

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, because 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 burns 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 burns 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 burn intensity, being most pronounced for intense burns. Cavity-nesting birds, timber-drilling birds, granivores, and some aerial insectivores often respond positively to intense burns 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 Black-

backed 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 burns 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 burns can create or maintain habitat for species that prefer open forest (Marshall 1963, Hutto 1995). Thus, some species are favored by low-intensity burns, whereas others are favored by high-intensity burns. 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 caerulea*), Black-throated Gray Warbler (*Dendroica nigrescens*), Scott's Oriole (*Icterus parisorum*), 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 burned 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 burns, 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 unburned areas (Bock et al. 1976). Most of this difference was attributable to increased abundance of two seed-eating birds, Mourning Doves (*Zenaidura 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 burn 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 burned 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 burn.

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 burn 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 burn 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 burn 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 condi-

tions. 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 burns, 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 burns 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 depen-

dent 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 patterns in terms of frequency, intensity, and extent. Unless variation in timing, intensity, and scale of fires is incorporated in prescribed burns, such burns are unlikely to closely mimic natural fire patterns (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 in-

sects 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 windthrow, and to provide concentrated food sources for woodpeckers. Preference should also be given to retaining large snags that existed prior to the burn, as these are used more often for feeding and nesting than case-hardened snags resulting from the burn (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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LITERATURE CITED

- Allen, L. S. 1995. Fire management in the Sky Islands. Pp. 386-388 *in*: L. F. DeBano, P. F. Ffolliott, A. Ortega-Rubio, G. J. Gottfried, R. H. Hamre, and C. B. Edminster, tech. coords. Biodiversity and management of the Madrean Archipelago: The Sky Islands of southwestern United States and northwestern Mexico. USDA For. Serv. Gen. Tech. Rep. RM-264. Rocky Mtn. For. and Range Exper. Stn. Ft. Collins, CO.
- American Ornithologists Union. 1983. Checklist of North American birds. Sixth ed. Allen Press, Inc. Lawrence, KS.
- American Ornithologists Union. 1995. Fortieth supplement to the American Ornithologists' Union check-list of North American birds. *Auk* 112: 819-830.
- Arno, S. F., M. G. Harrington, C. E. Fiedler, and C. E. Carlson. 1995. Restoring fire-dependent ponderosa pine forests in western Montana. *Restoration and Management Notes* 13:32-36.
- Baisan, C. H., and T. W. Swetnam. 1990. Fire history on a desert mountain range: Rincon Mountain Wilderness, U.S.A. *Can. J. For. Res.* 20:1559-1569.
- Balda, R. P. 1975. The relationship of secondary cavity nesters and snag densities in western coniferous forests. USDA For. Serv. Wildl. Hab. Tech. Bull. 1. Southwestern Region. Albuquerque, NM.
- Barton, A. M. 1995. Fire adaptations in pines and oaks: Tree population responses to fire suppression in Arizona's Madrean forests. Pp. 159-163 *in*: J. K. Brown, R. W. Mutch, C. W. Spoon, and R. H. Wakimoto, tech. coords. Proceedings: Symposium on fire in wilderness and park management. USDA For. Serv. Gen. Tech. Rep. INT-320. Intermtn. Res. Stn. Ogden, UT.
- Bendell, J. F. 1974. Effects of fire on birds and mammals. Pp. 73-138 *in*: T. T. Kozlowski and C. E. Ahlgren, eds. *Fire and ecosystems*. Academic Press. New York.
- Blake, J. G. 1982. Influence of fire and logging on nonbreeding bird communities of ponderosa pine forests. *J. Wildl. Manage.* 46:404-415.
- Block, W. M., J. L. Ganey, K. E. Severson, and M. L. Morrison. 1992. Use of oaks by Neotropical migratory birds in the southwest. Pp. 65-70 *in*: P. F. Ffolliott, G. J. Gottfried, D. A. Bennett, V. M. Hernandez C., A. Ortega-Rubio, and R. H. Hamre, tech. coords. *Ecology and management of oak and associated woodlands: perspectives in the southwestern United States and northern Mexico*. USDA For. Serv. Gen. Tech. Rep. RM-218. Rocky Mtn. For. and Range Exper. Stn. Ft. Collins, CO.
- Bock, C. E., and J. H. Bock. 1990. Effects of fire on wildlife in southwestern lowland habitats. Pp. 50-64 *in*: J. S. Krammes, tech. coord. *Effects of fire management of southwestern natural resources*. USDA For. Serv. Gen. Tech. Rep. RM-191. Rocky Mtn. For. and Range Exper. Stn. Ft. Collins, CO.
- Bock, J. H., C. E. Bock, and J. R. McKnight. 1976. A study of the effects of grassland fires at the Research Ranch in southeastern Arizona. *J. Arizona Acad. Science* 11:49-57.
- Brawn, J. D., and R. P. Balda. 1988. The influence of silvicultural activity on ponderosa pine forest bird communities in the southwestern United States. *Bird Conservation* 3:3-21.
- Caprio, A. C., and M. J. Zwolinski. 1995. Fire and vegetation in a Madrean oak woodland, Santa Catalina Mountains, southeastern Arizona. Pp. 389-398 *in*: L. F. DeBano, P. F. Ffolliott, A. Ortega-Rubio, G. J. Gottfried, R. H. Hamre, and C. B. Edminster, tech. coords. *Biodiversity and management of the Madrean Archipelago: The Sky Islands of southwestern United States and northwestern Mexico*. USDA For. Serv. Gen. Tech. Rep. RM-264. Rocky Mtn. For. and Range Exper. Stn. Ft. Collins, CO.
- Chambers, M. S., and E. A. Duncan. 1995. Prescribed Natural Fire and air quality: Identifying the real problem. Pp. 77-79 *in*: J. K. Brown, R. W. Mutch, C. W. Spoon, and R. H. Wakimoto, tech. coords. *Proceedings: Symposium on fire in wilderness and park management*. USDA For. Serv. Gen. Tech. Rep. INT-320. Intermtn. Res. Stn. Ogden, UT.
- Covington, W. W., and M. M. Moore. 1994a. Postsettlement changes in natural fire regimes and forest structure: Ecological restoration of old-growth ponderosa pine forests. *J. Sustain. For.* 2:153-181.
- Covington, W. W., and M. M. Moore. 1994b. Southwestern ponderosa forest structure and resource conditions: Changes since Euro-American settlement. *J. For.* 92(1):39-47.
- Cunningham, J. B., R. P. Balda, and W. S. Gaud. 1980. Selection and use of snags by secondary cavity-nesting birds of the ponderosa pine forest. USDA For. Serv. Res. Pap. RM-222. Rocky Mtn. For. and Range Exper. Stn. Ft. Collins, CO.
- Daniel, T. C. 1990. Social/political obstacles and opportunities in prescribed fire management. Pp. 134-138 *in*: J. S. Krammes, tech. coord. *Effects of fire management of southwestern natural resources*. USDA For. Serv. Gen. Tech. Rep. RM-191. Rocky Mtn. For. and Range Exper. Stn. Ft. Collins, CO.

- DesGranges, J., and G. Rondeau. 1993. Forest bird response to natural perturbations and silvicultural practices: Does logging mimic nature? Pp. 80-92 *in*: D. H. Kuhnke, ed. *Birds in the boreal forest: Proc. of a workshop held March 10 - 12 in Prince Albert, Saskatchewan*. Northern Forestry Centre. Forestry Canada, Northwest Region. Edmonton, Alberta.
- Dickson, J. G., R. N. Conner, and J. H. Williamson. 1983. Snag retention increases bird use of a clear-cut. *J. Wildl. Manage.* 47:799-804.
- Dobkin, D. S. 1994. Conservation and management of Neotropical migrant landbirds in the northern Rockies and Great Plains. Univ. of Idaho Press. Moscow, ID. 220pp.
- Felger, R. S., and M. F. Wilson. 1995. Northern Sierra Madre Occidental and its Apachian outliers: A neglected center of biodiversity. Pp. 36-59 *in*: L. F. DeBano, P. F. Ffolliott, A. Ortega-Rubio, G. J. Gottfried, R. H. Hamre, and C. B. Edminster, tech. coords. *Biodiversity and management of the Madrean Archipelago: The Sky Islands of southwestern United States and northwestern Mexico*. USDA For. Serv. Gen. Tech. Rep. RM-264. Rocky Mtn. For. and Range Exper. Stn. Ft. Collins, CO.
- Fulé, P. Z., and W. W. Covington. 1994. Fire-regime disruption and pine-oak forest structure in the Sierra Madre Occidental, Durango, Mexico. *Restoration Ecol.* 2:261-272.
- Fulé, P. Z., and W. W. Covington. 1995. Changes in fire regimes and forest structures of unharvested Petran and Madrean pine forests. Pp. 408-415 *in*: L. F. DeBano, P. F. Ffolliott, A. Ortega-Rubio, G. J. Gottfried, R. H. Hamre, and C. B. Edminster, tech. coords. *Biodiversity and management of the Madrean Archipelago: The Sky Islands of southwestern United States and northwestern Mexico*. USDA For. Serv. Gen. Tech. Rep. RM-264. Rocky Mtn. For. and Range Exper. Stn. Ft. Collins, CO.
- Fulé, P. Z., and W. W. Covington. 1996. Conservation of pine-oak forests in northern Mexico. Pp. 80-88 *in*: W. Covington and P. K. Wagner, tech. coords. *Conference on adaptive ecosystem restoration and management: Restoration of cordilleran conifer landscapes of North America*. USDA For. Serv. Gen. Tech. Rep. RM-278. Rocky Mtn. For. and Range Exper. Stn. Ft. Collins, CO.
- Grissino-Mayer, H. D., C. H. Baisan, and T. W. Swetnam. 1995. Fire history in the Pinaleno Mountains of southeastern Arizona: Effects of human-related disturbances. Pp. 399-407 *in*: L. F. DeBano, P. F. Ffolliott, A. Ortega-Rubio, G. J. Gottfried, R. H. Hamre, and C. B. Edminster, tech. coords. *Biodiversity and management of the Madrean Archipelago: The Sky Islands of southwestern United States and northwestern Mexico*. USDA For. Serv. Gen. Tech. Rep. RM-264. Rocky Mtn. For. and Range Exper. Stn. Ft. Collins, CO.
- Harrington, M. G., and S. S. Sackett. 1990. Using fire as a management tool in southwestern ponderosa pine. Pp. 122-133 *in*: J. S. Krammes, tech. coord. *Effects of fire management of southwestern natural resources*. USDA For. Serv. Gen. Tech. Rep. RM-191. Rocky Mtn. For. and Range Exper. Stn. Ft. Collins, CO.
- Hejl, S. J. 1994. Human-induced changes in bird populations in coniferous forests in western North America during the past 100 years. *Stud. Avian Biol.* 15:232-246.
- Hejl, S. J., R. L. Hutto, C. R. Preston, and D. M. Finch. 1995. Effects of silvicultural treatments in the Rocky Mountains. Pp. 55-84 *in*: T. E. Martin and D. M. Finch, eds. *Ecology and management of Neotropical migratory birds*. Oxford Univ. Press. Oxford, UK. 489pp.
- Horton, S. P., and R. W. Mannan. Effects of prescribed fire on snags and cavity-nesting birds in southeastern Arizona pine forests. *Wildl. Soc. Bull.* 16:37-44.
- Hutto, R. L. 1995. Composition of bird communities following stand-replacement fires in northern Rocky Mountain (U.S.A.) conifer forests. *Conservation Biol.* 9:1041-1058.
- Hutto, R. L., S. J. Hejl, C. R. Preston, and D. M. Finch. 1992. Effects of silvicultural treatments on forest birds in the Rocky Mountains: Implications and management recommendations. Pp. 386-391 *in*: D. M. Finch and P. W. Stangel, eds. *Status and management of Neotropical migratory birds*. USDA For. Serv. Gen. Tech. Rep. RM-229. Rocky Mtn. For. and Range Exper. Stn. Ft. Collins, CO.
- Johnson, T. H., and R. H. Wauer. In press. Avifaunal response to the 1977 La Mesa fire. *In*: Allen, C. D., and L. Eskew, tech. coords. *Proc. of the 1994 La Mesa fire symp.* USDA For. Serv. Gen. Tech. Rep. Rocky Mtn. For. and Range Exper. Stn. Fort Collins, CO.
- Koplin, J. R. 1969. The numerical response of woodpeckers to insect prey in a subalpine forest in Colorado. *Condor* 71:436-438.
- Krammes, J. S., tech. coord. 1990. Effects of fire management of southwestern natural resources. USDA For. Serv. Gen. Tech. Rep. RM-191. Rocky Mtn. For. and Range Exper. Stn. Ft. Collins, CO.
- Lahm, P., D. Fox, and A. Riebau. 1990. Smoke management: An emerging profession. Pp. 139-145 *in*: J. S. Krammes, tech. coord. *Effects of fire management of southwestern natural resources*. USDA For. Serv. Gen. Tech. Rep. RM-191. Rocky Mtn. For. and Range Exper. Stn. Ft. Collins, CO.
- Lotan, J. E., and J. K. Brown, compilers. 1985. Fire's effects on wildlife habitat - Symposium Proc. USDA For. Serv. Gen. Tech. Rep. INT-186. Intermountain Res. Stn. Ogden, UT.
- Lotan, J. E., B. M. Kilgore, W. C. Fischer, and R. M. Mutch, tech. coords. 1985. Proceedings - Symp. and workshop on wilderness fire. USDA For. Serv. Gen. Tech. Rep. INT-182. Intermountain Res. Stn. Ogden, UT.
- Lowe, P. O., P. F. Ffolliott, J. H. Dieterich, and D. R. Patton. 1978. Determining potential benefits from wildfire in

- Arizona ponderosa pine forests. USDA For. Serv. Gen. Tech. Rep. RM-52. Rocky Mtn. For. and Range Exper. Stn. Fort Collins, CO.
- MacArthur, R. H., H. Recher, and M. Cody. 1966. On the relation between habitat selection and species diversity. *Am. Nat.* 100:310-332.
- Mannan, R. W., M. L. Morrison, and E. C. Meslow. 1984. Comment: The use of guilds in forest bird management. *Wildl. Soc. Bull.* 12:426-430.
- Marshall, J. T., Jr. 1957. Birds of the pine-oak woodland in southern Arizona and adjacent Mexico. *Pacific Coast Avifauna* 32:1-125.
- Marshall, J. T., Jr. 1963. Fire and birds in the mountains of southern Arizona. *Proc. Tall Timbers Fire Ecol. Conf.* 2:134-141.
- Minnich, R. A., M. G. Barbour, J. H. Burk, and R. F. Fernau. 1995. Sixty years of change in Californian conifer forests of the San Bernardino Mountains. *Conservation Biol.* 9:902-914.
- Moeur, S., and D. A. Guthrie. 1984. The effects of clearing fire-killed trees on wildlife. Pp. 135-144 *in*: T. S. Foxx, compiler. *La Mesa fire symp. LA-9236-NERP*. Los Alamos Natl. Lab. Los Alamos, NM.
- Mutch, R. W. 1995. Prescribed fires in wilderness: How successful? Pp. 38-41 *in*: J. K. Brown, R. W. Mutch, C. W. Spoon, and R. H. Wakimoto, tech. coords. *Proceedings: Symposium on fire in wilderness and park management*. Usda For. Serv. Gen. Tech. Rep. INT-320. Intermtn. Res. Stn. Ogden, UT.
- Overturf, J. H. 1979. The effects of forest fire on breeding bird populations of ponderosa pine forests of northern Arizona. M.S. thesis. Northern Ariz. Univ. Flagstaff. 108 p.
- Raphael, M. G., and M. White. 1984. Use of snags by cavity-nesting birds in the Sierra Nevada. *Wildl. Monogr.* 86:1-66.
- Raphael, M. G., and M. L. Morrison. 1987. Decay and dynamics of snags in the Sierra Nevada, California. *Forest Science* 33:774-783.
- Raphael, M. G., M. L. Morrison, and M. P. Yoder-Williams. 1987. Breeding bird populations during twenty-five years of postfire succession in the Sierra Nevada. *Condor* 89:614-626.
- Robinson, S. K. 1992. Population dynamics of breeding Neotropical migrants in a fragmented Illinois landscape. Pp. 408-418 *in*: J. M. Hagan, III, and D. W. Johnston, eds. *Ecology and conservation of Neotropical migrant landbirds*. Smithsonian Inst. Press. Washington, DC.
- Root, R. B. 1967. The niche exploitation pattern of the Blue-gray Gnatcatcher. *Ecol. Monogr.* 37:317-350.
- Roppe, J. A., and D. Hein. 1978. Effects of fire on wildlife in a lodgepole pine forest. *Southwestern Naturalist* 23:279-288.
- Rotenberry, J. T. 1985. The role of habitat in avian community composition: Physiognomy or floristics? *Oecologia* 67:213-217.
- Rotenberry, J. T., R. J. Cooper, J. M. Wunderle, and K. G. Smith. 1995. When and how are populations limited? The roles of insect outbreaks, fires, and other natural perturbations. Pp. 55-84 *in*: T. E. Martin and D. M. Finch, eds. *Ecology and management of Neotropical migratory birds*. Oxford Univ. Press. Oxford, UK. 489pp.
- Sackett, S. S., S. Haase, and M. G. Harrington. 1994. Restoration of southwestern ponderosa pine ecosystems with fire. Pp. 115-121 *in*: W. W. Covington and L. F. DeBano, tech. coords. *Sustainable ecological systems: Implementing an ecological approach to land management*. USDA For. Serv. Gen. Tech. Rep. RM-247. Rocky Mtn. For. and Range Exper. Stn. Ft. Collins, CO.
- Sackett, S. S., S. Haase, and M. G. Harrington. 1996. Lessons learned from fire use for restoring southwestern ponderosa pine ecosystems. Pp. 54-61 *in*: W. Covington and P. K. Wagner, tech. coords. *Conference on adaptive ecosystem restoration and management: Restoration of cordilleran conifer landscapes of North America*. USDA For. Serv. Gen. Tech. Rep. RM-278. Rocky Mtn. For. and Range Exper. Stn. Ft. Collins, CO.
- Scott, V. E. 1979. Bird response to snag removal in ponderosa pine. *J. For.* 77:26-28.
- Skinner, N. G. 1989. Seasonal avifauna use of burned and unburned lodgepole pine forest ecotones. M.S. thesis. Univ. of Montana. Missoula, MT.
- Swetnam, T. W. 1990. Fire history and climate in the southwestern United States. Pp. 6-17 *in*: J. S. Krammes, tech. coord. *Effects of fire management of southwestern natural resources*. USDA For. Serv. Gen. Tech. Rep. RM-191. Rocky Mtn. For. and Range Exper. Stn. Ft. Collins, CO.
- Swetnam, T. W., and J. L. Bettancourt. 1990. Fire-Southern Oscillation relations in the southwestern United States. *Science* 249:1017-1020.
- Taylor, D. L., and W. J. Barmore, Jr. 1980. Post-fire succession of avifauna in coniferous forests of Yellowstone and Grand Teton National Parks. Pp. 130-145 *in*: R. M. DeGraaf and N. G. Tilghman, eds. *Management of western forests and grasslands for nongame birds*. USDA For. Serv. Gen. Tech. Rept. INT-86. Intermountain Res. Stn. Ogden, UT.
- Touchan, R., T. W. Swetnam, and H. D. Grissino-Mayer. 1995. Effects of livestock grazing on presettlement fire regimes in New Mexico. Pp. 268-272 *in*: J. K. Brown, R. W. Mutch, C. W. Spoon, and R. H. Wakimoto, tech. coords. *Proceedings: Symposium on fire in wilderness and park management*. Usda For. Serv. Gen. Tech. Rep. INT-320. Intermtn. Res. Stn. Ogden, UT.
- Villanueva-Díaz, J., and G. R. McPherson. 1995. Forest stand structure in mountains of Sonora, Mexico and New Mexico, USA. Pp. 416-423 *in*: L. F. DeBano, P. F. Ffolliott, A. Ortega-Rubio, G. J. Gottfried, R. H. Hamre, and C. B. Edminster, tech. coords. *Biodiversity and management of the Madrean Archipelago: The Sky*

Islands of southwestern United States and northwestern Mexico. USDA For. Serv. Gen. Tech. Rep. RM-264. Rocky Mtn. For. and Range Exper. Stn. Ft. Collins, CO.

Warshall, P. 1995. The Madrean Sky Island Archipelago: A planetary overview. Pp. 6-18 *in*: L. F. DeBano, P. F. Ffolliott, A. Ortega-Rubio, G. J. Gottfried, R. H. Hamre, and C. B. Edminster, tech. coords. Biodiversity and management of the Madrean Archipelago: The Sky

Islands of southwestern United States and northwestern Mexico. USDA For. Serv. Gen. Tech. Rep. RM-264. Rocky Mtn. For. and Range Exper. Stn. Ft. Collins, CO.

Wauer, R. H., and T. Johnson. 1984. La Mesa fire effects on avifauna - Changes in avian population and biomass. Pp. 145-171 *in*: T. S. Foxx, compiler. La Mesa fire symp. LA-9236-NERP. Los Alamos Natl. Lab. Los Alamos, NM.