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BREEDING BIRDS OF RIPARIAN WOODLAND IN SOUTH-CENTRAL ARIZONA

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Riparian woodland habitats in the Southwest are extremely important breeding places, wintering areas, and corridors for migration of birds. These habitats are the least extensive in the region but they have the highest densities and diversities of avian species (Bottorff 1974, Carothers and Johnson 1975).

Diversity of bird species has been correlated with diversity of foliage height in riparian habitats of the southwestern United States such as desert riparian, mesquite shrub, sycamore-cottonwood, and mixed deciduous habitats (Austin 1970, Cody 1974, MacArthur 1964, Carothers et al. 1974). In contrast, Carothers et al. (1974) found bird species diversity in homogeneous cottonwood plots on the upper Verde River in north-central Arizona not to be correlated with foliage height diversity.

My objectives were to determine the density and distribution of breeding birds in two riparian woodland habitats (mesquite and cottonwood) on the lower Verde River and to examine the relationship between the vegetative structure of the habitats and the avian populations.

MATERIALS AND METHODS

STUDY SITES

The study sites were near the lower Verde River, Maricopa Co., about 40 km NE of Phoenix, Arizona. The lower Verde River valley is bordered on the east by the Mazatzal Mountains and on the west by the McDowell Mountains. This alluvial basin is characterized by river channels, floodplains 800 to 1,600 m wide and rising terraces.

Flanked by Lower Sonoran Desert shrub, the vegetation along the lower Verde River consisted of cottonwood (*Populus fremontii*) stands, mesquite (*Prosopis velutina*) bosques, and infrequent tamarix (*Tamarix chinensis*) habitats. On terraces and high floodplain, the mesquite habitats included such species as blue and yellow palo verde (*Cercidium floridum* and *C. microphyllum*), catclaw (*Acacia greggi*), whitethorn (*A. constricta*), *Lycium* sp., *Condalia* sp., and *Opuntia* sp. The cottonwood stands occurred in strips 15 to 210 m wide and up to 2,400 m long paralleling the river. Willow (*Salix gooddingii*) contributed to the overstory, the understory consisting mainly of mesquite and some tamarix, arrowweed (*Pluchea sericea*), and *Baccharis* sp. Plant nomenclature is from Kearney and Peebles (1964).

Two plots were established in mid-February 1975 (breeding season began in February for some birds). The plots were marked in a grid pattern by stakes 30 m apart. Sites were chosen for the largest possible area of uniform vegetation at a distance at least 200 m from the river.

The mesquite plot (10 ha, elevation 411 m) was approximately 300 m from the river. It consisted mostly of mature mesquite with a few cottonwoods on the western edge and several cottonwoods and willows adjacent to the plot on the eastern edge. Both the eastern and western edges were about 30 m from unpaved roads. Grazing occurred on both plots, but ground cover was only markedly disturbed in a few places. From May through August some woodcutting occurred on the mesquite plot.

The cottonwood plot (5 ha, elevation 432 m, about 500 m from the river) was dominated by Fremont cottonwood with occasional willows and an understory predominantly of mesquite. The western side of the plot was bordered by an abruptly rising mesquite terrace with a 3 to 6 m bank. The eastern edge opened onto a sandy, rocky floodplain with a stand of cottonwoods 60 to 120 m away paralleling the plot.

VEGETATIVE SAMPLING

The point-quarter method (Cottam and Curtis 1956) was used for vegetative analysis. For overstory trees, understory trees and shrubs, I measured height, height of lowest branch, diameter of crown, crown shape (cylindrical, spherical, hemispherical or cone), diameter at breast height (DBH), and distance from sampling point. Foliage volume (FV) was calculated from the first four items. Saplings with a DBH of less than 5 cm were treated as shrubs. Tree heights were determined using a clinometer. I determined the percentage of mistletoe (*Phoradendron californicum*) infestation on mesquite by recording trees with and without mistletoe in belt transects (30 × 792 m) totaling 7.2 ha.

Measurements for foliage height diversity (FHD) were made in June and July by the board (MacArthur and MacArthur 1961) and rod (Carothers et al. 1974) methods. Using the board method, 20 randomly chosen points on the mesquite plot and 10 on the cottonwood site were measured at height intervals of 0–0.013 m, 0.013–0.6 m, 0.6–1.5 m, 1.5–3.0 m, 3.0–4.5 m, 4.5–6.0 m, 6.0–9.0 m, and greater than 9.0 m. For the rod method, 90-m lines were randomly chosen and sampled on the mesquite (20 lines) and cottonwood (10 lines) plots. Observations of green foliage were made at 2-m intervals along each transect at the same height intervals sampled by the board method.

For the mesquite plot, FHD was determined using height intervals of 0–0.6, 0.6–4.5 and greater than 4.5 m. The intervals were chosen using a foliage density profile and plotting foliage height diversities against bird species diversity. The intervals used to calculate FHD for the cottonwood plot were 0–0.6, 0.6–6.0 and greater than 6.0 m. The height intervals were determined by a foliage density profile and appeared to fit natural breaks observed in the foliage.

Both vegetative and avian diversities were calculated by:

TABLE 1. Summary of features of the Karr (1968) and MacArthur and MacArthur (1961) methods for determining the relationship between bird species diversity (BSD) and foliage height diversity (FHD).

	Karr method	MacArthur and MacArthur method
Basis of BSD calculation	pairs per 40 ha	20–25 pairs per area
Basis of FHD calculation	rod and similar methods[a]	board method
Regression equation[b]	BSD = 1.57 + 1.55 FHD	BSD = 0.46 + 2.01 FHD

[a] Similar methods from Carothers et al. (1974).
[b] The first equation is calculated from data of Karr and Roth (1971).

$$H' = -\sum_{i=1}^{s} p_i \log_e p_i$$

where p_i is the proportion of items in the ith category and s is the number of categories as applied to biological measurements (Pielou 1966). Percent vegetative cover (PVC) was calculated by summing the percent vegetative cover of the three assigned foliage layers in each habitat as determined using the rod method (Karr 1968). The maximum possible PVC value was 300%.

Percent vegetative cover and foliage volume values were not distributed normally. Consequently, Spearman rank and Kendall rank correlations (Siegel 1956) were used to examine bird species diversity (BSD) as a function of these measurements of habitat structure at the 5% level of significance. The standard error of the predicted value (BSD) was determined for the regression equation relating BSD and FV (Zar 1974).

CENSUSING BIRDS

I censused breeding birds by spot mapping (Kendeigh 1944). Singing males, song posts, nests, females with and without nesting material, and juveniles were recorded on maps. The plots were censused in the 2-h period beginning one-half hour after sunrise. Areas were walked in alternate patterns starting at different points and travelling either north-south or east-west along the grid lines.

The plots were censused six to eight times per month from mid-February through July. The mesquite plot was walked 39 times and the cottonwood plot, 35 times. Species maps were made from the observational maps to determine number of breeding pairs. Densities of White-winged Doves, Mourning Doves, Black-chinned Hummingbirds, and Anna's Hummingbirds were based on the number of concurrent nests for each species. Densities of Brown-headed Cowbirds were based on the average number of females, because this species may be polygynous, with mating being restricted to special perch sites of adult males (Payne 1973).

Two BSDs were calculated for each plot. The first BSD was determined by reducing the size of the plots by concentric circles around the central point of the plot maps until 20–25 avian pairs were obtained (Karr and Roth 1971). The second BSD was determined by extrapolating the densities of the plots to pairs per 40 ha.

Table 1 illustrates the differences between the two methods used in determining BSD and FHD values. The 95% confidence limits for predicted BSDs were determined from FHD-BSD regression equations (Karr and Roth 1971, MacArthur and MacArthur 1961) and FHDs from cottonwood and mesquite plots (Carothers et al. 1974, Austin 1970, Cody 1974, and the present study; see Zar 1974).

RESULTS

The mesquite plot had 19 species and 244 breeding pairs per 40 ha (Table 2). Mourning Doves, White-winged Doves, Lucy's Warblers, and Abert's Towhees comprised 54.1% of the total density and 21.1% of the total species. Permanent residents were 41.4% by density and 63.2% by species. The summer population of Mourning Doves on the mesquite plot was 85% greater than the winter population as determined by censusing with the Emlen (1971) technique on the western side of the plot during the winter months (N. E. Stamp and R. D. Ohmart, unpubl. data). Apparently, some of the Mourning Doves were permanent residents while most were only summer residents. However, it is possible that the Mourning Doves wintering there were migrants rather than permanent residents.

Both the number of breeding pairs (684 per 40 ha) and number of species (28) were higher on the cottonwood plot than on the mesquite site (Table 2). The four predominant bird species were the same, but they comprised only 30.4% of the density and 14.3% of the total species on the cottonwood plot. Permanent residents on the cottonwood plot were 49.4% by density and 50.0% by species.

FHD on the cottonwood plot was 0.99 using the board method and 0.94 with the rod method. On the mesquite site, FHD was 0.93 and 0.86, respectively. The cottonwood plot had a BSD of 2.40 and the mesquite plot had a BSD of 2.31 with bird species diversity based on 20–25 pairs per area. Based on the number of pairs per 40 ha, BSD was 3.15 on the cottonwood site and 2.60 on the mesquite plot.

I found no correlation between BSD and FHD or BSD and PVC for riparian woodland habitats on the upper (Carothers et al. 1974) and lower (this study) Verde River in Ari-

TABLE 2. Estimated densities of breeding birds (no. pairs per 40 ha) in two riparian woodland habitats of south-central Arizona.

Species	Cottonwood	Mesquite	Status[a]
Cooper's Hawk (*Accipiter cooperii*)	1	–	P
Black Hawk (*Buteogallus anthracinus*)	1	–	S
Gambel's Quail (*Lophortyx gambelii*)	24	8	P
White-winged Dove (*Zenaida asiatica*)	48	24	S
Mourning Dove (*Z. macroura*)	56	60	P,S[b]
Yellow-billed Cuckoo (*Coccyzus americanus*)	8	–	S
Great Horned Owl (*Bubo virginianus*)	1	–	P
Black-chinned Hummingbird (*Archilochus alexandri*)	40	4	S
Anna's Hummingbird (*Calypte anna*)	8	–	W[c]
Common Flicker (*Colaptes auratus*)	8	4	P
Gila Woodpecker (*Melanerpes uropygialis*)	32	4	P
Ladder-backed Woodpecker (*Picoides scalaris*)	16	8	P
Wied's Crested Flycatcher (*Myiarchus tyrannulus*)	40	8	S
Ash-throated Flycatcher (*M. cinerascens*)	24	12	S
Rough-winged Swallow (*Stelgidopteryx ruficollis*)[d]	1	–	S
Verdin (*Auriparus flaviceps*)	32	12	P
Bewick's Wren (*Thryomanes bewickii*)	16	–	P
Crissal Thrasher (*Toxostoma dorsale*)	–	4	P
Starling (*Sturnus vulgaris*)	16	4	P
Lucy's Warbler (*Vermivora luciae*)	48	24	S
Yellow Warbler (*Dendroica petechia*)	32	–	S
Yellow-breasted Chat (*Icteria virens*)	8	–	S
Northern Oriole (*Icterus galbula*)	16	8	S
Brown-headed Cowbird (*Molothrus ater*)[e]	40	12	S
Summer Tanager (*Piranga rubra*)	32	–	S
Cardinal (*Cardinalis cardinalis*)	32	8	P
House Finch (*Carpodacus mexicanus*)	32	8	P
Lesser Goldfinch (*Carduelis psaltria*)	16	–	P
Abert's Towhee (*Pipilo aberti*)	56	24	P
Black-throated Sparrow (*Amphispiza bilineata*)	–	8	P
Total	684	244	

[a] P, permanent resident; S, summer resident; W, winter resident.
[b] For cottonwood plot, P = 15% and S = 85%; for mesquite plot, P = 0.5% and S = 99.5%.
[c] Breeding in winter; censused by concurrent nests in February through March.
[d] Nested in bank on northeast edge of plot.
[e] Based on number of females with assumption of one male per female.

zona. However, bird species diversity was correlated with percent vegetative cover (Spearman rank correlation with $r_s = 1.00$, $P < 0.01$, n = 5) for the cottonwood site of

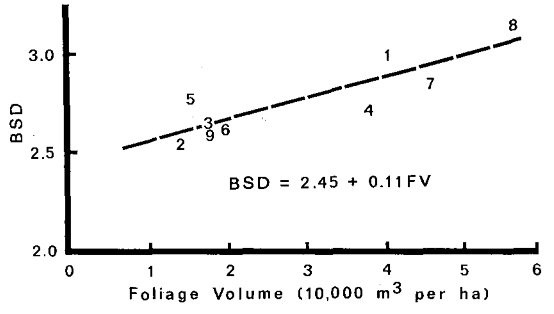

FIGURE 1. Bird species diversity (BSD) as a function of foliage volume (FV) for riparian habitats in Arizona. The Kendall rank correlation was 0.611 ($P < 0.05$, n = 9). Points 1–4 are cottonwood stands and points 5–7 are mixed deciduous plots from Carothers et al. (1974). Point 8 is the cottonwood site and point 9 is the mesquite plot from the present study.

the present study and the four cottonwood plots on the upper Verde River (Carothers et al. 1975).

Foliage volume determined by the point-quarter method was 46,373 m^3 per ha for overstory trees, 8,492 for understory trees and 1,742 for shrubs on the cottonwood plot. On the mesquite plot, foliage volume was 15,965 m^3 per ha for trees and 2,158 for shrubs. BSD was not correlated with foliage volume using the Spearman rank correlation ($r_s = 0.767$, $0.10 < P < 0.05$, n = 9) but it was, using the Kendall rank correlation ($\tau = 0.611$, $P < 0.05$, n = 9) (Fig. 1).

DISCUSSION

AVIAN DENSITY AND DISTRIBUTION

The cottonwood plot of this study had a high avian density, the highest number of species, and the highest BSD in comparison to upper Verde River cottonwood plots (Carothers et al. 1974). The lower Verde River cottonwood plot showed a high tree-understory density with moderate tree-overstory, a high foliage volume for shrubs, and a high overall FV which yielded a higher FHD in comparison with the upper Verde River cottonwood plots. As a percentage of the total foliage volume, the cottonwood plot had 10 times the volume of shrubs as the cottonwood plots in north-central Arizona (Carothers et al. 1974). The lower Verde River site was relatively free from natural and man-made disturbances in comparison to other riparian woodland habitats.

Class A territories are those used for mating, nesting and feeding young (Nice 1941). Carothers et al. (1974) concluded that higher avian densities in homogeneous cottonwood habitats on the upper Verde River were produced by an abundance of birds without class A territories who foraged in adjacent agricultural areas. Class A territorial birds comprised only 36% of avian species and 22% of pairs (Carothers et al. 1974).

The percentages of birds with class A territories in the cottonwood plot on the lower Verde River were similar to those of mixed deciduous habitats (Carothers et al. 1974) and the mesquite plot of this study. The cottonwood plot had 61% of the species and 63% of the pairs and the mesquite plot had 68% of the species and 56% of the pairs with class A territories. The cottonwood plot had more doves and quail (non-class A territorial birds) than the homogeneous cottonwood areas of the upper Verde River. The lower Verde plot also had correspondingly higher numbers of fringillids, which have class A territories. Unlike the upper Verde River areas, no agricultural areas occurred near the lower plots. This may account for the differences in percentages of class A territorial birds between the upper and lower Verde River cottonwood areas.

In comparison with other mesquite habitats (Austin 1970, Cody 1974), the mesquite site on the lower Verde River had high density and diversity of birds, and the highest number of species. Although comparable quantitative plant data were not available for these studies, one major difference was the greater average tree height on the mesquite plot (5.8 m) compared to Austin's (1970) mesquite plot in southern Nevada (less than 3.9 m) and Cody's (unpubl. data) mesquite shrub site in southern Arizona (less than 3.3 m).

AVIAN DIVERSITY AND FOLIAGE HEIGHT DIVERSITY

Avian species diversity has been found to be positively associated with several measurements of habitat structure. Two methods used to examine the relationship between foliage height and avian species diversities resulted in remarkably similar slopes in regression of plotted points (MacArthur and MacArthur 1961, Karr and Roth 1971). Using these two methods for the same breeding bird plots provided some understanding of the patterns of variation around these regression lines.

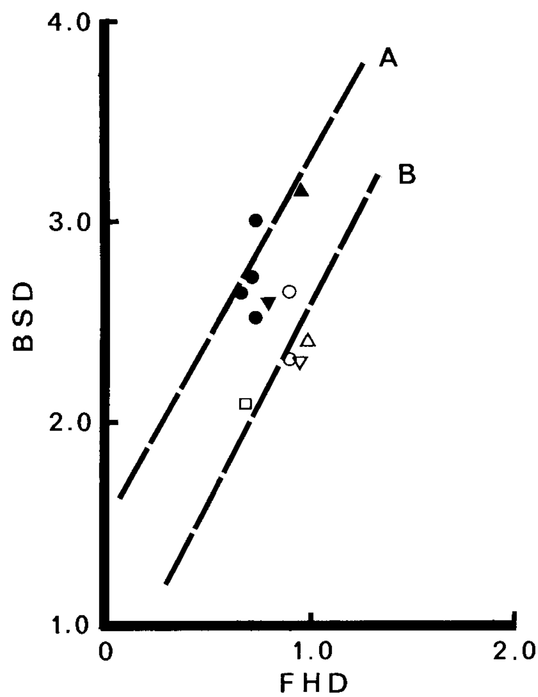

FIGURE 2. Bird species diversity (BSD) as a function of foliage height diversity (FHD) in cottonwood and mesquite habitats. Regression line A is from Karr and Roth (1971). The black dots are cottonwood plots from Carothers et al. (1974); black triangle is the cottonwood plot and black inverted triangle, the mesquite plot from the present study. These FHD-BSD points were determined by Karr's (1968) methods. Regression line B is from MacArthur et al. (1966). The white dots are mesquite plots from Austin (1970); white square, mesquite plot from Cody (1974); white inverted triangle is the mesquite plot and white triangle, the cottonwood plot of the present study. These FHD-BSD points were determined by MacArthur and MacArthur's (1961) methods.

The cottonwood and mesquite plots of the lower Verde River fell close to the regression line (B) of MacArthur et al. (1966), with BSD based on 20–25 pairs per area and FHD determined by the board method (Fig. 2). However, the number of avian species is lowered, and an accurate determination of abundance is difficult when study areas are delineated by 20–25 pairs in diverse avian populations (Karr and Roth 1971). This resulted in a 21.4% reduction in the number of species and a 23.8% decrease in BSD when avian numbers were based on 23.5 pairs (representing 2 ha) in the cottonwood plot. Reducing the size of the mesquite site (to 5 ha and 22.5 pairs) resulted in a decrease in number of species by 5.3% and BSD by 11.2%.

In contrast, my cottonwood plot corresponded to the regression line (A) of Karr and Roth (1971), but the mesquite site did not, with BSD based on the number of pairs per 40 ha and FHD determined by the rod method (Fig. 2). In relation to the A regression line, either BSD for this mesquite site is lower than expected or FHD is higher. A lower BSD value on the mesquite plot is the more reasonable explanation for the discrepancy from the A regression line, due to the variation exhibited in BSD values on plots from year to year (Austin 1970). To consider this problem, I will first discuss avian numbers in mesquite habitats and than examine the rod method used to measure FHD and PVC.

AVIAN DENSITIES IN MESQUITE COMMUNITIES

MacArthur (1964) suggested that some avian species respond to areas of abundant fruit supply rather than foliage profile in selecting habitats. Austin (1970) noted an increase in fruit-eating Phainopeplas (*Phainopepla nitens*), Mockingbirds (*Mimus polyglottos*), Crissal Thrashers, and Cactus Wrens (*Campylorhynchus brunneicapillus*) during a bumper year for mistletoe berries.

The Verde River mesquite plot had no breeding pairs of Phainopeplas or Mockingbirds, although they occasionally occurred on the plot and bred in adjacent and similar mesquite areas. The mesquite plot had only 0.5% mistletoe parasitism in contrast to another Verde River mesquite area with 8.7% mistletoe infestation and nesting Phainopeplas and Mockingbirds. Lack of this additional dimension to the habitat could account for a lower number of species and BSD for the mesquite plot. Presence or absence of an abundant fruit supply such as mistletoe berries would not be detected by FHD and PVC measurements.

Weakness or age of trees may account for the differences in mistletoe infestation of mesquite habitats (Cowles 1936). Low infestation of mistletoe on the mesquite plot may be due to wood cutting in the past (especially of lower, older branches).

There is additional evidence for lower avian numbers on the mesquite plot than might be expected. Mesquite habitats on the lower Verde River censused by the Emlen (1971) technique from March through June revealed 26 to 31 breeding species per 40 ha in contrast to 19 species in the plot (N. E. Stamp and R. D. Ohmart, unpubl. data). The average density of known breeding species was 510 birds per 40 ha compared to 488 on the plot.

RELATIONSHIP BETWEEN FHD AND BSD

It is not clear what FHD means as a predictor of BSD, although a correlation between BSD and FHD, regardless of the method used to determine FHD, has been demonstrated for several communities in both temperate and tropical areas (Willson 1974). Birds apparently respond to the layering aspect of habitat structure which FHD attempts to measure. However, they may occupy areas with different densities of vegetation as the environment of a species changes over geographical range, habitats, or seasons (Cody 1974). In addition, species may exhibit spatial and temporal variation in responses to foliage layers within a habitat.

Bird species diversity of cottonwood and mesquite habitats of the Southwest appears to be correlated with foliage height diversity. Observed BSDs were within the 95% confidence intervals of the predicted values for all of the cottonwood and mesquite plots considered using Karr and Roth's (1971) and MacArthur and MacArthur's (1961) regression equations (Table 3). However, the 95% confidence intervals of the predicted BSDs encompassed a much wider range of values than generally observed. Thus, FHD is at best a general, ambiguous predictor of BSD.

Carothers et al. (1974) based BSD on pairs per 40 ha and used methods similar to Karr's (1968) to determine FHD. They stated that the FHD–BSD points of their cottonwood plots were too low relative to the regression line (A) of Karr and Roth (1971) even though those points clustered around the regression line (Fig. 2). Carothers et al. (1974) reasoned that the added presence of permanent water near their plots would raise the FHD–BSD points above the regression line. But Karr (1968) and MacArthur (1964) discussed the dimension of water raising BSD by 0.5 to 0.9 units as a function of "$\log_e$ pairs" (usually based on 20–25 pairs) and not as a function of FHD. FHD–BSD points of habitats associated with water occurred near the regression line (A) as shown by early shrub, late shrub, and bottomland forest plots

TABLE 3. Comparison of BSD values predicted from regression equations with those obtained from riparian woodland habitats. Individual confidence intervals were calculated with each FHD value of mesquite and cottonwood. See text for explanation.

Habitat	Karr method		MacArthur and MacArthur method		Source
	predicted	observed	predicted	observed	
Mesquite	2.90 ± 1.66	2.60	2.34 ± 1.31	2.31	Present study
	–	–	1.92 ± 1.30	2.10	Cody (1974)
	–	–	2.24 ± 1.31	2.67	Austin (1970)[a]
	–	–	2.24 ± 1.31	2.34	
Cottonwood	3.03 ± 1.66	3.15	2.44 ± 1.31	2.40	Present study
	2.70 ± 1.66	2.98	–	–	Carothers et al. (1974): C1
	2.72 ± 1.66	2.53	–	–	C2
	2.61 ± 1.66	2.68	–	–	C3
	2.67 ± 1.66	2.71	–	–	C4

[a] First value is for 1968 and second is for 1969.

in Illinois (Karr 1968, Karr and Roth 1971). Thus, the conclusion of Carothers et al. (1974) that BSD was not correlated with FHD for their homogeneous cottonwood plots and that BSD was correlated with FHD for three mixed deciduous plots on the upper Verde River is incorrect.

AVIAN DIVERSITY AND FOLIAGE VOLUME

For tropical and temperate habitats, BSD was correlated with percent vegetative cover, a measure of foliage volume (Karr and Roth 1971, Willson 1974, Røv 1975). BSD also was correlated with PVC for the cottonwood plot of the present study and four cottonwood

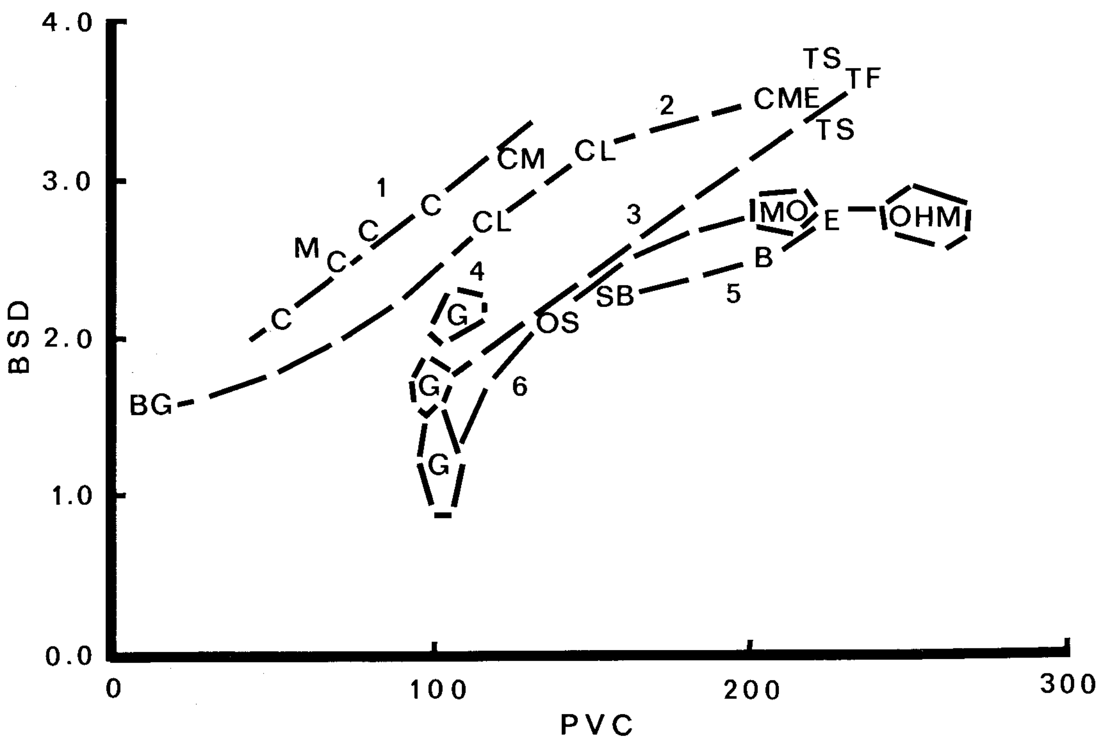

FIGURE 3. Bird species diversity as a function of percent vegetative cover (PVC, sum of all layers). Group 1 points are from Arizona with CM and M from the present study and C from Carothers et al. (1975). Group 2 points are from Illinois (Karr 1968), as are those in group 6 (Willson 1974). Group 3 (Panama) and group 4 (Texas) are taken from Karr and Roth (1971), and group 5 (Norway) is from Røv (1975). Dashed enclosures indicate more than one point. Forest or woodland habitats are cottonwood-mesquite (CM), cottonwood (C), mesquite (M), cottonwood-maple-elm (CME), maple-oak (MO), oak-hickory-maple (OHM), tropical forest (TF), subalpine birch (SB), birch (B), and elm (E). Shrub habitats are cottonwood-locust (CL), tropical shrub (TS), and oak-sumac (OS). Grass habitats (G) and bare ground (BG) are also included.

plots on the upper Verde River (Carothers et al. 1974) (Fig. 3). However, when comparing studies, the variation of points among studies was large. For shrub and deciduous forest habitats in Illinois (Karr 1968, Willson 1974), BSD as a function of PVC appears to be sensitive to the particular vegetative structure of the habitats. This is shown by the similarity of PVC values but dissimilarity of BSDs for these shrub and forest habitats.

As another example, mesquite stands in which the foliage of both trees and shrubs extends from the ground upward, often with a spherical or hemispherical shape, are difficult to differentiate into herbaceous, shrub and tree layers. Extensions of one layer into another could cause over- or underrepresentation of layers in the percent cover index (Røv 1975). The rod method also affects FHD values because FHD is based on the same measurements as PVC.

In addition, the rod and similar methods (Carothers et al. 1974, Karr 1968) may be more or less sensitive to the physiognomy of the vegetation. In contrast to broad-leafed deciduous trees, mesquite trees have small, bipinnately compound leaves which, when measured in terms of presence or absence of foliage touching a rod (1.4 cm average diameter), may yield lower values than measurements of foliage volume by other methods such as the point-quarter method. The cottonwood plot (CM) of the present study, with a high understory density of mesquite, and the cottonwood-locust sites (CL) in Illinois (Karr 1968) had similar vegetative physiognomy and occur near each other in Figure 3.

BSD was weakly correlated with foliage volume determined by the point-quarter method for the cottonwood and mixed deciduous plots of the upper Verde River (Carothers et al. 1974), and the cottonwood and mesquite plots of the lower Verde River (Fig. 1). FV was based on shrub and tree foliage volume and not on assigned height intervals. The relationship between BSD and FV needs to be examined carefully in terms of undisturbed and disturbed deciduous habitats and presence or absence of nearby agricultural lands.

BIRD SPECIES DIVERSITY VALUES

Differences in bird species diversity due to yearly fluctuations of avian populations on study areas account for some variation around the regression lines on the FHD–BSD relationship. An example of this is shown by Austin's (1970) data on Figure 2. Large edge effect of cottonwood groves and adjacent agricultural lands could contribute to higher BSDs in contrast to lower BSDs in habitats with flooding or low water table (Bottorff 1974, Carothers et al. 1974). Breeding bird density decreased an average of 42.8% in two years on a plot in central Arizona where tree density was reduced by 17.8% (Carothers and Johnson 1975).

Censusing study areas for consecutive years would provide some measure of acceptable variation about the FHD–BSD regression line due to changes in BSD and some indication of influence by other factors such as bumper fruit crops, flooding and man-made disturbances. Future studies should also investigate climatic variables as estimators of resource variation, measure resources and avian densities during both the breeding and nonbreeding seasons, and determine reproductive success (Cody 1974, Fretwell 1972).

SUMMARY

Breeding bird populations were studied in mesquite and cottonwood habitats on the lower Verde River in south-central Arizona. The cottonwood plot had a high avian density, the highest number of species, and the highest bird species diversity (BSD) in comparison to other Verde River cottonwood habitats. This was probably due to high tree-understory density and high foliage volume (FV) of shrubs which contributed to a high foliage height diversity (FHD) and total foliage volume.

The mesquite site had a high avian density, a high BSD, and a high number of avian species in comparison to other mesquite habitats. Although few comparable vegetative measurements were available, some major differences among these mesquite habitats such as higher average tree height and presence of permanent water near the plot of the present study might account for higher avian numbers. The relationship between BSD and FHD remains ambiguous, although BSDs of cottonwood and mesquite habitats of the Southwest appear to be correlated with FHD. For cottonwood habitats in Arizona, BSD was correlated with percent vegetative cover (PVC), a measure of foliage volume. BSD was weakly correlated with foliage volume, determined by the point-quarter method for riparian woodland habitats on the Verde River in Arizona. FHD, PVC, and FV appear to be indefinite predictors of BSD. Therefore, breeding birds should be censused on study plots for consecutive years due to fluctuations

in species diversities from year to year with seasonal measurements of habitat structure, fruit crops, and other resources to determine the relationship between vegetative structure and avian populations.

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