

AVIFAUNAL RESPONSE TO THE 1977 LA MESA FIRE

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Abstract.--Three of 4 breeding bird transects in habitats ranging from mixed conifer to pinyon-juniper were burned by the 1977 La Mesa Fire. Large portions (25-80 percent) of the 3 burned transects suffered forest loss from crown fire or scorching, but the pinyon-juniper transect did not burn. The transects were surveyed during the breeding season before the fire and 1, 2, 4, 6, and 14 years afterwards.

Species diversity increased after the fire, but breeding populations generally declined for several years before increasing above prefire levels. This temporary population decline was more pronounced and lasted longer on the more severely burned transects. Conversely, the population on the unburned pinyon-juniper transect temporarily increased after the fire. After 14 years, avian diversity and populations in the burn remained well above prefire levels, except on the transect with 80% forest loss, where the population was 22% lower due to a reduction in insectivores. Populations of seed-eating birds and raptors were consistently higher than before the fire. All 3 burned transects experienced both immediate and successional changes in species composition.

Even an uncontrolled crown fire such as the La Mesa Fire can increase the diversity and population of breeding birds. High fire intensity appears to delay recovery of avian populations from short-term postfire declines, and extensive crown fire appears to reduce populations after most snags have fallen, but even the most severely burned areas of the La Mesa Fire generally retained some live trees and snags and supported diverse, substantial populations of breeding birds after the fire. Application of moderate intensity prescribed fire to relatively dense stands such as those burned by the La Mesa Fire can enhance avian diversity and populations without the disadvantages of high intensity crown fires.

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INTRODUCTION

In May and June, 1977, before the La Mesa Fire, Wauer began to survey 7 avian population transects in different habitats in Bandelier National Monument. In mid-June, 1977, the La Mesa Fire burned 3 transects (near Apache Spring, on Escobas Mesa, and on Burnt Mesa) and burned to within 400 m of a fourth (on Frijoles Mesa). These 4 transects are all located on the mesas between Frijoles Canyon and State Highway 4, ranging from higher to lower elevations in the order of Apache, Escobas, Burnt, and Frijoles. The major vegetation types range along the gradient from mixed conifer to pinyon-juniper (Table 1). Wauer and Johnson (1984) described vegetation on the 3 burned transects in more detail, as did Wauer and Dennis (1980) for the unburned Frijoles Mesa transect.

These 4 transects were again surveyed for breeding birds in 1978, 1979, 1981, 1983, and 1991--1, 2, 4, 6, and 14 years after the fire--except for Frijoles, which was not surveyed in 1983. Analysis of the short-term effects of the fire on avifauna, based on 1977-79 data for the 3 burned transects, was presented at the 1981 La Mesa Fire Symposium (Wauer and Johnson 1984). These included increased species diversity, marked increases in woodpeckers, and declines in total population. Subsequent surveys recorded long-term trends and succession after the fire. These data also highlight some differences among the transects, which can provide guidance for fire management.

METHODS

All transects were permanently marked fixed lines, each 1 mile long. Fifty-two 31 m intervals along the center line and four 31 m intervals on each side defined 416 cells that totaled 40 ha (Emlen 1971). Transects were surveyed during the first 2-3 hours after sunrise by slowly walking the transect line and recording all birds heard or seen on a gridded field form (Wauer and Johnson 1984). The species, type of detection (song, note, or sight), breeding activities, and movements were also recorded, making the field form a complete record of observations during

the survey. Occasional excursions from the center line were made to aid identification and detection. All transects were surveyed during the height of the breeding season, on dates ranging from May 13 to June 17 for Frijoles, and May 16 to June 20 for Apache. Wauer initiated the study and did all the fieldwork in 1977, Johnson and Wauer each did half in 1978, Johnson did all the fieldwork in 1979, 1981 and 1983, and Wauer returned to do it all in 1991.

Each field form is essentially a map of the distribution of birds that were detected during that survey. For analysis, each survey was summarized by the counts of each species in each of the 4 lateral distance intervals, on either side of the center line. Breeding species were assumed to be paired and counted in pairs, i.e., counting 2 for a singing male, an isolated individual, or 2 birds together. Conversely, non-breeding species were counted singly. Species were classified as breeding if they could breed in the habitat of each transect (whether or not firm evidence of breeding was recorded) or non-breeding if they were known not to breed in that habitat. Classification was based on personal observations and a local breeding bird atlas (Travis 1992). Birds were counted in the cell where they were first detected, and recorded movements were used to avoid double counting.

Rather than using coefficients of detectability to estimate population densities (Emlen 1977), an effective survey area was determined for each species, its population was estimated in that area, and the result was normalized to the density of birds per 40 ha. For each species, counts in each interval were totaled for all years and transects to judge the lateral range of intervals in which birds of that species were regularly detected, which was never less than 2 intervals. A regular detection range of 2, 3, or 4 intervals corresponded with an effective survey area of 20, 30, or 40 ha, and only birds counted within the detection range of each species were used to estimate its population (see Appendix 1). For 20% of the species (mainly the smaller flycatchers, nuthatches, and warblers), prefire and postfire detection ranges differed due to the loss of forest cover, and the smaller prefire ranges were used both before and after the fire.

Compared to mapping census techniques, transect surveys cover more ground and attempt to compensate for less precision with better statistics. The essential premise in

estimating populations of breeding birds from survey counts is that they are paired and resident during the breeding season. Actually, some birds may not be paired, some may be moving through the area, and double counts are possible, all of which would exaggerate pair counts, but more birds are likely to be paired but sometimes undetected. Wauer and Johnson (1984) used the maximum count for each species as a reasonable estimator of population, because most breeding birds probably do meet the premise of being paired residents, and in that case the counts could not exceed the population. However, the maximum count is a statistically biased estimator because it tends to increase the more times a transect is surveyed, which varied from 3 to 6 times in our study (Table 2).

We refined this approach with the conjecture that the average maximum count should approach a limit as the number of surveys increases, and that this limit is a better estimator of population. The actual maximum in any particular sample is likely to be less but may be more than the expected value of the maximum. The standard deviation of transect survey counts was low for highly detectable species such as solitary vireos, and high for less consistently detected species such as western bluebird. Nonetheless, the average maximum count, expressed as a number of standard deviations above the mean, was similar for all species. Combining all species in all years, the average maximum count exponentially approached a value of 1.58 standard deviations above the mean (Figure 1).

Assuming a normal distribution, the mean, standard deviation, and the variances of the sampling distributions of survey counts can be estimated (Bulmer 1979). From unbiased estimators of these values, the population of each breeding species on each transect each year was estimated as the mean plus 1.58 times the estimated standard deviation of its survey counts, and a standard error was calculated to represent the statistical uncertainty in this estimate. The variance provided an estimate of the standard error of the population estimate, which is a measure of the statistical variability of the data, and not necessarily of the uncertainty in the true population. True population uncertainty may also include a number of unquantifiable potential

biases related to methods of gathering and analyzing data, which should not primarily affect comparisons between years or transects.

In cases where birds were readily detected and counts were consistent, e.g., 10-12 birds, the standard deviation was small and the population estimate was not far above the mean count, but in cases where birds were not as easily detected and the counts varied considerably, e.g., 0-12 birds, the standard deviation was large, and the estimate was well above the mean. In both cases, the estimate was generally similar to the maximum count. The 1977 data on Apache were limited to a single survey before the fire, so neither the standard deviation nor population can be estimated for that year.

The species diversity index was calculated as $H' = - \sum P_i \log(P_i)$, where P_i is the proportion of the total population filled by each species (Shannon and Weaver 1963). This number is higher the more species are present and the more equal the populations of each, but does not depend on the total population. No attempt was made to compensate for the tendency of the known number of species to increase with the number of surveys, which affects the species diversity index, or to estimate uncertainty in these results. Observer differences might also affect species totals through the ability of a more experienced observer to identify uncommon species quickly. However, the data do not manifest any obvious variations due to survey effort or observers. Biomass estimates were derived from population estimates and published average individual weights of each species (Bock and Lynch 1970; Salt 1957; Wauer and Dennis 1980; Terres 1980).

Classification of each species into nesting and foraging guilds (Appendix 1) was determined by observations and known behavior (Ehrlich et al. 1988; Terres 1980). Four nesting guilds were distinguished: ground, cavity, foliage, and parasitic. Species were assigned to foraging guilds (Table 3) similar to those developed by Salt (1957), except that omnivores were placed in the category that best represents their primary consumption during the breeding season. These guilds represent both a kind of food gathered and a method of gathering it. Many species consume a variety of foods, e.g., both seeds and insects, and some gather it in a variety of

ways, but each species was assigned to a single guild for purposes of comparison. Western and mountain bluebirds and Townsend's solitaires (all of which habitually swoop from perches to insects near the ground) and house wrens (which often glean insects from downed wood) were moved from the foliage insect guild (Wauer and Johnson 1984) to the ground insect guild to better distinguish their foraging habits from the more arboreal habits of warblers and vireos. Foraging guilds were grouped into those of primary consumers (seed and nectar), insectivores (including crustaceans and other invertebrates gathered in a variety of ways), and predators.

Habitat use by non-breeding species is not comparable to use by breeding species, but may be significant. For non-breeding species, which do not nest but may forage on a transect, the mean survey count was used instead of the maximum as a reasonable estimate of presence, and hence foraging use. Only breeding species were included in analyses of species richness and diversity, population, biomass, and nesting guilds, but foraging use estimates for non-breeding species were combined with population estimates of breeding species in analysis of foraging guilds.

Potter and Foxx (1984) mapped foliar damage of trees in the La Mesa Fire area, and we used that information to assess the intensity and extent of the fire on and around each transect. Nearly all trees died in areas of crown fire (all needles consumed) or scorching fire (all needles browned), but many survived in areas of less intense ground fire (foliar damage classes 1-4). Browned needles, which subsequently fell to the ground and reduced erosion, indicate somewhat lower fire temperatures than consumed needles. The Escobas transect had the largest area of crown fire (one third). Combining areas of crown fire and scorching fire, Apache lost about one quarter of its forest, Escobas lost one third, and Burnt lost four fifths (Figure 2). Forest loss was proportionately greater on both the Apache and Burnt transects than in the surrounding areas, but it was similar in the case of Escobas.

Although the habitats on the 3 burned transects ranged from mixed conifer and ponderosa pine at higher elevations to ponderosa pine with pinyon-juniper at lower elevations (Table 1), and characteristics of the burn were different on each transect, their data were averaged. In a

broad sense, all burned transects were forested with a component of ponderosa pine, and were burned by an intense, uncontrolled fire. They were also examined individually for information on response of avifauna in the specific habitats to different burn characteristics. The only unburned transect was pinyon-juniper with ponderosa pine and we compared that to the 3 burned transects primarily as a check on methods, weather variations, and large scale trends. Finally, we have assumed orderly change to represent periods when transects were not surveyed. This is displayed graphically by straight lines connecting data of surveyed years.

RESULTS

Species Richness and Diversity

Overall, 85 species of birds were detected on a total of 89 transect surveys, including 71 breeding species, with 51 on Apache, 50 on Escobas, 51 on Burnt, and 38 on Frijoles. The average number of breeding species (richness) on the 3 burned transects temporarily increased the year after the fire, decreased the second year, increased from 2-6 years after the fire, and remained high thereafter. It followed the same pattern on each of the burned transects (Table 2), except that it did not increase the year after the fire on Escobas. The study period concluded with more breeding species on each burned transect than before the fire, increasing from 29 (only 1 survey) to 41 on Apache, 32 to 36 on Escobas, and from 32 to 37 on Burnt. In contrast, species richness on unburned Frijoles changed little, ranging from 29-31 throughout the study period.

Before the fire, the average breeding species diversity (H') on the 3 burned transects (Figure 3) was lower than on unburned Frijoles. Similar to changes in the number of breeding species, species diversity on the 3 burned transects temporarily increased the year after the fire, increased from 2-4 years after the fire, and remained high thereafter. Species diversity on the unburned Frijoles transect changed little. Each of the 3 burned transects had similar species

diversities before the fire and from 6-14 years after the fire, but differed during the period from 1-4 years after the fire, especially on Escobas, where diversity increased more slowly.

Population and Biomass

The average population of breeding birds on the 3 burned transects (Figure 4) dropped during the first 2 years after the fire, but recovered by the fourth year and remained high at the end of the study. In contrast, the population on unburned Frijoles was higher 1-4 years after the fire than before it, but thereafter declined to below its prefire level. Population trends on the 3 burned transects differed.

The Apache breeding bird population increased for 1-4 years after the fire (Figure 5), and declined slightly thereafter, but remained higher than immediately after the fire (the prefire population is uncertain). Some species, such as pygmy nuthatch and pine siskin, declined then recovered, while others, such as violet-green swallow and house wren, simply increased. Some species, such as mourning dove and several woodpeckers, were most common from 1-4 years after the fire.

The Escobas breeding bird population declined to a minimum 4 years after the fire, then increased to its highest level at the end of the study (Figure 5). Some species, such as hermit thrush and Virginia's warbler were immediately reduced by the fire, while others, such as solitary vireo and yellow-rumped warbler, experienced slower declines. Some species, such as violet-green swallow and western bluebird, increased fairly steadily. Others, such as acorn woodpecker and rufous-sided towhee, did not appear until 6 years after the fire, and then increased markedly.

The Burnt breeding bird population decreased for 1-2 years, increased markedly the fourth year, but declined thereafter, ending lower than before the fire (Figure 5). Some species, such as Hammond's flycatcher and Grace's warbler, were initially reduced by the fire, and remained low, while others, such as mountain bluebird and black-headed grosbeak, increased from 2-4 years after the fire, then declined.

The average standing crop biomass of breeding birds on the 3 burned transects and unburned Frijoles were similar before and for the first 2 years after the fire, both with a temporary increase in total biomass the year after the fire (Figure 5). However, the burned average biomass increased 4 years after the fire and remained higher than before the fire, while the unburned Frijoles biomass decreased and remained lower than at the beginning of the study. As with population, the burned average biomass was compiled from broadly similar changes on Apache and Burnt and markedly different changes on Escobas.

Comparison of population and total biomass (Figure 5) reveals average bird biomass (biomass/population) in the relative position of the two graphs. At the chosen scales, when the biomass graph falls on top of the population graph, average bird mass is 33 g, and when the biomass graph is lower than the population graph, average bird mass is lower. Average bird mass on the 3 burned transects increased from about 23 g before the fire to 30 g after, and has remained higher than before. This increase was greatest and persisted throughout the study period on Escobas and Burnt, but lasted only 2-4 years on Apache. On unburned Frijoles, the average bird size decreased from 1-4 years after the fire.

Nesting guilds

Overall, average populations in the nesting guilds on the 3 burned transects (Figure 6) were fairly steady except for a decreased number of foliage nesters the year after the fire and a temporary decrease in the number of cavity nesters 2 years after the fire. Parasitic nesters (solely the brown-headed cowbird) generally increased after the fire.

On Apache, where prefire data were not reliable, the population of ground nesters declined after the first postfire year, which was primarily due to a decline in dark-eyed juncos. Cavity nesters increased slightly but fairly steadily after the fire, due first to temporary increases in populations of several species of woodpeckers, then violet-green swallows, western bluebirds, and house wrens. Foliage nesters peaked 4 years after the fire, when populations of species such as warbling vireo and western tanager were highest.

On Escobas, changes in nesting guild populations were more dramatic. Populations of ground nesters, especially dark-eyed juncos, and cavity nesters, especially pygmy nuthatches and western bluebirds, were lowest 2 years after the fire, but foliage nesters were lowest 4 years after. Foliage nesters such as Hammond's flycatchers and Grace's warblers were still declining then, and increases in species such as broad-tailed hummingbird and Virginia's warbler had not yet overtaken those declines. The decline and recovery of foliage nesters took longest here, as some species were gradually replaced by others.

On Burnt, a dip in the population of cavity nesters occurred 2 years after the fire, as pygmy nuthatches suffered a delayed decline. Cavity nesters recovered from 2-4 years after the fire, led by western bluebirds and house wrens, but declined from 4-14 years after the fire, due to decreases in mountain bluebirds, black-headed grosbeaks and others. Foliage nesters also reached a low point 2 years after the fire, but increased from 2-4 years after the fire, led by rufous-sided towhees and lesser goldfinches.

On unburned Frijoles, ground nesters, especially Virginia's warblers, temporarily increased 2 years after the fire. Cavity nesters, such as western bluebirds, were actually less numerous 2-4 years after the fire than earlier or later, which is when they increased on Burnt. Foliage nesters, such as rufous-sided towhees and lesser goldfinches, were more numerous for 1-4 years after the fire. The parasitic nesting brown-headed cowbird increased more on this transect than on any other. Sometime from 4-14 years after the fire, ground and foliage nesting guilds declined to below their prefire populations, while cavity nesters maintained their numbers.

Foraging guilds

Primary consumers

Overall, populations of all primary consumers (ground seed, foliage seed, and foliage nectar guilds) on the 3 burned transects increased fairly steadily after the fire, except for a temporary decline in 1979 (Figure 7). The same pattern held on each of the 3 burned transects.

By the end of the study, each of the guilds of primary consumers had increased well above prefire levels. The decline in population 2 years after the fire and recovery 4 years afterward occurred mainly in the foliage seed guild on all 3 burned transects, especially among Steller's jays and pine siskins. The foliage nectar guild, solely the broad-tailed hummingbird, increased markedly on all 3 burned transects.

On Apache, where prefire data were not reliable, population of the ground seed guild decreased somewhat from the year after the fire until the end of the study, but still remained higher than the single count before the fire. Long-term growth in the foliage seed guild was led by red crossbills and pine siskins, which overcame a decline in evening grosbeaks.

On Escobas, population of the ground seed guild was slightly higher the year after the fire, but fell back and did not increase significantly until near the end of the study, due to marked increases in rufous-sided towhees and mourning doves. Long-term growth in the foliage seed guild was led by red crossbills.

On Burnt, population of the ground seed guild was lower the first 2 years after the fire, but increased by the fourth year, led by rufous-sided towhees and dark-eyed juncos. The dark-eyed junco had declined by the end of the study, but the mourning dove and rufous-sided and green-tailed towhee had increased more. Population of the foliage seed guild did not change much, and ended the study near its prefire level.

On unburned Frijoles, primary consumers temporarily increased for 1-4 years after the fire. Population of the ground seed guild, led by rufous-sided towhees, was higher for 2 years after the fire than before, but returned to its prefire level by the end of the study. The foliage seed guild was higher for 4 years after the fire, due primarily to higher numbers of lesser goldfinches. The foliage nectar guild was slightly higher during the whole period after the fire than before.

Insectivores

Overall, total populations of all insectivores (ground insect, timber drilling insect, timber searching insect, foliage insect, air perching insect, and air soaring insect guilds) on the 3 burned transects decreased the year after the fire, but changed little thereafter (Figure 8). However, only the timber drilling and timber searching insect guilds responded similarly on all 3 transects. Average timber drilling insect guild (woodpecker) populations increased during the first year after the fire, especially hairy and three-toed woodpeckers. At the same time, the timber searching insect guild (nuthatches) decreased for the first 2 years after the fire, and never recovered to prefire levels.

Overall, populations of the ground insect guild increased, as increases in western bluebirds and house wrens overwhelmed dramatic losses of hermit thrushes, but details differed among transects. The foliage insect guild decreased after the fire, due to loss of warbler habitat, but responses were different on the 3 burned transects. The air perching insect guild includes all the flycatchers and changed little, except for being lower the year after the fire, due primarily to decreases in *Empidonax* flycatchers, but that response was not universal. The air soaring insect guild is dominated by the violet-green swallow, and generally increased after the fire, but this did not occur everywhere either.

On Apache, where prefire data were not reliable, population of the ground insect guild appeared to decrease initially, then gradually increased, driven by a steady increase in western bluebirds. The foliage insect guild remained steady after the fire, but fell back at the end of the study, when warbling vireos and Grace's warblers decreased. The air perching insect guild remained fairly steady except for the year after the fire, but populations of Hammond's flycatchers and western wood-pewees varied and tended to compensate for each other. The air soaring insect guild increased fairly steadily.

On Escobas, population of the ground insect guild changed little before increasing in the final year of the study, due to a marked increase in western bluebirds. The foliage insect guild decreased initially, and again after 2 years, due to similar trends in yellow-rumped and Grace's warblers. Virginia's warblers, which were not found here for 2 years after the fire, increased

toward the end of the study, as the habitat became more shrubby. Unlike the other transects, the air perching insect guild did not decrease on Escobas the year after the fire, but it was lower 4-6 years later, due to decreases in Hammond's flycatchers. The air soaring insect guild increased slowly but steadily.

On Burnt, population of the ground insect guild was variable after the fire, except for being markedly higher from 4-6 years after the fire, due to the temporary appearance of many mountain bluebirds and lasting increases in house wrens and western bluebirds. The foliage insect guild was lowest the year after the fire, but fairly steady after that, as solitary vireos and Virginia's warblers increased the second year. The air perching insect guild not only declined temporarily the year after the fire, but declined again toward the end of the study, due to a decline in western wood-pewees. The air soaring insect guild decreased the year after the fire, rebounded, and subsequently declined slowly.

On unburned Frijoles, population of the ground insect guild decreased gradually through most of the study, but recovered at the end of the study, due to a marked increase in western bluebirds. The timber drilling insect guild was higher from 2-4 years after the fire. The foliage insect guild population was slightly higher for 1-4 years after the fire, especially plain titmice and black-throated gray warblers, neither of which occurred in the fire area. The air perching and air soaring insect guilds remained steady throughout the study.

Predators

The ground predator guild includes all raptors, even those that take their prey in the air. Population density estimates for these species are variable, as their territories are much larger than the transects, and a nest may be located on the transect one year and elsewhere the next. Nonetheless, enough species were involved that predator guild totals consistently increased on each of the 3 burned transects (Appendix 4). Raptor foraging populations did not change on unburned Frijoles. American kestrels were the most consistently found nesting raptor on each burned transect, and they increased especially 4-14 years after the fire.

DISCUSSION

Fire Effects

Apache was the least intensely burned transect, where about one quarter of the mainly mixed conifer forest was lost. This extent of burn seems to have resulted in increased diversity, with a relatively quick recovery of forest species. Although Burnt suffered much more extensive forest loss than Apache, about 80% compared to 25%, both transects experienced about the same amount of crown fire (Figure 2). The population on Burnt peaked during a window of time when snags were falling but still plentiful, and the ground was still open, and then declined as the snags disappeared and the habitat became more brushy.

Escobas experienced more forest loss than Apache and less than Burnt, and is located midway between the elevations of Apache and Burnt, but it had the largest area of crown fire. We found no other feature that separated Escobas from Apache and Burnt, and assume that this greater extent of crown fire accounts for the longer decline and slower recovery of the population on Escobas than on Apache or Burnt.

Bird biomass data indicate that, on average, more large and fewer small birds were found after the fire. The strength of the effect seems to be related to the extent of forest loss, as average mass increase was smallest and temporary on Apache, but continued through the end of the study on Burnt. Birds that are more suited to the more open habitat found after extensive forest loss, such as Lewis' woodpecker, tend to be larger, and birds that are suited to living among the branches of trees, such as Grace's warbler and pygmy nuthatch, tend to be smaller. While fewer small birds occupied the burned transects after the fire, more small birds occupied Frijoles for 1-4 years after the fire. However, this is evidently not directly related to the fire, as the only species that increased significantly on Frijoles while decreasing significantly on Burnt was the rufous-sided towhee, a larger than average bird. Two species that were not even present on the burned transects, black-throated gray warbler and plain titmouse also increased

significantly on unburned Frijoles. It is possible that weather conditions or deposition of airborne ash temporarily increased the biological productivity of the Frijoles transect.

Experience with Frijoles and other transects where the habitat was not changing suggests that annual population variations of as much as 20% are possible due to weather and other causes. Weather may cause some species to shift their breeding to higher or lower elevations in warmer and drier or colder and wetter seasons. For example, 1979 was a cold, wet season, and was the only year of our study that the ruby-crowned kinglet or orange-crowned warbler were found on Escobas or the warbling vireo or dark-eyed junco were found on Frijoles. Also, higher or lower productivity one year may affect breeding populations the next year. Pygmy nuthatches generally took 2 years to reach their lowest level on the 3 burned transects, while woodpecker populations took the same time to peak. The increase in numbers of woodpeckers on Frijoles from 2-4 years after the fire, seems like an overflow from the earlier and larger increase of woodpeckers on the burned transects.

A note of caution should be sounded concerning the possibility that long-term effects other than fire succession might be operating on the avifauna over the 14 years of this study. In particular, large scale trends in populations of neotropical migrants are in question. From 1981-1991, populations on Apache, Burnt, and Frijoles all declined, and only the population on Escobas increased. Because the transects were surveyed only 1 year after 1983, more data are needed to determine if any declines in neotropical migrants could be account for some of the population changes observed here.

Ecological relationships

The most obvious effect of a high intensity fire such as the La Mesa Fire is to kill trees, creating more open habitat and initiating a series of successional events. It is important to realize that none of the fire-killed trees were removed in Bandelier, and the presence of snags and downed logs benefited the avifauna (Moeur and Guthrie 1984). While site-specific ecological succession after the La Mesa Fire was to a large extent a function of the different

habitat of each transect and the different intensities and extents of forest loss each transect sustained, some generalities are apparent. These are summarized in Table 4.

Successional events began with the establishment of more herbaceous growth in the first 1-2 years, in both more open forested areas and in deforested areas with abundant snags. The year after the fire, perennial or annual grasses and forbs seeded artificially or naturally the year before often grew to gigantic proportions, fertilized by nutrients released by the fire. This may account for increased avian populations that year, which took place among primary consumers (Figure 7), but not among insectivores (Figure 8). Mortality of so many trees provided a short term benefit to woodpeckers, as insects proliferated within fire-killed trees, but evidently reduced the availability of insects on the bark, as nuthatches declined dramatically (Figure 8).

From 2-4 years after the fire, many snags fell, more structure was added to the ground, and the herbaceous layer became more fully developed. Bluebirds and house wrens benefited from these changes. Finally (in our study period), from 4-14 years after the fire, some snags persisted, understory shrubs grew in surviving forest patches, and brush developed in deforested areas. Primary consumers, such as towhees and hummingbirds, continued to increase, and species that utilize acorns, such as acorn woodpecker, appeared. Species associated with shrubs, such as Virginia's warbler and the towhees multiplied.

Not a single species of bird detected before the fire failed to be detected afterwards. On the other hand, by creating diversity in the physical habitat, the La Mesa Fire created openings for species that were not found there before the fire. Not counting rarely detected species, which are not adequately represented by just 1 year of prefire data, fully 11 breeding species that had not been found on the 3 burned transects before the fire were found there afterwards. These include the northern goshawk, American kestrel, Lewis' and acorn woodpecker, olive-sided flycatcher, rock, canyon and house wren, mountain bluebird, green-tailed towhee, and Cassin's finch. Populations of some species, such as Steller's jay, Townsend's solitaire, and American robin were generally little changed by the fire.

Habitat preferences of each species dictate where it will be found. Several examples illustrate this. The three-toed woodpecker prefers, and is able to find, recent burns. Before the fire, it was only found in a recent (1976) burn on one transect, whereas it was found on all 3 burned transects for 1-6 years after the fire. It was not detected on any transect 14 years afterwards. The mountain bluebird prefers open grassland situations, and was not found before the fire. Unlike the western bluebird, which increased the year after the fire, the mountain bluebird did not appear in numbers until 4-6 years afterwards, when snag fall had resulted in more open habitat. Like the three-toed woodpecker, it had disappeared by the end of the study, as brush had encroached on the grassland habitat. The green-tailed towhee, acorn and Lewis' woodpecker did not appear until 4-6 years after the fire, when some of the habitat became brushy, oaks became productive, and many old cavities became available in snags.

Predators increased, probably due to increased prey availability, as the northern goshawk, for example, nested near the Burnt transect 4 years after the fire, which was well below its normal nesting elevation. The spotted owl, which is generally viewed as an inhabitant of dense, old growth forests, was not detected in this daytime study but was known throughout the study period to inhabit canyons within the fire area where most of the forest was underburned. Spotted owls have also been heard at night in areas of adjacent mesas that were deforested by the fire, which still provide both hunting perches and abundant prey.

CONCLUSIONS

The avifauna adapted well to the changing conditions brought about by the 1977 La Mesa Fire. On each of the 3 burned transects, species richness and diversity increased. Prefire conditions generally included fairly uniform stands of dense, second-growth forest, which were variously replaced by more open forests or complete loss of forest. Species that lacked habitat before the fire found it in these new, varied conditions, while all of the species present before the fire continued to find some habitat afterwards.

The effect of the fire on the total avian breeding population depended on the severity of the burn. On Apache, where the burn was least severe and about one quarter of the forest was lost, the population increased. On Escobas, where the intensity of the fire was greatest (the most crown fire), and about one third of the forest was lost, the population declined for 4 years, then increased above its prefire level. On Burnt, where the fire intensity was not as great as on Escobas, but four fifths of the forest was lost, the population declined for 2 years, increased to peak after 4 years, then declined to a lower level than before the fire. By comparison, the population on unburned Frijoles was temporarily higher after the fire.

Several management lessons are apparent. Fire has beneficial effects on avian diversity, and moderate fire can increase populations. Up to 25% forest loss in a 40 ha transect (Apache) does not seem to affect total breeding bird populations, and provides habitat for a diverse avifauna, at least when fire-killed trees are left standing. Therefore, managers who are attempting to restore fire to the ecosystem should not be too concerned if 10 ha pockets of tree mortality occur during the process. However, intense crown fire (Escobas) appears to depress and delay recovery of bird populations, and extensive forest loss (Burnt) appears to result in a long-term lower population. In both cases, the resulting habitat still supports diverse bird populations, but crown fire and extensive forest loss should be avoided by implementing prescribed and natural fire plans to restore the role of fire as a natural ecosystem process.

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Table 1. Percent coverage of major vegetation types on four 40 ha bird transects before the La Mesa Fire. Data were derived from GIS analysis of Koehler (1974) and Potter and Foxx (1981) maps of prefire vegetation. Average transect elevations are in parentheses.

Vegetation type	Apache (2540 m.)	Escobas (2250 m.)	Burnt (2210 m.)	Frijoles (2030 m.)
Montane meadow	1			
Mixed conifer	51			
Ponderosa/mixed conifer	38	70		
Ponderosa pine	10	30	56	
Ponderosa/pinyon-juniper			44	41
Pinyon-juniper				59
Total	100	100	100	100

Table 2. Number of breeding species detected on each transect from 1977-1991. The number of surveys is listed in parentheses.

Transect	1977	1978	1979	1981	1983	1991
Apache	29 (1)	39 (5)	34 (3)	40 (5)	39 (6)	41 (3)
Escobas	32 (3)	31 (4)	30 (3)	34 (5)	39 (6)	36 (3)
Burnt	32 (4)	36 (5)	30 (3)	38 (4)	39 (5)	37 (3)
Frijoles	31 (5)	29 (3)	29 (4)	31 (3)	(0)	30 (3)
Average (total)	31 (13)	34 (17)	31 (13)	36 (17)	39 (17)	36 (12)

Table 3. Foraging guilds, modified from Salt (1957).

Consumer Category	Foraging guild	Abbreviation	Example
Primary hummingbird	Ground seed	GS	Mourning dove
	Foliage seed	FS	Red crossbill
	Foliage nectar	FN	Broad-tailed
Insectivore	Ground insect	GI	American robin
	Timber drilling insect	TDI	Hairy woodpecker
	Timber searching insect	TSI	White-breasted nuthatch
	Foliage insect	FI	Yellow-rumped warbler
	Air perching insect	API	Western wood-pewee
	Air soaring insect	ASI	Violet-green swallow
Predator	Ground predator	GP	Cooper's hawk

Table 4. Ecological succession after the La Mesa Fire.

<u>Period</u>	<u>Environmental change</u>	<u>Favored species</u>	<u>Disfavored species</u>
1-2 yrs	Forest and foliage loss		Pygmy nuthatch Mountain chickadee Ruby-crowned kinglet Orange-crowned warbler Grace's warbler Pine siskin
	Abundant snags, wood insects	Hairy woodpecker Three-toed woodpecker	
	Open understory	Western bluebird	Hermit thrush Virginia's warbler Rufous-sided towhee
	Abundant nutrients, vigorous herbaceous growth, seed production	Broad-tailed hummingbird Dark-eyed Junco	
	Increasing ground debris	House wren	
2-4 yrs	Falling snags, declining wood insects	Mountain bluebird Violet green swallow Olive-sided flycatcher	Hairy woodpecker Three-toed woodpecker
	Mature herbaceous layer, seed production	Mourning dove	
	Shrubs developing	Virginia's warbler	
4-14 yrs	Shrubs, aspen maturing, most snags fallen	Dusky flycatcher Rufous-sided towhee Green-tailed towhee	Mountain bluebird
	Tree foliage recovering	Pygmy nuthatch Grace's warbler	
	Acorn production	Acorn woodpecker Lewis' woodpecker	

FIGURE CAPTIONS

Figure 1. Average dependence of the maximum count on the number of surveys performed. The maximum count was measured by the number of standard deviations by which it exceeded the mean, which was similar for all species. Combining all species and transects, this plot shows the average value of the maximum count for 3 surveys ($n = 373$), 4 surveys ($n = 151$), 5 surveys ($n = 242$), and 6 surveys ($n = 82$). Error brackets display a range of plus or minus 1 standard error. An exponential approach to a limit was assumed, and the population of each breeding species was estimated as the mean plus 1.58 standard deviations of the sample count, which is unbiased by the number of surveys.

Figure 2. Relative extent and intensity of the La Mesa Fire on the 3 burned 40 ha transects and on 300 ha surrounding and including the transects. Nearly all trees died on both scorched and crowned areas, but the fire consumed all needles in the crowned areas. Data were derived from GIS analysis of the Potter and Foxx (1984) map of foliar damage.

Figure 3. Shannon diversity index for populations of breeding birds on the 3 burned transects (Apache, Escobas, and Burnt) and the unburned Frijoles transect from 1977-1991. Dependence of diversity on species richness and hence the number of surveys performed (Table 2) precludes calculating standard errors for these data.

Figure 4. Population of breeding birds on the 3 burned transects (Apache, Escobas, and Burnt) and the unburned Frijoles transect from 1977-1991. Error bars display a range of plus or minus 1 standard error in the population estimates.

Figure 5. Population and biomass for populations of breeding birds on the 3 burned transects (Apache, Escobas, and Burnt) and each individual transect from 1977-1991. Error bars display a range of plus or minus 1 standard error in the population and biomass estimates. Apache data for 1977 were based on only 1 survey, and underestimate prefire values.

Figure 6. Populations of breeding bird nesting guilds on the 3 burned transects (Apache, Escobas, and Burnt) and each individual transect from 1977-1991. Apache data for 1977 were based on only 1 survey, and underestimate prefire values.

Figure 7. Populations of 3 avian primary foraging guilds on the 3 burned transects (Apache, Escobas, and Burnt) and each individual transect from 1977-1991. Apache data for 1977 were based on only 1 survey, and underestimate prefire values.

Figure 8. Populations of 6 avian insect foraging guilds on the 3 burned transects (Apache, Escobas, and Burnt) and each individual transect from 1977-1991. Apache data for 1977 were based on only 1 survey, and underestimate prefire values.

APPENDICES

Appendix 1. Avifauna species data. Foraging guild abbreviations are listed in Table 3.

Area is the effective survey area, which depends on the detectability of each species.

Common name	Latin name	Weight (g)	Nesting Guild	Foraging Guild	Area (ha)
Turkey Vulture	<i>Cathartus aura</i>	2030.0	Ground	GP	40
Sharp-shinned Hawk	<i>Accipiter striatus</i>	177.0	Foliage	GP	40
Cooper's Hawk	<i>Accipiter cooperii</i>	428.5	Foliage	GP	40
Northern Goshawk	<i>Accipiter gentilis</i>	937.5	Foliage	GP	40
Red-tailed Hawk	<i>Buteo jamaicensis</i>	1105.0	Foliage	GP	40
American Kestrel	<i>Falco sparverius</i>	113.5	Cavity	GP	40
Peregrine Falcon	<i>Falco peregrinus</i>	699.0	Cavity	GP	40
Band-tailed Pigeon	<i>Columba fasciata</i>	406.0	Foliage	GS	40
Mourning Dove	<i>Zenaida macroura</i>	137.5	Foliage	GS	40
Great Horned Owl	<i>Bubo virginianus</i>	1971.0	Cavity	GP	20
Northern Pygmy-Owl	<i>Glaucidium gnoma</i>	52.5	Cavity	GP	30
Common Nighthawk	<i>Chordeiles minor</i>	80.0	Ground	ASI	30
Common Poorwill	<i>Phalaenotilus nuttallii</i>	47.3	Ground	GI	20
White-throated swift	<i>Aeronautes saxatalis</i>	14.5	Cavity	ASI	30
Black-chinned Hummingbird	<i>Archilochus alexandri</i>	2.5	Foliage	FN	20
Broad-tailed Hummingbird	<i>Selasphorus platycercus</i>	4.0	Foliage	FN	20
Lewis' Woodpecker	<i>Melanerpes lewis</i>	138.0	Cavity	TDI	30
Red-headed Woodpecker	<i>Melanerpes erythrocephalus</i>	73.2	Cavity	TDI	40
Acorn Woodpecker	<i>Melanerpes formicivorus</i>	67.4	Cavity	TDI	40
Red-naped Sapsucker	<i>Sphyrapicus nuchalis</i>	45.0	Cavity	TDI	40
Williamson's Sapsucker	<i>Sphyrapicus thyroides</i>	61.5	Cavity	TDI	40
Downy Woodpecker	<i>Picoides pubescens</i>	26.5	Cavity	TDI	30
Hairy Woodpecker	<i>Picoides villosus</i>	69.8	Cavity	TDI	30
Three-toed Woodpecker	<i>Picoides tridactylus</i>	62.0	Cavity	TDI	30
Northern Flicker	<i>Colaptes auratus</i>	145.0	Cavity	GI	40
Olive-sided Flycatcher	<i>Contopus borealis</i>	31.5	Foliage	API	40
Western Wood-Pewee	<i>Contopus sordidulus</i>	14.0	Foliage	API	30
Hammond's Flycatcher	<i>Empidonax hammondii</i>	12.1	Foliage	API	20
Dusky Flycatcher	<i>Empidonax oberholseri</i>	12.5	Foliage	API	20
Gray Flycatcher	<i>Empidonax wrightii</i>	12.6	Foliage	API	30
Cordilleran Flycatcher	<i>Empidonax occidentalis</i>	12.5	Cavity	API	30
Say's Phoebe	<i>Sayornis saya</i>	18.8	Cavity	API	40
Ash-throated Flycatcher	<i>Myiarchus cinerascens</i>	27.6	Cavity	API	30

Cassin's Kingbird	<i>Tyrannus vociferans</i>	45.4	Foliage	ASI	40
Violet-green Swallow	<i>Tachycineta thalassina</i>	10.6	Cavity	ASI	20
Cliff Swallow	<i>Hirundo pyrrhonota</i>	12.5	Cavity	ASI	30
Steller's Jay	<i>Cyanocitta stelleri</i>	106.5	Foliage	FS	40
Scrub Jay	<i>Aphelocoma coerulescens</i>	72.0	Foliage	FS	40
Pinyon Jay	<i>Gymnorhinus cyanocephalus</i>	108.0	Foliage	FS	40
Clark's Nutcracker	<i>Nucifraga columbiana</i>	130.0	Foliage	FS	40
Common Raven	<i>Corvus corax</i>	1027.0	Cavity	GP	40
Mountain Chickadee	<i>Parus gambeli</i>	11.5	Foliage	TSI	20
Plain Titmouse	<i>Parus inornatus</i>	15.0	Foliage	FI	30
Bushtit	<i>Psaltiriparus minimus</i>	5.8	Foliage	FI	20
Red-breasted Nuthatch	<i>Sitta canadensis</i>	10.1	Cavity	TSI	30
White-breasted Nuthatch	<i>Sitta carolinensis</i>	18.0	Cavity	TSI	30
Pygmy Nuthatch	<i>Sitta pygmaea</i>	10.0	Cavity	TSI	20
Brown Creeper	<i>Cethia americana</i>	7.7	Cavity	TSI	20
Rock Wren	<i>Salpinctes obsoletus</i>	16.4	Ground	GI	30
Canyon Wren	<i>Catherpes mexicanus</i>	16.0	Ground	GI	30
Bewick's Wren	<i>Thryomanes bewickii</i>	10.1	Cavity	FI	30
House Wren	<i>Troglodytes aedon</i>	10.0	Cavity	GI	40
Golden-crowned Kinglet	<i>Regulus satrapa</i>	5.1	Foliage	FI	20
Ruby-crowned Kinglet	<i>Regulus calendula</i>	6.1	Foliage	FI	30
Blue-gray Gnatcatcher	<i>Poliophtila caerulea</i>	5.0	Foliage	FI	20
Western Bluebird	<i>Sialia mexicana</i>	24.6	Cavity	GI	30
Mountain Bluebird	<i>Sialia currucoides</i>	26.6	Cavity	GI	30
Townsend's Solitaire	<i>Myadestes townsendi</i>	32.0	Cavity	GI	30
Hermit Thrush	<i>Catharus guttatus</i>	25.6	Foliage	GI	30
American Robin	<i>Turdus migratorius</i>	88.0	Foliage	GI	40
Solitary Vireo	<i>Vireo solitarius</i>	15.3	Foliage	FI	30
Warbling Vireo	<i>Vireo gilvus</i>	11.3	Foliage	FI	30
Orange-crowned Warbler	<i>Vermivora celata</i>	9.6	Foliage	FI	30
Virginia's Warbler	<i>Vermivora virginiae</i>	8.4	Ground	FI	20
Yellow Warbler	<i>Dendroica petechia</i>	9.3	Foliage	FI	30
Yellow-rumped Warbler	<i>Dendroica coronata</i>	13.1	Foliage	FI	30
Black-throated Gray Warbler	<i>Dendroica nigrescens</i>	7.5	Foliage	FI	30
Grace's Warbler	<i>Dendroica graciae</i>	7.5	Foliage	FI	20
MacGillivray's Warbler	<i>Oporornis tolmiei</i>	10.8	Foliage	FI	30
Hepatic Tanager	<i>Piranga flava</i>	40.0	Foliage	FI	40
Western Tanager	<i>Piranga ludoviciana</i>	29.0	Foliage	FI	30
Black-headed Grosbeak	<i>Pheucticus melanocephalus</i>	46.0	Foliage	FI	40
Green-tailed Towhee	<i>Pipilo chlorurus</i>	34.0	Foliage	GS	40
Rufous-sided Towhee	<i>Pipilo erythrophthalmus</i>	39.0	Foliage	GS	30
Canyon Towhee	<i>Pipilo fuscus</i>	45.9	Ground	GS	40
Chipping Sparrow	<i>Spizella passerina</i>	12.2	Foliage	GI	30
Dark-eyed Junco	<i>Junco hyemalis</i>	20.3	Ground	GS	30
Brewer's Blackbird	<i>Euphagus cyanocephalus</i>	65.1	Ground	GI	30
Brown-headed Cowbird	<i>Molothrus ater</i>	34.8	Parasitic	GS	30

Cassin's Finch	<i>Carpodacus cassinii</i>	27.6	Foliage	FS	40
House Finch	<i>Carpodacus mexicanus</i>	19.3	Foliage	FS	40
Red Crossbill	<i>Loxia curvirostra</i>	38.5	Foliage	FS	30
Pine Siskin	<i>Carduelis pinus</i>	12.1	Foliage	FS	30
Lesser Goldfinch	<i>Carduelis psaltria</i>	8.7	Foliage	FS	30
Evening Grosbeak	<i>Coccothraustes vespertinus</i>	64.2	Foliage	FS	30

Appendix 2: Survey data (birds/40 ha). An asterisk marks each transect where a species breeds. Statistical uncertainty in each population estimate is indicated by plus or minus 1 standard error, except on Apache in 1977, where only 1 prefire survey occurred.

Species	Breed	Transect	1977	1978	1979	1981	1983	1991
Turkey Vulture		Apache	0	0.2 $\pm$.2	0.3 $\pm$.3	0	0	0.7 $\pm$.3
		Escobas	0	0	0	0	0	0
		Burnt	0	0	0	0	0	2 $\pm$.3
		Frijoles	0	0	0.3 $\pm$.3	0.7 $\pm$.3	-	0.7 $\pm$.7
Sharp-shinned Hawk	*	Apache	0	0	0	0	0.8 $\pm$.3	0
		Escobas	0	0	0	0	0	0
		Burnt	0	0	0	0	0	0.3 $\pm$.3
		Frijoles	0	0	0	0	-	0
Cooper's Hawk	*	Apache	0	0	0	0	0	1 $\pm$.7
	*	Escobas	0	0	2 $\pm$ 1	0.9 $\pm$.4	2 $\pm$.7	0
	*	Burnt	1 $\pm$.5	0.9 $\pm$.4	0	0	0	0
		Frijoles	0	0	0	0	-	0.3 $\pm$.3
Northern Goshawk	*	Apache	0	0	1 $\pm$.7	0	0	0
		Escobas	0	0	0	0	0	0
	*	Burnt	0	0	0	3 $\pm$ 1	0	0
		Frijoles	0	0	0	0	-	0
Red-tailed Hawk		Apache	0	0	0	0	0	0
		Escobas	0	0	0	0	0	0.3 $\pm$.3
		Burnt	0.3 $\pm$.3	0	0	0.3 $\pm$.3	0.4 $\pm$.2	0
		Frijoles	0	0	0	0	-	0
American Kestrel	*	Apache	0	0	0	0	0	3 $\pm$.7
	*	Escobas	0	0	0	3 $\pm$ 1	2 $\pm$ 0	2 $\pm$.7
	*	Burnt	0	0.9 $\pm$.4	0	3 $\pm$ 1	5 $\pm$.8	3 $\pm$.7
		Frijoles	0.2 $\pm$.2	0	0	0	-	1 $\pm$ 0
Peregrine Falcon		Apache	0	0	0	0	0	0
		Escobas	0	0	0	0	0	0
		Burnt	0	0.2 $\pm$.2	0	0	0	0
		Frijoles	0.2 $\pm$.2	0	0	0	-	0
Band-tailed Pigeon		Apache	0	0	5 $\pm$ 5	0	0.3 $\pm$.3	0
		Escobas	0.7 $\pm$.7	0	0	0	0.5 $\pm$.5	0
		Burnt	0	0	0	0	0	0.3 $\pm$.3
		Frijoles	0	0	0	0	-	0
Mourning Dove	*	Apache	0	0	2 $\pm$ 1	5 $\pm$ 2	2 $\pm$.8	2 $\pm$.7
	*	Escobas	3 $\pm$ 1	0	3 $\pm$ 1	0	0	11 $\pm$ 4
	*	Burnt	7 $\pm$ 3	4 $\pm$ 2	2 $\pm$ 0	5 $\pm$ 2	3 $\pm$ 1	11 $\pm$ 4

Great Horned Owl	* Frijoles	14 ±4	13 ±6	10 ±3	2 ±1	-	7 ±2
	Apache	0	0	0	0	0	0
	Escobas	0	0	0	0	0	0
	Burnt	0	0	0	0.5 ±.5	0	0
Northern Pygmy-Owl	Frijoles	0	0	0	0	-	0
	* Apache	0	0	0	0	0	0
	Escobas	0	0	0	0	0	0
	* Burnt	3 ±1	0	0	0	0	0
Common Nighthawk	* Frijoles	0	3 ±2	0	0	-	0
	Apache	0	0	0	0	0	0
	* Escobas	0	0	0	0	4 ±2	8 ±5
	* Burnt	3 ±1	0	3 ±2	4 ±2	0	2 ±1
Common Poorwill	* Frijoles	0	0	0	3 ±2	-	0
	Apache	0	0	0	0	0	0
	Escobas	0	0	0	0	0	0
	* Burnt	0	0	0	0	0	5 ±3
White-throated swift	* Frijoles	4 ±2	0	0	0	-	0
	Apache	3+	0	0.9 ±.9	0	0	0
	Escobas	0	0	0	0	0	0
	Burnt	0.7 ±.7	0.3 ±.3	2 ±.9	1 ±.6	0	0
Black-chinned Hummingbird	Frijoles	2 ±.8	1 ±.8	0	0.9 ±.9	-	0.4 ±.4
	Apache	0	0	0	0	0	0
	Escobas	0	0	0	0	0	0
	Burnt	0	0	0	0	0	0
Broad-tailed Hummingbird	Frijoles	0	0	0	0	-	0.7 ±.7
	* Apache	4+	11 ±4	9 ±3	5 ±2	12 ±4	18 ±5
	* Escobas	3 ±1	11 ±5	10 ±3	8 ±3	14 ±4	34 ±12
	* Burnt	11 ±2	26 ±8	25 ±10	28 ±10	16 ±3	32 ±6
Lewis' Woodpecker	* Frijoles	15 ±2	16 ±5	34 ±9	18 ±5	-	24 ±9
	Apache	0	0	0	0	0	0
	Escobas	0	0	0	0	0	0
	* Burnt	0	0	0	0	2 ±1	8 ±3
Red-headed Woodpecker	Frijoles	0	0	0	0	-	0
	Apache	0	0	0	0	0	0
	* Escobas	0	0	0	2 ±.8	0	0
	Burnt	0	0	0	0	0	0
Acorn Woodpecker	Frijoles	0	0	0	0	-	0
	Apache	0	0	0	0	0	0
	* Escobas	0	0	0	0	2 ±1	13 ±3
	* Burnt	0	0	0	0	4 ±2	4 ±1
Red-naped Sapsucker	Frijoles	0	0	0.3 ±.3	0	-	0
	* Apache	0	2 ±.8	0	2 ±.8	0	0
	Escobas	0	0	0	0	0	0
	Burnt	0	0	0	0	0	0
	Frijoles	0	0	0	0	-	0

Williamson's Sapsucker	* Apache	12+	9 ±3	5 ±1	4 ±.8	11 ±1	2 ±.7
	* Escobas	0	8 ±4	0	0	2 ±.8	0
	Burnt	0	0	0	0	0	0
	Frijoles	0	0	0	0	-	0
Downy Woodpecker	* Apache	3+	5 ±2	0	0	0	3 ±2
	Escobas	0	0	0	0	0	0
	Burnt	0	0	0	0	0	0
	Frijoles	0	0	0	0	-	0
Hairy Woodpecker	* Apache	4+	19 ±4	26 ±12	17 ±4	7 ±2	15 ±5
	* Escobas	5 ±2	19 ±8	23 ±6	17 ±5	8 ±1	8 ±3
	* Burnt	11 ±4	26 ±9	29 ±6	16 ±3	10 ±2	6 ±3
	* Frijoles	6 ±1	5 ±0	14 ±6	11 ±5	-	3 ±1
Three-toed Woodpecker	* Apache	0	8 ±3	11 ±5	5 ±2	3 ±1	0
	* Escobas	2 ±1	0	13 ±7	4 ±1	9 ±2	0
	* Burnt	0	2 ±1	4 ±2	0	5 ±2	0
	Frijoles	0	0	0	0	-	0
Northern Flicker	* Apache	0	6 ±2	15 ±6	6 ±2	7 ±2	7 ±2
	* Escobas	4 ±2	14 ±6	5 ±3	8 ±2	10 ±2	6 ±1
	* Burnt	6 ±2	7 ±2	2 ±1	5 ±2	12 ±3	7 ±3
	* Frijoles	6 ±2	2 ±1	7 ±3	0	-	3 ±.7
Olive-sided Flycatcher	* Apache	0	2 ±.8	0	7 ±2	6 ±2	1 ±.7
	* Escobas	0	3 ±1	2 ±1	3 ±1	2 ±.7	3 ±1
	* Burnt	0	0	0	3 ±1	2 ±0	1 ±.7
	Frijoles	0	0	0	0	-	0.3 ±.3
Western Wood-Pewee	* Apache	3+	6 ±2	5 ±3	28 ±7	29 ±4	6 ±3
	* Escobas	13 ±8	6 ±2	15 ±7	9 ±2	19 ±4	19 ±3
	* Burnt	14 ±5	15 ±5	29 ±12	33 ±7	22 ±6	9 ±3
	* Frijoles	15 ±5	7 ±2	6 ±2	10 ±5	-	6 ±1
Hammond's Flycatcher	* Apache	42+	23 ±5	61 ±23	22 ±5	42 ±7	25 ±3
	* Escobas	30 ±5	57 ±22	59 ±10	40 ±8	21 ±6	31 ±6
	* Burnt	35 ±12	16 ±3	13 ±3	8 ±2	12 ±4	13 ±4
	* Frijoles	0	0	0	0	-	7 ±4
Dusky Flycatcher	* Apache	0	0	0	0	0	15 ±6
	* Escobas	16 ±8	0	0	0	0	17 ±6
	* Burnt	4 ±2	0	0	0	0	0
	Frijoles	0	0	0	0	-	0
Gray Flycatcher	Apache	0	0	0	0	0	0
	Escobas	0	0	0	0	0	0
	Burnt	0	0	0	0	0	0
	* Frijoles	30 ±6	38 ±9	41 ±9	36 ±13	-	24 ±4
Cordilleran Flycatcher	* Apache	11+	6 ±2	12 ±6	12 ±3	4 ±.9	5 ±3
	* Escobas	12 ±4	6 ±3	0	0	2 ±.9	0
	* Burnt	0	2 ±1	3 ±2	3 ±1	0	0
	Frijoles	0	0	0	0	-	0
Say's Phoebe	Apache	0	0	0	0	0	0
	Escobas	0	0	0	0	0	0

Ash-throated Flycatcher	Burnt	0	0	0	0	0	0
	Frijoles	0	0	0	0	-	0.3 ±.3
	Apache	0	0	0	0	0	0
	* Escobas	0	3 ±1	0	0	0	0
	* Burnt	14 ±7	6 ±2	4 ±2	4 ±2	2 ±1	1 ±0
Cassin's Kingbird	* Frijoles	21 ±7	21 ±6	17 ±5	12 ±2	-	21 ±3
	Apache	0	0	0	0	0	0
	Escobas	0	0	0	0	0	0
	* Burnt	0	0	0	0	0	2 ±0
	Frijoles	0	0	0	0	-	0
Violet-green Swallow	* Apache	8+	15 ±6	16 ±8	29 ±10	38 ±7	35 ±13
	* Escobas	15 ±4	10 ±3	12 ±4	23 ±6	22 ±4	32 ±9
	* Burnt	51 ±9	24 ±8	56 ±15	45 ±7	42 ±4	27 ±5
	* Frijoles	24 ±9	16 ±4	18 ±2	18 ±5	-	19 ±3
	Apache	0	0	0	0	0	0
Cliff Swallow	Escobas	0	0	0	0	0	0
	Burnt	0	0	0	0	0	0
	Frijoles	0	0.4 ±.4	0	0	-	0
	* Apache	2+	24 ±8	4 ±1	11 ±3	5 ±.8	13 ±3
	* Escobas	8 ±4	18 ±7	7 ±3	12 ±3	12 ±2	14 ±5
Steller's Jay	* Burnt	17 ±6	19 ±7	12 ±7	12 ±4	21 ±5	11 ±2
	Frijoles	0	0	0.3 ±.3	0	-	0
	Apache	0	0	0	0	0	0
	Escobas	0	0	0	0	0	0
	* Burnt	0	0	0	0	3 ±1	2 ±.7
Scrub Jay	* Frijoles	13 ±3	17 ±4	17 ±6	13 ±3	-	13 ±3
	Apache	0	0	0	0	0	0
	Escobas	0	0	0	0	0	0
	Burnt	0	0	3 ±3	0	0	0
	Frijoles	1 ±1	0	1 ±.9	0	-	0.3 ±.3
Clark's Nutcracker	* Apache	0	0.9 ±.4	0	7 ±3	2 ±.7	3 ±1
	* Escobas	0	1 ±.5	0	1 ±.5	2 ±.8	3 ±1
	Burnt	0.3 ±.3	2 ±1	0	1 ±.4	0.2 ±.2	5 ±2
	Frijoles	0.2 ±.2	2 ±.3	0.3 ±.3	0.3 ±.3	-	0
	Apache	1+	0.4 ±.2	1 ±.6	0.6 ±.2	0.8 ±.4	0.7 ±.3
Common Raven	Escobas	0.3 ±.3	1 ±.4	0.3 ±.3	0.6 ±.2	1 ±.4	1 ±.6
	Burnt	0.3 ±.3	1 ±0	0.3 ±.3	0.3 ±.3	0	2 ±.7
	Frijoles	1 ±.4	1 ±0	0.5 ±.5	0.3 ±.3	-	0.7 ±.7
	* Apache	46+	15 ±3	27 ±15	26 ±8	13 ±3	24 ±5
	* Escobas	24 ±9	6 ±2	5 ±3	4 ±2	0	3 ±1
Mountain Chickadee	* Burnt	22 ±8	0	0	4 ±2	5 ±2	7 ±4
	* Frijoles	13 ±4	18 ±5	10 ±2	14 ±6	-	7 ±3
	Apache	0	0	0	0	0	0
	Escobas	0	0	0	0	0	0
	Burnt	0	0	0	0	0	0
Plain Titmouse	* Frijoles	16 ±4	44 ±18	14 ±3	34 ±15	-	15 ±2

Bushtit	Apache	0	0	0	0	0	0
	Escobas	0	0	0	0	0	0
	Burnt	0	0	0	0	0	0
	* Frijoles	2 ±.8	5 ±3	4 ±2	10 ±5	-	3 ±1
Red-breasted Nuthatch	* Apache	0	3 ±1	3 ±2	5 ±2	2 ±.9	5 ±3
	Escobas	0	0	0	0	0	0
	Burnt	0	0	0	0	0	0
	Frijoles	0	0	0	0	-	0
White-breasted Nuthatch	* Apache	3+	2 ±1	3 ±2	15 ±6	5 ±1	3 ±1
	* Escobas	9 ±3	8 ±4	0	8 ±2	12 ±4	10 ±2
	* Burnt	6 ±3	5 ±2	8 ±4	17 ±5	11 ±3	8 ±3
	* Frijoles	9 ±3	12 ±3	11 ±3	3 ±0	-	0
Pygmy Nuthatch	* Apache	52+	31 ±9	10 ±5	18 ±3	29 ±8	55 ±8
	* Escobas	77 ±18	48 ±15	19 ±8	29 ±6	19 ±3	57 ±13
	* Burnt	71 ±3	54 ±17	18 ±5	28 ±6	17 ±5	17 ±3
	* Frijoles	17 ±4	21 ±6	6 ±2	10 ±5	-	16 ±0
Brown Creeper	* Apache	4+	8 ±3	5 ±3	10 ±4	5 ±2	5 ±1
	* Escobas	2 ±1	0	0	0	3 ±1	0
	Burnt	0	0	0	0	0	0
	Frijoles	0	0	0	0	-	0
Rock Wren	Apache	0	0	0	0	0	0
	Escobas	0	0	0	0	0	0
	* Burnt	0	0	3 ±2	4 ±2	4 ±1	0
	* Frijoles	0	0	4 ±2	3 ±2	-	0
Canyon Wren	Apache	0	0	0	0	0	0
	Escobas	0	0	0	0	0	0
	* Burnt	0	2 ±1	0	0	3 ±1	3 ±1
	Frijoles	0	0	0	0	-	0
Bewick's Wren	Apache	0	0	0	0	0	0
	Escobas	0	0	0	0	0	0
	Burnt	0	0	0	0	0	0
	* Frijoles	1 ±.5	0	0	3 ±2	-	0
House Wren	* Apache	0	14 ±2	26 ±9	28 ±3	33 ±4	34 ±12
	* Escobas	0	21 ±8	25 ±7	16 ±2	18 ±2	20 ±3
	* Burnt	0	6 ±2	5 ±3	19 ±1	27 ±4	16 ±4
	Frijoles	0	0	0	0	-	0
Golden-crowned Kinglet	* Apache	0	4 ±2	0	0	0	0
	* Escobas	6 ±3	0	0	0	0	0
	Burnt	0	0	0	0	0	0
	Frijoles	0	0	0	0	-	0
Ruby-crowned Kinglet	* Apache	21+	14 ±6	10 ±2	6 ±2	5 ±2	7 ±1
	* Escobas	0	0	3 ±2	0	0	0
	Burnt	0	0	0	0	0	0
	Frijoles	0	0	0.3 ±.3	0	-	0
Blue-gray Gnatcatcher	Apache	0	0	0	0	0	0
	Escobas	0	0	0	0	0	0

	* Burnt	0	4 ±2	0	0	0	0
	* Frijoles	19 ±6	14 ±6	21 ±6	18 ±5	-	5 ±3
Western Bluebird	* Apache	0	2 ±1	3 ±2	8 ±1	11 ±2	24 ±9
	* Escobas	5 ±3	18 ±8	9 ±1	20 ±5	28 ±5	53 ±10
	* Burnt	11 ±4	24 ±7	7 ±2	34 ±4	42 ±10	31 ±4
	* Frijoles	12 ±3	18 ±9	4 ±1	3 ±0	-	27 ±7
Mountain Bluebird	* Apache	0	0	0	2 ±1	0	0
	* Escobas	0	0	0	0	2 ±.9	0
	* Burnt	0	2 ±1	0	20 ±7	14 ±5	0
	Frijoles	0	0	0	0	-	0
Townsend's Solitaire	* Apache	3+	10 ±4	3 ±2	6 ±2	11 ±3	0
	* Escobas	5 ±3	6 ±2	7 ±2	4 ±1	4 ±1	3 ±2
	* Burnt	3 ±0	9 ±3	3 ±0	3 ±1	2 ±1	0
	Frijoles	0	0	0	0	-	0
Hermit Thrush	* Apache	44+	10 ±3	11 ±2	12 ±2	12 ±3	8 ±3
	* Escobas	39 ±12	8 ±3	7 ±2	4 ±1	3 ±1	0
	* Burnt	28 ±10	6 ±2	0	6 ±3	0	0
	Frijoles	0.3 ±.3	0	1 ±1	0	-	0.4 ±.4
American Robin	* Apache	10+	10 ±3	2 ±0	6 ±2	7 ±2	7 ±1
	* Escobas	6 ±2	3 ±1	8 ±3	2 ±.8	4 ±1	7 ±1
	* Burnt	0	7 ±3	0	6 ±3	7 ±2	4 ±1
	* Frijoles	7 ±2	0	0	4 ±2	-	6 ±2
Solitary Vireo	* Apache	5+	2 ±1	7 ±3	10 ±3	11 ±2	5 ±1
	* Escobas	20 ±7	17 ±4	25 ±6	16 ±6	9 ±2	12 ±3
	* Burnt	13 ±2	8 ±3	18 ±4	19 ±4	11 ±2	8 ±1
	* Frijoles	12 ±3	12 ±3	19 ±5	7 ±4	-	2 ±1
Warbling Vireo	* Apache	27+	28 ±9	26 ±8	42 ±8	30 ±7	13 ±2
	* Escobas	2 ±1	6 ±3	10 ±5	6 ±2	0	1 ±0
	* Burnt	0	0	3 ±2	7 ±3	0	5 ±3
	Frijoles	0	0	0.7 ±.7	0	-	0
Orange-crowned Warbler	* Apache	11+	2 ±1	3 ±0	4 ±1	0	6 ±2
	* Escobas	0	0	3 ±2	0	0	0
	Burnt	0	0	0	0	0	0.4 ±.4
	Frijoles	0	0	0	0	-	0
Virginia's Warbler	* Apache	8+	0	0	8 ±3	0	3 ±1
	* Escobas	21 ±10	0	0	6 ±2	12 ±3	15 ±5
	* Burnt	26 ±9	8 ±3	14 ±3	14 ±5	8 ±3	32 ±7
	* Frijoles	13 ±4	5 ±3	25 ±12	10 ±6	-	5 ±3
Yellow Warbler	Apache	0	0	0	0	0	0
	Escobas	0	0	0	0	0	0
	Burnt	0	0	0	0.3 ±.3	0	0
	Frijoles	0	0	0	0	-	0
Yellow-rumped Warbler	* Apache	27+	40 ±10	37 ±11	24 ±4	29 ±4	24 ±9
	* Escobas	29 ±10	13 ±3	18 ±5	4 ±1	7 ±2	3 ±1
	* Burnt	6 ±2	5 ±2	7 ±4	6 ±2	18 ±6	2 ±1
	Frijoles	4 ±3	3 ±3	0	0	-	0

Black-throated Gray Warbler	Apache	0	0	0	0	0	0
	Escobas	0	0	0	0	0	0
	Burnt	0	0	0	0	0	0
	* Frijoles	5 ±2	23 ±10	21 ±7	23 ±10	-	6 ±1
Grace's Warbler	* Apache	0	16 ±4	26 ±10	16 ±3	16 ±4	0
	* Escobas	39 ±15	28 ±9	33 ±15	12 ±3	11 ±3	29 ±3
	* Burnt	40 ±7	11 ±3	14 ±5	8 ±2	5 ±2	13 ±4
	* Frijoles	12 ±4	10 ±5	13 ±3	11 ±5	-	11 ±3
MacGillivray's Warbler	Apache	0	0	0	0	0	0
	Escobas	0	0	0	0	0	0
	Burnt	0	0	0	0	0	0.4 ±.4
	Frijoles	0	0	0	0	-	0
Hepatic Tanager	Apache	0	0	0	0	0	0
	Escobas	0	0	0	0	0	0
	Burnt	0	0	0	0	0	0
	* Frijoles	3 ±.8	0	0	3 ±1	-	2 ±.7
Western Tanager	* Apache	5+	12 ±4	16 ±4	19 ±2	18 ±4	11 ±5
	* Escobas	10 ±4	7 ±3	13 ±6	11 ±3	18 ±4	6 ±2
	* Burnt	17 ±6	12 ±4	24 ±9	17 ±6	16 ±4	7 ±2
	* Frijoles	2 ±1	0	4 ±2	7 ±3	-	11 ±2
Black-headed Grosbeak	* Apache	4+	5 ±2	4 ±1	6 ±2	5 ±1	0
	* Escobas	14 ±5	21 ±10	5 ±1	4 ±2	3 ±.8	5 ±1
	* Burnt	2 ±1	0	5 ±3	14 ±6	6 ±2	3 ±1
	* Frijoles	5 ±2	7 ±4	4 ±2	7 ±4	-	8 ±4
Green-tailed Towhee	* Apache	0	0	0	0	2 ±.7	8 ±4
	* Escobas	0	0	0	0	5 ±1	9 ±5
	* Burnt	0	0	0	5 ±2	4 ±1	7 ±2
	Frijoles	0	0	0	0	-	0
Rufous-sided Towhee	* Apache	0	0	0	0	0	3 ±2
	* Escobas	0	0	0	0	6 ±2	22 ±7
	* Burnt	12 ±5	7 ±2	4 ±2	23 ±3	19 ±3	35 ±6
	* Frijoles	22 ±7	48 ±7	41 ±10	22 ±9	-	24 ±8
Canyon Towhee	Apache	0	0	0	0	0	0
	Escobas	0	0	0	0	0	0
	Burnt	0	0	0	0	0	0
	* Frijoles	0	3 ±1	0	0	-	0
Chipping Sparrow	* Apache	8+	6 ±1	3 ±2	6 ±2	3 ±1	0
	* Escobas	3 ±2	8 ±4	8 ±4	6 ±2	5 ±1	8 ±3
	* Burnt	17 ±4	21 ±3	18 ±3	21 ±5	8 ±1	3 ±2
	* Frijoles	27 ±7	23 ±2	23 ±3	21 ±3	-	16 ±3
Dark-eyed Junco	* Apache	13+	43 ±12	26 ±11	21 ±3	18 ±5	6 ±1
	* Escobas	15 ±6	35 ±12	14 ±6	18 ±4	20 ±4	8 ±4
	* Burnt	11 ±3	6 ±2	6 ±2	20 ±6	7 ±2	0
	* Frijoles	0	0	4 ±2	0	-	0
Brewer's Blackbird	Apache	0	0	0	0	0	0
	Escobas	0	0	0	0	0	0

	Burnt	0	0	0	0	0	0
	Frijoles	0.5 ±.5	0	0	0	-	0
Brown-headed Cowbird	* Apache	0	3 ±1	3 ±2	8 ±3	10 ±3	6 ±3
	* Escobas	0	0	7 ±2	6 ±2	5 ±1	9 ±2
	* Burnt	2 ±.8	3 ±1	3 ±2	7 ±2	4 ±.5	7 ±3
	* Frijoles	1 ±.5	13 ±6	9 ±4	20 ±8	-	6 ±2
Cassin's Finch	* Apache	0	0	0	0	2 ±.7	2 ±1
	* Escobas	0	0	0	0	0	6 ±4
	* Burnt	0	2 ±.8	0	0	0	0
	Frijoles	0	0.3 ±.3	0	0	-	0
House Finch	Apache	0	0	0	0	0	0
	Escobas	0	0	0	0	0	0
	Burnt	0	0.2 ±.2	0	0	0	0
	* Frijoles	2 ±.8	2 ±1	2 ±1	0	-	3 ±.7
Red Crossbill	* Apache	5+	4 ±2	0	26 ±11	2 ±.9	40 ±10
	* Escobas	7 ±3	3 ±1	0	7 ±2	4 ±2	40 ±14
	* Burnt	14 ±6	11 ±4	0	0	2 ±1	20 ±11
	* Frijoles	2 ±1	6 ±3	0	7 ±4	-	13 ±6
Pine Siskin	* Apache	12+	3 ±1	0	16 ±5	36 ±8	24 ±4
	* Escobas	11 ±6	6 ±3	0	3 ±1	5 ±1	7 ±3
	* Burnt	4 ±1	2 ±.7	0	5 ±2	15 ±6	0
	Frijoles	2 ±2	1 ±1	0	0	-	0.4 ±.4
Lesser Goldfinch	* Apache	0	0	0	0	0	2 ±1
	* Escobas	2 ±1	0	0	0	0	0
	* Burnt	4 ±2	5 ±2	3 ±2	13 ±5	8 ±3	3 ±2
	* Frijoles	0	12 ±6	7 ±3	25 ±8	-	3 ±2
Evening Grosbeak	* Apache	7+	22 ±5	19 ±8	22 ±7	19 ±5	2 ±1
	* Escobas	0	5 ±2	3 ±2	3 ±1	3 ±1	0
	Burnt	0	0.5 ±.5	0	0	0	0
	Frijoles	0.5 ±.5	0	1 ±1	0	-	0

Appendix 3. Nesting guild data (birds/40 ha). Statistical uncertainty in each population estimate is indicated by plus or minus 1 standard error, except on Apache in 1977, where only 1 prefire survey occurred.

Nesting Guild	Transect	1977	1978	1979	1981	1983	1991
Ground	Apache	21+	43 $\pm$ 12	26 $\pm$ 11	30 $\pm$ 4	18 $\pm$ 5	9 $\pm$ 2
	Escobas	37 $\pm$ 12	35 $\pm$ 12	14 $\pm$ 6	24 $\pm$ 4	36 $\pm$ 6	32 $\pm$ 8
	Burnt	40 $\pm$ 10	17 $\pm$ 4	27 $\pm$ 4	42 $\pm$ 8	22 $\pm$ 4	42 $\pm$ 8
	Frijoles	16 $\pm$ 5	8 $\pm$ 3	33 $\pm$ 12	17 $\pm$ 6	-	5 $\pm$ 3
Cavity	Apache	99+	142 $\pm$ 14	139 $\pm$ 21	168 $\pm$ 14	165 $\pm$ 12	196 $\pm$ 22
	Escobas	137 $\pm$ 19	162 $\pm$ 22	113 $\pm$ 15	132 $\pm$ 12	144 $\pm$ 9	203 $\pm$ 19
	Burnt	175 $\pm$ 14	169 $\pm$ 23	140 $\pm$ 18	197 $\pm$ 14	197 $\pm$ 14	129 $\pm$ 10
	Frijoles	96 $\pm$ 13	99 $\pm$ 14	76 $\pm$ 9	60 $\pm$ 9	-	89 $\pm$ 8
Foliage	Apache	283+	262 $\pm$ 20	276 $\pm$ 34	325 $\pm$ 22	308 $\pm$ 18	269 $\pm$ 19
	Escobas	288 $\pm$ 29	225 $\pm$ 28	242 $\pm$ 24	156 $\pm$ 12	155 $\pm$ 11	289 $\pm$ 25
	Burnt	268 $\pm$ 24	180 $\pm$ 16	179 $\pm$ 22	247 $\pm$ 19	202 $\pm$ 15	201 $\pm$ 17
	Frijoles	233 $\pm$ 18	316 $\pm$ 29	292 $\pm$ 22	293 $\pm$ 29	-	219 $\pm$ 17
Parasitic	Apache	0	3 $\pm$ 1	3 $\pm$ 2	8 $\pm$ 3	10 $\pm$ 3	6 $\pm$ 3
	Escobas	0	0	7 $\pm$ 2	6 $\pm$ 2	5 $\pm$ 1	9 $\pm$ 2
	Burnt	2 $\pm$.8	3 $\pm$ 1	3 $\pm$ 2	7 $\pm$ 2	4 $\pm$.5	7 $\pm$ 3
	Frijoles	1 $\pm$.5	13 $\pm$ 6	9 $\pm$ 4	20 $\pm$ 8	-	6 $\pm$ 2
Nesting totals	Apache	403+	449 $\pm$ 27	445 $\pm$ 41	530 $\pm$ 26	500 $\pm$ 22	481 $\pm$ 29
	Escobas	461 $\pm$ 37	422 $\pm$ 38	377 $\pm$ 29	318 $\pm$ 18	341 $\pm$ 16	533 $\pm$ 32
	Burnt	484 $\pm$ 29	368 $\pm$ 28	350 $\pm$ 28	493 $\pm$ 25	425 $\pm$ 21	378 $\pm$ 22
	Frijoles	348 $\pm$ 22	436 $\pm$ 33	410 $\pm$ 27	389 $\pm$ 32	-	319 $\pm$ 19

Appendix 4. Foraging guild data (birds/40 ha). Statistical uncertainty in each population estimate is indicated by plus or minus 1 standard error, except on Apache in 1977, where only 1 prefire survey occurred.

Foraging Guild	Transect	1977	1978	1979	1981	1983	1991
Ground seed	Apache	13+	45 $\pm$ 12	37 $\pm$ 12	33 $\pm$ 4	32 $\pm$ 6	25 $\pm$ 5
	Escobas	19 $\pm$ 6	35 $\pm$ 12	24 $\pm$ 7	24 $\pm$ 4	37 $\pm$ 5	59 $\pm$ 10
	Burnt	32 $\pm$ 6	20 $\pm$ 4	16 $\pm$ 3	61 $\pm$ 7	37 $\pm$ 4	60 $\pm$ 8
	Frijoles	37 $\pm$ 8	77 $\pm$ 11	64 $\pm$ 11	44 $\pm$ 12	-	37 $\pm$ 9
Foliage seed	Apache	26+	54 $\pm$ 10	23 $\pm$ 8	82 $\pm$ 15	65 $\pm$ 10	85 $\pm$ 11
	Escobas	29 $\pm$ 8	32 $\pm$ 8	10 $\pm$ 3	27 $\pm$ 4	27 $\pm$ 4	70 $\pm$ 16
	Burnt	39 $\pm$ 9	40 $\pm$ 9	18 $\pm$ 8	31 $\pm$ 6	49 $\pm$ 9	41 $\pm$ 11
	Frijoles	21 $\pm$ 4	41 $\pm$ 8	29 $\pm$ 7	45 $\pm$ 9	-	34 $\pm$ 7
Foliage nectar	Apache	4+	11 $\pm$ 4	9 $\pm$ 3	5 $\pm$ 2	12 $\pm$ 4	18 $\pm$ 5
	Escobas	3 $\pm$ 1	11 $\pm$ 5	10 $\pm$ 3	8 $\pm$ 3	14 $\pm$ 4	34 $\pm$ 12
	Burnt	11 $\pm$ 2	26 $\pm$ 8	25 $\pm$ 10	28 $\pm$ 10	16 $\pm$ 3	32 $\pm$ 6
	Frijoles	15 $\pm$ 2	16 $\pm$ 5	34 $\pm$ 9	18 $\pm$ 5	-	24 $\pm$ 9
Ground insect	Apache	65+	59 $\pm$ 7	64 $\pm$ 12	73 $\pm$ 5	83 $\pm$ 7	80 $\pm$ 15
	Escobas	63 $\pm$ 13	78 $\pm$ 13	70 $\pm$ 9	59 $\pm$ 6	74 $\pm$ 6	96 $\pm$ 11
	Burnt	64 $\pm$ 11	84 $\pm$ 10	39 $\pm$ 5	118 $\pm$ 10	120 $\pm$ 12	69 $\pm$ 8
	Frijoles	56 $\pm$ 8	43 $\pm$ 10	39 $\pm$ 5	31 $\pm$ 4	-	52 $\pm$ 8
Timber drilling insect	Apache	19+	43 $\pm$ 6	42 $\pm$ 13	28 $\pm$ 5	21 $\pm$ 3	20 $\pm$ 5
	Escobas	6 $\pm$ 2	28 $\pm$ 9	36 $\pm$ 9	23 $\pm$ 5	22 $\pm$ 3	21 $\pm$ 4
	Burnt	11 $\pm$ 4	29 $\pm$ 9	33 $\pm$ 7	16 $\pm$ 3	21 $\pm$ 4	18 $\pm$ 4
	Frijoles	6 $\pm$ 1	5 $\pm$ 0	14 $\pm$ 6	11 $\pm$ 5	-	3 $\pm$ 1
Timber searching insect	Apache	105+	61 $\pm$ 10	49 $\pm$ 16	74 $\pm$ 11	53 $\pm$ 9	93 $\pm$ 10
	Escobas	113 $\pm$ 20	62 $\pm$ 16	24 $\pm$ 8	40 $\pm$ 7	34 $\pm$ 5	70 $\pm$ 13
	Burnt	99 $\pm$ 9	59 $\pm$ 18	27 $\pm$ 6	49 $\pm$ 8	34 $\pm$ 6	33 $\pm$ 6
	Frijoles	39 $\pm$ 7	51 $\pm$ 8	27 $\pm$ 4	27 $\pm$ 8	-	23 $\pm$ 3
Foliage insect	Apache	108+	124 $\pm$ 16	129 $\pm$ 18	136 $\pm$ 11	115 $\pm$ 10	69 $\pm$ 11
	Escobas	141 $\pm$ 23	92 $\pm$ 14	110 $\pm$ 19	59 $\pm$ 8	60 $\pm$ 6	71 $\pm$ 7
	Burnt	104 $\pm$ 13	48 $\pm$ 8	86 $\pm$ 13	86 $\pm$ 12	64 $\pm$ 8	73 $\pm$ 9
	Frijoles	93 $\pm$ 11	123 $\pm$ 24	126 $\pm$ 17	135 $\pm$ 22	-	70 $\pm$ 7

Air perching insect	Apache	55+	37 ±5	78 ±24	70 ±9	81 ±8	53 ±7
	Escobas	72 ±13	75 ±22	77 ±12	52 ±8	43 ±7	69 ±10
	Burnt	67 ±15	39 ±7	50 ±13	51 ±8	38 ±8	25 ±5
	Frijoles	66 ±10	65 ±11	64 ±11	58 ±14	-	60 ±6
Air soaring insect	Apache	11+	15 ±6	17 ±8	29 ±10	38 ±7	35 ±13
	Escobas	15 ±4	10 ±3	12 ±4	23 ±6	26 ±5	40 ±10
	Burnt	54 ±9	25 ±8	61 ±15	50 ±7	42 ±4	31 ±5
	Frijoles	26 ±9	18 ±4	18 ±2	22 ±6	-	19 ±3
Ground predator	Apache	1+	0.6 ±.3	3 ±1	0.6 ±.2	2 ±.5	5 ±1
	Escobas	0.3 ±.3	1 ±.4	3 ±1	4 ±1	5 ±.8	4 ±1
	Burnt	4 ±2	3 ±.6	0.3 ±.3	7 ±2	5 ±.8	6 ±1
	Frijoles	2 ±.5	4 ±2	0.8 ±.6	1 ±.5	-	3 ±1
Total foraging	Apache	406+	449 ±27	452 ±42	531 ±26	501 ±22	482 ±29
	Escobas	462 ±37	423 ±38	377 ±29	319 ±18	342 ±16	534 ±32
	Burnt	486 ±29	373 ±28	354 ±29	497 ±25	426 ±21	388 ±22
	Frijoles	359 ±22	445 ±33	416 ±27	391 ±32	-	325 ±19