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BIRD SPECIES DISTRIBUTION PATTERNS IN RIPARIAN HABITATS IN SOUTHEASTERN ARIZONA[1]

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Abstract. Bird species densities were determined for summer and winter on 132 study plots grouped into 25 riparian habitats in or near the Huachuca Mountains of southeastern Arizona. The habitats were defined based on the dominant riparian tree species, the size of the riparian stand, and the type of adjacent upland vegetation. Vegetation characteristics and physical environmental data were collected at each plot. The type of dominant riparian tree species influenced bird species richness and total density during the breeding season. Cottonwood habitats had the greatest richness, and both cottonwood and sycamore habitats had high densities. Upland vegetation was an important factor related to winter species richness and abundance, with plots in open grassland areas having greater richness and density. Riparian stand size was a relatively poor predictor of avian density or richness in either season. Groups of bird species that shared similar density distributions in the summer were associated with specific riparian habitats. The winter pattern of species groups was not as clear, and groups could not be assigned to riparian habitats, but they were related to either wooded or open upland vegetation. Riparian habitats were also clustered based on similar densities of birds. In summer, high-elevation habitats were distinct from low-elevation and foothill habitats. In winter, riparian habitats separated into categories of wooded vs. open adjacent vegetation.

Key words: Huachuca Mountains; Arizona; riparian; species richness; species densities; avian communities.

INTRODUCTION

Riparian woodlands comprise less than 0.5% of the land area of Arizona, yet they support an extraordinary variety and abundance of birds (Johnson et al. 1977, Szaro 1980). The bird life of cottonwood (*Populus fremontii*), mesquite (*Prosopis* spp.), and exotic saltcedar (*Tamarix chinensis*) woodlands in lowland river valleys has been well studied (e.g., Carothers et al. 1974, Anderson and Ohmart 1977, Stamp 1978, Szaro and Jakle 1985). Riparian woodlands at higher elevations in the Southwest include a greater variety of trees and shrubs than the river valleys (Pase and Layser 1977), but their bird populations have not been as thoroughly examined (Szaro 1980). The purpose of the present study was to describe patterns of bird species distribution and abundance in riparian woodlands of the Huachuca Mountains and vicinity in southeastern Arizona.

At least three factors could be important determinants of the abundance and variety of birds associated with a particular stand of riparian vegetation: (1) dominant tree species (Pase and Layser 1977); (2) patch size (e.g., Robbins 1979, Szaro and Jakle 1985, Blake 1986); and (3) nature of adjacent (upland) vegetation (Stevens et al. 1977). We measured the vegetation and physical environmental characteristics of 132 small riparian plots, and we counted their birds for three summers and two winters between 1984 and 1986. Each plot was dominated by one of seven riparian tree species, belonged to a large (greater than 1,000 m) or small (less than 200 m) linear riparian patch, and was adjacent either to open mesquite grassland or to woodlands of oak and/or pine.

The data collected during this study were analyzed with the goal of determining (1) if certain riparian habitat types supported significantly richer or more abundant avifaunas, (2) if the bird species grouped themselves into discrete, recognizable assemblages, (3) if these assemblages were associated with predictable vegetation and/or physical environmental patterns, and (4) if such patterns and assemblages differed between summer and winter.

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MATERIALS AND METHODS

STUDY AREA

This study was conducted in the vicinity of the Huachuca Mountains in Cochise and Santa Cruz counties in southeastern Arizona. The Huachuca Mountains reach a maximum elevation of 2,885 m (9,466 ft) at Miller Peak, while the surrounding valleys are about 1,350 m. The San Pedro and San Rafael valleys and the Sonoita Plain are semidesert grasslands, grading into oak woodlands in the foothills. The higher parts of the range are covered by pine-oak or mixed coniferous forests. The Huachucas are incised by several deep canyons in a roughly radial pattern. Many of these canyons have perennial streams or reliable seasonal stream flow. Virtually all drainages are subject to intermittent flooding during the winter rains or the late summer monsoons. The water available in the canyons supports a variety of riparian habitats that in turn support diverse bird communities which formed the focus of this project.

STUDY SITES

Habitats dominated by seven riparian tree species were included in this project. These tree species are the velvet ash (*Fraxinus velutina*), Fremont cottonwood (*Populus fremontii*), desert willow (*Chilopsis linearis*), big-tooth maple (*Acer grandidentatum*), Arizona sycamore (*Platanus wrightii*), Arizona walnut (*Juglans major*), and willow (*Salix* spp.). For each tree species, both large and small stands were selected. For the purposes of this project, a large stand was 1,000 m or more of continuous riparian habitat along a drainage, and a small stand was 200 m or less of continuous riparian habitat. The riparian stands were usually less than 50 m in width, and some were less than 20 m. For both large and small stands, areas were selected with either open or wooded adjacent uplands. An open upland area was primarily grassland, but many sites included some mesquite or other desert shrubs. A wooded upland was dominated by oaks (*Quercus* spp.) and/or pines (*Pinus* spp.). Control sites were selected in wooded and open areas along drainages with no riparian trees. Several replicate study plots were selected for each combination of factors. A total of 132 study plots grouped into 25 habitat types (see Appendix A) were included in this project. The study sites were located along several major drainages near the north end of the range. These included O'Donnell and Post canyons on the National Audubon Society Appleton-Whittell Research Ranch and the Canelo Hills Preserve owned by the Nature Conservancy; Huachuca, Garden, Sawmill, Scheelite, and Blacktail canyons on the Fort Huachuca Military Reservation; the Babocomari River and Vaughan Canyon on the Babocomari Ranch; and Lyle and Woodyard canyons on Coronado National Forest.

CENSUS TECHNIQUE

The variable circular-plot method (VCPM) (Reynolds et al. 1980) was selected for this project. By their nature, the small stands of this project could not be censused by transect methods. VCPM is appropriate for sampling the sites in winter as well as in summer. Szaro and Jakle (1982) have compared VCPM and the spot-mapping method (SMM) in desert riparian and scrub habitats near Superior, Arizona. For all but one species, the density estimates from SMM were within the 95% confidence limits of the density estimates from VCPM, and they recommended VCPM for censusing in small habitat "islands." Verner and Ritter (1985) compared VCPM with transect counts in oak-pine woodlands of California. They preferred point counts to transects, but they cautioned that small sample sizes permit density estimates for only a small portion of the species detected. They also questioned whether the density estimates from either method were acceptably accurate. For the purposes of this project, the absolute accuracy of density estimates was less important than the relative density estimates between different plots or habitats. Because we used the same census procedure at each study plot and during each season of data collection, we assumed that the density estimates for all plots or all habitats were comparable, and that statistical comparisons based on these estimates were legitimate.

In applying the variable circular-plot method to this project, we used 5-m increments of radius out to 40 m from the central point, and 10-m intervals beyond that out to 200 m. Each plot was censused for a 5-min period six times each season during the breeding seasons of 1984, 1985, and 1986 (May through July), six times during the winter of 1985–1986, and five times during the winter of 1984–1985 (December through February). Because the activity level of birds decreased drastically during the middle part of the day, the census times were restricted to the first 4 hr after sunrise. To obtain more reliable estimates of detection limits, all replicate plots were lumped for each riparian habitat type, and the resulting detection limits were then used for each plot within that habitat. If no individuals of a species were seen within that limit at a particular plot, but they were observed farther away, then the greater distance was used to calculate the species' density at that plot.

VEGETATION ANALYSIS

Vegetation and physical environmental data were collected at each of the 132 study plots. The methods used roughly follow the techniques proposed by James and Shugart (1970), with modifications as appropriate for these riparian habitats. An area within a radius of 35 m from the center point of each plot was selected for analysis. This distance was selected based on an average bird species detection limit of 37.3 m reported by Szaro and Jakle (1982). Within this circle, all riparian trees were identified and measured. Because of the tendency of willows and desert willows to branch very close to the ground, the diameters of all trees were taken at boot height. In heavily wooded areas, the nonriparian trees, primarily oaks and pines, were counted on four subplots of 10 m radius each. Two plots were centered at distances of 15 m from the center point, and the other two were at distances of 20 m and 25 m. The subplots were oriented such that they did not overlap the drainage, if possible. The subplots represented nearly one-third of the full plot. In more open areas, all nonriparian trees were counted. No distinction was made between the species of oak or the species of pine. From the data collected in the field, densities and basal areas for all tree species were calculated. All trees were grouped into size classes as follows: less than 30 cm diameter, between 30 and 60 cm, and greater than 60 cm.

Understory plants and ground cover were measured on 5-m radius subplots with the same centers as the 10-m subplots. Two tape measures were laid out on the ground, one oriented parallel to the stream channel and the other perpendicular, such that they crossed at the center of the subplot. At 0.5-m intervals along each tape, the ground cover was recorded as either grass/herb cover or bare ground/litter. At each point, the presence and species of shrub or sapling canopy was recorded. Forty points were recorded on each of the four subplots, with the results combined and converted to percentages.

Upland tree abundance was measured at points 50 m from the plot center on each side of the stream channel. At each point the distance to the three nearest trees was measured. The reciprocal of the average of these distances provided an estimate of upland tree density. Canopy coverage at each site was measured with a spherical densiometer. For the riparian canopy, readings were taken at the center point and from the center of each subplot looking toward the center point. For the upland canopy, two readings were taken at each upland tree point, one looking upstream and one downstream. The canopy height at the center point was determined by measuring the angle up to the canopy from a point 35 m from the center point and using appropriate trigonometric relationships. Because hours of sunlight might be an important factor in the vegetation and bird densities, angles to the east and west horizons were measured from the center point. The elevation at each site was estimated from USGS topographic maps.

Several factors were used to describe each site qualitatively. These factors included stand size, distance to the next stand, presence of water, upland vegetation, and upland tree density. Each of these factors was broken down into several ordinal categories, which allowed a better description of the site characteristics than the broad groups of large vs. small stands and wooded or open adjacent upland.

ANALYTICAL PROCEDURES

Bird species densities were calculated for all habitats and for each plot within each habitat for both summer and winter. The number of bird species observed (species richness) and the total density of birds recorded in each habitat or plot also were determined. Differences in total bird population densities and species richness between plots with different riparian tree types, different stand sizes, and different upland vegetation were tested with analysis of variance (ANOVA) procedures. Comparisons were made using pooled data from the three breeding seasons or the two winter seasons. The replicate plots within each habitat type were used to generate the means and variances needed for the comparisons. To isolate the effects of stand size or upland vegetation, one-way ANOVAs tested for one variable while holding the other constant. For example, the large wooded stands were compared with the small wooded stands to test for stand size effects, or the small wooded stands were compared with the small open stands to test for effects of adjacent upland vegetation. Two-way ANOVA was not used because of missing cells in the control, maple, and willow habitats. Throughout this paper, the terms "wooded" and "open" will refer to the nature of the vegetation adjacent to the riparian zone. Control plots could not be assigned to a large or small category and were not included in the analyses based on stand size. Bird species richness and the total density for both summer and winter were analyzed with the Komolgorov-Smirnov goodness-of-fit test for normality. Raw data for species richness could not be distinguished from a normal distribution for either summer or winter. Raw data for total density were not normally distributed, but natural log transformations of the density data resulted in distributions that could not be distinguished from normal for both summer and winter. For this reason, natural log transformations of density data were used in all analysis of variance procedures. In each analysis, the Scheffé a posteriori procedure was used to identify homogeneous subsets.

Multivariate statistical procedures were applied to the data set with the goals of (1) recognizing groups of bird species with similar habitat associations and (2) grouping riparian habitat types supporting similar avian assemblages. For the first objective, Pearson's product moment correlation coefficients were computed between densities of each bird species and the 47 physical and vegetation characteristics measured for each plot (see Appendix D). These correlations then were used as ecological descriptors of each bird species, and the birds were clustered based on those descriptors. The clustering method used was single-linkage (UPGMA; Rohlf et al. 1972). For the second objective, the plots were grouped a priori into major riparian habitat types, based on shared characteristics of dominant riparian tree species, stand size, and type of adjacent upland vegetation. Mean densities of each bird species were computed for each habitat type, and these densities were used as descriptors for clustering the habitat types.

RESULTS

RELATIONSHIPS WITH RIPARIAN TREE SPECIES

Summer bird species richness, sorted by dominant riparian tree species (Fig. 1, top), separated into four overlapping subsets ($F = 16.079$, $P < 0.0001$). The data used in this figure and others are available in Strong (1987). Maple plots, with low bird species richness, and cottonwood plots, with high bird species richness, were the only groups that fell into only one subset. The species richness of winter birds revealed three overlapping subsets ($F = 8.302$, $P < 0.0001$). Maple plots, with low species richness, and cottonwood plots, with high richness, were again the only groups falling into a single subset.

In summer, avian densities in the various riparian habitats separated into three overlapping subsets (Fig. 1, bottom; $F = 25.532$, $P < 0.0001$). Maple and control (no riparian trees) habitats had low bird densities, while sycamore and cottonwood habitats had much higher densities. The sequence of riparian tree species from minimum to maximum bird density was similar to that based on bird species' richness, but one notable exception was the group of three willow plots. These plots had high densities of relatively few species, including the Red-winged Blackbird, Common Yellowthroat, and the Brown-headed Cowbird (see Appendices B and C for scientific names of all bird species). This habitat was unique in its high density of very small diameter willows, surrounded by marshy grassland. Blackbirds were common breeding birds in the marshy area, and yellowthroats were common in the willows and in grass of the marsh.

Total densities of winter birds in winter separated the riparian tree species into two overlapping subsets ($F = 5.623$, $P < 0.0001$). Maple and control habitats again had low bird densities, and cottonwood and sycamore habitats had higher densities. The sequence from minimum to maximum bird densities was nearly identical to that observed in summer, but the range of differences was much lower in the winter data.

RELATIONSHIPS WITH RIPARIAN STAND SIZE

The first set of comparisons to test the effects of stand size was restricted to plots with wooded uplands (Fig. 2). In summer, control plots had lower average species richness than plots in large,

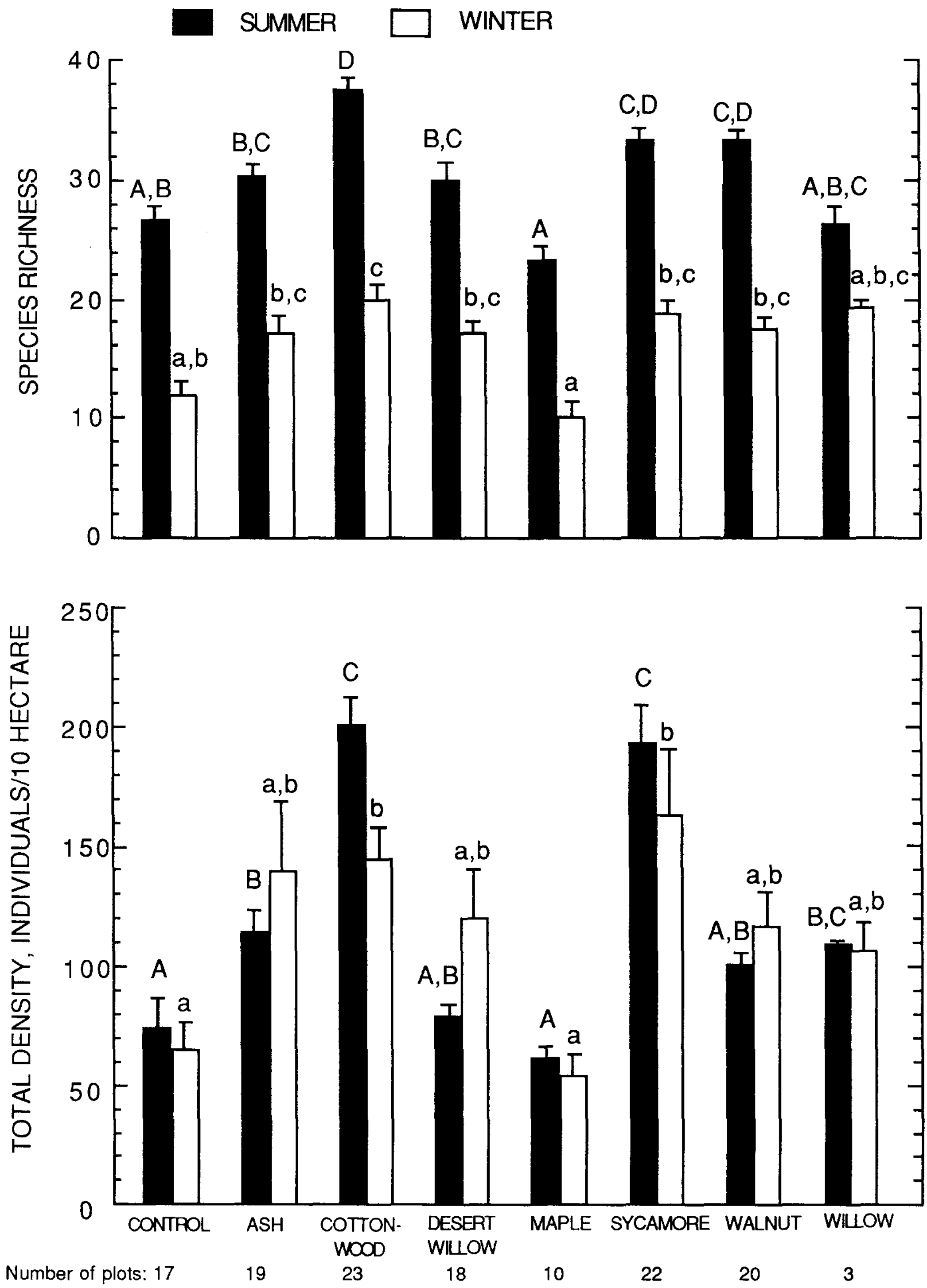

FIGURE 1. Means and standard errors of bird species richness and total bird density on plots dominated by various riparian trees in southeastern Arizona. For both variables, homogeneous subsets were distinguished by the Scheffé a posteriori test with ANOVA. Upper and lower case letters indicate groups that did not differ significantly in summer and winter, respectively.

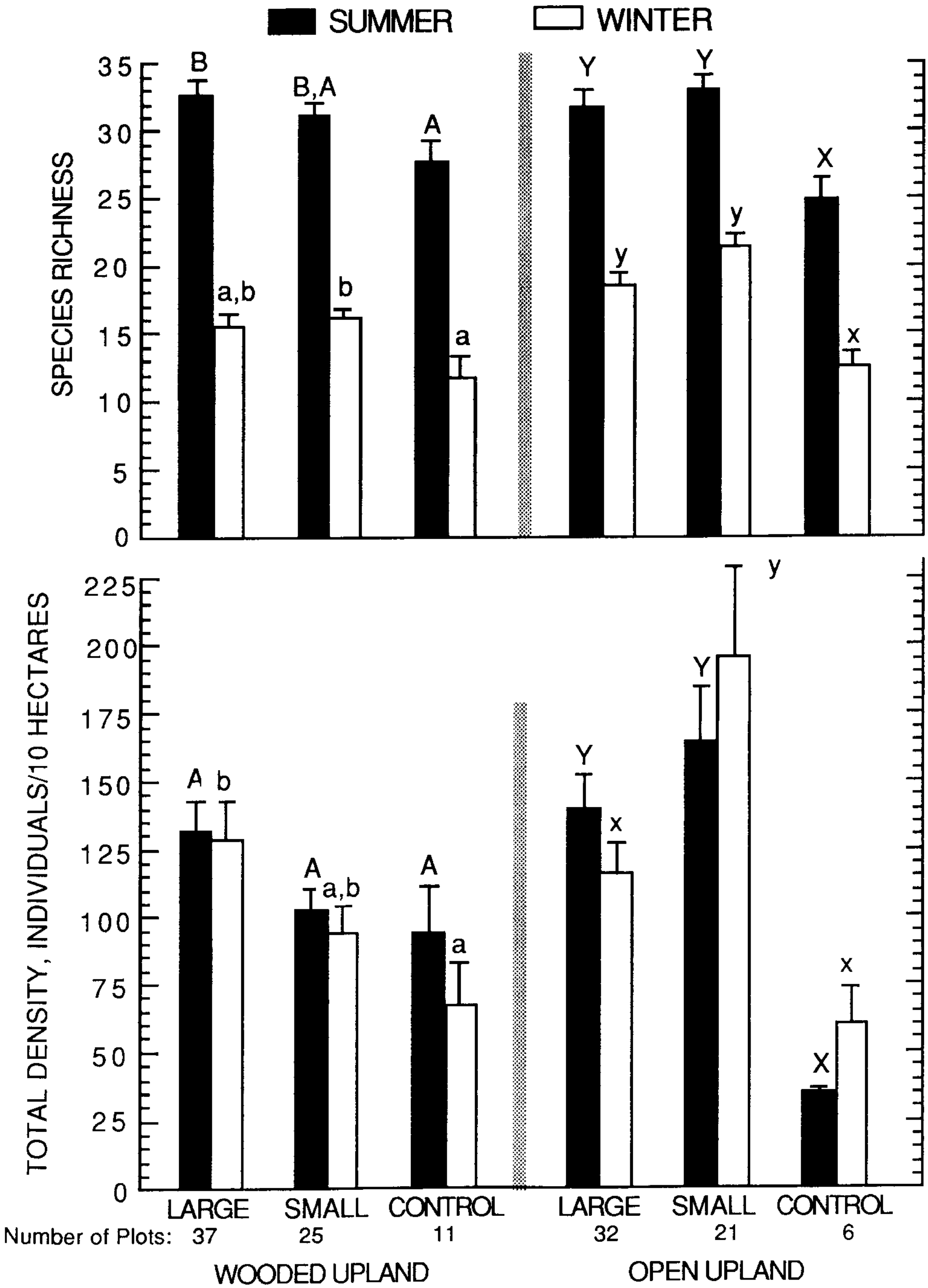

FIGURE 2. Means and standard errors of species richness and total bird density on plots in large riparian stands, small riparian stands, and control stands without riparian trees. The comparisons are restricted to sites located in either wooded areas or open grasslands. For each comparison, homogeneous subsets were distinguished by the Scheffé a posteriori test with ANOVA. Upper and lower case letters indicate groups that did not differ significantly in summer and winter, respectively.

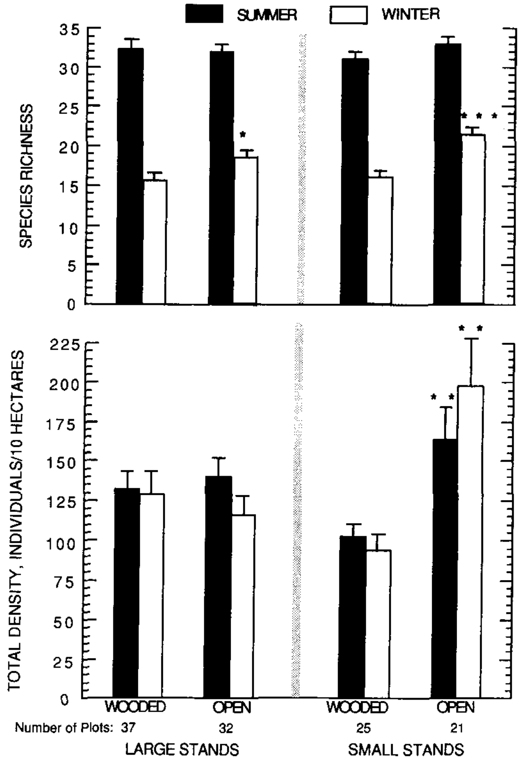

FIGURE 3. Means and standard errors of bird species richnesses and total bird density on study plots in riparian stands located in wooded areas or in open grasslands. All comparisons are restricted within seasons and to either large or small riparian stands. Asterisks indicate significant differences (* = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$).

wooded stands ($F = 3.196$, $P = 0.047$). The control plots also had lower bird densities than either large or small riparian stands, but these differences were not statistically significant. In winter, control plots had significantly lower species richness than small riparian stand plots ($F = 3.416$, $P = 0.038$). The control plots also had significantly lower densities than large riparian stands ($F = 4.98$, $P = 0.0095$).

The apparent preference of bird species for sites with riparian trees was particularly noticeable in plots adjacent to open upland vegetation. Summer species richness ($F = 5.114$, $P = 0.0091$) and total density ($F = 17.593$, $P < 0.0001$) were greater in both large and small riparian stands than in control plots in open areas (Fig. 2), but there were no differences between large and small stands. Winter bird species richness in both large and small stands was greater than that on control plots ($F = 8.881$, $P = 0.0004$). Small stands had higher winter density than either control or large stand plots ($F = 7.046$, $P = 0.0019$). This relationship probably was affected by the high densities of wintering bird species in the subfamily Emberizinae (family Emberizidae) and the family Fringillidae in the small, open study plots. Some common emberizine species were the Vesper Sparrow, Chipping Sparrow, White-crowned Sparrow, and Dark-eyed Junco, and common fringillids included the House Finch, Lesser Goldfinch, and American Goldfinch. These species are primarily granivorous in winter and foraged in the grasslands in small flocks. Riparian trees appeared to provide important cover for perching and resting. Small riparian stands apparently provided the ideal amount of cover for these species.

RELATIONSHIPS WITH UPLAND VEGETATION

In the breeding season, no significant relationship was observed between upland vegetation and species richness for either large or small stands (Fig. 3). Winter species richness in large stands with open uplands was significantly greater than that in large stands with wooded uplands ($t = 2.261$, $P = 0.027$). This result was strongly influenced by low species richness on plots in ash and maple stands. Plots in small riparian stands with open uplands had significantly greater winter species richness than plots in small stands with wooded uplands ($t = 4.882$, $P < 0.0001$).

Upland vegetation had no significant relationship with total bird density in large stands in either summer or winter. However, plots in small stands in open areas had significantly higher average densities than similar plots adjacent to wooded uplands in summer ($t = 2.857$, $P = 0.0065$) and winter ($t = 3.473$, $P = 0.0012$). These results suggest that for summer densities, small stands of riparian trees were of greater value to birds in open areas than they were in wooded areas. This relationship was probably influenced by high summer densities of birds in small, open sycamore, cottonwood, walnut, and willow plots, and low average summer densities of birds in small, wooded ash, desert willow, maple, and walnut study plots. The high winter density of birds in small riparian stands in open grasslands was due to the presence of large numbers of wintering emberizids and fringillids.

CLUSTERS OF BREEDING BIRD SPECIES

Plot densities of 87 breeding bird species (Appendix B) were correlated with 47 plot vegetation and physical environmental characteristics (Appendix D), and the resulting correlation matrix was used to generate a dendrogram (Fig. 4). This procedure clustered groups of bird species that shared similar environmental associations. Appendix B also indicates the habitats that were utilized most frequently by each species. It is apparent from this list that many species were generalists and could be found in many different habitats, while other species were common in only one or two habitats.

The first major division in this dendrogram was between lowland and foothill species (branch A) vs. highland species (branch E). Within the set of highland species groups, branch I included only the Scott's Oriole (85; species numbers in this section refer to Appendix B and Fig. 4), which was found in relatively low densities in a wide range of habitats. The other highland groups included species associated with specific habitat types. Branch F species were found in relatively dry canyons with some maples, and heavily wooded with oaks. Branch G species were most abundant in wooded canyons with large riparian trees and perennial water. Branch H species were found at the highest elevations in open pine forest, with a few sycamores. Within the lowland or foothill sets, branch D was somewhat unusual. These species, including the American Kestrel (4), Acorn Woodpecker (22), Sulphur-bellied Flycatcher (36), and Northern Oriole (84), appeared to share a strong affinity for large sycamore trees, regardless of upland vegetation or elevation. Within the remaining groups there was a clear and major break between species in open areas with scrubby vegetation (branch C) and species in areas with large riparian trees (branch B). The species in branch C were found in a variety of habitats, all of which were open, with low stature riparian vegetation. Branch B included species common in lowland areas with large riparian trees and perennial water. The Northern Flicker (26) and Phainopepla (57) shared high densities in a large, wooded cottonwood stand. The Black-chinned Hummingbird (19), Ash-throated Flycatcher (34), and Northern Mockingbird (55) were found in lowland areas with large riparian trees, particularly sycamores, and in drier areas than those for other species in branch B. Three species, the Red-tailed Hawk

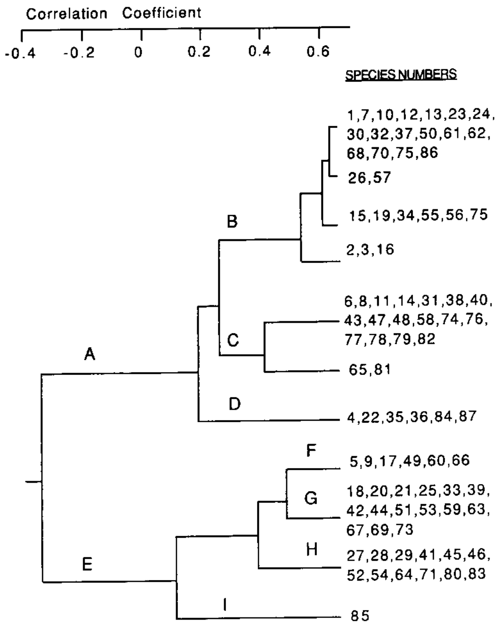

FIGURE 4. Dendrogram of 87 breeding bird species based on correlations of their densities on 132 study plots with 47 vegetation and physical environmental characteristics at each plot. The species numbers given for each branch correspond with species numbers in Appendix B. Cophenetic correlation = 0.874. Major groups, indicated by letters, are defined in the text.

(3), Common Nighthawk (16), and Turkey Vulture (2), were widely but sparsely distributed in lowland and foothill habitats.

CLUSTERS OF WINTERING BIRD SPECIES

A corresponding dendrogram for 60 winter species (Appendix C) was based on their correlations with the same physical and vegetation characteristics (Fig. 5). Appendix C also includes lists of habitats commonly used by each of the species. The first major division separated groups of species most common in lowland, open areas (branch A) from groups of species in wooded areas (branch H). Within the set of open country species, another important branch isolated birds common in open areas with scrubby vegetation or no trees (branch B). Typical species in branch B were the Mourning Dove (9; numbers in this section refer to Appendix C and Fig. 5), Chihuahuan Raven (23), Loggerhead Shrike (39), Canyon Towhee (44), and Song Sparrow (49). Branch C included the Scaled Quail (5) and Horned Lark (20). The other open area division

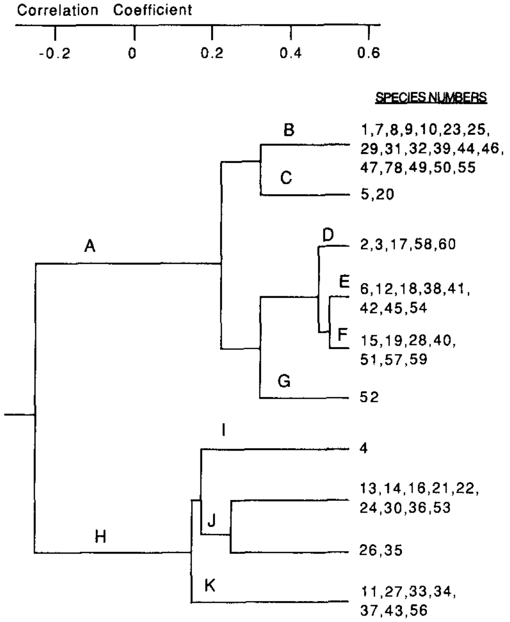

FIGURE 5. Dendrogram of 60 winter bird species based on correlations of their densities on 132 study plots with 47 vegetation and physical environmental characteristics at each plot. The species numbers given for each branch correspond with species numbers in Appendix C. Cophenetic correlation = 0.812. Major groups, indicated by letters, are defined in the text.

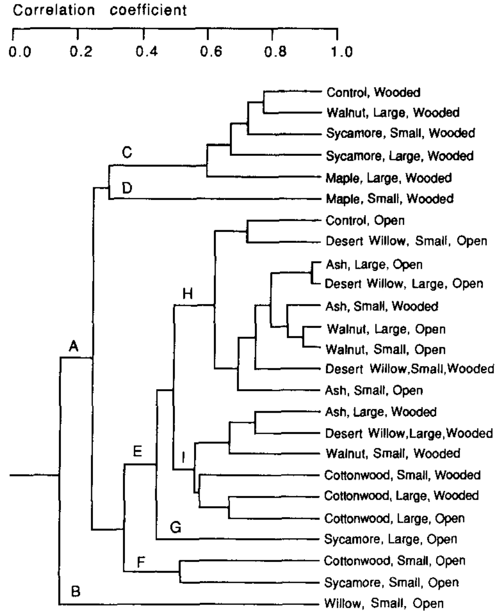

FIGURE 6. Dendrogram of 25 riparian habitat types based on densities of 87 breeding bird species listed in Appendix B. Wooded = adjacent uplands are oak or pine/oak woodlands; open = adjacent uplands are largely grassland; large = riparian stand is greater than 1,000 m along stream channel; small = riparian stand is less than 200 m along stream channel. Cophenetic correlation = 0.767.

included bird species found in sites with small clumps of large riparian trees (branch D), areas with large trees and mesquite (branch E), or areas with small-stature to medium-stature trees (branch F). Some representative species of these groups were the American Kestrel (3), Northern Flicker (17), and Pine Siskin (58) in branch D, Gambel's Quail (6), Gila Woodpecker (12), and Abert's Towhee (45) in branch E, and Ladder-backed Woodpecker (15), Yellow-rumped Warbler (40), and Lesser Goldfinch (59) in branch F. Branch G contained only a single species, the Dark-eyed Junco (52), which was widespread and abundant in many habitats.

Within the groups of species more common in wooded areas, branch I included only one species, the Montezuma Quail (4), which was recorded in several habitats at relatively low densities. The species in branch J, including Williamson's Sapsucker (14), Steller's Jay (21), Hermit Thrush (36), and Yellow-eyed Junco (53), were most common in highland canyons that were heavily wooded with oaks and pines. The species in branch K were rather widespread, with variable abundances, in wooded areas. These species included the Acorn Woodpecker (11), White-breasted Nuthatch (27), Ruby-crowned Kinglet (33), and Rufous-sided Towhee (43).

CLUSTER OF HABITATS—SUMMER

The first dendrogram of 25 habitats (Fig. 6) is based on densities of 87 breeding bird species within those habitats. The clusters of habitats in this diagram show a reasonable and biologically meaningful pattern. The first division of the dendrogram separates the small, open willow habitat (branch B) from all others (branch A). This habitat was unique in being in a marshy grassland area, with a high density of low-stature willows. The next major division was between high elevation, wooded habitats (branches C and D) and lowland or foothill habitats (branches E and F).

CLUSTER OF HABITATS—WINTER

A corresponding dendrogram of the same 25 habitats using density data for 60 species of wintering birds (Fig. 7) revealed a pattern different from that obtained from the summer data. The first division of this dendrogram identified two habitats as having winter bird species densities distinctive from those in all other habitats. These two were the small, open, cottonwood and willow habitats, both of which included plots in low, grassland areas, with a lot of water available. The next branch point was very clean and significant, separating all but one of the riparian habitats adjacent to open (grassy) uplands (B) from all those adjacent to wooded uplands (A).

DISCUSSION

FACTORS INFLUENCING BIRD SPECIES RICHNESS AND TOTAL DENSITY

Results of this study demonstrate the importance of riparian tree species, riparian stand size, and adjacent upland vegetation to bird species richness and total density in southeastern Arizona. Species richness and total density varied significantly with the riparian tree species. In general, maple habitats had the lowest species richness and density, and sycamore and cottonwood stands had the highest richness and density. These relationships appeared stronger in summer than in winter, although they were highly significant in both seasons.

The importance of riparian vegetation to bird species in arid or semi-arid environments has been discussed by many authors. In particular, the lower Colorado River valley in Arizona has been the site for much riparian research. Anderson and Ohmart (1977) correlated bird population parameters during different seasons of the year with vegetation parameters along the Colorado River. In summer, they found the greatest numbers of birds in areas with the greatest amount of total vegetation. However, in fall the greatest numbers were found in relatively open areas, and in winter, bird densities were most highly correlated with low vegetation (1–3 m). Johnson et al. (1977) noted that the highest breeding bird densities in North America have been reported from cottonwood riparian zones in the Southwest, and that loss of these habitats could result in the loss of 47% of breeding bird species in this region. Bock and Bock (1984) found that sycamores provide both food resources and nesting sites for birds. Sycamores are particularly important to the Elegant Trogon (Taylor 1980). Our results concur with these previous studies in emphasizing the importance of sycamores and cottonwoods to breeding bird species.

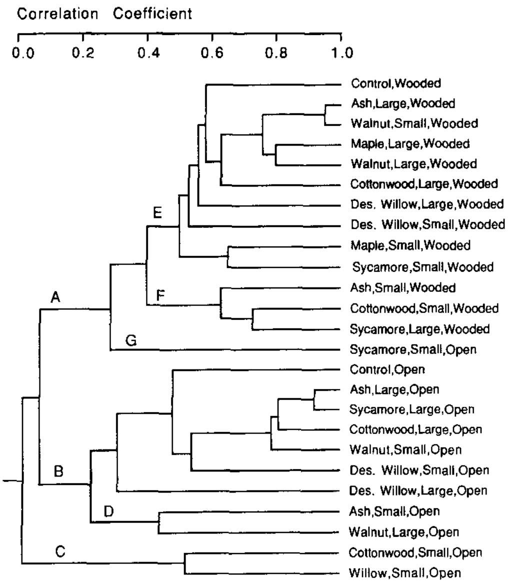

FIGURE 7. Dendrogram of 25 riparian habitat types based on densities of 60 winter bird species listed in Appendix C. Definitions are the same as those in Figure 6. Cophenetic correlation = 0.866.

The generally low bird species richness and total density in control habitats were primarily due to very low numbers of birds in open control plots, although wooded control plots also were relatively low. The paucity of birds in maple habitats was somewhat surprising. These plots were in narrow, high-walled canyons where they could receive relatively little sunlight. These conditions created a cooler microclimate that may have been less attractive to birds than other habitats. Karr and Freemark (1983) considered microclimate to be more important than vegetation factors in determining avian species assemblages. Petit et al. (1985) found species richness to be positively correlated with relative humidity in a mature deciduous forest in Ohio, but they believed that species richness was directly related to food resources that were in turn correlated with relative humidity. In our study area, the cottonwood habitats were relatively wet and had high species richness, but the large maple habitat also was along a permanent stream and had relatively few species.

Other species of riparian trees, such as ash, desert willow, and walnut, are generally smaller than the cottonwoods and sycamores, and they are a less dominant part of the vegetation. These trees tend to be relatively short, and in wooded areas there is not as great a contrast between the riparian trees and the adjacent vegetation. Some of these trees, particularly ash and walnut, tend to have very hard wood, which might be more resistant to decay and have fewer cavities, thus providing fewer nest sites for several species.

The riparian trees in our study area are all deciduous, and they are a much less dominant part of the environment in winter than in summer. This difference may at least partially account for the observed differences between summer and winter in the patterns of bird species richness and total density based on riparian tree species. Another important factor is the effect of migratory species. Many species that are present in this area only as summer breeding species are insectivorous, especially the warblers and flycatchers. These species appear to be dependent on the riparian vegetation, particularly in the open areas. In contrast, many winter migrants are granivorous species that are not dependent on riparian zones as a foraging habitat, although riparian vegetation does provide cover. In a study of migratory insectivorous birds in the Chiricahua Mountains, Hutto (1985) found significant differences in habitat use between the spring and fall migration seasons, and there were distinct groups of species that shared similar seasonal distribution patterns. He reported that the densities of all species were significantly positively correlated with measures of food availability. In our study area, it seems very likely that the relatively lush vegetation associated with riparian zones would provide greater resources for insectivorous birds than either surrounding grasslands or oak forests. Morrison et al. (1986) also found differences in bird species habitat use between summer and winter in the Blodgett Forest in the Sierra Nevada in California. In their study, large diameter trees, used for singing and foraging, were more important in summer, while dense canopy cover for thermal protection was more important in winter.

Results of this project suggest that the presence of some riparian vegetation is very important to species richness and total density, because control habitats had significantly lower diversity and fewer individuals than either large or small riparian habitats. These findings are consistent with those of Stevens et al. (1977) who found greater passerine species richness and density in riparian habitats than in adjacent nonriparian areas in central and southeastern Arizona. Knopf (1985) also found greater bird species diversity in riparian vegetation than in adjacent upland areas in an elevational transect in the Platte River drainage in northern Colorado.

The lack of differences between large and small stands suggests that stand size was unimportant to most bird species, except in open habitats in winter. These results would appear to be in conflict with the positive species-area correlation reported by Blake (1986) for isolated woodlots, and with the species disappearances associated with forest fragmentation reported by Whitcomb (1977) and Robbins (1979). However, in a study in small woodlots in the Netherlands, Opdam et al. (1985) found no correlation between the number of bird species present and variables describing the isolation of the woodlots. They did find that different species showed different responses to isolation and area of woodlots, and that the species most affected were those restricted to mature woods. Blake and Karr (1984) also reported bird species differences in response to forest size, with long-distance migrants and forest-interior species being poorly represented in small forest patches. Our results are consistent with different species showing different preferences based on stand size, and migratory species in particular affected the patterns of species richness and density in summer and winter.

In our study area, the large riparian habitats were never part of a continuous, widespread, homogeneous habitat. They were very narrow strips restricted to stream drainages, and virtually all of our study sites could be considered habitat edges. Even in the widest riparian stand, it usually was not possible to be more than 50 m from upland, nonriparian vegetation. These areas then are not comparable to the fragmented forests mentioned above, although they might be comparable to the corridors that Robbins (1979) recommended to connect isolated woodland fragments.

Another difference between summer and winter seasons was seen in the comparisons between large and small stands in open grasslands. The greater richness and density in the small stands in winter suggest that either the large stands of riparian trees were less important to the birds in the winter than in summer, or the open grasslands were more important than the riparian zones in winter. The latter option seems plausible because of high densities of several wintering emberizid species, but it is not consistent with the low richness and density in the open, control plots. A possible explanation is that the grasslands are important as a feeding area, but some riparian vegetation is important to provide cover. The grasslands might have been less important in the summer because of the lower proportion of emberizids in the summer avifauna.

The type of adjacent upland vegetation has also been shown to have significant effects on birds in riparian vegetation. Carothers (1977) reported higher densities of breeding birds in cottonwood stands adjacent to agricultural lands than in stands surrounded by pinyon-juniper, oak, or chaparral vegetation. However, Conine et al. (1978) found that certain riparian bird species were lost from a riparian community following agricultural encroachment, even though overall densities were higher. Szaro and Jakle (1985) found that bird densities decreased sharply from a riparian zone to a surrounding desert upland. They also found that the riparian bird community made a substantial contribution to bird populations in the desert uplands, but the desert bird community contributed very little to riparian populations.

In our study area, adjacent upland vegetation had significant relationships with richness and density. In open grasslands, isolated riparian trees of almost any size will act as a focal point for bird nesting and foraging activities, leading to very high local densities around the central trees that were not representative of the surrounding grassland. For example, Cassin's and Western kingbirds were common nesting species in small cottonwood and sycamore plots. In winter, flocks of fringillids and emberizines foraged in grasslands around the riparian trees. Because of the small size of these stands (often just a single tree or a very small grove), finches and sparrows could be feeding in the grassland and still be very close to the center tree of a study plot. The low winter density and richness of the open control plots compared with the small open plots suggests that the riparian vegetation was providing some essential requirement for these birds. It seems most likely that the trees provided cover in the form of perching sites between foraging bouts and possibly additional protection from predators. This finding is consistent with that of Pulliam and Mills (1977) who reported that several emberizine sparrows partitioned space based on the distance to trees or shrubs that could provide cover. In general, the type of adjacent upland vegetation had a greater impact on bird populations in winter than in summer. The most consistent effect was on species richness of winter birds, with open plots having a greater diversity of birds than wooded plots, in either large or small stands.

Overall, the primary factor influencing bird species richness and total density in summer was the dominant riparian tree species. In contrast, adjacent upland vegetation had a more important impact on the diversity and abundance of wintering bird populations. The sizes of riparian stands appeared to be less important than either riparian tree species or the nature of adjacent upland vegetation.

PATTERNS OF BIRD SPECIES DISTRIBUTION—SUMMER

Cluster analysis of habitats based on breeding bird densities (Fig. 6) revealed a clear distinction between montane, heavily wooded habitats vs. lowland and foothill habitats. Within the lower elevation habitats, there were breaks between those dominated by smaller riparian trees (ash, desert willow, and walnut) and those dominated by sycamores and cottonwoods. This pattern indicates that the bird species were distributing themselves partially according to an elevational gradient and partially according to the riparian vegetation. This result is consistent with the patterns of species distributions among habitats reported by Anderson et al. (1977) in the Colorado River Valley, although they were working at much lower elevations in areas with local habitat diversity.

The dendrogram based on breeding bird densities correlations with vegetation characteristics (Fig. 4) shows a definite pattern of species groups which is consistent with the pattern of habitats. Groups of high montane bird species were distinct from the groups of lowland or foothill species. Some bird species groups were easily assigned to specific habitats, while other species were widely distributed in many habitats. It might be appropriate to consider some of these groups as distinctive avian communities that were coincident with specific vegetation habitats.

Within the Huachuca Mountains riparian habitats, there were a number of bird species that were restricted to or reached their greatest densities in a large cottonwood cienega. This habitat was dominated by very large cottonwood trees, with abundant water, surrounded by open grassland with some mesquite. Some typical bird species in this community included the Yellow-billed Cuckoo, Vermilion Flycatcher, and Yellow Warbler. Several species, such as the Gila Woodpecker, Yellow-breasted Chat, and Abert's Towhee, appeared to be restricted to this habitat, and were rarely, if ever, recorded in other areas. Gambel's Quail was commonly recorded in this habitat, but it did not appear to be dependent on the cottonwoods. Rather, it seemed to prefer the dry, mesquite habitat adjacent to the riparian zone. The strong correspondence between bird species and cottonwood trees is consistent with the relationships between species richness and density and cottonwoods. In a cottonwood/willow habitat in the Colorado River Valley, Rosenberg et al. (1982) found many insectivorous bird species sharing similar resources, and in particular, several species concentrated on cicadas, a superabundant, seasonally predictable resource. Although we collected no data on foraging behavior or food availability, it seems reasonable that a stand of very large cottonwood trees along an active stream would provide food resources for a large variety of species and quantities adequate for high densities of birds.

A grassland/desert scrub bird community (branch C, Fig. 4) included many species common in the lowland, open grassland areas with some mesquite and desert willow, and relatively little water. Some representative bird species include the Scaled Quail, Greater Roadrunner, Western Kingbird, Chihuahuan Raven, Cactus Wren, Canyon Towhee, and Botteri's Sparrow.

A montane canyon bird community (branch G, Fig. 4) was common in upper elevation canyons dominated by sycamores and maples, with fairly dense oak woodlands on upper slopes. These canyons were fairly broad and contained reliable seasonal or permanent water. This community included several of the species whose range within the United States is restricted to mountains in this corner of Arizona, such as the Magnificent Hummingbird, Elegant Trogon, Strickland's Woodpecker, Dusky-capped Flycatcher, and Painted Redstart.

A montane, coniferous forest bird community (branch H, Fig. 4) was found in areas that included the highest of our study plots, dominated by a relatively open pine forest. Some typical species of this group were the Greater Pewee, Buff-breasted Flycatcher, Steller's Jay, American Robin, Grace's Warbler, and Yellow-eyed Junco.

Recognition of a cottonwood cienega community, a grassland/desert scrub community, a montane canyon community, and a montane coniferous forest community emphasizes the importance of elevation in the distribution of breeding bird species in the Huachuca Mountains. This distribution of bird species tends to parallel the elevational distribution of dominant riparian plant species described by Pase and Layser (1977) for arid and semi-arid environments of the Southwest, although many plants and birds in the Huachuca Mountains showed fairly wide elevational tolerances, and many species overlapped in their distributions.

Rice et al. (1984) found that tree species composition was very important in bird species habitat selection in riparian areas along the lower Colorado River. They reported that birds were selecting for specific trees rather than showing an avoidance of other trees. Wiens and Rotenberry (1981) also reported many significant correlations between bird species' abundances and the coverage of shrub species in a shrubsteppe environment. They found both positive and negative correlations, indicating that birds were choosing some shrub species while avoiding others. The relationships that we observed between certain bird species and specific riparian tree species, especially cottonwoods and sycamores, again demonstrate the importance of measuring tree species composition in habitat analysis studies, as recommended by Rice et al. (1984).

Each described avian assemblage was based on a set of bird species sharing similar patterns of distribution and similar correlations with vegetation. However, the bird species mentioned above were usually not the most common species within any given habitat. There were several species that occurred in relatively high densities in a wide variety of habitats. These species were often numerically dominant, but they could not be easily assigned to any single community, and they were not indicators of specific assemblages. Some examples of these widespread species were the Western Wood-Pewee, Ash-throated Flycatcher, Cassin's Kingbird, Gray-breasted Jay, Bewick's Wren, Lucy's Warbler, Brown-headed Cowbird, and House Finch. This observed pattern is consistent with the results of Wiens and Rotenberry (1981) who found that the most widely distributed bird species showed little correlation with habitat features, but species with localized distributions tended to have much stronger associations with habitat characteristics. Holmes et al. (1986) found that different bird species showed different patterns of abundance over a 15-year period in the Hubbard Brook Experimental Forest, suggesting that each species was responding to different factors in the environment. Some species seemed more closely tied to local habitat variables, while others were affected more by regional or global scale events. They took a very broad view of avian community structure, with many different factors interacting to determine the assemblage of birds at any particular time. Although our study was over a much shorter time period, our results support this view of avian communities.

PATTERNS OF BIRD SPECIES DISTRIBUTION—WINTER

During the winter season, different patterns of bird species and vegetation relationships were apparent. The dendrogram of habitats based on winter bird densities (Fig. 7) showed a very clear break between wooded and open habitats. This was somewhat similar to the summer habitat pattern, but the separation was more clearly related to upland vegetation than to elevation. This contrast suggests that dominant riparian tree species are less important than upland vegetation in determining winter bird communities, as opposed to the importance of riparian trees in summer bird communities. The dendrogram of winter bird species based on vegetation correlations (Fig. 5) gave patterns that were consistent with the pattern of habitats. Groups of species were clearly associated with wooded areas or open areas. However, within each main division, there were no obvious associations with specific riparian habitats.

Some permanent resident species, such as the Abert's Towhee, were found in the same habitat in both summer and winter, but others, like the Gila Woodpecker, were found in a greater variety of habitats in the winter. This observation for Abert's Towhee is in contrast to Anderson and Ohmart (1977), who found this species to be more of a habitat specialist during winter than in summer. Other species that were year-round residents within the study area were found in different elevation zones in the winter. For example, the House Wren and the Rufous-sided Towhee were found in a variety of lowland habitats in the winter, but they were primarily found in the mountains during the summer.

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LITERATURE CITED

ANDERSON, B. W., A. E. HIGGINS, AND R. D. OHMART. 1977. Avian use of salt cedar communities in the Lower Colorado River Valley, p. 128–136. *In* R. R. Johnson and D. A. Jones [tech. coords.], Importance, preservation, and management of riparian habitats: a symposium. U.S.D.A. For. Serv. Gen. Tech. Rep. RM-43. Fort Collins, CO.

ANDERSON, B. W., AND R. D. OHMART. 1977. Vegetation structure and bird use in the Lower Colorado River Valley, p. 23–34. *In* R. R. Johnson and D. A. Jones [tech. coords.], Importance, preservation, and management of riparian habitats: a symposium. U.S.D.A. For. Serv. Gen. Tech. Rep. RM-43. Fort Collins, CO.

BLAKE, J. G. 1986. Species-area relationship of migrants in isolated woodlots in east-central Illinois. Wilson Bull. 98:291–296.

BLAKE, J. G., AND J. R. KARR. 1984. Species composition of bird communities and the conservation of large versus small forests. Biol. Conserv. 30: 173–187.

BOCK, C. E., AND J. H. BOCK. 1984. Importance of sycamores to riparian birds in southeastern Arizona. J. Field Ornithol. 55:97–103.

CAROTHERS, S. W. 1977. Importance, preservation, and management of riparian habitat: an overview, p. 2–4. *In* R. R. Johnson and D. A. Jones [tech. coords.], Importance, preservation, and management of riparian habitat: a symposium. U.S.D.A. Forest Service Gen. Tech. Rep. RM-43. Fort Collins, CO.

CAROTHERS, S. W., R. R. JOHNSON, AND S. W. AITCHISON. 1974. Population and social organization of southwestern riparian birds. Am. Zool. 14:97–108.

CONINE, K. H., B. W. ANDERSON, R. D. OHMART, AND J. F. DRAKE. 1978. Responses of riparian species to agricultural conversions, p. 248–262. *In* R. R. Johnson and J. F. McCormick [tech. coords.], Strategies for protection and management of floodplain wetlands and other riparian ecosystems. U.S.D.A. For. Serv. Gen. Tech. Rep. WO-12. Washington, DC.

HOLMES, R. T., T. W. SHERRY, AND F. W. STURGES. 1986. Bird community dynamics in a temperate deciduous forest: long-term trends at Hubbard Brook. Ecol. Monogr. 56:201–220.

HUTTO, R. L. 1985. Seasonal changes in the habitat distribution of transient insectivorous birds in southeastern Arizona: competition mediated? Auk 102:120–132.

JAMES, F. C., AND H. H. SHUGART, JR. 1970. A quantitative method of habitat description. Audubon Field Notes 24:727–736.

JOHNSON, R. R., L. T. HAIGHT, AND J. M. SIMPSON. 1977. Endangered species vs. endangered habitat: a concept, p. 68–79. *In* R. R. Johnson and D. A. Jones [tech. coords.], Importance, preservation, and management of riparian habitats: a symposium. U.S.D.A. For. Serv. Gen. Tech. Rep. RM-43. Fort Collins, CO.

KARR, J. E., AND K. E. FREEMARK. 1983. Habitat selection and environmental gradients: Dynamics in the "stable" tropics. Ecology 64:1481–1494.

KNOPF, F. L. 1985. Significance of riparian vegetation to breeding birds across an altitudinal cline. U.S.D.A. For. Serv. Gen. Tech. Rep. RM-120: 105–111. Fort Collins, CO.

MORRISON, M. L., K. A. WITH, AND I. C. TIMOSSI. 1986. The structure of a forest bird community during summer and winter. Wilson Bull. 98:214–230.

OPDAM, P., G. RIJSDIJK, AND F. HUSTINGS. 1985. Bird communities in small woods in an agricultural landscape: effects of area and isolation. Biol. Conserv. 34:333–352.

PASE, C. P., AND E. F. LAYSER. 1977. Classification of riparian habitat in the southwest, p. 5–9. *In* R. R. Johnson and D. A. Jones [tech. coords.], Importance, preservation, and management of riparian habitats: a symposium. U.S.D.A. For. Serv. Gen. Tech. Rep. RM-43. Fort Collins, CO.

PETIT, D. R., K. E. PETIT, AND T. C. GRUBB, JR. 1985. On atmospheric moisture as a factor influencing distribution of breeding birds in temperate deciduous forest. Wilson Bull. 97:88–96.

PULLIAM, H. R., AND G. S. MILLS. 1977. The use of space by wintering sparrows. Ecology 58:1393–1399.

REYNOLDS, R. T., J. M. SCOTT, AND R. A. NUSSBAUM. 1980. A variable circular-plot method for estimating bird numbers. Condor 82:309–313.

RICE, J., B. W. ANDERSON, AND R. D. OHMART. 1984. Comparison of the importance of different habitat attributes to avian community organization. J. Wildl. Manage. 48:895–911.

ROBBINS, C. S. 1979. Effects of forest fragmentation on bird populations, p. 198–212. *In* R. M. DeGraaf and K. E. Evans [comps.], Management of north central and northeastern forests for nongame birds. U.S.D.A. For. Serv. Gen. Tech. Rep. NC-51. St. Paul, MN.

ROHLF, F. J., J. KISHPAUGH, AND D. KIRK. 1972. Numerical taxonomy system of multivariate statistical programs (NT-SYS). State Univ. of New York, Stony Brook.

ROSENBERG, K. V., R. D. OHMART, AND B. W. ANDERSON. 1982. Community organization of riparian breeding birds: response to an annual resource peak. Auk 99:260–274.

STAMP, N. E. 1978. Breeding birds of riparian woodlands in south-central Arizona. Condor 80:64–71.

STEVENS, L. E., B. R. BROWN, J. M. SIMPSON, AND R. R. JOHNSON. 1977. The importance of riparian habitat to migrating birds, p. 156–164. *In* R. R. Johnson and D. A. Jones [tech. coords.], Importance, preservation, and management of riparian habitats: a symposium. U.S.D.A. For. Serv. Gen. Tech. Rep. RM-43. Fort Collins, CO.

STRONG, T. R. 1987. Bird communities in the riparian habitats of the Huachuca Mountains and vicinity in southeastern Arizona. Ph.D.diss., Univ. of Colorado, Boulder.

SZARO, R. C. 1980. Factors influencing bird population is southwestern riparian forests, p. 403–418. *In* R. M. DeGraff [tech. coord.], Management of western forests and grasslands for nongame birds. U.S.D.A. For. Serv. Gen. Tech. Rep. INT-86. Ogden, UT.

SZARO, R. C., AND M. D. JAKLE. 1982. Comparison of variable circular-plot and spot-map methods in desert riparian and scrub habitats. Wilson Bull. 94:546–550.

SZARO, R. C., AND M. D. JAKLE. 1985. Avian use of a desert riparian island and its adjacent scrub habitat. Condor 87:511–519.

TAYLOR, C. 1980. The Coppery-tailed Trogon: Arizona's "bird of paradise." Borderland Publications, Portal, AZ.

VERNER, J., AND L. V. RITTER. 1985. A comparison of transects and point counts in oak-pine woodlands of California. Condor 87:47–68.

WHITCOMB, R. F. 1977. Island biogeography and "habitat islands" of eastern forest. I. Introduction. Am. Birds 31:3–5.

WIENS, J. A., AND J. T. ROTENBERRY. 1981. Habitat association and community structure of birds in shrubsteppe environments. Ecol. Monogr. 51:21–41.

APPENDIX A. Habitat list. List of 25 habitat types used in the multivariate statistical analyses. Numbers correspond with those used in Appendices B and C to indicate which habitats were utilized by each species.

Number	Tree species	Stand size	Upland vegetation
1	Control		Wooded
2	Control		Open
3	Ash	Large	Wooded
4	Ash	Large	Open
5	Ash	Small	Wooded
6	Ash	Small	Open
7	Cottonwood	Large	Wooded
8	Cottonwood	Large	Open
9	Cottonwood	Small	Wooded
10	Cottonwood	Small	Open
11	Desert willow	Large	Wooded
12	Desert willow	Large	Open
13	Desert willow	Small	Wooded
14	Desert willow	Small	Open
15	Maple	Large	Wooded
16	Maple	Small	Wooded
17	Sycamore	Large	Wooded
18	Sycamore	Large	Open
19	Sycamore	Small	Wooded
20	Sycamore	Small	Open
21	Walnut	Large	Wooded
22	Walnut	Large	Open
23	Walnut	Small	Wooded
24	Walnut	Small	Open
25	Willow	Small	Open

APPENDIX B. Species list—summer. List of 87 species used in the multivariate statistical analyses. Species numbers correspond to those used in Figure 4. Habitat numbers for each species correspond to the habitats listed in Appendix A and indicate those in which the species' density was greater than one individual per 10 ha. An asterisk (*) indicates the habitat of maximum density for a species whose density was less than one individual per 10 ha in all habitats.

Species number		Habitats
1 Mallard	*Anas platyrhynchos*	8, 25
2 Turkey Vulture	*Cathartes aura*	8*
3 Red-tailed Hawk	*Buteo jamaicensis*	9*
4 American Kestrel	*Falco sparverius*	10, 20
5 Montezuma Quail	*Cyrtonyx montezumae*	5, 10, 11, 16, 17, 20
6 Scaled Quail	*Callipepla squamata*	6, 22, 24
7 Gambel's Quail	*Callipepla gambelii*	8, 24
8 Killdeer	*Charadrius vociferus*	6, 10, 11, 14, 20, 24
9 Band-tailed Pigeon	*Columba fasciata*	15*
10 White-winged Dove	*Zenaida asiatica*	3, 5, 6, 7, 8, 9, 10, 11, 14, 17, 18, 20, 21, 22, 23, 25
11 Mourning Dove	*Zenaida macroura*	2, 4, 6, 7, 8, 9, 10, 11, 12, 14, 18, 20, 21, 22, 23, 24
12 Common Ground-Dove	*Columbina passerina*	8*
13 Yellow-billed Cuckoo	*Coccyzus americanus*	21*
14 Greater Roadrunner	*Geococcyx californianus*	12*
15 Great Horned Owl	*Bubo virginianus*	18, 23
16 Common Nighthawk	*Chordeiles minor*	7*
17 White-throated Swift	*Aeronautes saxatalis*	15, 16
18 Magnificent Hummingbird	*Eugenes fulgens*	15, 17, 19, 21
19 Black-chinned Hummingbird	*Archilochus alexandri*	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25
20 Broad-tailed Hummingbird	*Selasphorus platycercus*	1, 15, 16, 17, 19, 21
21 Elegant Trogon	*Trogon elegans*	17
22 Acorn Woodpecker	*Melanerpes formicivorus*	3, 7, 9, 10, 11, 13, 17, 19, 20, 21, 22, 23, 25
23 Gila Woodpecker	*Melanerpes uropygialis*	8
24 Ladder-backed Woodpecker	*Picoides scalaris*	8, 10, 22, 24
25 Strickland's Woodpecker	*Picoides stricklandi*	16, 17
26 Northern Flicker	*Colaptes auratus*	3, 5, 7, 8, 10, 11, 17, 19, 20, 21, 22, 23
27 Greater Pewee	*Contopus pertinax*	19
28 Western Wood-Pewee	*Contopus sordidulus*	1, 3, 7, 8, 9, 10, 11, 15, 17, 18, 19, 21, 24
29 Buff-breasted Flycatcher	*Empidonax fulvifrons*	1, 19
30 Black Phoebe	*Sayornis nigricans*	5, 6, 7, 8, 9, 20, 25
31 Say's Phoebe	*Sayornis saya*	6, 7, 11
32 Vermilion Flycatcher	*Pyrocephalus rubinus*	6, 8, 10, 14, 18, 20, 25
33 Dusky-capped Flycatcher	*Myiarchus tuberculifer*	1, 3, 7, 16, 17, 18, 19
34 Ash-throated Flycatcher	*Myiarchus cinerascens*	1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 17, 18, 19, 20, 21, 22, 23, 24
35 Brown-crested Flycatcher	*Myiarchus tyrannulus*	8, 10
36 Sulphur-bellied Flycatcher	*Myiodynastes luteiventris*	3, 15, 17
37 Cassin's Kingbird	*Tyrannus vociferans*	1, 3, 4, 6, 7, 8, 9, 10, 11, 13, 17, 18, 19, 20, 21, 22, 23, 24, 25
38 Western Kingbird	*Tyrannus verticalis*	6, 9, 10, 14, 18, 19, 20, 22, 24, 25
39 Violet-green Swallow	*Tachycineta thalassina*	18
40 Barn Swallow	*Hirundo rustica*	6, 9, 10, 24
41 Steller's Jay	*Cyanocitta stelleri*	19, 21
42 Gray-breasted Jay	*Aphelocoma ultramarina*	1, 3, 5, 9, 11, 13, 15, 16, 17, 19, 23
43 Chihuahuan Raven	*Corvus cryptoleucus*	18*

APPENDIX B. Continued.

Species number		Habitats
44 Bridled Titmouse	*Parus wollweberi*	1, 3, 5, 7, 9, 11, 13, 15, 16, 17, 18, 19, 20, 21, 23
45 Bushtit	*Psaltriparus minimus*	1, 3, 5, 7, 8, 9, 11, 13, 15, 17, 19, 20, 21, 23
46 White-breasted Nuthatch	*Sitta carolinensis*	1, 3, 7, 17, 23
47 Cactus Wren	*Campylorhynchus brunneicapillus*	4, 12
48 Rock Wren	*Salpinctes obsoletus*	2, 11
49 Canyon Wren	*Catherpes mexicanus*	16
50 Bewick's Wren	*Thryomanes bewickii*	1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 16, 17, 18, 19, 20, 21, 22, 23, 24
51 House Wren	*Troglodytes aedon*	17
52 Eastern Bluebird	*Sialia sialis*	9, 11, 17, 21, 23
53 Hermit Thrush	*Catharus guttatus*	17*
54 American Robin	*Turdus migratorius*	1, 7, 9, 15, 17, 19, 21
55 Northern Mockingbird	*Mimus polyglottos*	2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 18, 20, 21, 22, 23, 24
56 Curve-billed Thrasher	*Toxostoma curvirostre*	8
57 Phainopepla	*Phainopepla nitens*	4, 5, 7, 8, 10, 13
58 Loggerhead Shrike	*Lanius ludovicianus*	10
59 Solitary Vireo	*Vireo solitarius*	1, 3, 15, 17, 19, 21
60 Virginia's Warbler	*Vermivora virginiae*	16, 23
61 Lucy's Warbler	*Vermivora luciae*	3, 4, 7, 8, 9, 10, 11, 12, 14, 18, 21, 22, 23, 24
62 Yellow Warbler	*Dendroica petechia*	7, 8, 10
63 Black-throated Warbler	*Dendroica nigrescens*	1, 3, 10, 16, 17, 19, 20
64 Grace's Warbler	*Dendroica graciae*	1, 19
65 Common Yellowthroat	*Geothlypis trichas*	2, 5, 6, 7, 9, 10, 14, 20, 21, 22, 24, 25
66 Red-faced Warbler	*Cardellina rubrifrons*	16
67 Painted Redstart	*Myioborus pictus*	1, 3, 15, 16, 17, 19, 21
68 Yellow-breasted Chat	*Icteria virens*	8
69 Hepatic Tanager	*Piranga flava*	15, 17
70 Summer Tanager	*Piranga rubra*	3, 4, 5, 7, 8, 9, 11, 18
71 Black-headed Grosbeak	*Pheucticus melanocephalus*	1, 3, 5, 7, 9, 15, 16, 17, 19, 21, 23
72 Blue Grosbeak	*Guiraca caerulea*	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 17, 18, 19, 20, 21, 22, 23, 25
73 Rufous-sided Towhee	*Pipilo erythrophthalmus*	7, 15, 16, 19, 21
74 Canyon Towhee	*Pipilo fuscus*	4, 6, 13, 14, 18, 20, 21, 22, 24
75 Abert's Towhee	*Pipilo aberti*	8
76 Botteri's Sparrow	*Aimophila botterii*	2, 4, 6, 10, 14, 22, 24
77 Rufous-crowned Sparrow	*Aimophila ruficeps*	1, 2, 3, 4, 5, 10, 11, 12, 13, 17, 18, 20, 21, 22, 23, 24
78 Lark Sparrow	*Chondestes grammacus*	5, 9, 10, 22, 23
79 Black-throated Sparrow	*Amphispiza bilineata*	2
80 Yellow-eyed Junco	*Junco phaeonotus*	15, 19
81 Red-winged Blackbird	*Agelaius phoeniceus*	7, 9, 10, 14, 25
82 Eastern Meadowlark	*Sturnella magna*	2, 4, 6, 10, 12, 14, 22, 23, 24, 25
83 Brown-headed Cowbird	*Molothrus ater*	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 16, 17, 18, 19, 20, 21, 22, 24, 25
84 Northern Oriole	*Icterus galbula*	6, 8, 10, 18, 20, 24
85 Scott's Oriole	*Icterus parisorum*	5, 20, 24
86 House Finch	*Carpodacus mexicanus*	3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14, 17, 18, 20, 21, 22, 23, 24, 25
87 Lesser Goldfinch	*Carduelis psaltria*	4, 7, 8, 11, 17, 18, 19

APPENDIX C. Species list—winter. List of 60 bird species used in the multivariate statistical analyses. Numbers correspond with those used in Figure 5. Habitat numbers for each species correspond to the habitats listed in Appendix A and indicate those in which the species' density was greater than one individual per 10 ha.

Species number			Habitats
1	Northern Harrier	*Circus cyaneus*	12
2	Red-tailed Hawk	*Buteo jamaicensis*	10, 20, 24
3	American Kestrel	*Falco sparverius*	7, 8, 20
4	Montezuma Quail	*Cyrtonyx montezumae*	2, 12, 16
5	Scaled Quail	*Callipepla squamata*	2, 20
6	Gambel's Quail	*Callipepla gambelii*	8
7	Killdeer	*Charadrius vociferus*	6, 10, 14, 25
8	Common Snipe	*Gallinago gallinago*	6, 10, 14, 20, 25
9	Mourning Dove	*Zenaida macroura*	6, 10, 14, 20, 25
10	Greater Roadrunner	*Geococcyx californianus*	9, 20, 24
11	Acorn Woodpecker	*Melanerpes formicivorus*	3, 7, 9, 13, 17, 19, 20
12	Gila Woodpecker	*Melanerpes uropygialis*	6, 8, 21
13	Yellow-bellied Sapsucker	*Sphyrapicus varius*	1, 3, 5, 7, 8, 15, 16, 17, 21
14	Williamson's Sapsucker	*Sphyrapicus thyroideus*	1, 19
15	Ladder-backed Woodpecker	*Picoides scalaris*	3, 4, 7, 8, 10, 18, 22, 24, 25
16	Strickland's Woodpecker	*Picoides stricklandi*	13, 21
17	Northern Flicker	*Colaptes auratus*	7, 8, 10, 11, 13, 14, 16, 17, 19, 20, 22, 24
18	Black Phoebe	*Sayornis nigricans*	5, 6, 7, 8, 9, 10, 11, 14, 18, 20, 25
19	Say's Phoebe	*Sayornis saya*	3, 4, 6, 7, 8, 14, 20, 25
20	Horned Lark	*Eremophila alpestris*	2
21	Steller's Jay	*Cyanocitta stelleri*	9
22	Gray-breasted Jay	*Aphelocoma ultramarina*	1, 7, 11, 13, 15, 16, 17, 20, 21
23	Chihuahuan Raven	*Corvus cryptoleucus*	10, 20, 22, 23
24	Bridled Titmouse	*Parus wollweberi*	1, 3, 5, 7, 9, 11, 13, 15, 16, 17, 19, 23
25	Verdin	*Auriparus flaviceps*	2, 4, 12, 18, 22, 23, 24, 25
26	Bushtit	*Psaltriparus minimus*	1, 3, 5, 6, 7, 9, 11, 13, 14, 15, 16, 17, 20, 21, 22, 23
27	White-breasted Nuthatch	*Sitta carolinensis*	3, 7, 9, 11, 13, 15, 17, 21, 22
28	Cactus Wren	*Campylorhynchus brunneicapillus*	18
29	Rock Wren	*Salpinctes obsoletus*	2, 5, 8, 11, 12, 17, 22, 23
30	Canyon Wren	*Catherpes mexicanus*	15, 16, 21
31	Bewick's Wren	*Thryomanes bewickii*	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 17, 18, 19, 20, 21, 22, 23, 24, 25
32	House Wren	*Troglodytes aedon*	9, 24
33	Ruby-crowned Kinglet	*Regulus calendula*	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 25
34	Eastern Bluebird	*Sialia sialis*	7
35	Western Bluebird	*Sialia mexicana*	1, 5, 17, 21
36	Hermit Thrush	*Catharus guttatus*	1, 16, 19
37	American Robin	*Turdus migratorius*	7, 18
38	Curve-billed Thrasher	*Toxostoma curvirostre*	3, 4, 8, 12
39	Loggerhead Shrike	*Lanius ludovicianus*	4, 6, 7, 9, 10, 18
40	Yellow-rumped Warbler	*Dendroica coronata*	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 14, 17, 18, 20, 21, 22, 24, 25
41	Pyrrhuloxia	*Cardinalis sinuatus*	4, 8, 13, 18, 21
42	Green-tailed Towhee	*Pipilo chlorurus*	8
43	Rufous-sided Towhee	*Pipilo erythrophthalmus*	1, 3, 5, 7, 8, 9, 11, 13, 16, 18, 19, 20
44	Canyon Towhee	*Pipilo fuscus*	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 17, 18, 20, 21, 22, 23, 24
45	Abert's Towhee	*Pipilo aberti*	8, 9

APPENDIX C. Continued.

Species number		Habitats
46 Rufous-crowned Sparrow	*Aimophila ruficeps*	1, 2, 3, 4, 7, 9, 10, 13, 14, 18, 19, 20, 21, 22, 23, 24
47 Chipping Sparrow	*Spizella passerina*	1, 3, 5, 6, 7, 9, 11, 12, 13, 14, 17, 18, 20, 21, 22, 23, 24
48 Vesper Sparrow	*Pooecetes gramineus*	2, 4, 6, 8, 9, 12, 14, 18, 20, 24, 25
49 Song Sparrow	*Melospiza melodia*	3, 4, 6, 8, 10, 14, 18, 20, 24
50 Lincoln's Sparrow	*Melospiza lincolnii*	3, 9, 10, 11, 14, 18, 19, 20, 21, 24
51 White-crowned Sparrow	*Zonotrichia leucophrys*	2, 4, 6, 8, 9, 12, 14, 18, 20, 21, 22, 23, 24
52 Dark-eyed Junco	*Junco hyemalis*	1, 3, 4, 5, 7, 9, 11, 13, 15, 16, 17, 18, 19, 20, 21, 23
53 Yellow-eyed Junco	*Junco phaeonotus*	1, 3, 9, 15, 17, 19, 21
54 Red-winged Blackbird	*Agelaius phoeniceus*	6, 8, 9, 10, 24, 25
55 Eastern Meadowlark	*Sturnella magna*	2, 4, 10, 12, 22, 24, 25
56 Cassin's Finch	*Carpodacus cassinii*	3, 11, 17
57 House Finch	*Carpodacus mexicanus*	3, 4, 6, 8, 10, 12, 17, 18, 20, 21
58 Pine Siskin	*Carduelis pinus*	5, 7, 8, 9, 10, 11, 14, 17, 20, 21
59 Lesser Goldfinch	*Carduelis psaltria*	8, 9, 12, 18, 19
60 American Goldfinch	*Carduelis tristis*	4, 6, 8, 10, 11, 17, 18, 20

APPENDIX D. List of physical and vegetation characteristics measured on 132 riparian study plots and used in statistical analyses.

Stand size—Ordinal	Maple density, trees/ha
Distance to next stand—Ordinal	Maple basal area, m^2/ha
Presence of water—Ordinal	Sycamore density, trees/ha
Upland tree type—Ordinal	Sycamore basal area, m^2/ha
Upland tree density—Ordinal	Walnut density, trees/ha
Elevation, meters	Walnut basal area, m^2/ha
Horizon angle—east	Willow density, trees/ha
Horizon angle—west	Willow basal area, m^2/ha
Canopy height, meters	Juniper density, trees/ha
Riparian canopy, %	Juniper basal area, m^2/ha
Upland canopy, %	Madrone density, trees/ha
Garss-herb cover, %	Madrone basal area, m^2/ha
Shrub canopy, total, %	Mesquite density, trees/ha
Sapling canopy, total, %	Mesquite basal area, m^2/ha
Upland tree average distance, meters	Oak density, trees/ha
Tree density, total, trees/ha	Oak basal area, m^2/ha
Tree basal area, total, m^2/ha	Pine density, trees/ha
Number of trees >30 cm and <60 cm dbh	Pine basal area, m^2/ha
Number of trees >60 cm dbh	Pinyon density, trees/ha
Ash density, trees/ha	Pinyon basal area, m^2/ha
Ash basal area, m^2/ha	Snag density, trees/ha
Cottonwood density, trees/ha	Snag basal area, m^2/ha
Cottonwood basal area, m^2/ha	
Desert willow density, trees/ha	
Desert willow basal area, m^2/ha	