where p_i is the proportion of the ith species in the population composed of s species.

Evenness (E) was calculated by

$$E = H'/\ln s$$

In order to assess the behavioral similarity between pairs of species on any given study plot we may construct an m-dimensional Euclidean space in which the relative position of the species can be measured. The relationship among pairs of species within an ecological space may be measured by their Euclidean distances, D (Power 1971). Distance between the jth and kth species is given by

$$D_{jk} = \left[\sum_{i=1}^{m} (p_{ij} - p_{ik})^2\right]^{1/2}$$

where p_{ij} is the proportion of the jth species and p_{ik} is the proportion of the kth species in m number of behavioral categories. Euclidean distances between pairs of species were calculated for the following behavioral parameters: activity pattern, foraging method, tree species selection, horizontal tree position, perch selection, stance, and foliage use.

Then to examine the overall relationship among pairs of species we can measure the composite Euclidean distance (*CED*). The *CED* between the jth and kth species is given by

$$CED = \left[\sum_{i=1}^{n} (D_{ijk})^2\right]^{1/2}$$

where n is the number of behavioral parameters.

Dendrograms showing hierarchial arrangements of species were obtained by subjecting the matrices of D and *CED* to cluster analysis. The unweighted pair-group method on arithmetic averages was used (Sokal and Sneath 1963, Rohlf 1970, Power 1971, Cody 1974).

The foliage use index (*FUI*) was the calculation of the Euclidean distance between a particular bird species and the composite foliage configuration for a particular study plot. Distance between the jth species and the foliage profile is given by

$$FUI = \left[\sum_{i=1}^{n} (p_{ij} - p_{ik})^2\right]^{1/2} \Big/ n$$

where p_{ij} is the proportion of bird observations and p_{ik} is the proportion of the total foliage volume in n number of foliage strata. The *FUI* has a range of 0 to $\sqrt{2}/n$ where 0 indicates a bird species is using the foliage profile in exact relation to its availability. In contrast a *FUI* of $\sqrt{2}/n$ indicates the selection of a single stratum in which the proportion of the foliage volume is close to zero. Thus as the *FUI* becomes smaller the fit with the foliage profile becomes better. That is, an individual bird species or the entire bird community uses the foliage profile in closer relation to its availability.

The correlation coefficient (r) was calculated between foliage volume and bird density or a given behavioral parameter (Sokal and Rohlf 1973).

Consuming biomass (*CB*) was calculated using fresh dead weights whenever possible (Karr 1968). *CB* is given by

$$CB = W^{0.633}$$

where W is the mean weight of a given species.

Existence energy (*EMR*) was calculated as suggested by Kendeigh (1970) and later modified by Weiner and Glowacinski (1975). Thus, the relationship between ambient temperature and body weight in a passerine bird is given by

$$EMR = 1.572W^{0.621} + 0.06514W^{0.3625}(30 - t)$$

where t is ambient temperature in degrees celsius. The above expression was also used for the non-passerines on the study plots as they are undoubtedly closer to the passerines than to the Galliformes, Anseriformes, and Falconiformes on which the non-passerine equation is based.

DESCRIPTION OF STUDY AREAS

The five study areas are in the Coconino National Forest, Coconino County, Arizona (Fig. 1). All the areas are located within a 21-km radius on the Beaver Creek Watershed. The areas included a clear cut, a uniformly thinned, a strip cut, a silviculturally cut, and a control plot. All study sites were cut before the

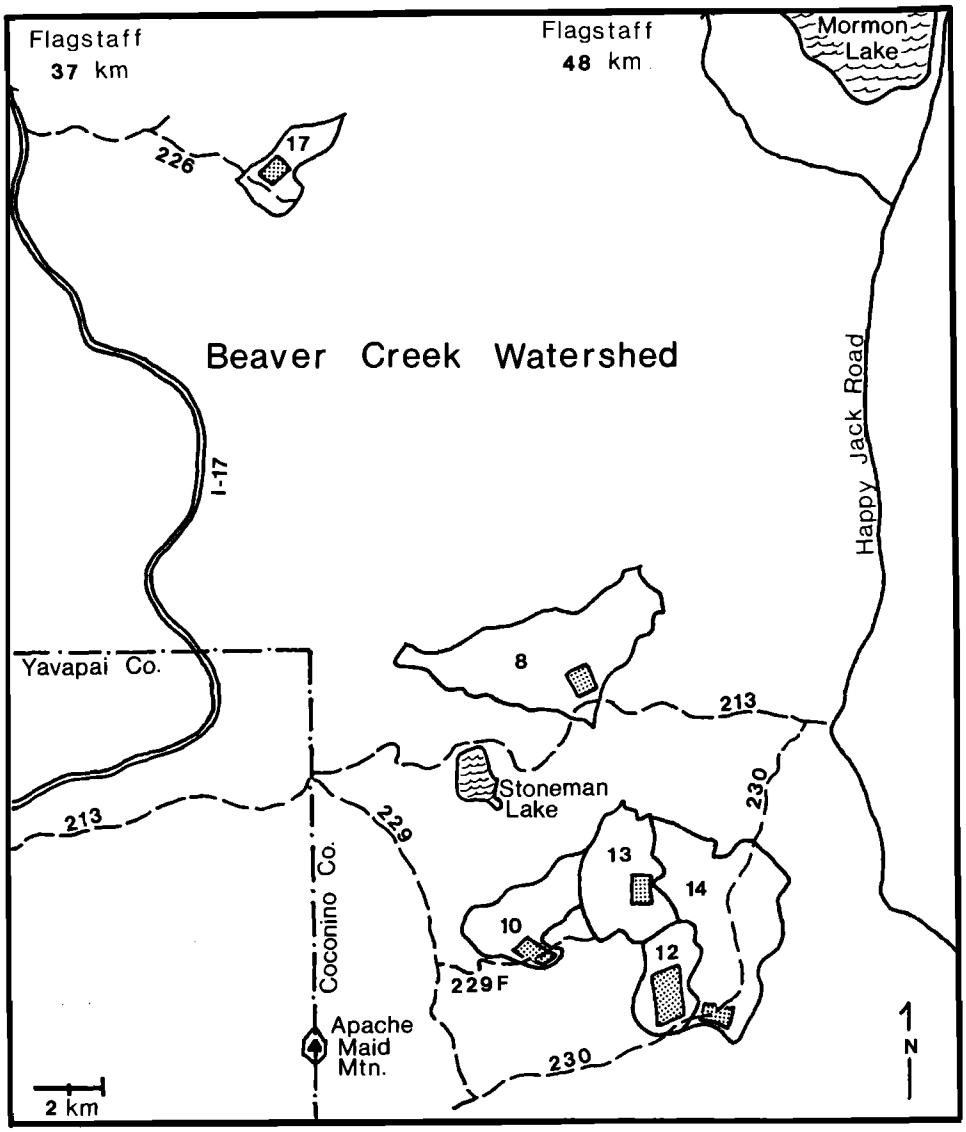

FIGURE 1. Map of Beaver Creek Watershed, Coconino National Forest, Arizona. Stippled areas represent the study areas. Areas enclosed by solid lines are numbered watersheds. Dashed lines represent numbered Forest Service roads.

study began except for the silviculturally cut area which was cut during the spring of 1974.

The ponderosa pine vegetation type, which was found on all study areas before treatment, is found primarily in areas of brolliar, siesta, and sponsellar soils (Williams and Anderson 1967).

Control Plot

The control is located on watershed 13 approximately 66 km southeast of Flagstaff on FS-230 (Forest Service road 230) at an elevation of 2195 m and at

TABLE 1
COMPOSITION OF TREES ON ALL STUDY PLOTS

Species	Relative density	Relative dominance	Relative frequency	Importance value	Absolute density[a]
		Control plot			
P. ponderosa	90.1	85.7	77.0	252.8	582.5
Q. gambelii	8.4	8.3	19.3	36.0	54.3
J. deppeana	1.5	6.0	3.7	11.2	9.3
		Silviculturally cut plot			
P. ponderosa	92.3	93.6	81.3	267.2	271.4
Q. gambelii	7.7	6.4	18.7	32.8	22.6
		Silviculturally cut plot			
P. ponderosa	91.5	92.5	79.4	263.4	216.1
Q. gambelii	8.5	7.5	20.6	36.6	20.1
		Strip cut plot			
P. ponderosa	79.1	82.0	67.1	228.2	145.4
Q. gambelii	20.4	15.7	31.5	67.6	34.4
J. deppeana	0.5	2.3	1.4	4.2	0.8
		Severely thinned plot			
P. ponderosa	86.8	91.9	74.3	253.0	59.7
Q. gambelii	13.2	8.1	25.7	47.0	9.0

[a] Trees/ha.

34°29′00″N, 110°45′21″W (Fig. 1). The study area is on a southwest-facing slope of about 17° in the west-central portion of the 149-ha watershed.

Watershed 13 was left untreated as the control area. Ponderosa pine was the major dominant tree species with an importance value of 252.8 (Table 1, Fig. 2). There were approximately 646 trees/ha with a canopy volume of 19,370 m^3/ha and a total basal area of 26.7 m^2/ha. The mean tree height was 15.5 m and the lower live limb height was 8.7 m. The bulge area, specifically that region of the foliage profile that encompasses at least 70% of the foliage, was between 4 and 18 m and included 82.1% of the foliage volume on the study area.

SILVICULTURALLY CUT PLOT

The silviculturally cut plot is located on watershed 8, approximately 64 km southeast of Flagstaff on FS-213 near Stoneman Lake at an elevation of 2256 m and at 34°29′37″N, 111°47′52″W (Fig. 1). The study area is on a west-facing slope of about 13° in the southwest corner of the 729-ha watershed.

Stands made up of trees less than 25.4 cm DBH were thinned to a growing stock level of 13.8 m^2 of basal area per ha (F. R. Larson, unpublished data). Stands consisting of trees 30.5 cm in DBH and larger were thinned to an actual 16.1 m^2 of basal area per ha. Trees were cut so as to upgrade the stand rather than to obtain uniform spacing. In most cases gambel oak were left intact.

Prior to treatment, ponderosa pine was the major dominant tree species with an importance value of 267.2 (Table 1). There were approximately 294 trees/ha with a canopy volume of 23,976 m^3/ha and a total basal area of 28.9 m^2/ha. The mean height of the trees was 14.1 m and the mean lower live limb height was 7.4

FIGURE 2. Control plot. Note the large trees and dense thickets.

m. The bulge area, between 4 and 20 m, encompassed 76.6% of the foliage volume on the study area.

The treatment in April 1974 reduced ponderosa pine by 55 trees/ha of 20% whereas gambel oak was reduced by 2 trees/ha or 10% (Table 1, Fig. 3). There were approximately 236 trees/ha with a canopy volume of 17,039 m^3/ha. This

FIGURE 3. Silviculturally cut plot. Note the openings created by treatment.

amounted to a reduction of 28.9% in the available foliage. The total basal area for all tree species was 23.3 m^2/ha. The mean tree height was 13.2 m, with a mean lower live limb height of 7.1 m. The bulge area, between 4 and 20 m, included 76.9% of the foliage volume on the study area.

Strip Cut Plot

The strip cut plot is located on watershed 14, approximately 68 km southeast of Flagstaff on FS-230 at an elevation of 2149 m and at 34°27′44″N, 111°44′54″W (Fig. 1). The study area is on a south-facing slope of about 9° in the southeast corner of the 221-ha watershed.

The objective of the treatment was to increase water yield while at the same time providing good timber production and pleasing aesthetics (H. E. Brown, unpublished data). Clear cut strips were designed primarily to increase streamflow. The alternative "leave" strips were thinned in a manner to improve production.

The pattern was one of alternate cut and leave strips. The cut and leave strips averaged 18 and 36 m in width respectively. Spacers of uncut trees were left in the cut strips at intervals to break up the visual continuity of the strips. These were of irregular shapes, 15–21 m long, at intervals of about 122 m. Most of the gambel oak were left in the cut strips and where there was enough oak to break up the continuity of the strips it was not necessary to use spacers. Width of the clear cut areas within any strip varied as much as 50% (i.e., 36 ± 18 m) in order to provide an aesthetically pleasing, irregular pattern of elongated openings.

The treatment was completed in the spring of 1970. Ponderosa pine was the major dominant tree species with an importance value of 228.2 (Table 1, Fig. 4). There were approximately 181 trees/ha with a canopy volume of 6526 m^3/ha and a total basal area of 12.4 m^2/ha. The mean tree height was 11.5 m and the lower live limb height was 6.0 m. The bulge area, between 2 and 14 m, encompassed 75.8% of the foliage volume on the study area.

Severely Thinned Plot

The severely thinned plot is located on watershed 17, approximately 43 km south of Flagstaff off I-17 on FS-226 at an elevation of 2091 m and at 34°34′25″N, 111°53′56″W (Fig. 1). The study area is on a southwest-facing slope of about 8° in the southwest corner of the 49-ha watershed.

The treatment was intended to provide a reasonable opportunity for increased water yield while leaving a light stocked timber stand that could be subjected to even-aged management (H. E. Brown, unpublished data). Slash was piled in strategically arranged windrows. Windrows were piled as high and narrow as possible in order to maximize snow trapping and retention. Windrows were arranged with 10-m breaks at intervals of 60 m or less in order to reduce possible fire spreading.

The treatment was completed in the spring of 1969. Ponderosa pine was the major dominant tree species with an importance value of 253.0 (Table 1, Fig. 5). There were approximately 69 trees/ha with a canopy volume of 3990 m^3/ha and a total basal area of 7.9 m^2/ha. The mean tree height was 11.0 m and the mean lower live limb height was 6.2 m. The bulge area, between 4 and 16 m, encompassed 70.9% of the foliage on the study area.

FIGURE 4. Strip cut plot. Note the open strip area.

Clear Cut Plot

The clear cut plot is located on watershed 12, approximately 69 km southeast of Flagstaff on FS-230 at an elevation of 2146 m and at 34°28′35″N, 111°44′25″W (Fig. 1). The study area is on a southwest-facing slope of about 10° in the southeast corner of the 80-ha watershed.

The treatment was designed to test the effects of clear cutting all the woody

FIGURE 5. Severely thinned plot. Note the slash windrows and uniform thinning of this area.

FIGURE 6. Clear cut plot. Note the growth of gambel oak sprouts which obscure the windrows.

vegetation on the watershed and windrowing the resultant slash (H. E. Brown, unpublished data). All wood products that could be sold were removed from the watershed. The remaining slash and debris were machine windrowed in such a way as to trap and retain snow, reduce evapotranspiration losses, and increase the drainage efficiency of the watershed. In areas of heavy slash the windrows were at least 1.5 m high and were spaced about 30 m apart. In areas of lighter slash the windrows were spaced further apart in order to achieve the minimum height. Windrows were placed in either an east-west or northeast-southwest direction.

The treatment was completed during the spring of 1967. Since that time there has been a considerable amount of shrubby growth by gambel oak next to the slash windrows (Fig. 6).

Weather

Total winter and early spring precipitation (Oct.–Apr.) was 106.5 cm in 1972–1973, 28.8 cm in 1973–1974, and 48.6 cm in 1974–1975 on the silviculturally cut area. The winter and early spring of 1973–1974 had 73% less accumulated precipitation than the same period of 1972–1973. The precipitation during the winter and early spring of 1974–1975 amounted to 69% more than 1973–1974 but was still 54% less than in 1972–1973. Most of the precipitation during each of the three winters came in the form of snow.

The mean maximum temperature during the period of November to April rose from 5°C in 1972–1973 to 8.5°C in 1973–1974 and decreased to 6.3°C in 1974–1975. The mean minimum temperature remained approximately the same at −9.3° to −9.4°C.

During the breeding season (May-July) the mean daily temperature rose from 14.1°C in 1973 to 15.2°C in 1974 and then dropped to 12.6°C in 1975. Precipitation

TABLE 2
BREEDING DENSITIES (prs/40 ha) OF SPECIES AND FORAGING AND NESTING GUILDS IN 1973

	Study plots[a]				
	C. cut	S. Thn.	Strip	Cntrl.	Silv. (PT)
Species (guilds)					
Mountain Chickadee (PG,CD)	—	1.5	—	—	—
Pygmy Nuthatch (PG,CD)	—	—	—	13.5	7.5
House Wren (PG,CD)	—	—	2.3	—	2.3
Solitary Vireo (PG,FN)	—	3.8	6.0	1.5	—
Yellow-rumped Warbler (PG,FN)	—	—	3.0	—	—
Grace's Warbler (PG,FN)	—	3.8	7.5	7.5	11.2
Red-faced Warbler (PG,GN)	—	—	—	2.3	3.0
Western Tanager (PG,FN)	—	1.5	3.0	—	3.0
Rock Wren (GF,GN)	5.0	5.2	3.8	—	—
Robin (GF,FN)	—	6.8	5.2	—	—
Hermit Thrush (GF,GN)	—	—	—	0.8	—
Gray-headed junco (GF,GN)	2.0	9.8	6.0	9.0	12.7
Rufous-sided Towhee (GF,FN)	5.5	—	—	—	—
Chipping Sparrow (GF,FN)	—	6.0	4.5	—	3.0
Common Flicker (HT,CD)	—	3.0	2.3	3.0	3.0
Hairy Woodpecker (HT,CD)	—	2.3	2.3	3.0	3.0
Steller's Jay (HT,FN)	—	—	3.0	—	3.0
White-br. Nuthatch (HT,CD)	—	5.2	4.5	3.0	3.0
Black-headed Grosbeak (HT,FN)	—	—	—	—	1.5
Broad-td. Hummingbird (AF,FN)	—	—	3.0	—	—
Western Flycatcher (AF,CD)	—	—	—	6.0	3.0
Western Wood Pewee (AF,FN)	—	3.0	8.2	—	2.3
Violet-green Swallow (AF,CD)	—	—	—	9.0	6.0
Western Bluebird (AF,CD)	—	6.0	6.7	4.5	5.2
Foraging guilds					
Pickers and gleaners (PG)	—	10.5	20.8	24.8	27.0
Ground feeders (GF)	12.5	27.8	19.5	9.8	15.8
Hammerers and tearers (HT)	—	10.5	12.0	9.0	13.5
Aerial feeders (AF)	—	9.0	18.0	19.5	16.5
Nesting guilds					
Cavity and depression (CD)	—	18.0	18.0	42.0	33.0
Foliage nesters (FN)	5.5	24.8	43.5	9.0	24.0
Ground nesters (GN)	7.0	15.0	9.8	12.0	15.8
Totals	12.5	57.8	71.3	63.0	72.8

[a] C. cut = clear cut plot; S. Thn. = severely thinned plot; Strip = strip cut plot; Cntrl. = control plot; Silv. (PT) = silviculturally cut plot (pre-treatment).

during the months of May and June amounted to 3.1 cm in 1973, 0.0 cm in 1974, and 0.8 cm in 1975. Precipitation during the breeding season (May–July) was 7.3 cm in 1973 and 1974, 8.2 cm in 1975.

RESULTS

BREEDING SEASON CENSUSES

Densities.—There was a tremendous amount of variability in breeding bird densities between study plots (Tables 2–4). The densities in pairs per 40 ha varied from 12.5 to 72.8 in 1973 with the lowest densities on the clear cut plot and the