Effects of Fire on Birds in Madrean Forests and Woodlands

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Abstract.--Fire usually affects birds indirectly, by altering habitat or food resources. Bird response may be positive or negative, depending on life-history characteristics and fire extent, intensity, and duration. Disruption of natural fire regimes may have far-reaching consequences for these birds and their habitat. The effects of fire on forest birds should be studied experimentally, at both species and community levels, in conjunction with efforts to restore fire as a natural process in Madrean forests. The effects of fire on important habitat components (e.g., snags, logs, and oaks) should be monitored, and the effects of salvage logging on post-fire bird communities should be carefully evaluated.

INTRODUCTION

Concern about the effects of fires on western forests and woodlands in recent years (Lotan and Brown 1985, Lotan et al. 1985, Krammes 1990) reflects a growing awareness that fire is a natural process in these ecosystems, and that suppressing fire has unintended consequences. In forest types normally subject to frequent low-intensity fires, fire suppression, coupled with heavy grazing, has resulted in increased stand density and fuel loading (Harrington and Sackett 1990; Covington and Moore 1994a,b; Sackett et al. 1994,1996; Arno et al. 1995; Minnich et al. 1995; Touchan et al. 1995). Consequently, when fires do break out in these forests, they are becoming larger, more intense, and more likely to result in stand replacement than historical fires (Harrington and Sackett 1990, Swetnam 1990, Covington and Moore 1994a, Sackett et al. 1994).

The forests and woodlands of the Madrean Sky Island Archipelago of the southwestern United States and northern Mexico (Warshall 1995) are also subject to this trend. As a result of decades of fire suppression and grazing, intervals between fires, stand density, and fuel loadings have increased in these mountain ranges from encinal woodlands upward through pine-oak (*Pinus* spp. -*Quercus* spp.), pine, and mixed-conifer forests (Baisan and Swetnam 1990; Fulé and Covington 1994,1995,1996; Barton 1995; Caprio and Zwolinski 1995; Grissino-Mayer et al. 1995; Villanueva-Díaz and McPherson 1995).

The threat of stand-replacing wildfire is exacerbated in dry years (Swetnam 1990, Swetnam and Bettancourt 1990). For example, 1994 was an unusually severe fire year in the mountains of southeastern Arizona and southwestern New Mexico, with 589 fires burning more than 34,000 ha (84,000 acres; Allen 1995). The 1996 fire season promises to be even worse, with record low fuel-moisture conditions as a result of lack of winter precipitation.

Because the forests in the Sky Island Archipelago are restricted to isolated mountains, some of which are relatively small, a single large wildfire could damage or completely remove a considerable portion of the existing forest in some of these mountains. The danger of such wildfires is increasing yearly.

The Sky Island mountain ranges are important centers of biodiversity, due to the intermingling of northern and southern floral and faunal elements (Barton 1995, Felger and Wilson 1995, Warshall 1995). Organisms residing in Madrean forests and woodlands have evolved with fire as a natural process. The types of stand-replacing fires likely to occur under current conditions could have far-reaching effects on these organisms, however, becaue they are not similar to the fires that these organisms evolved with.

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Here, we summarize current knowledge on the possible effects of fires on the rich and unique avifauna (Marshall 1957, Felger and Wilson 1995, Warshall 1995) of the Madrean Sky Island Archipelago. Our treatment is limited to montane forests and woodlands, with the lower bound defined by encinal woodland (e.g., Warshall 1995: fig. 2). We first evaluate current knowledge on the effects of fire on forest birds in general, then review what is known about fire and birds in the Madrean Archipelago. Finally, we discuss some implications of this information for forest managers.

EFFECTS OF FIRE ON FOREST BIRDS IN GENERAL

Fire can affect forest birds positively or negatively, depending on the type and extent of fire and the particular life history of the species involved. Direct effects, such as mortality due to fire, are generally considered to be minor. Rather, fires influence birds indirectly through habitat modification, changes in food supply, or changes in abundance of competitors and/or predators (Rotenberry et al. 1995). The effects of fire on habitat structure, floristic composition, and food resources may be especially important, singly or in combination, as many birds respond strongly to these features of their habitat (MacArthur et al. 1966, Koplin 1969, Rotenberry 1985).

Several authors have reviewed the effects of fire on forest birds (Bendell 1974, Hutto et al. 1992, Dobkin 1994, Hejl 1994, Hejl et al. 1995, Rotenberry et al. 1995). These reviews suggest that generalizing about fire effects is difficult, for many reasons.

First, fires vary widely in extent, intensity, and duration (Rotenberry et al. 1995). Because of this variation in fire behavior, the effects of fire on birds and their habitat also varies widely.

Second, fire effects also vary across temporal scales. For example, cavity-nesting birds may respond positively to fire in the short term, but long-term effects may be negative as the burned snags fall (Raphael and Morrison 1987, Raphael et al. 1987, Hejl et al. 1995, Johnson and Wauer in press). Conversely, intense bums that greatly alter bird habitat in the short-term may be necessary for long-term maintenance of natural patterns of forest succession in some forest types (Hutto 1995).

Third, differences in the life histories of various bird species can result in different responses to fires. For example, cavity-nesting birds, timber-drilling birds, and granivores often respond positively to bums because of increased nesting substrates and/or food supplies (Lowe et al. 1978, Overturf 1979, Wauer and Johnson. 1984, Hejl 1994, Hejl et al. 1995, Hutto 1995, Johnson and Wauer in press). In contrast, foliage gleaners may respond negatively (Roppe and Hein 1978, Overturf 1979, Blake 1982) due to decreased foraging substrate. Response patterns may even vary within guilds (Root 1967) in some cases (Skinner 1989, Hutto 1995, see also Mannan et al. 1984).

Finally, methodological problems plague many of the studies of the effects of fire on birds. Most studies have been conducted opportunistically rather than planned, limiting the inferences that can be drawn (Dobkin 1994:14, Hutto 1995). Most were also restricted in both spatial and temporal scale, and lacked the replication necessary to show general patterns (Dobkin 1994:14, Hutto 1995). Most studies have focused on breeding bird communities, and ignored wintering and migrating birds (but see Blake 1982). Many studies that reported few differences in bird communities between burned and unburned areas relied on composite statistics such as total bird abundance or species richness, rather than examining responses of individual species. Because individual species may respond in opposite fashion, such composite measures may hide rather than reveal patterns (Mannan et al. 1984., Rotenberry 1985, Hejl et al. 1995, Hutto 1995). Finally, even studies that have evaluated responses of individual species typically have not examined demographic parameters (Hejl 1994). Burned areas could contain many birds, yet function as population sinks if reproduction is insufficient to balance mortality (Robinson 1992).

The point of the above discussion is not to denigrate past studies, but simply to note the many difficulties involved in documenting general patterns with respect to the effects of fires on forest birds. Nevertheless, some broad generalizations are possible; note that all of these are somewhat dependent on the spatial scale of the observations.

First, patterns differ with bum intensity, being most pronounced for intense burns. Cavity-nesting birds, timber-drilling birds, granivores, and some aerial insectivores often respond positively to intense bums in the short term (Hejl et al. 1995, Hutto 1995) due to increases in perching, feeding, and nesting substrates. A few species, such as the Blackbacked Woodpecker (*Picoides* arcticus; species names for birds follow AOU 1983, 1995) are nearly restricted to intense burns, and may require such burns for long-term population maintenance (Hutto 1995).

Effects of low- and moderate-intensity bums are less dramatic. In the short-term, bird species richness may increase in moderate-intensity burns, because birds characteristic of both burned and unburned forest may use the area (Taylor and Barmore 1980). Low-intensity bums can create or maintain habitat for species that prefer open forest (Marshall 1963, Hutto 1995). Thus, some species are favored by low-intensity bums, whereas others are favored by high-intensity bums. In general, fire suppression has probably resulted in declines of birds that use snags preferentially in burned areas (Hejl 1994; see also Brawn and Balda 1988), and may have reduced numbers of some open-forest species as well (Marshall 1963).

EFFECTS OF FIRE ON BIRDS IN MADREAN FORESTS

Few studies are available documenting responses of birds to fire in the Madrean Archipelago. Marshall (1963) noted that fire regime, habitat conditions, and bird communities all varied in parallel between the mountains of southern Arizona and northern Mexico (Sonora and Chihuahua). Fires had been effectively suppressed in Arizona, but not in Mexico. As a result, forests and woodlands in Arizona were denser than similar types in Mexico. Several bird species common to brush or dense forest, including the Elf Owl (Micrathene whitneyi), Ash-throated Flycatcher (Myiarchus cinerascens), Blue-gray Gnatcatcher (*Polioptila* caerula), Black-throated Gray Warbler (*Dendroica nigrescens*), Scott's Oriole (*Icterus* parisorurn), and Spotted Towhee (*Pipilo maculatus*), were more abundant in Arizona than in Mexico. In contrast, several species preferring open forest conditions were more abundant and/or occurred at higher elevations in Mexico, presumably because open forest conditions persisted to a higher elevation there. These included the American Kestrel (*Falco sparverius*), Cassin's Kingbird (*Tyrannus vociferans*), Curve-billed Thrasher (*Toxostoma curvirostre*), Common Nighthawk (*Chordeiles* minor), Purple Martin (*Progne subis*), Chipping Sparrow (*Spizella* passerina), and both Eastern (Sialia *sialis*) and Western (*S. mexicana*) Bluebirds.

Bock and Bock (1990:54-55) summarized the effects of two "cool" fires on birds and/or vegetation in open oak savannah (encinal) on the Appleton-Whittell Research Ranch, in the foothills of the Huachuca Mountains. This area is at the lower elevational bound discussed here. Fires bumed in February and May. Little mortality of oak trees was observed, and shrubs were reduced in height but not in density. Grass cover was reduced in both bums, but recovered on one area within two years. Seed production increased in the first year following the fire. On one burned area, bird numbers were about 18% higher following the fire than on adjacent unbumed areas (Bock et al. 1976). Most of this difference was attributable to increased abundance of two seed-eating birds, Mourning Doves (*Zenaida macroura*) and Chipping Sparrows. The Grasshopper Sparrow (*Ammodramus savannarum*), which depends on heavy grass cover, disappeared entirely from the burned area for the duration of the study. Bock and Bock (1990:55) concluded that much more research was needed on the effects of fire in lowland encinal on birds and their habitat.

Horton and Mannan (1988) studied the effects of prescribed burning on snags and cavity-nesting birds in pine-oak forest in the Santa Catalina Mountains, Arizona. They sampled abundance of snags in different size and decay classes and bird abundance before and after burning in three stands. They also sampled three control (unburned) stands.

The prescribed bum resulted in a moderately-intense surface fire which remained within prescribed limits. Nearly half of all ponderosa pine (*P. ponderosa*) snags ≥ 15 cm in diameter at breast height were bumed down or drastically altered. Because few large trees were killed immediately, there was a net 45% decrease in large snags in the first season following the prescribed bum.

Few differences were observed in bird populations before and after fire. Only Northern Flickers (*Colaptes auratus*) and Violet-green Swallows (Tachycineta thalassina) declined in abundance in burned stands, and only Mountain Chickadees (*Parus gambeli*) increased. Horton and Mannan (1988) concluded that observed declines in cavity-nesting birds (Northern Flicker and Violet-green Swallow) were not due to a shortage of nest sites, because post-fire snag densities exceeded densities theoretically required to support pre-fire populations of cavity-nesting birds.

MANAGEMENT IMPLICATIONS

Restoring Fire to the System

Fire is obviously important as a natural process in Madrean forests and woodlands, and there are compelling ecological reasons to restore fire to these systems (Baisan and Swetnam 1990; Harrington and Sackett 1990; Covington and Moore 1994a; Fulé and Covington 1994,1995,1996; Sackett et al. 1994,1996; Grissino-Mayer et al. 1995). Recent experience suggests that if low-intensity fire is not restored to these forests, sooner or later they will be subject to stand-replacing wildfire (Covington and Moore 1994a, Sackett et al. 1994). Such wildfires may not be totally negative as far as birds are concerned. They may be beneficial in areas where they bum in a mosaic pattern, or for some species that require intense burns. Stand-replacing wildfires can also destroy habitat for many species, however. For example, Johnson and Wauer (in press) observed "diverse, substantial populations of breeding birds" even in areas subjected to severe crown fire. They also noted that recovery of bird populations following fire was delayed in areas of high-intensity fire, however.

The substantial economic costs involved in fighting intense wildfires provide another incentive for restoring more natural fire regimes. For example, consider two fires on the Gila National Forest, New Mexico (data on file, Gila National Forest Supervisor's Office, Silver City, NM). The Pigeon Fire (June/July 1994) burned approximately 3,240 ha (8,000 acres) in the Aldo Leopold Wilderness, despite active suppression efforts conducted at a cost of roughly $7,500,000. In contrast, the Bonner Fire (June/July 1995), 8 km (5 mi) north of the Pigeon Fire, was allowed to bum under the Prescribed Natural Fire (Mutch 1995) program. This fire burned a much larger area (approximately 11,540 ha [28,500 acres]), but the cost for monitoring this fire (approximately $100,000.) was far lower than the cost to fight the Pigeon Fire. Further, the expensive efforts to fight the Pigeon fire were unsuccessful; both fires were extinguished by rain. Under more natural fire regimes, we anticipate that more fires could be allowed to bum naturally, substantially reducing the economic costs of fire suppression (Fulé and Covington 1996, Sackett et al. 1996).

Restoring more natural conditions in these forests and woodlands is problematic given current conditions. Heavy fuel loadings that have accumulated as a result of fire suppression can result in hot burns that kill overstory trees. Harrington and Sackett (1990) reported 35% mortality in old-growth ponderosa pines following prescribed burning in northern Arizona. These trees had survived numerous presettlement bums, but were unable to survive the first burns in 100 years due to the excessive fuels that had accumulated. This suggests that several applications of cool fire may be required in many areas to reduce fuels without killing overstory trees. Relatively frequent maintenance burns will also be required to prevent new buildup of fuels (Harrington and Sackett 1990; Sackett et al. 1994, 1996). These repeated cool bums may result in more smoke and particulate matter than the public is currently willing to accept (Daniel 1990, Lahm et al. 1990), and may result in conflicts with existing air quality standards (Chambers and Duncan 1985). Thus, restoring more natural conditions in these forests will take not only time and money, but also considerable education of the public on fire as a process and the costs (both economic and ecological) of fire suppression.

Evaluating the Effects of Fire on Forest Birds

Having argued for restoration of natural fire regimes in the Sky Islands, we must also point out that it may not be possible to accomplish this without some impacts to their unique avifauna. To minimize such impacts, we must know more about the effects of fire on birds in Madrean forests and woodlands. Recent (and future) intense wildfires will provide opportunities for monitoring bird community composition through various stages of post-fire succession. This may be the only feasible approach to studying effects of large stand-replacing fires on birds. For low- to moderate-intensity fires, however, we believe that more could be learned through an experimental approach using prescribed burning.

Researchers should work with land managers to design and conduct studies documenting the effects of a range of fire prescriptions on birds and their habitat. In evaluating the effects of fire on birds, both species- and community-level responses should be considered (Hejl et al. 1995, Hutto 1995), along with demographic parameters (Hejl 1994, Dobkin 1994) and patterns of resource use. Particular efforts should be made to identify any species that may be dependent on or sensitive to fire. Important habitat components that should be evaluated include snags, logs, oaks, and under- and mid-story vegetation. Snags are important as feeding and nesting sites, particularly for woodpeckers and other cavity-nesting birds (Koplin 1969, Balda 1975, Scott 1979, Cunningham et al. 1980, Raphael and White 1984, Horton and Mannan 1988, Hejl et al. 1995, Hutto 1995). Down logs can also serve as feeding sites (Horton and Mannan 1988), and several species of oaks provide important resources for forest birds in the Madrean Archipelago (Block et al. 1992). Ground-nesting birds and species that primarily forage in the under- and mid-story may be particularly sensitive to the effects of fire on under- and mid-story vegetation.

Some or all of these habitat components may be vulnerable to fire (e.g. Horton and Mannan 1988, Bock and Bock 1990, Barton 1995) and special protective measures may be required to maintain them at adequate levels. Both managers and the public must realize and accept that there may be short-term declines in some of these habitat components despite such measures, however.

Ideally, studies of fire effects could be designed in conjunction with efforts to restore fire as a natural process in these forest types. Such efforts should aim to reduce fuel loads in the short term, with a long term goal of returning these systems toward natural disturbance regimes. This would require mimicking natural disturbance pattems in terms of frequency, intensity, and extent. Unless variation in timing, intensity, and scale of fires is incorporated in prescribed bums, such bums are unlikely to closely mimic natural fire pattems (e.g., DesGranges and Rondeau 1993).

Evaluating the Effects of Salvage Logging on Forest Birds

The effects of salvage logging on post-fire bird communities should also be carefully evaluated. Snags can provide important resources for birds in general (Balda 1975, Scott 1979, Cunningham et al. 1980, Taylor and Barmore 1980, Dickson et al. 1983, Raphael and White 1984, Brawn and Balda 1988, Raphael et al. 1988) and specifically for post-fire bird communities (Koplin 1969, Taylor and Barmore 1980, Raphael and White 1984, Horton and Mannan 1988, Hejl et al. 1995, Hutto 1995). For example, woodpeckers may concentrate in burned areas to feed on insects in snags (Koplin 1969, Wauer and Johnson 1984, Hutto 1995, Johnson and Wauer in press) and may be recruited to such areas over long distances (Wauer and Johnson 1984). Thus, retention of snags could mitigate the effects of wildfires on forest bird communities (Moeur and Guthrie 1984, Hutto 1995, Johnson and Wauer in press). Retaining significant groups of snags would be preferable to retaining scattered isolated snags, both to minimize short-term snag loss to wind throw, and to provide concenhated food sources for woodpeckers. Preference should also be given to retaining large snags that existed prior to the bum, as these are used more often for feeding and nesting than case-hardened snags resulting from the bum (Moeur and Guthrie 1984, Hutto 1995).

CONCLUSIONS

Clearly, we know far less about the effects of fire on birds than we would like. Further, most of what we do know relates to areas or forest types outside of the Madrean Sky Islands, and may not be directly applicable to the Sky Island avifauna. This lack of knowledge is particularly troubling because:

1. The avifauna of the Sky Islands is unique;
2. Fire is important as a natural process in the Sky Islands; and
3. Some of the forests in this area are relatively small and thus highly vulnerable to impacts from intense wildfires.

We know too little about the effects of fire on the avifauna of the Sky Islands to accurately predict the effects of particular types of fire on that avifauna. Because these species evolved with fire as an important process shaping their habitats, we believe that restoration of natural fire regimes is both desirable in these areas and compatible with maintaining this unique avifauna. The process of restoring more natural conditions may result in declines in some habitat components and/or some avian species. We suspect that these impacts will be short-term, and outweighed by the long-term benefits. Impacts to forest birds and their habitat should be minimized where possible, however, by approaching restoration cautiously, by carefully monitoring bird populations and habitat conditions, and by paying special attention to any avian species that appear to be declining as a result of burning. In particular, efforts should be made to identify thresholds of acceptable decline, and to ensure that no avian species decline beyond the point from which it would be difficult for them to recover.

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