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AVIAN COMMUNITIES IN THE PINYON-JUNIPER WOODLAND: A DESCRIPTIVE ANALYSIS

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ABSTRACT

The expansive range and elevational distribution of the pinyon-juniper woodland in the western United States contributes to the wide variety of forms of this habitat type. Similarily, the breeding-bird community expresses this variety. A total of at least 73 different bird species are known to breed here. About 31 of these species breed with regularity in pinyon-juniper woodlands. Only about 5 of these species are restricted to this habitat type. Usually less than half of the breeders are permanent residents. A high proportion of the breeding birds forage for seeds or insects on the ground. The number of species that breed in cavities and/or forage on trunks and branches is positively correlated with pinyon pine density. Seasonal densities of breeding birds vary greatly depending on annual fluctuations in precipitation and seed and berry production. Winter diversity and density is strongly correlated with juniper berry production. Both junipers and pinyons show an adaptive suite of characters for dispersal by birds.

KEYWORDS: pinyon pine, juniper, avifauna, guilds, diversity, density, breeding-birds, winter birds.

The pinyon-juniper woodland could be labeled the characteristic habitat-type of the southwest because of its expansive range.

Extending over large areas of Arizona, Colorado, Nevada, New Mexico, and Utah it occupies somewhere between 43 and 76 million acres of land in the West. In New Mexico alone the woodland covers over 32,000 square miles or 26 percent of the state (Pieper 1977). The woodland stretches from the east slope of the Sierras to Oklahoma and from Oregon to Texas and into Mexico. It is the common vegetation-type of the foothills, low mountains, escarpments, and mesas of the southwest (Fig. 1). Throughout its range this "pygmy forest" shows broad tolerance limits ranging in elevation from a high of 10,000 ft. in the Sierras to a low of 3200 ft. in the four corners area, with junipers alone extending even lower in many areas (West et al. 1975). It is found on a variety of soils derived from granite, basalt, limestone, and mixed alluvium (Hurst 1975).

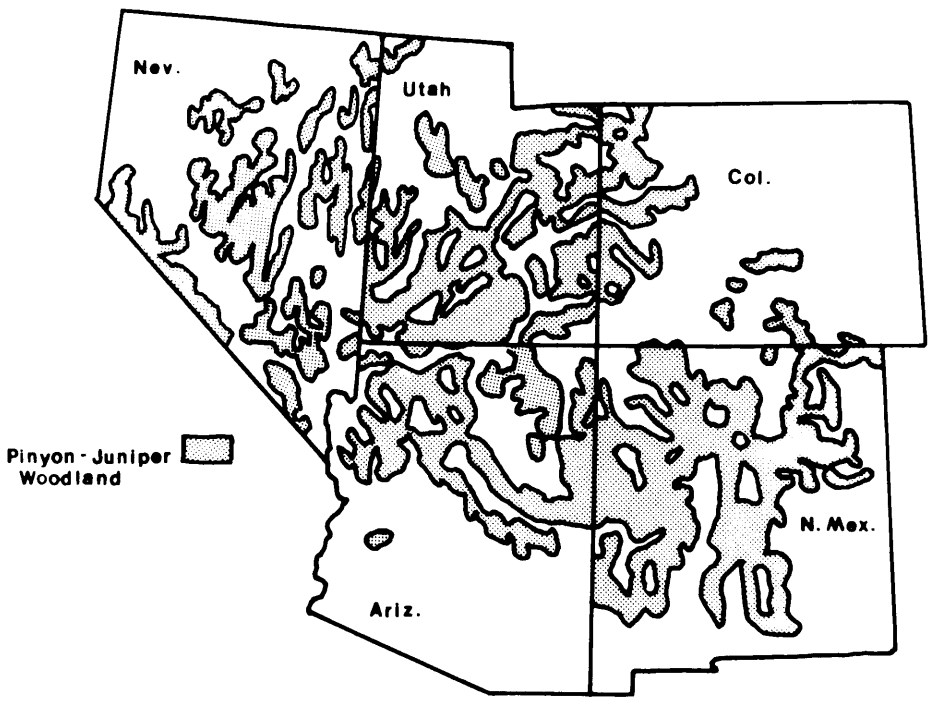

Figure 1. The distribution of pinyon-juniper woodland in the five western states where it is most abundant (From Clary 1975).

The major trees of this woodland consist of four species of junipers, Juniperus occidentalis, J. deppeana, J. monosperma and J. osteosperma. The latter species is the most wide-spread of the junipers. The two most common pinyon pines are Pinus monophylla and P. edulis with the latter species having the most extensive distribution. The dominant trees of the area are relatively small (hence the name pygmy forest) ranging in height from 15-40 ft. with individual trees having dense foliage. In general the junipers are more drought-resistant than pinyon pines and therefore occur in highest densities at lower elevations, whereas, pinyon pines become more abundant at higher elevations in this woodland (Short and

McCullock 1977). The density of these trees varies from very sparse to very dense depending on elevation, climate, and soil type. Total plant cover increases with elevation up to about 6600 ft. (Tueller et al. 1979).

The understory vegetation of the pinyon-juniper woodland is highly variable depending on soil type, exposure, and climatic pattern. Tueller et al. (1979) lists 240 positively identified species of vascular plants from the Great Basin pinyon-juniper woodlands. The list includes 67 species of shrubs and succulents, 46 grasses, and 122 forbs that grow under pinyon and juniper trees. Major shrubs include sagebrush (Artemisia sp.), bitterbrush (Purshia tridentata), rabbitbrush (Chrysothamnus sp.), and various species of oaks (Quercus spp.). Few of these species are found growing in association with one another, as the understory is reasonably depaupered. None of the shrubs, succulents, grasses or forbs are listed as rare and endangered and none are restricted to this vegetation type. Most woodlands contain only a few of these species. Thus, plant species diversity (as well as density) is reasonably low compared to other vegetation types in the southwest.

The climate of this vegetation-type can be summarized as being rather severe with hot summers, cold winters, low amounts of precipitation in the form of rain and snow, low relative humidity and high winds. Mean daily maximum temperatures for the hottest month of the year vary from 26°C to 36°C. Total yearly precipitation varies between 8 and 18 inches (West et al. 1975).

The lower limits of this woodland now mingle with grassland, desert scrub, Great Basin Desert or shrublands in different parts of its range. Because of climatic cycles (cool, moist to hot, dry) this lower boundary has been very active during the last 10,000 years (Martin and Mehringer 1964, Wright et al. 1973, Wells and Berger 1967). Evidence from pollen deposits, sloth dung, and wood rat middens indicate a considerable lowering of this boundary. This depression caused isolated areas of the woodland to come into contact with other such areas thus increasing the potential for redistribution of the flora and fauna. The return of a warmer, drier climate caused an upward retreat leaving behind isolated relict pockets of pinyon-juniper woodland, with its faunal components.

Even though early settlers heavily used pinyons and junipers for mine props, fence posts, and fuel, during the last 130 years the vegetation type is undergoing an expansion into low shrublands, grasslands and Great Basin Deserts (West et al. 1975). At the same time the density of trees in more permanent stands is also increasing. Numerous causes have been proposed to explain this increase, but the major culprit seems to be overgrazing by cattle and sheep (Aro 1971). Improper grazing has reduced forage production thereby releasing the trees from competition with the herbs and shrubs. Johnsen (1962) believes the spread of juniper in northern Arizona is due to the increased spread of seeds by livestock, lack of periodic fire, overgrazing which reduces competition of grasses with juniper seedlings, and a gradually changing climate which favors the spread of juniper. La Marche (1974) presents evidence that the period from 1850 to 1940 was wetter and warmer than the period before or after this.

It is evident that this woodland as a whole is an extremely complex, variable community. As stated by West et al. (1975), "Early attempts to explain distribution, composition, successional changes, and management responses in terms of single factors were overly simplistic. These variations can be better explained in terms of a complex of environmental patterns, historical events, and successional mechanisms. The relative importance of each factor of the environmental complex varies with the synecological context."

A major characteristic of this woodland as far as birds are concerned is the periodic production of vast quantities of pinyon pine seeds and juniper berries. Large crops of pine seeds are produced once every five or six years whereas juniper berry production occurs every two to three years. In many years neither tree forms reproductive propagules. Both life-forms appear to have intra-specific synchrony. For example, in a year of a good berry crop, one hectare contains between 19 and 38 million berries. A cubic meter of foliage holds 20,000 berries. The number declines steadily through the late fall and winter as birds and mammals consume them. The flesh of a single berry has about 315 calories making it a desirable source of energy. The berries are a shiny blue in color making them conspicuous; they ripen in the fall when insects are sparse and bird densities are high due to migration (Salomonson 1978). Thus junipers have adaptations favoring zoochory (Morton 1973). The pinyon pine also has a constellation of adaptations that favor dispersal by animals, especially birds (Table 1) (Vander Wall and Balda 1977). This pine not only allows animals easy access to its seeds but may entice dispersal agents. This means the seeds are easily located, extracted from the cones and eaten or cached for future use (Vander Wall and Balda 1977, Ligon 1978). More *Pinus edulis* seeds are cached in dry, exposed soils than can be used by the birds in years of high cone crops. In some years, pinyon pines produce absolutely no cones per hectare (Balda, unpubl. data), whereas in other years they may produce as many as 1800 cones/tree (Ligon 1971). These seeds are extremely nutritious, containing about 7400 cal/g (Little 1938).A pinyon pine seed contains 14.5 percent protein, 60 percent fat, and 18.7 percent carbohydrate (Botkin and Shires 1948). The large size, high energy content, and high protein level makes this seed a highly desirable food stuff.

Management of pinyon-juniper woodlands since the mid-40's has largely consisted of control of the spread of junipers (and in some cases pinyon) into grasslands and type-conversion of pinyon-juniper woodlands into grazing lands. Both eradication of the type and control has been justified on public lands because the trees are generally considered as of low commercial value relative to other harvestable trees of the West. During the period 1950 to 1964 Box et al. (1966) estimate that approximately three million acres of pinyon-juniper woodland were converted to grazing lands. Between 1950 and 1961, more than one million acres were converted in Arizona alone (Arnold et al. 1964).

The major objective of most type-conversion projects, often referred to as "Range Improvement Projects" is to produce additional forage for livestock (Terrel and Spillett 1975). These conversions represent "a change from multiple use to one use, grazing" (Little 1977). Land managers today are going through a period of cautious

soul-searching about how to proceed with management on these lands. This treatment has not been popular, leaves the area an aesthetic diaster, has questionably proven long range benefits and "Most questions concerning wildlife and pinyon-juniper range conversion are unanswered and probably will remain so." (Terrel and Spillett 1975). The best synopsis of pinyon-juniper management and guidelines for future use can be found in a symposium edited by Gifford and Busby (1975).

TABLE 1. Features of pines with different dispersal strategies

Characteristic	*P. ponderosa* (wind)	*P. edulis* (animal)
Seed size	small	large
Seed conspicuous	no	yes
Seed quickly released	yes	no
Seed coat labelled	no	yes
Synchronous cone opening	yes	no
Position of cone	down, out	up, out
Cone scales	present	absent

BREEDING BIRDS

A total of 73 different species of birds are reported to breed in pinyon-juniper woodlands (Table 2). Undoubtedly more records are known but these will most often be rare or unusual occurrences. These 73 species are taxonomically aligned in 8 orders and 25 families. Because of the geographic area span by this plant community and the wide physiognomic variety (over its range), no one area contains near this breeding diversity. For example, in north-central Arizona 5 pinyon-juniper plots were sampled intensively during two breeding seasons (Grue 1977, Masters 1979) and the number of breeding species per 40 ha plot ranged from 12 to 24 and averaged 19 species. Rasmussen (1941) reports 43 species inhabiting the pinyon-juniper woodland on the Kaibab Plateau in summer but has good evidence for breeding by only 12 species. Hardy (1945) lists 22 species as regular breeders in Utah pinyon-juniper woodlands whereas Hering (1957) reports 15 breeding species.

Relatively few of the 73 species are restricted to pinyon-juniper woodland. Table 2 lists 5 obligates and 13 semi-obligates. An obligatory species is defined for purposes of this presentation as one which nests only in pinyon-juniper woodland within a geographic area that contains other habitat types. A semi-obligatory species may nest in one additional plant community. This definition is knowingly broad as most of these species nest in different habitat types in portions of their range where pinyon-juniper woodland is absent. Hardy (1945) mentions only the Piñon Jay and Plain Titmouse as being obligatory and the Bushtit as a semi-obligatory species in this woodland type.[1/] But, the Piñon Jay often nests and forages in ponderosa pine forest (Balda and Bateman 1971) and the Bushtit is also known to use other habitats.

[1/] Scientific names for all birds mentioned in the text or tables are given in Appendix I.

TABLE 2. Breeding birds of pinyon-juniper woodlands[1)]

Species	Status[2)]	Distribution[3)]	Niche Width[4)]
Turkey Vulture	S	4	
Cooper's Hawk	P	2	
Red-tailed Hawk	P	4	
Swainson's Hawk	S	1	
Ferruginous Hawk	P	2	
Golden Eagle	P	3 (Sp.)	
Prairie Falcon	P	2 (Sp.)	
American Kestrel	P-S	4	
Gambel's Quail	P	2	
Mourning Dove	P-S	7	
Screech Owl	P	3	obligatory
Great Horned Owl	P	3	
Long-eared Owl	S	1	
Saw-whet Owl	P	1	
Poor-will	S	2	
Common Nighthawk	S	3	
Lesser Nighthawk	S	2	
White-throated Swift	S	2 (Sp.)	
Black-chinned Hummingbird	S	4	semi-obligatory
Costa's Hummingbird	S	1	
Broad-tailed Hummingbird	S	3	
Common (red-shafted) Flicker	P	6	
Hairy Woodpecker	P	4	
Ladder-backed Woodpecker	P	1	
Western Kingbird	S	1	
Cassin's Kingbird	S	2	
Ash-throated Flycatcher	S	7	semi-obligatory
Say's Phoebe	S	2	
Gray Flycatcher	S	2	obligatory
Western Wood Pewee	S	1	
Violet-green Swallow	S	2	
Cliff Swallow	S	1 (Sp.)	
Scrub Jay	P	6	obligatory
Black-billed Magpie	P	2	
Common Raven	P	6	
Piñon Jay	P	5	semi-obligatory
Mountain Chickadee	P	3	
Plain Titmouse	P	7	obligatory
Bushtit	P	6	semi-obligatory
White-breasted Nuthatch	P	3	
House Wren	S	1	
Bewick's Wren	P-S	3	semi-obligatory
Cañon Wren	P-S	3 (Sp.)	
Rock Wren	P-S	4	
Mockingbird	S	4	semi-obligatory
American Robin	P-S	1	
Western Bluebird	P-S	1	
Mountain Bluebird	P-S	4	
Blue-gray Gnatcatcher	S	5	semi-obligatory
Loggerhead Shrike	S	2	

TABLE 2. (cont.)

Species	Status[2]	Distribution[3]	Niche Width[4]
Gray Vireo	S	3	obligatory
Solitary Vireo	S	2	
Black-throated Gray Warbler	S	5	semi-obligatory
Scott's Oriole	S	3	
Brown-headed Cowbird	S	4	
Hepatic Tanager	S	1	
Black-headed Grosbeak	S	5	
Lazuli Bunting	S	2	
Cassin's Finch	S	1	
House Finch	P-S	5	semi-obligatory
Lesser Goldfinch	S	2	
Red Crossbill	S	1	
Green-tailed Towhee	S	2	
Rufous-sided Towhee	P	6	semi-obligatory
Brown Towhee	P	2	semi-obligatory
Vesper Sparrow	P-S	2	
Lark Sparrow	S	4	semi-obligatory
Black-throated Sparrow	P-S	3	
Sage Sparrow	S	1	
Dark-eyed Junco	S	1	
Gray-headed Junco	P-S	1	
Chipping Sparrow	P-S	6	
Brewer's Sparrow	S	1	
Black-chinned Sparrow	P	2	semi-obligatory
Total: n = 74	P = 23 (32%) S = 38 (51%) P-S = 13 (17%)	s-o = 13 o = 5	

1) Data from Rasmussen (1941), Hardy (1945), Miller (1946), Hering (1957), Grue (1977), Masters (1979)
2) P = permanent resident; S = summer resident
3) The number indicates the number of census plots or study areas used for breeding. The maximum is 7. Sp. = special landscape required.
4) Obligatory = in a given geographic area the species breeds only in the pinyon-juniper woodland; semi-obligatory = same as above but breeds in one additional plant community.

Few, if any other natural habitat-types in North America have so few truly obligatory species. The reason(s) such should be the case is not clear but may relate to the great physiognomic diversity found in the pinyon-juniper woodland. Just as there is no typical pinyon-juniper woodland there are few obligate pinyon-juniper birds.

Just as the number of breeding species varies between woodlands so does breeding bird density. In southwestern Arizona where many oaks are found in the woodlands breeding bird density may reach 250 pairs per 40 ha (Balda 1967). This density is seldom if ever reached in the pinyon-juniper woodland where densities vary between 30 and 190 pairs

per 40 ha (Table 3). Ninety-five pairs is about an average figure. Grasslands usually have fewer breeding pairs and ponderosa pine forests more than the pinyon-juniper woodland.

TABLE 3. Characteristics of the avian woodland breeding birds

Study	Habitat	No. of Breeding Species	No. of Breeding Pairs/40 ha
Balda, 1967	oak-juniper	36	224
Balda, 1967	oak-juniper-pine	36	267
Grue, 1977	juniper-parkland	17-23	54-179
Beatty, 1978	juniper-grassland	11-12	35-40
Grue, 1977	juniper-pinyon	24-26	66-130
Masters, 1979	pinyon-juniper I	9-10	90-87
Masters, 1979	pinyon-juniper II	18-21	191-138
Masters, 1979	pinyon-juniper III	19-19	122-133
Hering, 1957	pinyon-juniper (?)	15	33
Beidleman, 1960	pinyon-juniper	2	30
Hardy, 1945	pinyon-juniper	22	--
Miller, 1946	pinyon dominated	55	--

Breeding bird densities in a single location show rather large annual fluctuations that appear to be linked to biotic and physical factors. In very dry years the breeding bird populations may be reduced between 50 and 70% (Grue 1977). Possibly pinyon pine seed crops may attract breeding birds the next spring. Masters (1979) found a 28% increase in populations after a large cone crop (Table 4).

Table 4. Changes in breeding bird densities (pairs/40 ha) and diversities between years

Study	First Year Density/Diversity	Second Year Density/Diversity	%Change	Reason
Masters, 1979	191/21	138/18	28/14	Pinon seed crop before first year
Grue, 1977	130/26	66/24	49/8	Annual fluctuation in precipitation
Grue, 1977	179/23	54/17	70/26	Same as above

Masters (1979) attempted to explain the relationship between various habitat parameters and characteristics of the breeding bird

fauna. At the level of the community, she found that the number of breeding bird species was significantly correlated with a) the density of pinyon pine, b) total tree density and c) pinyon pine foliage volume. Foliage height diversity (as measured in two-meter height classes) was a significant predictor of bird species diversity. Breeding bird density was significantly correlated with pinyon pine density when the bird population figures following a large pinyon pine cone crop are ignored.

A "typical avifauna" of the pinyon-juniper woodland thus appears to be as simplistic an approach as trying to describe a typical vegetation for this woodland type. Never-the-less we have selected from the list of 74 breeding species a group that has a distribution score (Table 2) of four or higher and/or is listed as obligatory or semi-obligatory in niche width. A major danger here is that two closely related species may be sympatric and thus neither would have achieved the criteria for inclusion. Such could have been the case for nighthawks, kingbirds, hummingbirds, bluebirds, medium-billed sparrows and a few other cases. In these instances the most common of the dyad or triad was added to the list to make it as representative as possible. From Table 2, 29 species met the first criteria and the nighthawk and kingbird were added for reasons given above.

Resident Status

Of the 31 species that fit our "typical avifauna" criteria 14 (45%) are summer residents and 11 (35%) are permanent residents. Six species show variable patterns of residency either based on geographic considerations (i.e. summer residents in the northern portion of their range and permanent residents in the more southern areas) or variable weather conditions (i.e. migrate in harsh winter, remain stationary in mild winters). Hardy (1945) in eastern Utah described 36% of the nesting species as permanent residents and 64% as summer residents, almost identical to our typical avifauna if one includes the "switchers" in the summer category.

Data from intensively censused plots in central Arizona over a two year period showed about the same split as does the Utah data (Grue 1977). The proportion of permanent resident species ranged from 35 to 40%.

In north-central Arizona however, Masters (1979) censusing three pinyon-juniper plots for two years found a range of permanent resident breeders from 32 to 56% (Table 5), and Hering (1957) near Mesa Verde, Colorado had 53% permanent residents. One could expect permanent residency to increase in the woodlands with decreasing latitudes but such an increase is not apparent from either the proportion of the breeding population that is permanent or the absolute number of species that do so. On both of Masters' (1979) plots with proportion of permanent residence above 50% the ratio of pinyon to juniper trees was better than 2:1. (Hardy's 1945 ratio was 0.36 to 1). Hering (1957) did not provide the necessary data to assess this habitat feature but the general area of her study contains high densities of P. edulis (pers. obs. R. P. Balda). Of the 55 species of breeding birds (a woodland high!) listed by Miller (1946) in a southern California woodland predominated by pinyon pine, 27 species or 49% were apparently permanent residents. Two areas without pinyons had 33 and 35%

permanent resident breeders. Thus, we suggest with caution that a positive correlation may exist between the proportion of permanent residents in the community and the proportion of trees in the woodland that are pinyon pines. In all probability no one factor will answer the question, but this one does deserve future investigation. Of the 18 species listed as either obligatory or semi-obligatory in this woodland 8 are permanent residents.

Table 5. Residence status of breeding birds from specific sites in north-central Arizona (Masters 1979)

Status	Number of Species (%) Sites I		II		III	
Permanent Resident	3.0*	(32)	8.0	(53)	7.5	(56)
Summer Resident	6.5	(68)	7.0	(47)	6.0	(44)

* 2 yr. average

Foraging Guilds

An instructive way to look at avian communities is the use of foraging guilds (Root 1967). A guild is defined as one or more species in a community that use similar foraging techniques. Guilds can be defined as broadly or narrowly as the observations and data base permit. Here for the sake of simplicity and accuracy (but sacrificing specifics) I define foraging guilds only by substrate-type. This is done because very little information is known about the species under consideration to allow for finer distinctions. Foraging guilds used include ground, foliage, air, bark, and flowers. If a species used two of these substrates I assigned half the value to each guild.

The descriptive analysis from nine different intensively studied woodland sites shows few trends. The number of ground foragers varied from 6 (Hering 1957) to 16 (Grue 1977) species. Relative proportions of ground foragers varied between 40% (Hering 1957) and 57% (Grue 1977). No significant correlation (Spearman Rank Correlation) between the density of pinyon pine or juniper and either the number or proportion of ground foraging species was found.

The number of foliage foragers in the breeding community varied from a low of three in a juniper-grassland (Beatty 1978) to a high of 12 in a predominantly pinyon pine stand. The mean number of species that used foliage as a substrate where both pinyon and junipers were represented was 5. The number or proportion of foliage foraging species showed no significant correlation with pinyon or juniper density.

The number of species of hummingbirds (nectar feeders) also shows no correlation with tree species density. Hummingbirds most likely respond more to the species composition and flowering patterns of the shrub and forb strata which may be limited by physical factors (temperature, moisture, etc.).

There is also no trend for aerial feeders. Aerial foraging species number between 1 (Hering 1957) and 9 (Miller 1946). On areas containing both pinyon and junipers the mean number of aerial feeders was 4.

In some woodlands a small group of breeding species forage extensively on trunks and large branches. In no intensive study area analyzed for this report where the ratio of pinyon to junipers was less than 1:1 did any of these species breed. Where pinyons outnumbered junipers by 2:1 or better two species appeared. Almost invariably these two species were the Hairy Woodpecker and White-breasted Nuthatch. The former species obtains insects by hammering holes through the bark or flaking layers of bark off in small plates. The latter species probes the crevices in the bark to obtain insects. Both species reach higher densities in ponderosa pine forests (Szaro and Balda 1979) than in the woodlands. Either there are more insects in, under, and on pinyon pine bark than juniper or the bark pattern is such that insects are easily extracted.

The "typical avifauna" for pinyon-juniper woodlands has a slightly higher number of ground and foliage foragers than the studies described above (Table 6). This probably occurred because our selected sample of birds is slightly larger than would be found in any one woodland area.

Table 6. Foraging Guilds for a "typical pinyon-juniper woodland"

Guild	*Number of Breeding Species (%)
Ground	14.5 (52)
Foliage	7.0 (24)
Aerial	4.5 (16)
Bark	1.0 (4)
Flower	1.0 (4)

*Carnivores not included

The above analysis has dealt solely with numbers of species because of the high year-to-year variability in densities. Master's (1979) regression models to predict characteristics of the bird populations included foraging guilds. Eight independent foliage variables were used. Pinyon density was significantly correlated with densities of aerial feeders, bark feeders, and total density of all insectivorous birds (Table 7). No variable contributed solely by junipers was important as a predictor of any of the breeding bird characteristics measured. Why the above result should occur is not immediately obvious but suggests pinyon pine may provide a more suitable foraging substrate than juniper.

Only fragmentary data exists to support the contention that juniper is less attractive as a foraging substrate than is pinyon pine. In an oak-juniper-pine (*Pinus cembroides* and *P. leiophylla*) woodland in southeastern Arizona, Balda (1969) studied foliage use by the 36 breeding species. The number of observations in each tree species were compared to the foliage volume contributed by each tree species. Based on foliage volume an expected number of bird observations per tree species was calculated. Actual foraging

observations in juniper were far less than expected, whereas foraging observations in pines were much greater than expected. At that time Balda proposed that the breeding birds may simply have not yet learned to use juniper as it is known that juniper is presently spreading into new areas and increasing in areas where it was once sparse. The Black-throated Gray Warbler, Chipping Sparrow, Bridled Titmouse and Common Bushtit utilized juniper more than any other species. Three of the four species listed above are members of our "typical woodland avifauna." In a pinyon-juniper-ponderosa pine ecotone Laudenslayer and Balda (1976) found that pinyon pine was selected more intensely than predicted by expected numbers generated from foliage volume. Juniper was selected approximately as often as expected. We explained this difference by using the relative proportion of foraging surface within both trees. Although both species have their green foliage concentrated on the outer edges of the branches, needles of pinyon pine are found growing farther inward than in juniper. Thus, if the growing areas and areas of green vegetation on these trees are used as prime foraging surfaces then pinyon provides more of this surface per tree than does juniper.

Table 7. Percent variability explained (r^2) of breeding bird parameters by vegetation factors which are significantly correlated (Masters 1979)

Factor	Density of Feeding Guilds		
	Aerial Feeders	Bark Feeders	Insectivores
Pinyon Pine Density	.980	.781	.949
Total Tree Density	.979	.776	.947
Pinyon Foliage Volume	.902	NS	.834

Insect densities in pinyons and junipers may also be a reason why pinyon density is a good predictor of density of insect eating birds. Masters (1979) found, however, that junipers had a higher number of insect taxa than did pinyon. Insect abundance (as measured by total length) was about the same in both trees. The similarity coefficient (a measure of community similarity) indicated that pinyon and juniper have different arthropod faunas associated with them.

Nesting Guilds

The classification of the avian community by nesting habits may also provide clues as to how breeding birds interact with the structure of the vegetation. Of the 31 species used as a "typical avifauna" 60% (18.5) nested in foliage (the 0.5 is for the Mourning Dove that uses both foliage and ground for a nest substrate), 23% (7) used cavities and the remainder nest on the ground. Hardy's data (1945) fits well with 61% of the breeding birds nesting in the foliage, 21% in cavities, and 18% of the species nesting on the ground.

On two intensively studied plots in central Arizona Grue (1977)

found an average of from 60 to 68% foliage nesting species in the breeding bird community. From 15 to 20% of the species nested in cavities. Again the fit is reasonable with what a "typical avifauna" would show (Table 8).

Table 8. Nesting guilds of breeding birds from specific sites in central Arizona (Grue 1977)

Nesting Guild	Number of Species (%) Pinyon-Juniper Woodland	Juniper Parkland
Foliage	16.5* (66)	14.0 (68)
Cavity	5.0 (20)	3.0 (15)
Ground	3.5 (14)	3.5 (17)
Total	25.0	20.5

* 2 yr. averages

In north-central Arizona Master's (1979) found cavity nesters to make up almost half of the breeding species on areas where pinyons outnumbered junipers (Table 9). Hering (1957) found cavity nesting species made up 47% of the breeding species on an area of presumable high pinyon densities. Both studies had 7 to 8 cavity nesting species present. The pinyon dominated woodland in California (Miller 1946) contained 11 cavity nesting species.

Table 9. Nesting guilds of breeding birds from specific sites in north-central Arizona (Masters 1979)

Nesting Guild	Number of Species (%) Sites I	II	III
Foliage	7.0* (74)	7.5 (50)	6.5 (48)
Cavity	2.0 (21)	7.0 (47)	6.5 (48)
Ground	0.5 (5)	0.5 (3)	0.5 (4)

* 2 yr. averages

The emerging pattern is more than suggestive that cavity nesting species will occur with higher probability in woodlands containing large numbers of pinyon pines. On three study sites in north-central Arizona Masters (1979) found that 79% of the variability (r^2) in density of the combined cavity nesting species (not species numbers as discussed above) was explained by the density of pinyon pines.

Both density and diversity of cavity nesting species may be related to pinyon pine in some manner. Since cavity nesters depend on weakened or diseased trees to excavate cavities in, it is possible that pinyon pine are more prone to attack by insects and other disease

causing organisms. Also, it may be that pinyon branches are more brittle and are therefore more prone to breaking thus allowing disease agents entry. Dead junipers are hard whereas dead pinyon pines contain soft wood (pers. obs.).

The question that remains deals with tree-type selection by the foliage breeding birds: Do foliage breeders select for either juniper or pinyon when choosing a nest site? Both Hardy (1945) and Short and McCulloch (1977) make unsubstantiated comments that foliage nesting birds prefer junipers over pinyons for nest-sites. Based on the amount of data presently available it is not possible to answer that question and more research is required to show if any preference is shown (Table 10). The two species that showed regular use of juniper were the Black-chinned Hummingbird and Black-throated Gray Warbler whereas the Chipping Sparrow showed no preference for either tree (Masters 1979, Balda 1969).

Table 10. Nest sites of foliage nesting birds in western woodlands

Study		Number of Nests in pinyon	juniper	other
Balda, 1967	oak-juniper 67 1	(not present)	1	12
Balda, 1967	juniper-oak-pine 46 46 29	--	11	10
Laudenslayer and Balda, 1976	pinyon-juniper-ponderosa pine 48 46 27	3	--	--
Masters, 1979	pinyon-juniper I 32 33	--	1	--
Masters, 1979	pinyon-juniper II 87 33	10	5	--
Masters, 1979	pinyon-juniper III 87 34	6	2	--

WINTERING BIRDS

Winter bird populations of the woodland have been studied in central Arizona by Grue (1977) and in north-central Arizona by Shrout (1977). A total of 32 species have been recorded as wintering in these woodlands. These 32 species belong to five orders and 14 families. Of these, 18 are permanent residents, 10 are winter residents, and 4 are switchers. The most regular winter residents are the two species of juncos, White-crowned Sparrow, and Ruby-crowned Kinglet. Three of these four species are seed eaters. Prominent "switcher" species are the Mourning Dove, American Robin, the two bluebirds, and the House Finch. Only the Bushtit, kinglet and wren are insectivorous (Table 11).

Species numbers vary considerably from year-to-year. Shrout (1977) reported a diversity of 10 species in one winter and 20 the next on the same 40 ha plot. Mean number of wintering species in Arizona woodlands is about 15 (Grue 1977, Shrout 1977).

Table 11. Birds wintering in pinyon-juniper woodlands

Species	Status*	Distribution (max = 3)
Rough-legged Hawk	W	1
Merlin	W	1
Prairie Falcon	P	(pers. obs.)
Gambel's Quail	P	1
Mourning Dove	P-S	2
Hairy Woodpecker	P	1
Common (red-shafted) Flicker	P	3
Horned Lark	P	1
Common Raven	P	3
Piñon Jay	P	1
Scrub Jay	P	3
Mountain Chickadee	P	1
Plain Titmouse	P	3
Common Bushtit	P	3
White-breasted Nuthatch	P	(pers. obs.)
Red-breasted Nuthatch	W	(pers. obs.)
Bewick's Wren	P	2
Ruby-crowned Kinglet	W	2
American Robin	P-S	1
Townsend's Solitaire	W	1
Western Bluebird	P-S	1
Mountain Bluebird	P-S	1
Sage Thrasher	W	1
Evening Grosbeak	W	1
House Finch	P-S	2
Cassin's Finch	W	(pers. obs.)
Rufous-sided Towhee	P	1
Vesper Sparrow	P	1
Dark-eyed Junco	W	3
Gray-headed Junco	W	3
Chipping Sparrow	P	3
White-crowned Sparrow	W	3
n = 32	P=16, W=11 and P-S=5	

Winter densities vary greatly from place-to-place and from year-to-year. For example during the winter of 1973-74 Grue (1977) reported 318 individuals per 40 ha in a pinyon-juniper woodland and 251 wintering birds in a 40 ha juniper parkland. This is a 21% difference.

Year-to-year variations are even more striking. In some years the woodland supports huge flocks (too large to count) of bluebirds, American Robins and mixed flocks of juncos. In other years one can walk for hours seeing only a very few birds (Vaughan pers. comm., R. P. Balda pers. obs.). Shrout (1977) found 293 wintering birds per 40 ha in the winter of 1973-74 and 75 individuals during the winter of 1974-75 on the same plot. Using a conservative calculation this is a 74% change in population density between years.

These fluctuations appear to be caused by a combination of physical and biotic factors. Open water appears to be critical to winter birds of this habitat-type. This may occur because most are feeding on tree, shrub, grass and forb seeds as water-bearing insects are rare. Large flocks of sparrows, jays, juncos, bluebirds and robins concentrate at different times of day at cattle watering tanks. In high density years flocks of robins have been seen by the authors flying kilometers to and from water holes. Heavy winter snows, however, cause a temporary movement to lower elevations (pers. obs.).

Heavy crops of juniper cones occur at irregular intervals but generally a heavy crop can be expected every two to five years (Tueller and Clark 1975). Shrout's (1977) data are for a year with a "bumper crop" of juniper cones and then for a year with no berry production. Large crops may be local or synchronized over relatively large areas. The "berry" crops ripen in the fall and attract large numbers of birds. Some birds such as the Cassin's Finch and Evening Grosbeak consume the pulpy flesh and seed whereas others such as the bluebirds, robins, and solitaires digest only the fleshy pulp and defecate the seeds (Salomonson 1978). Johnsen (1962) and Salomonson (1978) found that fresh, ripe seeds passed through the digestive tract of birds germinate faster than other seeds. Due to bird dispersal Salomonson (1978) found that most seedlings germinate and grow away from the source trees but most berries were found below the trees. In early fall most juniper seed eaters are highly nomadic in their search for large crops. Defecation by these birds during nomadic flights over grassland and other rangelands may be one of the causes for the encroachment of junipers into other habitat types.

Other birds respond differently to large juniper berry crops. Some Townsend's Solitaires (Salomonson 1978) and possibly some American Robins (T. A. Vaughan pers. obs.) set-up permanent, exclusive, defended winter territories in these woodlands. All observations suggest that the birds defend (or attempting to defend) an adequate supply of juniper berries to survive the winter. Salomonson & Balda (1977) found that Townsend's Solitaires spent as much, if not more time wintering in pinyon-juniper woodland than on the breeding grounds. These birds should, thus, show adaptations that promote survival during the winter. Average territory size during a "bumper" berry crop averaged 0.70 ha and contained between 13 and 25 million juniper berries. Each territory contained more than a solitaire could possibly harvest. This may insure the solitaires an adequate berry supply against heavy snow, heavy consumption by flocking bluebirds and robins, and consumption by birds that sneak into their territories. At the same time the junipers make no attempt to conceal their seeds or make them difficult for animals (especially birds) to locate and consume. Thus, one must conclude that southwestern junipers rely on birds to disperse their seeds.

The other dominant trees in this woodland show the same erratic production of propagules. *Pinus edulis* produces large synchronized crops of seeds every 6 or 7 years and intermediate crops every three to four years (Balda 1978). *Pinus monophylla* produces an abundant crop of cones every two to three years (Graves 1917). References too numerous to mention (in English, Navajo and Hopi) refer to the activities of birds in the consumption of pinyon pine seeds. It is generally concluded that dispersal of the large, wingless seeds occurs by the

actions of both mammals and birds.

Estimates of how many pinyon pine seeds are carried off during a good crop have been made and range from 18,000 to 33,000 seeds/autumn/bird (Table 12).

Table 12. Approximate number of pine seeds cached by a single bird when pinyon pine cone crop is high

Bird	Tree	Number of Seeds	Reference
Piñon Jay	*Pinus edulis*	21,500	Balda, 1978
Piñon Jay	*Pinus edulis*	18,000	Ligon, 1978
Clark's Nutcracker	*Pinus edulis*	22-33,000	Vander Wall and Balda, 1977

Seeds harvested from cones by the permanent resident Piñon Jay and Scrub Jay are often stored in shallow subterranean caches from which they can be reclaimed at a later time (Balda and Bateman 1972, Ligon 1978). Two other corvids descend into the pinyon-juniper woodlands to harvest pinyon pine seeds. The Steller's Jay carries up to 15 seeds in its mouth and throat up into the ponderosa pine forest where they are cached. A single bird may make six or seven trips per day. If the woodlands are within 20 km of a mixed coniferous forest Clark's Nutcrackers, which often forage on and store seeds of limber pine and white-bark pine, will descend to harvest pine seeds for caching in the coniferous forest (Tomback 1977, Vander Wall and Balda 1977).

Caching sites are usually on relatively dry sites that are snow free or quick to melt. Seeds that are not found by the birds often germinate and grow. In this manner pinyon pine is planted in the woodland and in grasslands below (Ligon 1971) and in the coniferous forest above it (Vander Wall and Balda, unpubl. data). The Clark's Nutcracker, as it resembles its European congener has a remarkable memory for finding its hidden caches (Turcek and Kelso 1968, Balda in press, Tomback in press).

MANAGEMENT CONSIDERATIONS

Until quite recently the standard management procedure for pinyon-juniper woodlands was to get rid of it. This was done with little consideration for the nongame birds. Wise management guidelines of today require that we know what we are managing and the constraints imposed by each group of organisms that occur in the habitat type. Avian ecologists have long ignored this expansive plant community. The result is we do not have the data in hand to make concrete suggestions to the "What if we do..." questions so often asked by wildlife managers. We urge that a concerted, organized effort be made in the four-state region where this woodland is so abundant to find out what species are present, in what densities,

and what factors control their presence and abundance.

This woodland is biologically unique in the sense that both dominant tree species are adapted to have their seeds dispersed by animals. Here some seed predators are also mutualistic agents of the trees. This fact alone should be a constraint. Because of the mobility of the dispersal agents, type conversion projects will probably never be permanent as pinyon pine and juniper seeds will be defecated and/or cached in these "converted" areas.

The winter use of juniper berries by hundreds of thousands of robins, bluebirds and other species must also be considered. We often hear statements about the futility of trying to manage our forests and rangelands for nongame birds that winter far from the breeding grounds. The pinyon-juniper woodland is one such wintering ground and also deserves consideration from that point-of-view.

The strong correlations between various bird community characteristics and pinyon pine parameters suggest that this tree species has important implications for breeding birds. Just what these properties of pinyon pine are remains to be seen but selective removal of pinyon pine will most likely have a serious impact on the breeding bird community.

Thus, both the pinyon pine and the junipers play key roles in maintaining the integrity, survival and propagation of some (or all) components of the bird community. Both tree species provide different requisites at different times of year.

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Appendix I. -- Scientific names for bird species mentioned in the text and tables.

Common Name	Scientific Name
Turkey Vulture	*Cathartes aura*
Cooper's Hawk	*Accipiter cooperii*
Red-tailed Hawk	*Buteo jamaicensis*
Swainson's Hawk	*Buteo swainsoni*
Rough-legged Hawk	*Buteo lagopus*
Ferruginous Hawk	*Buteo regalis*
Golden Eagle	*Aquila chrysaetos*
Prairie Falcon	*Falco mexicanus*
Merlin	*Falco columbarius*
American Kestrel	*Falco sparverius*
Gambel's Quail	*Lophortyx gambelii*
Mourning Dove	*Zenaida macroura*
Screech Owl	*Otus asio*
Great Horned Owl	*Bubo virginianus*
Long-eared Owl	*Asio otus*
Saw-whet Owl	*Aegolius acadicus*
Poor-will	*Phalaenoptilus nuttallii*
Common Nighthawk	*Chordeiles minor*
Lesser Nighthawk	*Chordeiles acutipennis*
White-throated Swift	*Aeronautes saxatalis*
Black-chinned Hummingbird	*Archilochus alexandri*
Costa's Hummingbird	*Calypte costae*
Broad-tailed Hummingbird	*Selasphorus platycercus*
Common {red-shafted} Flicker	*Colaptes auratus cafer*
Hairy Woodpecker	*Picoides villosus*
Ladder-backed Woodpecker	*Picoides scalaris*
Western Kingbird	*Tyrannus verticalis*
Cassin's Kingbird	*Tyrannus vociferans*
Ash-throated Flycatcher	*Myiarchus cinerascens*
Say's Phoebe	*Sayornis saya*
Gray Flycatcher	*Empidonax wrightii*
Western Wood Pewee	*Contopus sordidulus*
Horned Lark	*Eremophila alpestris*
Violet-green Swallow	*Tachycineta thalassina*
Cliff Swallow	*Petrochelidon pyrrhonata*
Scrub Jay	*Aphelocoma coerulescens*
Black-billed Magpie	*Pica pica*
Common Raven	*Corvus corax*
Pinon Jay	*Gymnorhinus cyanocephalus*
Clark's Nutcracker	*Nucifraga columbiana*
Mountain Chickadee	*Parus gambeli*
Plain Titmouse	*Parus inornatus*
Bridled Titmouse	*Parus wollweberi*
Common Bushtit	*Psaltriparus minimus*
White-breasted Nuthatch	*Sitta carolinensis*
Red-breasted Nuthatch	*Sitta canadensis*
House Wren	*Troglodytes aedon*
Bewick's Wren	*Thryomanes bewickii*
Cañon Wren	*Catherpes mexicanus*
Rock Wren	*Salpinctes obsoletus*
Mockingbird	*Mimus polyglottos*
Sage Thrasher	*Oreoscoptes montanus*
American Robin	*Turdus migratorius*

Appendix I. -- continued.

Common Name	Scientific Name
Western Bluebird	*Sialia mexicana*
Mountain Bluebird	*Sialia currucoides*
Townsend's Solitaire	*Myadestes townsendi*
Blue-gray Gnatcatcher	*Polioptila caerulea*
Ruby-crowned Kinglet	*Regulus calendula*
Loggerhead Shrike	*Lanius ludovicianus*
Gray Vireo	*Vireo vicinior*
Solitary Vireo	*Vireo solitarius*
Black-throated Gray Warbler	*Dendroica nigrescens*
Scott's Oriole	*Icterus parisorum*
Brown-headed Cowbird	*Molothrus ater*
Hepatic Tanager	*Piranga flava*
Black-headed Grosbeak	*Pheucticus melanocephalus*
Lazuli Bunting	*Passerina amoena*
Evening Grosbeak	*Hesperiphona vespertina*
Cassin's Finch	*Carpodacus cassinii*
House Finch	*Carpodacus mexicanus*
Lesser Goldfinch	*Carduelis psaltria*
Red Crossbill	*Loxia curvirostra*
Green-tailed Towhee	*Pipilo chlorurus*
Rufous-sided Towhee	*Pipilo erythrophthalmus*
Brown Towhee	*Pipilo fuscus*
Vesper Sparrow	*Pooecetes gramineus*
Lark Sparrow	*Chondestes grammacus*
Black-throated Sparrow	*Amphispiza bilineata*
Sage Sparrow	*Amphispiza belli*
Dark-eyed Junco	*Junco hyemalis*
Gray-headed Junco	*Junco caniceps*
Chipping Sparrow	*Spizella passerina*
Brewer's Sparrow	*Spizella breweri*
Black-chinned Sparrow	*Spizella atrogularis*
White-crowned Sparrow	*Zonotrichia leucophrys*