4	1.8	0.5	0.3	0.5	3.2
Bark gleaning insect/frugivore	0.1		0.1	0.2			0.1			0.1	0.1	
Ground gleaning insectivore	5.8	4.3	3.9	4.0	6.2	4.6	6.7	2.6	2.0	1.7	5.4	3.3
Ground gleaning granivore	10.6	9.9	9.9	9.4	7.8	2.3	7.0	1.5	1.5	0.2	3.2	7.0
Ground foraging omnivore	13.5	16.4	18.4	14.5	18.9	18.8	13.1	21.4	24.6	15.3	13.3	9.1
Ground hawking carnivore		0.1		0.9	0.5			0.6		0.1		0.1
Other	0.2					0.2						
Habitat Zone Guilds (Feeding - Nesting)												
Air-ground		1.2	1.0		0.7	0.2	1.2			3.9		
Bole-bole	0.1		0.1	0.2			0.1			0.01	0.1	
Lower canopy-lower canopy	3.2	3.0	3.3	2.8	2.8	4.0	0.7	1.6	1.7	0.5	0.7	3.5
Lower canopy-bole	3.4	2.4	1.0	1.2	2.0	2.6	4.7	1.8		0.6	3.2	4.8
Shrub-shrub	2.0	0.2	0.3		0.9	0.2	0.8		1.2	1.4	1.4	1.0
Shrub-bole	5.3	0.8	1.1	2.8	3.2	3.3	8.0	2.4	1.5	1.0	4.1	2.0
Ground-ground	5.5	9.7	13.5	7.7	12.5	11.7	7.8	13.6	15.1	10.7	5.9	5.9
Ground-lower canopy	18.1	19.2	16.8	18.2	14.6	11.0	14.1	10.4	9.7	3.1	7.3	10.5
Ground-bole	0.2	0.4	0.1		1.5	0.1				0.2	0.1	0.2
Other	1.3	0.7	0.9	0.6	2.2	1.2	0.1	0.3	1.3	1.4	3.8	0.6

APPENDIX D: HABITAT MEASUREMENTS

Table D1

Habitat Measurements Obtained for Each of 17 Prairie Sites in 1985

Site	Bare Ground (%)	Grass (%)	Short Grass (%)	Medium Grass (%)	Forb (%)	Small Shrub (m²/ha)	Large Shrub (m²/ha)	Broad-Leaved (m²/ha)	Yucca (m²/ha)	Cholla (#/ha)	Tree* (pres.)	AVHIT (#)	H1 (#)	H2 (#)	H3 (#)	H4 (#)	AVHGT (dm)	AVMAX (dm)
3	18.0	47.8	21.5	10.5	18.0	457.7	640.9	0.0	452.6	215	1	26.0	116	66	16	16	0.66	5.19
7	42.5	52.3	40.3	9.3	4.5	2.0	6.0	0.0	0.0	15	0	18.4	115	22	6	4	0.39	3.00
8	38.5	45.5	31.3	12.5	7.3	519.2	108.6	82.1	13.7	30	0	16.8	100	29	4	1	0.38	2.75
10	19.5	72.8	58.0	11.0	5.5	143.0	243.1	71.4	0.0	205	0	25.6	150	35	14	6	0.53	3.38
12	24.5	57.8	47.5	1.3	11.3	246.10	269.5	0.0	225.0	65	0	20.6	136	21	4	4	0.43	2.81
13	32.0	56.8	30.5	16.8	6.0	185.7	0.0	0.0	0.0	0	0	19.0	117	32	3	0	0.39	2.25
15	12.8	73.0	23.3	39.5	11.3	5.0	154.4	0.0	0.0	235	0	33.1	165	71	21	8	0.70	3.94
17	20.3	60.0	29.3	23.5	11.8	282.0	35.9	0.0	28.4	15	0	24.4	138	46	4	7	0.56	3.63
19	28.8	32.8	6.0	16.0	23.0	174.5	383.0	1377.9	0.0	5	0	29.4	111	65	27	32	0.74	5.63
29	22.5	60.5	33.3	0.5	10.8	204.2	0.0	0.0	0.0	50	1	22.3	129	43	6	0	0.47	2.25
35	25.3	51.5	37.5	12.0	8.8	923.7	21.6	4.5	17.1	0	0	20.5	122	29	12	1	0.44	3.00
37	28.0	47.5	36.5	4.5	18.3	287.5	37.0	0.0	0.0	50	1	22.3	129	46	6	0	0.46	2.88
38	30.3	71.8	59.5	9.0	7.3	7.2	32.3	0.0	0.0	20	0	21.3	143	16	4	4	0.44	2.94
PT1	21.3	69.5	58.8	7.3	9.0	2.2	4.6	0.0	4.6	0	0	23.9	140	45	4	2	0.50	2.75
PT2	24.5	64.3	56.3	6.8	10.5	13.7	34.8	0.0	0.0	40	0	22.1	142	26	6	3	0.48	3.19
PC1	16.8	72.0	16.8	42.0	9.0	138.7	6.4	1.7	3.8	5	0	30.6	137	71	32	5	0.66	3.38
PC2	21.5	69.0	12.3	43.8	8.0	115.5	3.2	3.2	0.0	0	0	29.9	128	79	29	3	0.65	3.13

*1 = present; 0 = absent

Table D2

Habitat Measurements Obtained for Each of 12 Pinyon-Juniper Sites in 1985

Site	Juniper (#/ha)	Pinyon Pine (#/ha)	Dead Tree (#/ha)	Small Shrub (m^3/ha)	Broad-Leaved (m^3/ha)	Yucca (m^3/ha)	Cholla (m^3/ha)	Bare Ground (%)	Grass (%)	Forb (%)
2	158.00	116.00	21.00	79.00	79.00	0.00	91.00	45.30	20.70	7.30
6	111.00	0.00	21.00	148.00	0.00	0.00	19.00	46.00	33.00	6.30
11	127.00	0.00	9.00	597.00	0.00	0.00	0.00	35.70	42.70	5.00
21	139.00	1.00	36.00	25.00	41.00	0.00	15.00	53.70	27.00	9.30
26	184.00	0.00	12.00	75.00	13.00	11.00	0.00	42.00	32.70	9.30
28	173.00	26.00	14.00	109.00	23.00	84.00	61.00	32.70	34.30	7.70
31	227.00	190.00	44.00	109.00	27.00	0.00	0.00	53.00	12.70	4.30
36	100.00	0.00	0.00	270.00	113.00	0.00	71.00	45.00	29.00	3.30
39	95.00	0.00	0.00	131.00	13.00	92.00	0.00	47.00	20.00	6.70
45	124.00	0.00	0.00	92.00	75.00	107.00	100.00	44.00	40.00	5.70
PJS	174.00	44.00	20.00	10.00	59.00	0.00	0.00	29.70	33.70	6.30
PJN	307.00	337.00	73.00	1.00	44.00	0.00	0.00	32.30	17.30	1.70