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FIRE AND BIRDS IN THE SOUTHWESTERN UNITED STATES

Carl E. Bock and William M. Block

Abstract. Fire is an important ecological force in many southwestern ecosystems, but frequencies, sizes, and intensities of fire have been altered historically by grazing, logging, exotic vegetation, and suppression. Prescribed burning should be applied widely, but under experimental conditions that facilitate studying its impacts on birds and other components of biodiversity. Exceptions are Sonoran, Mojave, and Chihuahuan desert scrub, and riparian woodlands, where the increased fuel loads caused by invasions of exotic grasses and trees have increased the frequency and intensity of wildfires that now are generally destructive to native vegetation. Fire once played a critical role in maintaining a balance between herbaceous and woody vegetation in desert grasslands, and in providing a short-term stimulus to forb and seed production. A 3–5 yr fire-return interval likely will sustain most desert grassland birds, but large areas should remain unburned to serve species dependent upon woody vegetation. Understory fire once maintained relatively open oak savanna, pinyon-juniper, pine-oak, ponderosa pine (*Pinus ponderosa*), and low elevation mixed-conifer forests and their bird assemblages, but current fuel conditions are more likely to result in stand-replacement fires outside the range of natural variation. Prescribed burning, thinning, and grazing management will be needed to return fire to its prehistoric role in these habitats. Fire also should be applied in high elevation mixed-conifer forests, especially to increase aspen stands that are important for many birds, but this will be an especially difficult challenge in an ecosystem where stand-replacement fires are natural events. Overall, surprisingly little is known about avian responses to southwestern fires, except as can be inferred from fire effects on vegetation. We call for cooperation between managers and researchers to replicate burns in appropriate habitats that will permit rigorous study of community and population-demographic responses of breeding, migrating, and wintering birds. This research is critical and urgent, given the present threat to many southwestern ecosystems from destructive wildfires, and the need to develop fire management strategies that not only reduce risk but also sustain bird populations and other components of southwestern biological diversity.

Key Words: birds, chaparral, desert, fire, grassland, mixed-conifer, pine-oak, prescribed burning, riparian, savanna, Southwest, wildfire.

FUEGO Y AVES EN EL SUROESTE DE ESTADOS UNIDOS

Resumen. El fuego es una fuerza ecológica importante en varios ecosistemas sur-occidentales, pero sus frecuencias, tamaños e intensidades han sido alteradas históricamente por el pastoreo, aprovechamientos forestales, vegetación exótica y supresión. Las quemas prescritas deberían ser aplicadas, pero bajo condiciones experimentales las cuales faciliten el estudio de sus impactos en aves y otros componentes de biodiversidad. Algunas excepciones son el matorral xerófilo de Sonora, Mojave y Chihuahua, y bosques de galería, donde el incremento del material combustible causado por invasiones de pastos y árboles exóticos ha incrementado la frecuencia e intensidad de incendios, los cuales generalmente son dañinos para la vegetación nativa. Alguna vez el fuego jugó un papel importante para mantener el balance entre la vegetación herbácea y forestal en pastizales del desierto, así como para estimular el retoño y la producción de semilla en el corto plazo. Una repetición de incendio con intervalos de 4–5 años, sustentaría a la mayoría de las aves de pastizales, pero grandes áreas deberían permanecer sin incendiarse para servir a las especies dependientes de la vegetación forestal. El fuego algún tiempo mantuvo relativamente abierta la sabana de encinos, piñón-juníperos, pino-encino, pino ponderosa *(Pinus ponderosa)*, y bosques de coníferas mixtos de bajas elevaciones, así como sus aves correspondientes, pero las condiciones actuales de combustible tienden mas a resultar en reemplazos del crecimiento de plantas fuera del rango natural de variación. Se requerirían quemas preescritas, aclareos y el manejo de pastizales para regresar al papel que jugaba el fuego en la prehistoria en estos habitats. El fuego también debería ser aplicado en bosques de coníferas mixtos de alta elevación, especialmente para incrementar el crecimiento de aspen, el cual es importante para varias aves, pero esto sería un reto sumamente importante en ecosistemas donde el reemplazo del crecimiento de plantas en incendios es un evento natural. Es sorprendente lo poco que se conoce acerca de las respuestas de las aves a los incendios sur-occidentales, a excepción en lo que se refiere a la respuesta de la vegetación al fuego. Pedimos cooperación entre los manejadores e investigadores para replicar incendios en habitats apropiados, que permitan rigurosos estudios de respuestas demográficas de comunidades y poblaciones, de aves reproductoras, migratorias y aves que permanecen en estas regiones durante el invierno. Este estudio es crítico y urgente, dado el presente peligro que varios ecosistemas sur-occidentales enfrentan debido a incendios destructivos, así como por la necesidad de desarrollar estrategias de manejo las cuales no solo disminuyan el riesgo, sino también sustenten las poblaciones de aves y otros componentes de diversidad biológica de los ecosistemas sur-occidentales.

The conditions necessary and sufficient for fire in natural ecosystems include a source of ignition, such as lightning or anthropogenic burning, and an adequate quantity of dry fuel (Pyne et al. 1996). These conditions are met in most ecosystems of the southwestern United States (McPherson and Weltzin 2000), and the ecological importance of fire in the region has long been recognized (Leopold 1924, Humphrey 1958). We also know that humans have drastically altered historic frequencies, sizes, and intensities of fire by anthropogenic disturbances such as logging, livestock grazing, introduction of exotics, landscape fragmentation, and suppression efforts (Covington and Moore 1994, Bahre 1985, 1995, McPherson 1995, Moir et al. 1997). In 1988 and again in 1996, groups of researchers and managers assembled to synthesize the known effects of fire on natural resources in the southwestern United States, including its plant communities and wildlife, and to recommend ways to respond to wildfire and to use prescribed burning (Krammes 1990, Ffolliott et al. 1996). This paper is a follow-up to the results of those conferences, with a specific emphasis on populations and communities of southwestern birds.

For purposes of this review, we define the Southwest as that portion of the United States adjacent to Mexico, from the Mojave desert of southern Nevada and southeastern California eastward across Arizona and New Mexico and into trans-Pecos Texas (Fig. 1). Our definitions and descriptions of major ecosystems in the Southwest are taken largely from Brown (1982a) and Barbour and Billings (2000). We consider eight major ecosystems in this review: (1) Chihuahuan desert and associated desert grasslands, (2) Sonoran and Mojave deserts, (3) Madrean evergreen savanna, (4) interior chaparral, (5) pinyon-juniper woodland, (6) pine and pine-oak woodland, (7) mixed-conifer forest, and (8) riparian woodlands. For each of these ecosystems we describe the distribution, elevation, size, major vegetation, and characteristic birds, including those identified as priority species (Partners in Flight 2004). We describe the prehistoric importance of fire, fire-return interval, and its effects on vegetation. We then review how prehistoric fire regimes have been altered by recent human activities. We discuss known and probable effects of fire on birds under present conditions. At the end of each section, we suggest how both wild and prescribed fire should be managed for the benefit of birds, and identify the major unanswered questions and research priorities regarding the impact of fire on avian communities.

CHIHUAHUAN DESERT SCRUB AND DESERT GRASSLANDS

The Chihuahuan desert includes more than 45,000,000 ha, distributed mostly between 1,000 and 2,000 m elevation, from the Valley of Mexico north into Trans-Pecos Texas, southern New Mexico, and extreme southeastern Arizona (MacMahon 2000). Desert grassland (about 50,000,000 ha) generally surrounds the Chihuahuan Desert, forming a patchy belt that grades from desert scrub up into Madrean evergreen woodland, pinyon-juniper woodland, and pine-oak woodland from Mexico City north to the southwestern United States (McClaran 1995). We consider these ecosystems together because they are similar in vegetation (Axelrod 1985, Burgess 1995, MacMahon 2000, McLaughlin et al. 2001), they interdigitate on a fine geographic scale (Lowe and Brown 1982), and desert scrub has replaced large areas of southwestern grasslands within historic time, due at least in part to altered fire regimes (Humphrey 1974, McPherson 1995, Whitford 2002, Turner et al. 2003).

Dominant vegetation of the Chihuahuan desert includes shrubs and small trees, especially creosotebush (*Larrea tridentata*), tarbush (*Flourensia cernua*), mesquite (*Prosopis* spp.), and acacia (*Acacia* spp.), along with various species of *Yucca* and *Agave* (Brown 1982a, MacMahon 2000, Whitford 2002). Each of these plants extends into desert grasslands as well, along with smaller shrubs such as burroweed (*Isocoma tenuisecta*) and various species of *Baccharis* (McClaran 1995). Black grama (*Bouteloua eriopoda*) and tobosa (*Hilaria mutica*) are predominant grasses of the Chihuahuan desert, and these also extend into desert grasslands where they mix with a variety of warm-season perennial bunchgrasses, especially those in the genera *Bouteloua*, *Eragrostis*, and *Aristida* (McClaran 1995, McLaughlin et al. 2001).

Characteristic birds of desert grassland and Chihuahuan desert include species with a spectrum of habitat requirements, from those associated primar-

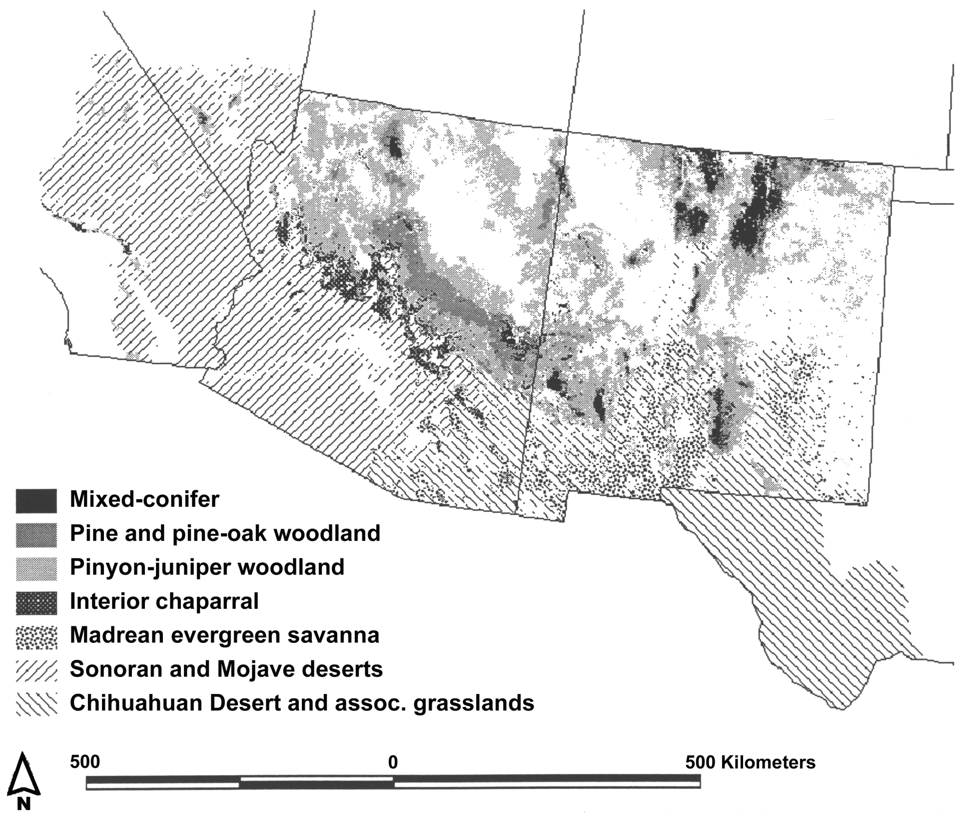

FIGURE 1. Ecosystems of the southwestern United States considered in this review.

ily with shrubs, such as Gambel's Quail (*Callipepla gambelii*) and Cactus Wren (*Campylrorhynchus brunneicapillus*), to those associated with relatively open grasslands, such as Horned Lark (*Eremophila alpestris*) and Grasshopper Sparrow (*Ammodramus savannarum*) (Brown 1982a). Desert grasslands are particularly important wintering habitat for a number of migratory sparrows, because of their seed production (Pulliam and Dunning 1987). Given historic conversions of grassland to desert scrub, it is not surprising that many Partners in Flight priority species for this region are associated with grasslands, or at least with areas that include significant grass cover. Examples include Ferruginous Hawk (*Buteo regalis*), Aplomado Falcon (*Falco femoralis*), Sprague's Pipit (*Anthus spragueii*), Cassin's Sparrow (*Aimophila cassinii*), Botteri's Sparrow (*Aimophila botterii*), Grasshopper Sparrow, and Baird's Sparrow (*Ammodramus bairdii*), and two birds restricted to grasslands of Arizona and Sonora, the endangered Masked Bobwhite (*Colinus virginianus ridgwayi*), and the Rufous-winged Sparrow (*Aimophila carpalis*).

Fire in Chihuahuan Desert Scrub and Desert Grasslands

Fires probably were very uncommon in Chihuahuan desert proper, and its dominant grass, black grama, is damaged by fire (Gosz and Gosz 1996). However, fires probably occurred once every 7–10 yr in higher, cooler, and wetter desert grasslands above the fringes of the Chihuahuan desert, and prehistoric fire served to keep these areas relatively free of trees and shrubs (McPherson 1995, McPherson and Weltzin 2000).

Southwestern grasslands from west Texas to southeastern Arizona almost universally experienced major invasions of woody plants over the course of the twentieth century (Buffington and Herbel 1965, Bahre and Shelton 1993, Archer 1994). These events have been attributed to climate change, livestock grazing, prairie dog (*Cynomys* spp.) control, and fire exclusion resulting from suppression efforts and loss of fine fuels to domestic grazers (Archer et al. 1995, Bahre 1995, Weltzin et al. 1997, Whitford 2002). Historical conversion of desert grassland to desert scrub has been nearly complete, and apparently permanent, in many black grama grasslands at the margins of the Chihuahuan desert (Schlesinger et al. 1990, Whitford 2002). However, recovery of native desert grasslands can occur after long-term livestock exclusion in relatively mesic areas (Valone et al. 2002), although it is not yet clear what role fire might play in this process (Valone and Kelt 1999).

Fire Effects on Chihuahuan Desert Scrub and Desert Grassland Birds

Birds associated with grasslands have declined more than other avian groups, both nationally and in the Southwest (Brown and Davis 1998, Vickery and Herkert 2001) begging the questions: (1) What have been the effects of contemporary fires on vegetation and birds in desert grasslands, and (2) What should be the role of prescribed burning in maintenance and restoration of southwestern grassland bird habitats?

Fire can have two categorically different effects on desert grassland vegetation and these in turn can have very different effects on birds. In the short term, fire reduces grass cover for one to three postfire growing seasons, while stimulating the abundance and variety of forbs, and generally increasing seed production (Bock et al. 1976, Bock and Bock 1978, Bock and Bock 1992a, McPherson 1995). Results of several studies in Arizona grasslands indicate that these short-term effects can improve habitat for seedeaters and open-ground species such as Scaled Quail (*Callipepla squamata*), doves, Horned Larks, and a variety of wintering sparrows (Table 1; Bock and Bock 1978, Bock and Bock 1992b, Gordon 2000, Kirkpatrick et al. 2002). At the same time, fire-caused reductions of grass cover temporarily reduce habitat quality for species dependent upon heavy ground cover, such as Montezuma Quail (*Cyrtonyx montezuma*), Cassin's Sparrow, Botteri's Sparrow, and Grasshopper Sparrow (Table 1).

Over the longer term, fire potentially can reduce (but probably not eliminate) cover of woody vegetation in desert grassland communities, although fire effects on vegetation are species-specific and related to season, grazing history, recent precipitation, and fire frequency (McPherson 1995, Valone and Kelt 1999, Drewa and Havstad 2001). Desert grasslands that include mesquite and other woody plants usually support a higher abundance and species richness of birds than open desert grasslands (Whitford 1997, Lloyd et al. 1998, Pidgeon et al. 2001). However, with the possible exception of the Cactus Wren (Table 1; Kirkpatrick et al. 2002), these negative effects have not yet been seen following fire, probably because fire frequencies and intensities have been insufficient to result in much long-term loss of woody cover.

Fire clearly had a historical importance in keeping southwestern desert grasslands relatively free of shrubs, but it has not yet been demonstrated that prescribed burning can be used to restore these conditions. This should be a high research priority. Given the vulnerability of black grama to fire in the most arid sites, the major application of prescription burning probably should be in relatively mesic areas dominated by a variety of other native perennial bunchgrasses. Some birds of the desert grassland depend upon woody vegetation that is a natural part of most Chihuahuan environments, while others require relatively open areas with substantial grass cover, and still others are attracted to the bare ground and heavy seed crops that come in the first 2–3 yr after a burn. All of this argues for maintaining a mosaic of landscapes in various stages of postfire succession, with some areas unburned for decades and others burned perhaps on a rotation of 3–5 yr.

In summary:

1. Prehistoric fires probably were uncommon in the Chihuahuan desert itself, but were important in sustaining the surrounding desert grasslands, and in determining the desert-grassland boundary.
2. Woody plants have increased in formerly open desert grasslands, following introduction of livestock and resulting decreases in fire frequency and intensity.
3. Contemporary fire in relatively mesic desert grasslands has the effect of reducing grass cover, while increasing bare ground, forb cover, and seed production for 2-3 yr postfire; over the longer term and with repeated burning, prescribed fire likely also could be used to reduce woody vegetation and benefit grasses.
4. Desert grassland and Chihuahuan desert avifaunas include some birds that depend on woody vegetation, others that require heavy grass cover, and still others that benefit from open ground and high seed production; the goal of prescription burning should be to restore and sustain this sort of habitat mosaic, with some areas rarely if ever burned, and others burned on a 3–5 yr rotation.
5. A research priority should be to determine if repeated fire in desert grassland can reduce woody vegetation to something resembling prehistoric levels, and to better understand the effects of such a fire regime on the abundance and demography of desert grassland birds.

TABLE 1. SUMMARY OF AVAILABLE LITERATURE ON THE RESPONSE OF BREEDING BIRDS (CHANGE IN ABUNDANCE) TO FIRE IN SOUTHWESTERN HABITATS OF NORTH AMERICA.

Species	State	Years after fire	Size (ha)	No. of sites	Response[a]	Type of fire	Reference[b]	Comments[c]
Scaled Quail (*Callipepla squamata*)	AZ	1–2	100, 150, 350	4	+	wild	1	Sacaton grassland; 1-yr increase.
Montezuma Quail (*Cyrtonyx montezumae*)	AZ	1–2	100, 150, 350	4	–	wild	1	Sacaton grassland; 1-yr decline.
Sharp-shinned Hawk (*Accipiter striatus*)	AZ	3	10,000	14	–	wild	2	Ponderosa pine; nonbreeding season.
White-winged Dove (*Zenaida asiatica*)	AZ	1–2	100, 150, 350	4	+	wild	1	Sacaton grassland; 1-yr increase; breeding season.
Mourning Dove (*Zenaida macroura*)	AZ	3	10,000	14	0	wild	2	Ponderosa pine; breeding season.
	AZ	1, 3, 9, 20	350–2,890	4	+	wild	3	Ponderosa pine; breeding season.
	AZ	1–2	100, 150, 350	4	+	wild	1	Sacaton grassland; 2-yr increase.
	AZ	1–2	1,596	14	+	prescr.	4	Mesquite grassland; breeding season.
	AZ	1–4	1,000	4	+	wild	5	Mesquite grassland; 1–3 yr increase.
	AZ	1–2	240, 120	4	+	wild	6	Oak savanna.
Broad-tailed Hummingbird (*Selasphorus platycerus*)	AZ	3	10,000	14	+	wild	2	Ponderosa pine; breeding season.
Lewis's Woodpecker (*Melanerpes lewis*)	AZ	3	10,000	14	+	wild	2	Ponderosa pine; breeding season; response to severe fire.
Ladder-backed Woodpecker (*Picoides scalaris*)	AZ	1–2	1,596	14	+	prescr.	4	Mesquite grassland; winter.
Hairy Woodpecker (*Picoides villosus*)	AZ	3	10,000	14	+	wild	2	Ponderosa pine; larger increase following severe fire than moderate fire.
	AZ	7	10,000	14	+	wild	7	Ponderosa pine; same area as above; population in severe fire areas greater than unburned areas, but lower than that recorded after 3 yr.
	AZ	1, 3, 9, 20	350–2,890	4	+	wild	3	Ponderosa pine; breeding season.
	AZ	1	4,800	6	+	wild	8	Ponderosa pine; nonbreeding season.
Northern Flicker (*Colaptes auratus*)	AZ	3	10,000	14	+	wild	2	Ponderosa pine.
	AZ	1–2	100	6	–	prescr.	9	Ponderosa pine & mixed-conifer; breeding season.
Olive-sided Flycatcher (*Contopus cooperi*)	AZ	3	10,000	14	+	wild	2	Ponderosa pine; breeding season; response to severe fire.
Western Wood-Pewee (*Contopus sordidulus*)	AZ	3	10,000	14	+	wild	2	Ponderosa pine; breeding season; positiive response to severe and moderate fire.
Ash-throated Flycatcher (*Myiarchus cinerascens*)	NM	14	6,250	4	–	wild	10	Ponderosa pine; breeding season.
	AZ	1–2	1,596	14	0	prescr.	4	Mesquite grassland; breeding season.
Loggerhead Shrike (*Lanius ludovicianus*)	AZ	1–2	1,596	14	0	prescr.	4	Mesquite grassland.
Plumbeous Vireo (*Vireo plumbeus*)	AZ	3	10,000	14	–	wild	2	Ponderosa pine; breeding season; negative response to severe fire.
Steller's Jay (*Cyanocitta stelleri*)	AZ	3	10,000	14	0	wild	2	Ponderosa pine.
	AZ	1, 3, 9, 20	350–2,890	4	+	wild	3	Ponderosa pine; breeding season.

TABLE 1. CONTINUED.

Species	State	Years after fire	Size (ha)	No. of sites	Response[a]	Type of fire	Reference[b]	Comments[c]
Pinyon Jay (*Gymnorhinus cyanocpehalus*)	AZ	3	10,000	14	0	wild	2	Ponderosa pine.
Clark's Nutcracker (*Nucifraga columbiana*)	AZ	3	10,000	14	0	wild	2	Ponderosa pine.
American Crow (*Corvus brachyrhynchos*)	AZ	3	10,000	14	0	wild	2	Ponderosa pine; nonbreeding season.
Common Raven (*Corvus corax*)	AZ	3	10,000	14	0	wild	2	Ponderosa pine.
Horned Lark (*Eremophila alpestris*)	AZ	1–4	1,000	4	+	wild	5	Mesquite grassland; 1–3 yr increase.
	AZ	1–2	100, 150, 350	4	+	wild	1	Sacaton grassland; 2nd yr increase.
Violet-green Swallow (*Tachycineta*	AZ	1–2	100	6	–	prescr.	9	Ponderosa pine & mixed-conifer; breeding season.
thalassina)	AZ	1	4,800	6	+	wild	8	Ponderosa pine; nonbreeding season.
Mountain chickadee (*Poecile gambeli*)	AZ	3	10,000	14	–	wild	2	Ponderosa pine; drastic decline in severe burns.
	AZ	1	10,000	14	–	wild	11	Ponderosa pine; drastic decline in severe burns.
	AZ	1–2	100	6	+	prescr.	9	Ponderosa pine & mixed-conifer; breeding season.
	NM	14	6,250	4	–	wild	10	Ponderosa pine & mixed-conifer; breeding season.
Verdin (*Auriparus flaviceps*)	AZ	1–2	1,596	14	0	prescr.	4	Mesquite grassland; winter.
White-breasted Nuthatch (*Sitta*	AZ	3	10,000	14	–	wild	2	Ponderosa pine; negative response to severe fire.
carolinensis)	AZ	1	10,000	14	–	wild	11	Ponderosa pine; negative response to severe fire.
	AZ	1	4,800	6	–	wild	8	Ponderosa pine; nonbreeding season.
Pygmy Nuthatch (*Sitta pygmaea*)	AZ	3	10,000	14	–	wild	2	Ponderosa pine; negative response to severe fire.
	AZ	1, 3, 9, 20	350–2,890	4	–	wild	3	Ponderosa pine; breeding season.
Brown Creeper (*Certhia americana*)	AZ	3	10,000	14	0/–	wild	2	Ponderosa pine; no change in breeding season; declines in severe areas during nonbreeding season.
	AZ	1, 3, 9, 20	350–2,890	4	–	wild	3	Ponderosa pine; breeding season.
Cactus Wren (*Campylorhynchus brunneicapillus*)	AZ	1–2	1,596	14	–	prescr.	4	Mesquite grassland.
House Wren (*Troglodytes aedon*)	NM	14	6,250	4	+	wild	10	Ponderosa pine & mixed-conifer; breeding season.
Ruby-crowned Kinglet (*Regulus calendula*)	AZ	1	4,800	6	–	wild	8	Ponderosa pine; nonbreeding season.
Western Bluebird (*Sialia mexicana*)	AZ	3	10,000	14	+	wild	2	Ponderosa pine; positive responses to severe and moderate fires.
	AZ	1	10,000	14	+	wild	11	Ponderosa pine; positive responses to severe and moderate fires.
	AZ	1	4,800	6	+	wild	8	Ponderosa pine; nonbreeding season.
	NM	14	6,250	4	+	wild	10	Ponderosa pine & mixed-conifer; breeding season.
Hermit Thrush (*Catharus guttatus*)	NM	14	6,250	4	–	wild	10	Ponderosa pine & mixed-conifer; breeding season.
American Robin (*Turdus migratorius*)	AZ	3	10,000	14	+	wild	2	Ponderosa pine; positive responses to severe and moderate fires.

TABLE 1. CONTINUED.

Species	State	Years after fire	Size (ha)	No. of sites	Response[a]	Type of fire	Reference[b]	Comments[c]
Northern Mockingbird (*Mimus polyglottos*)	AZ	1–2	1,596	14	0	prescr.	4	Mesquite grassland; breeding season.
Virginia's Warbler (*Vermivora virginiae*)	NM	14	6,250	4	–	wild	10	Ponderosa pine & mixed-conifer; breeding season.
Lucy's Warbler (*Vermivora luciae*)	AZ	1–2	1,596	14	0	prescr.	4	Mesquite grassland; breeding season.
Yellow-rumped Warbler (*Dendroica coronata*)	AZ	3	10,000	14	–	wild	2	Ponderosa pine; breeding season; negative response to severe fire.
Grace's Warbler (*Dendroica graciae*)	AZ	3	10,000	14	–	wild	2	Ponderosa pine; breeding season; avoidance of severe fire.
	AZ	1, 3, 9, 20	350–2,890	4	–	wild	3	Ponderosa pine; breeding season.
	AZ	1, 3, 9, 20	350–2,890	4	–	wild	12	Ponderosa pine; breeding season.
	NM	14	6,250	4	–	wild	10	Ponderosa pine & mixed-conifer; breeding season.
Common Yellowthroat (*Geothlypis trichas*)	AZ	1–2	150, 350, 100	4	–	wild	1	Sacaton grassland; 2-yr decline; breeding season.
Western Tanager (*Piranga ludoviciana*)	AZ	3	10,000	14	+	wild	2	Ponderosa pine; breeding season; positive response to moderate fire.
Green-tailed Towhee (*Pipilo chlorurus*)	AZ	1, 3, 9, 20	350–2,890	4	+	wild	3	Ponderosa pine; breeding season.
Spotted Towhee (*Pipilo maculatus*)	NM	14	6,250	4	+	wild	10	Ponderosa pine & mixed-conifer; breeding season.
Canyon Towhee (*Pipilo fuscus*)	AZ	1–2	1,596	14	0	prescr.	4	Mesquite grassland; winter.
Cassin's Sparrow (*Aimophila cassinii*)	AZ	1–2	1,596	14	–	prescr.	4	Mesquite grassland; breeding season.
	AZ	1–4	1,000	4	m	wild	5	Mesquite grassland; 2-yr decline in native grassland; breeding season.
	AZ	1	?	6	–	prescr.	13	Mesquite grassland; winter.
	AZ	1–2	150, 350, 100	4	+	wild	1	Sacaton grassland; 2-yr increase; breeding season.
Botteri's Sparrow (*Aimophila botterii*)	AZ	1–2	1,596	14	–	prescr.	4	Mesquite grassland; breeding season.
	AZ	1–4	1,000	4	–	wild	5	Mesquite grassland; 2-yr decline; breeding season.
	AZ	1–2	100, 150, 350	4	–	wild	1	Sacaton grassland; 1-yr decline; breeding season.
Chipping Sparrow (*Spizella passerina*)	AZ	3	10,000	14	+	wild	2	Ponderosa pine; breeding season.
	AZ	1, 3, 9, 20	350–2,890	4	+	wild	3	Ponderosa pine; breeding season.
	AZ	1–2	240, 120	4	+	wild	6	Oak savanna; winter.
Brewer's Sparrow (*Spizella breweri*)	AZ	1–2	1,596	14	0	prescr.	4	Mesquite grassland; winter.
	AZ	1	?	6	0	prescr.	13	Mesquite grassland; winter.
Vesper Sparrow (*Pooecetes gramineus*)	AZ	1–2	1,596	14	+	prescr.	4	Mesquite grassland; winter.
	AZ	1–4	1,000	4	+	wild	5	Mesquite grassland; 2–3 yr increase; winter.
	AZ	1	?	6	+	prescr.	13	Mesquite grassland; winter.
	AZ	1–2	100, 150, 350	4	+	wild	1	Sacaton grassland; 2-yr increase; winter.
	AZ	1–2	240, 120	4	+	wild	6	Oak savanna; winter.

TABLE 1. CONTINUED.

Species	State	Years after fire	Size (ha)	No. of sites	Response[a]	Type of fire	Reference[b]	Comments[c]
Lark Sparrow (*Chondestes grammacus*)	AZ	1–4	1,000	4	+	wild	5	Mesquite grassland; 2- yr increase; breeding season.
Black-throated Sparrow (*Amphispiza bilineata*)	AZ	1–2	1,596	14	0	prescr.	4	Mesquite grassland.
Savannah Sparrow (*Passerculus sandwichensis*)	AZ	1–4	1,000	4	+	wild	5	Mesquite grassland; 1-yr increase; winter.
	AZ	1	?	6	+	prescr.	13	Mesquite grassland; winter.
	AZ	1–2	100, 150, 350	4	+	wild	1	Sacaton grassland; 2-yr increase; winter.
Grasshopper Sparrow (*Ammodramus savannarum*)	AZ	1–2	1,596	14	0	prescr.	4	Mesquite grassland; winter.
	AZ	1–4	1,000	4	–	wild	5	Mesquite grassland; 2-yr decline.
	AZ	1	?	6	0	prescr.	13	Mesquite grassland; winter.
Baird's Sparrow (*Ammodramus bairdii*)	AZ	1	?	6	0	prescr.	13	Mesquite grassland; winter.
Lincoln's Sparrow (*Melospiza lincolnii*)	AZ	1	?	6	0	prescr.	13	Mesquite grassland; winter.
White-crowned Sparrow (*Zonotrichia leucophrys*)	AZ	1	?	6	0	prescr.	13	Mesquite grassland; winter.
	AZ	1–2	100, 150, 350	4	+	wild	1	Sacaton grassland; 1-yr increase; winter.
	AZ	1	4,800	6	+	wild	8	Ponderosa pine; winter.
Dark-eyed Junco (*Junco hyemalis*)	AZ	3	10,000	14	0	wild	2	Ponderosa pine.
Pyrrhuloxia (*Cardinalis sinuatus*)	AZ	1–2	1,596	14	0	prescr.	4	Mesquite grassland; breeding season.
Blue Grosbeak (*Passerina caerulea*)	AZ	1–2	1,596	14	0	prescr.	4	Mesquite grassland; breeding season.
	AZ	1–2	100, 150, 350	4	–	wild	1	Sacaton grassland; 2-yr decline; breeding season.
Eastern Meadowlark (*Sturnella magna*)	AZ	1–2	1,596	14	0	prescr.	4	Mesquite grassland.
	AZ	1–4	1,000	4	m	wild	5	Mesquite grassland.
	AZ	1–2	100, 150, 350	4	+	wild	1	Sacaton grassland; 2-yr increase.
Western Meadowlark (*Sturnella neglecta*)	AZ	3	10,000	14	+	wild	2	Ponderosa pine; breeding season.
Brown-headed Cowbird (*Molothrus ater*)	AZ	3	10,000	14	+	wild	2	Ponderosa pine; breeding season; increase with moderate fire.
House Finch (*Carpodacus mexicanus*)	AZ	1–2	100, 150, 350	4	+	wild	1	Sacaton grassland; 1-yr increase.
Red Crossbill (*Loxia curvirostra*)	AZ	3	10,000	14	–	wild	2	Ponderosa pine; decline with severe and moderate fire.

[a] Change in abundance: + = increase; – = decrease; 0 = no effect or study inconclusive; m = mixed response.
[b] References: 1 = Bock and Bock (1978); 2 = Bock and Block (in press); 3 = Lowe et al. (1978); 4 = Kirkpatrick et al. (2002); 5 = Bock and Bock (1992b); 6 = Bock et al. (1976); 7 = Block and Covert (unpubl. data); 8 = Blake (1982); 9 = Horton and Mannan (1988); 10 = Johnson and Wauer (1996); 11 = Dwyer and Block (2000); 12 = Overturf (1979); 13 = Gordon (2000).
[c] Unless otherwise indicated, includes data from both breeding and nonbreeding seasons.

SONORAN AND MOJAVE DESERT SCRUB

The Sonoran desert includes about 27,500,000 ha in the lowlands of southeastern California, southwestern Arizona, most of Baja California, and the western half of Sonora, Mexico (Robichaux 1999, MacMahon 2000). At its northwestern limits, Sonoran desert grades into Mojave desert, which includes another 14,000,000 ha of the lowest elevations in southeastern California, southern Nevada, and northwestern Arizona (MacMahon 2000). These deserts include species-rich, structurally complex, and in many ways similar mixtures of shrubs, trees, succulents, and annual forbs (Turner 1982, Turner et al. 1995, MacMahon 2000). Dominant shrubs common to both deserts include creosote bush (*Larrea tridentata*) and bur sage (*Ambrosia dumosa*). Characteristic taller vegetation includes small trees such as palo verde (*Cercidium* spp.) and columnar cacti such as the saguaro (*Cereus giganteus*) in the Sonoran Desert, and the Joshua tree (*Yucca brevifolia*) in the Mojave desert.

The avifaunas of these deserts are species rich compared to nearby desert grasslands (Tomoff 1974, Davis and Russell 1990), and they include a variety of cavity-nesting species such as the Elf Owl (*Micrathene whitneyi*), Ferruginous Pygmy-Owl (*Glaucidium brasilianum*), Gila Woodpecker (*Melanerpes uropygialis*), and Gilded Flicker (*Colaptes chrysoides*) that depend upon large trees and cacti for nest sites (Brown 1982a, Cartron and Finch 2000, Hardy and Morrison 2001). At least in the Sonoran desert, there is a strong positive relationship between vegetation volume and complexity, and the overall abundance and diversity of birds (Tomoff 1974, Mills et al. 1991). Partners in Flight priority species for one or both deserts include Gambel's Quail, Gilded Flicker, Gila Woodpecker, Costa's Hummingbird (*Calypte costae*), Cactus Wren, Black-tailed Gnatcatcher (*Polioptila melanura*), Rufous-winged Sparrow, and all four Southwestern thrashers (*Toxostoma bendirei*, *T. curvirostre*, *T. crissale*, and *T. lecontei*).

Fire in Sonoran and Mojave Desert Scrub

Wildfires probably were relatively uncommon in the Sonoran and Mojave deserts prehistorically, and restricted to periods following wet winters, when residual fine fuels left from annual forb production were sufficient to carry a burn across the otherwise sparse desert floor (McLaughlin and Bowers 1982). In the absence of dendrochronological data, Rogers and Steele (1980) attempted to use degree of fire adaptation in perennial plants as evidence for historical fire frequency in the Sonoran desert. They concluded that such adaptations were widespread but relatively weak, and that a fire-return interval of anything less than 20 yr would be highly destructive of most native trees, shrubs, and especially cacti (see also McLaughlin and Bowers 1982).

The introduction and spread of exotic grasses such as red brome (*Bromus rubens*) and buffelgrass (*Pennisetum ciliare*), and a variety of exotic forbs, increased both the frequency and intensity of fire in the Sonoran and Mojave deserts over the past century, causing substantial mortality of woody plants and succulents (Rogers 1985, Brown and Minnich 1986, Schmid and Rogers 1988, Burgess et al. 1991, Miller et al. 1995). Furthermore, both seed and foliar production of these exotics are likely to be enhanced by increased levels of carbon dioxide, so that anticipated climate changes may increase the frequency of fire in these ecosystems even beyond their present unnaturally high levels (Smith et al. 2000).

Fire Effects on Sonoran and Mojave Desert Scrub Birds

We could find no studies that compared avian species richness or abundance in burned versus unburned Sonoran and Mojave desert landscapes. However, there is little doubt that fire-caused mortality of desert woody plants and succulents would have a strongly negative impact on the majority of native bird populations, especially those dependent upon trees and cacti for nest sites.

The principal management objective for Sonoran and Mojave desert ecosystems should be to prevent and suppress wildfires that kill the native trees, shrubs, and succulents. A critical research need is to develop and test methods for limiting the spread and abundance of exotic grasses and forbs responsible for increased fuel loads. Cool-season, prescribed burning is one possible method for reducing fuels, but the risks are high because of the inherent fire-vulnerability of the native vegetation.

In summary:

1. Fires were historically uncommon in the Sonoran and Mojave deserts, and much of the native vegetation is relatively intolerant of the effects of burning.
2. Introduction and spread of exotic forbs and especially grasses have increased both the frequency and intensity of fire in these deserts, threatening many of the shrubs, trees, and succulents that are critical habitat components for birds.

3. The highest management and research priority is to find ways of reducing the frequency and intensity of wildfire in Sonoran and Mojave desert scrub habitats, by controlling the spread and abundance of exotic forbs and grasses.

MADREAN EVERGREEN SAVANNA

This oak-dominated ecosystem includes about 1,500,000 ha of the Sierra Madre Occidental, largely in Mexico, but extending north into southeastern Arizona, southern New Mexico, and Trans-Pecos Texas (Brown 1982a, McPherson 1997). Distributed mostly between 1,000 and 2,000 m elevation, Madrean evergreen savanna grades into desert grassland and mesquite savanna at its lower elevational limits, and into pine-oak woodland at its upper bounds. It is a typical savanna, with scattered broad-crowned trees and a grassy understory. The common oaks include *Quercus emoryi*, *Q. arizonica*, and *Q. grisea*, frequently with scattered populations of juniper (*Juniperus deppeana*, and *J. monosperma*), and pinyon pine (*Pinus cembroides*).

Typical birds of southwestern oak savannas include acorn-dependent species such as Acorn Woodpecker (*Melanerpes formicivorus*) and Mexican Jay (*Aphelocoma ultramarina*), foliage gleaners and insect hawkers such as Bridled Titmouse (*Baeolophus wollweberi*) and bluebirds (*Sialia* spp.), and species dependent on the grassy understory such as Montezuma Quail. Among these, the Montezuma Quail, Mexican Jay, Bridled Titmouse, and Eastern Bluebird (*Sialia sialis*) have been identified as Partners in Flight species of priority.

Fire in Madrean Evergreen Savanna

Fire almost certainly maintained Madrean evergreen savanna in a relatively open condition prehistorically, favoring grasses over understory shrubs and young trees (McPherson and Weltzin 2000). Cattle grazing and fire suppression have virtually eliminated wildfire from an ecosystem that probably evolved with a return interval of about 10 yr (McPherson 1997). The result has been a substantial increase in woody vegetation at the expense of the understory grasses, over the past century (Humphrey 1987, Turner et al. 2003). There have been few studies examining the effects of recent wildfires or prescribed burns on this habitat. Limited work suggests that the oaks can be top-killed by fire, but that they frequently resprout from the lower trunk or root crown (Johnson et al. 1962, Barton 1995).

Fire Effects on Madrean Evergreen Savanna Birds

Two cool spring wildfires in savannas at the distributional limits of oak in southeastern Arizona killed no mature trees, but they reduced grass cover and increased forb cover and seed production for two postfire years (Bock et al. 1976). Total bird abundance was greater on the burned areas, especially of winter seedeaters such as Mourning Dove (*Zenaida macroura*), Vesper Sparrow (*Pooecetes gramineus*), and Chipping Sparrow (*Spizella passerina*). This result is generally consistent with those from studies of wildfire and prescribed burning in mesquite grassland (Table 1). However, these results tell us virtually nothing about the likely responses of birds to hotter fires that change woodland structure, and we found no other published studies about fire effects on birds in Madrean evergreen savannas. In the midwestern United States, fires play a critical role in shaping the composition of oak savannas and their avifaunas (Davis et al. 2000, Brawn et al. 2001). Fires in Madrean oak savannas likely have similar effects, but they have not yet been documented.

The goal of fire management in Madrean evergreen savannas should be to prevent stand-replacement wildfires that kill mature oaks to the ground, since these events would eliminate a structural component of the habitat that is critical for most of its bird species. Cool-season, prescribed burning could have the double benefit of reducing fuels and the risk of catastrophic wildfire, and improving habitat for birds such as the Montezuma Quail that depend on dense understory grasses for escape cover (Brown 1982b). Determining avian responses to prescribed understory fire should be a research priority for Madrean evergreen savanna.

In summary:

1. Wildfire likely maintained oak-dominated Madrean evergreen savanna in a relatively open condition, with scattered broad-crowned trees and grassy understory.
2. Fire suppression and fuel reductions caused by livestock grazing have favored woody vegetation over grasses.
3. The risk of catastrophic wildfire has increased historically, and birds dependent upon open woodlands and grassy understory probably have declined, although this has not been studied.
4. Cool-season prescribed burning could reduce the risk of catastrophic wildfire and improve habitat for a variety of bird species in this habitat, but there has been virtually no research on this subject.

INTERIOR CHAPARRAL

North of Mexico, interior chaparral is best developed in a band south of the Mogollon Rim extending from northwestern to east-central Arizona, where it occupies about 1,400,000 ha (Pase and Brown 1982, Keeley 2000). This shrubby habitat is more patchily distributed to the south and east, across southeastern Arizona, southern New Mexico, southwest Texas, and onto the western slopes of the Sierra Madre Oriental of northeastern Mexico, where it again becomes a major vegetation type. Interior chaparral is distributed from 1,000–2,000 m elevation in the north, and from 2,000–3,000 m in the south. It usually intergrades with pine-oak woodland and with grassland-desertscrub at its upper and lower elevational limits, respectively (Pase and Brown 1982, Keeley 2000).

Interior chaparral consists primarily of a mixture of dense perennial shrubs, especially live oak (*Quercus turbinella*) and various species of manzanita (*Arctostaphylos* spp.) and *Ceanothus* (Keeley 2000). Some characteristic birds of interior chaparral given priority status by Partners in Flight include Crissal Thrasher (*Toxostoma crissale*), Virginia's Warbler (*Vermivora virginiae*), Green-tailed Towhee (*Pipilo chlorurus*), Canyon Towhee (*Pipilo fuscus*), and Black-chinned Sparrow (*Spizella atrogularis*).

Fire in Interior Chaparral

Fire-return interval for interior chaparral may be 50–100 yr, much longer than that for the better-studied California chaparral, and probably related to its relatively low productivity (Keeley 2000). Nevertheless, shrubs of interior chaparral recover well from fire, either by seed or by re-sprouting, and postfire recovery may take only 5–10 yr (Pase and Granfelt 1977, Carmichael et al. 1978). Drought, livestock grazing, and suppression have reduced fire frequency over the past century, resulting in increased shrub and reduced perennial grass cover in Arizona interior chaparral (Brejda 1997). Research and management have focused on effects of wildfire, prescription burning, grazing, and herbicide application on attributes of chaparral ecosystems such as livestock forage production, soil quality, and watershed function (Bolander 1981, Davis 1989, Overby and Perry 1996, Brejda 1997).

Fire Effects on Interior Chaparral Birds

We found no published information on responses of bird populations to fire alone in interior chaparral. Szaro (1981) compared bird populations between two stands of Arizona interior chaparral, one unburned and un-manipulated for 20 yr, and the other burned, treated with herbicides, and seeded with exotic grasses. The avian assemblage in the undisturbed chaparral was dominated by species such as Gambel's Quail, Mexican Jay (*Aphelocoma ultramarina*), Bewick's Wren (*Thryomanes bewickii*), Crissal Thrasher and Spotted Towhee (*Pipilo maculatus*). The manipulated watershed supported only two common birds, the Rock Wren (*Salpinctes obsoletus*) and Rufous-crowned Sparrow (*Aimophila ruficeps*). However, the herbicide and seeding treatments doubtless obscured fire effects, so the results of this study cannot be taken as indicative of avian responses to prescribed burning alone. In studies of California chaparral, postfire bird assemblages included higher proportions of grassland species than those in unburned stands, but the overall variety and abundance of birds were comparable (Lawrence 1966, Wirtz 1982).

Complete conversion of interior chaparral to grassland, by whatever means, almost certainly would negatively impact most birds. Prescribed burning might benefit birds and other wildlife in interior chaparral if it is used to create relatively small openings in areas of heavy shrub growth, in order to increase grass cover and habitat structural heterogeneity. This possibility should be tested, using a series of replicated cool-season burns, matched with unmanipulated control sites, and sampled both before and up to 5 yr after fire.

In summary:

1. Wildfire probably occurred prehistorically in interior chaparral once every 50–100 yr, and native shrubs are adapted to recover relatively quickly; these fires likely maintained patchiness in this habitat, and facilitated development of native grass cover.
2. Shrub cover has increased historically, as a result of livestock grazing and fire suppression, reducing habitat heterogeneity and increasing the likelihood of unnaturally large and intense wildfires.
3. Prescribed burning might be used to reduce the risk of wildfire and to increase landscape heterogeneity beneficial to chaparral birds, but this possibility needs much more study.

PINYON-JUNIPER WOODLANDS

Pinyon-juniper woodland occurs throughout the northern two-thirds of Arizona and New Mexico, an area encompassing over 10,000,000 ha (Conner et al. 1990, Van Hooser et al. 1993). These woodlands are found between 1,200 and 2,700 m elevation and are dominated by various pinyon pines (*Pinus edulis, P. discolor,* and *P. californiarum*) and junipers (*Juniperus deppeana*, *J. osteosperma*, *J. monosperma*, and *J. scopulorum*). Tree species composition and structure vary geographically and according to topography, ranging from closed-canopy, mesic woodland to open savanna (Moir and Carleton 1986).

Balda and Masters (1980) reported 73 bird species that breed in pinyon-juniper woodland. Of these, they concluded that 18 were highly dependent on this habitat, including Western Screech-Owl (*Otus kennicotti*), Black-chinned Hummingbird (*Archilochus alexandri*), Ash-throated Flycatcher (*Myiarchus cinerascens*), Gray Flycatcher (*Empidonax wrightii*), Western Scrub-Jay (*Aphelocoma californica*), Pinyon Jay (*Gymnorhinus cyanocephalus*), Juniper Titmouse (*Baeolophus ridgwayi*), Bushtit (*Psaltriparus minimus*), Bewick's Wren (*Thryomanes bewickii*), Northern Mockingbird (*Mimus polyglottos*), Blue-gray Gnatcatcher (*Polioptila careulea*), Gray Vireo (*Vireo vicinior*), Black-throated Gray Warbler (*Dendroica nigrescens*), House Finch (*Carpodacus mexicanus*), Spotted Towhee, Canyon Towhee, Lark Sparrow (*Chondestes grammacus*), and Black-chinned Sparrow (*Spizella atrogularis*). Species of concern within this ecosystem include Ferruginous Hawk (*Buteo regalis*), Gray Flycatcher (*Empidonax wrightii),* Pinyon Jay, Bendire's Thrasher (*Toxostoma bendirei*), Juniper Titmouse, Gray Vireo, and Black-throated Gray Warbler.

Fire in Pinyon-Juniper Woodlands

Historically, the primary role of fire in pinyon-juniper woodlands was more to limit its extent and distribution, and to regulate tree densities, than to change its composition or structure. This fire regime maintained large expanses of grassland, and grassy openings within an open woodland. In addition to regulating forest structure, fire played important roles in nutrient cycling, and in stimulating sprouting and fruiting that led to increased food production, especially for wintering populations of non-game birds (Balda and Masters 1980). Grassland birds, frugivores, and those that favored the interface between woodland and grassland almost certainly benefited from historical fire regimes.

More recently, fire suppression and the removal of fine herbaceous fuels by grazing livestock have facilitated expansion of pinyon-juniper woodlands into formerly open grasslands, and led to increased tree densities within existing woodlands (Pieper and Wittie 1990). Concomitantly, the fire regime has changed from low-severity, stand-maintenance burns to high-severity, stand-replacement burns. Bird species most likely to be negatively affected by this altered fire regime are those that require live trees for some aspect of their life history (O'Meara et al. 1981, Sedgwick and Ryder 1987).

Fire Effects on Pinyon-Juniper Woodlands Birds

Little information is available on fire effects in pinyon-juniper woodlands, particularly as related to birds (Balda and Masters 1980, Pieper and Wittie 1990, Severson and Rinne 1990). Although the ecological effects of chaining on bird habitats are not equivalent to those of fire, we consider effects of chaining as they relate to tree removal. As one would guess, species that depend on trees for foraging or nesting, such as Black-throated Gray Warbler, Plumbeous Vireo (*Vireo plumbeus*), White-breasted Nuthatch (*Sitta carolinensis*), and Gray Flycatcher, responded negatively to chaining (O'Meara et al. 1981, Sedgwick and Ryder 1987). Two species that favor more open habitats, Rock Wren (*Salpinctes obsoletus*) and Chipping Sparrow, appeared to benefit. However, we are reluctant to equate chaining with burning. Chaining removes all standing trees and snags, and reduces biomass and nutrients in the system. In contrast, some trees and snags remain standing following fire. Residual snags, for example, provide ephemeral (within 6 yr postfire) nesting substrates for cavity-nesting birds such as Hairy Woodpecker (*Picoides villosus*) and Western Bluebird (*Sialia mexicana*). As snags fall and are no longer available as nesting substrates, populations of cavity-nesting birds decline (Block, unpubl. data). Fire also plays important roles in nutrient cycling, and in stimulating sprouting and fruiting, which can lead to increased food production, especially for wintering populations of non-game birds (Balda and Masters 1980).

Ideally, pinyon-juniper woodland should be managed to restore ecosystem structure and function, which would include returning to the historical fire regime. The practicality of doing so is dubious given that it would entail concerted efforts to reduce both grazing intensity and tree densities to provide conditions needed to sustain low-severity, ground fires.

Given the near absence of information on fire effects on birds in pinyon-juniper woodland, there are numerous opportunities for research in this habitat type. Priority, however, should be given to understanding how disruption of natural fire regimes has altered bird habitats and affected bird populations. This research would focus on two general topics: (1)

the habitat and population ecologies of birds in areas that have lacked fire for the past century, and (2) the effects of recent large-scale, stand-replacement fires on bird habitats, populations, and communities. Once these studies are completed, research experiments should be conducted to elucidate effects of potential management options to reduce fuels and move toward conditions resulting from a more natural fire regime.

In summary:

1. Fire once maintained pinyon-juniper woodlands in a savanna-like condition, with numerous grassy openings.
2. Fire suppression and loss of fuels to livestock grazing reduced fire frequency, resulting in increased woodland density, and a shift to stand-replacement fires.
3. Almost nothing is known about bird responses to fire in pinyon-juniper woodland.
4. Research and management should focus on understanding the ecology of birds in existing unburned pinyon-juniper woodlands, on the effects of recent stand-replacement fires, and eventually on ways to restore these woodlands to their historic structural condition, including the use of prescribed burning.

PONDEROSA PINE AND PINE-OAK WOODLANDS

Southwestern montane forests include both Cordilleran and Madrean flora. Cordilleran flora dominates more northern latitudes, whereas Madrean flora is largely restricted to basin-and-range mountains in southeastern Arizona, southwestern New Mexico, and along the Mogollon escarpment (Brown 1982a). The primary differences between the two systems are the particular pine and oak species; the overall structure is similar. Regardless of the flora, woodland and forest vegetation generally occur in gradients influenced by topography, aspect, soils, and climate.

Ponderosa pine (*Pinus ponderosa*) is the most common forest type in the Southwest, comprising approximately 70% of the forested land base (Conner et al. 1990, Van Hooser et al., 1993). At lower elevations, ponderosa pine forest is bounded by pinyon-juniper woodlands or oak savannas (Whitaker and Niering 1964, 1965). These lower forests are xerophytic, and ponderosa pine is the climax tree species. Various pinyon pines (*Pinus edulis, P. discolor, P. californiarum*), junipers (*Juniperus deppeana*, *J. osteosperma*, *J. monosperma*, and *J. scopulorum*), and oaks (*Quercus grisea, Q. arizonica, Q. emoryi, Q. hyperleucoides, Q gambelii,* and *Q. undulata*) occur as subdominant trees. Big sagebrush (*Artemisia tridentata*), rabbitbrush (*Chrysothamnus nauseosus*), and New Mexican locust (*Robinia neomexicana*) are common shrubs, with blue grama (*Bouteloua gracilis*), Arizona fescue (*Festuca arizonica*), and mountain muhly (*Muhlenbergia montana*) as the primary grasses. With increasing elevation, ponderosa pine forests become more mesophytic and, although still the dominant tree, ponderosa pine is a seral species amid mixed-conifer forests (Moir et al. 1997).

Hall et al. (1997) list over 100 bird species using ponderosa pine forest. Some characteristic species include Mourning Dove, Broad-tailed Hummingbird (*Selasphorus platycercus*), Northern Flicker (*Colaptes auratus*), Hairy Woodpecker, Western Wood-Pewee (*Contopus sordidulus*), Violet-green Swallow (*Tachycineta thalassina*), Steller's Jay, Common Raven (*Corvus corax*), Mountain Chickadee (*Popecile gambeli*), White-breasted Nuthatch, Pygmy Nuthatch (*Sitta pygmaea*), Western Bluebird, Plumbeous Vireo, Yellow-rumped Warbler (*Dendroica coronata*), Grace's Warbler (*Dendroica graciae*), Western Tanager (*Piranga ludoviciana*), Red Crossbill (*Loxia curvirostra*), Cassin's Finch (*Carpodacus cassinii*), Pine Siskin (*Carduelis pinus*), Chipping Sparrow, and Dark-eyed Junco (*Junco hyemalis*). Bird species of special concern within southwestern pine forests include Northern Goshawk (*Accipiter gentilis*), Mexican Spotted Owl (*Strix occidentalis lucida*), Flammulated Owl (*Otus flammeolus*), Greater Pewee (*Contopus pertinax)*, Olive-sided Flycatcher (*Contopus cooperi*), Cordilleran Flycatcher (*Empidonax occidentalis*), Purple Martin (*Progne subris*), Olive Warbler (*Peucedramus taeniatus*), Virginia's Warbler, and Grace's Warbler.

Fire in Ponderosa Pine Forests and Pine-Oak Woodlands

Fire is perhaps the most important natural disturbance in southwestern pine forests (Moir and Dieterich 1988, Covington and Moore 1994, Moir et al. 1997), and it influences plant composition, forest structure, and successional pathways. Frequent, low-intensity fires were part of the evolutionary history of many lower-elevation forests, extending up through mesophytic ponderosa pine and lower elevation mixed-conifer (Savage and Swetnam 1990, Moir et al. 1997). Crown fires seldom occurred, and they were confined to relatively small patches (Pyne 1996). Within the xerophytic pine, fire occurred every 2–12 yr and maintained an open grassy understory and a patchy tree pattern. Given the frequency at which fires occurred, little wood debris accumulated on the forest floor, and most fire was fueled by dead herbaceous vegetation. These low-intensity fires reduced understory fuel levels and killed small trees, preserving the characteristic open stand structure (Cooper 1960, 1961; White 1985).

Within the past century, management and economic activities, primarily fire suppression, livestock grazing, and logging, have had profound effects, altering natural fire disturbance regimes and their effects on forest structure and composition (Cooper 1960, 1961, Covington and Moore 1994). The synergistic effects of these practices have resulted in dense forests consisting mostly of small trees, reductions in fine fuels, heavy accumulations of ground and ladder fuels, and forests at high risk of large-scale, stand-replacement fires (Cooper 1960, 1961, Covington and Moore 1994). In addition, fire exclusion has led to changes in forest composition. For example, lack of fire has allowed shade-tolerant firs (*Abies* spp.) to compete with dominant pines for nutrients, thereby moving mesophytic pine forests toward mixed-conifer forests (Moir et al. 1997). Over-topping by pines has shaded out oaks and aspen (*Populus tremuloides*), reducing their prevalence on the landscape (Moir et al. 1997). In other areas, pines are encroaching upon open meadows and parks, converting them to forest (Moir et al. 1997). These changes have combined to increase continuities of fuels within and among stands, thereby increasing the risk and prevalence of large-scale, stand-replacement fire (USDI 1995).

Given large-scale fires of the past decade and risks to lives and properties, land-management agencies are beginning to implement fuels reduction programs with the goal of abating fire risk. Fuels reduction includes tree thinning and prescribed fire, used singly or in combination. Little information is available on the response of birds to such treatments.

Fire Effects on Ponderosa Pine and Pine-Oak Woodlands Birds

Generalizing fire effects on birds in pine and pine-oak forests is difficult, given differences in fire severity, intensity, and size, as well as the scale and season of study. Short-term responses may differ from long-term responses; breeding bird response may differ from wintering bird response; and effects observed at the stand scale may differ from those at the landscape or regional scale. Lowe et al. (1978) examined a series of fires representing a chronosequence ranging from 1–20 yr postfire, and found that fire effects changed with time (Table 1). Ground-foraging birds and woodpeckers increased immediately following fire, presumably in response to increased food and nesting substrates, and then declined once canopy cover began to recover and food supplies diminished. Flycatchers reached their greatest abundance about seven years following fire, and then decreased. Concomitant with population responses might also be shifts in habitat-use patterns. Current studies indicate that Hairy Woodpeckers occupy smaller winter home ranges in forests 2 yr postfire than they use in forests 6 yr postfire (Covert and Block, unpubl. data). Presumably the amount of area used corresponds to that needed for adequate food.

Populations of secondary cavity-nesting birds responded differently to fires of varying severities in southwestern pine forests (Dwyer and Block 2000). Mountain Chickadee, Pygmy Nuthatch, and White-breasted Nuthatch populations were lower 2 yr postfire in areas of severe wildfire, whereas only the Mountain Chickadee declined in response to moderate understory fire. Western Bluebird populations were greater in severely burned forest than in unburned forest. Dwyer (2000) also found that populations of Western Bluebirds increased in a severely burned forest following introduction of nest boxes, suggesting that nest cavities might be limiting after fire. This situation might change in time, once primary cavity-nesting species reestablish themselves.

In one of the few published studies of responses by non-breeding birds, Blake (1982) found that, in the year following a wildfire, burned areas contained more individuals but fewer species than unburned areas. Some migrant and wintering species were unique to burned areas during the fall, including Common Poorwill (*Phalaenoptilus nuttalli*), Western Wood-Pewee, Western Scrub-Jay, House Wren (*Troglodytes aedon*), Hermit Thrush (*Catharus guttatus*), and Lesser Goldfinch (*Carduelis psaltria*).

Bird response to wildfire varies by season and fire severity. Bock and Block (in press) present data 3 yr post-wildfire from an ongoing study in northern Arizona (Table 1). Northern Flicker and Hairy Woodpecker populations increased in both moderately and severely burned areas, but increases were greater in response to severe fire. In contrast, Broad-tailed Hummingbird, Western Wood-Pewee, Plumbeous Vireo, and Western Tanager breeding populations increased following moderate-severity fire. When population declines were observed, most were in response to severe fire, including Williamson's Sapsucker (*Sphyrapicus thyroideus*; nonbreeding), Steller's Jay (breeding), Mountain

Chickadee (breeding and nonbreeding), Brown Creeper (nonbreeding), White-breasted Nuthatch (breeding and nonbreeding), Pygmy Nuthatch (breeding and nonbreeding), Plumbeous Vireo (breeding), Yellow-rumped Warbler (breeding), and Grace's Warbler (breeding).

Most studies of fire effects on birds in pine systems have focused on stand-replacement burns. These investigations provide little insight into the probable effects of understory burning, or on avian responses to habitat alterations associated with prescribed fire. Two studies are exceptions. Horton and Mannan (1988) examined effects of prescribed fire on cavity-nesting birds in a pine-oak forest in the Santa Catalina Mountains of Arizona. They sampled birds prior to prescribed fire, and then for one and two years afterwards. They found few changes in bird abundance, with Northern Flickers and Violet-green Swallows decreasing, and Mountain Chickadees increasing. In the other study, Marshall (1963) conducted a retrospective comparison of bird communities within the Madrean Archipelago in forests where natural fire had occurred in Mexico, versus similar forests north of the border where fire had been suppressed. He found that species common to brush or heavier forest cover, such as Ash-throated Flycatcher, Black-throated Gray Warbler, Scott's Oriole (*Icterus parisorum*), and Spotted Towhee were more abundant in the denser forests of Arizona and New Mexico. In contrast, species typical of relatively open conditions, American Kestrel (*Falco sparverius*), Cassin's Kingbird (*Tyrannus vociferans*), Purple Martin, Chipping Sparrow, and Western and Eastern bluebirds, were more abundant in Mexican forests.

Knowledge of the effects of wild and prescribed fire on birds is far less than what is needed to provide a basis for management of southwestern ponderosa pine forests. In particular, more studies are needed to better understand effects of understory wildfire and prescribed fire on birds. Meanwhile, we advocate that fire management strive to move toward historical fire regimes, wherever possible. The most immediate need is to reduce fuel continuity and the threats of large, stand-replacing crown fires. Research should continue on ramifications of past management so we have a basis for developing future management that ensures viable populations of species native to Southwestern ponderosa pine forests. As management options are developed, they should be applied within an adaptive management framework that monitors the response of bird populations and communities to enable adjustments to management through time.

In summary:

1. Wildifire once maintained most southwestern pine forests as relatively open stands, with large scattered trees and a grassy understory.
2. The combined effects of fire suppression, livestock grazing, and logging have caused most southwestern pine forests to become crowded by smaller trees, with a greatly-increased risk of stand-replacement fire.
3. The principal management objective for southwestern pine forests should be to return them to their open condition, using prescribed fire and other methods, both to reduce their vulnerability to catastrophic fire and to enhance their habitat value for birds and other wildlife.
4. Most research on avian responses to fire in southwestern ponderosa pine forests has centered on the results of high-intensity burns; future emphasis should be on results of low-intensity, ground fires that once characterized these forests, and that will be an essential aspect of their future management.

MIXED-CONIFER FORESTS

Mixed-conifer forests occur on approximately 20% of forested land in the Southwest (Conner at al. 1990, Van Hooser et al. 1993). This represents an increase since the 1960s, due in part to effects of fire suppression and the conversion of pine forest and aspen stands to mixed conifer. The reduction of wildfire disturbance in mesophytic ponderosa pine forests favors shade-tolerant Douglas-fir (*Pseudotsuga menziesii*) and white fir (*Abies concolor*) which become the dominant tree species. Once this happens, the forest is more appropriately described as mixed conifer.

At lower elevations (2,000–2,400 m), mixed-conifer stands are warm-climate forests dominated by Douglas-fir, white fir, ponderosa pine, and southwestern white pine (*Pinus strobiformis*), with various broadleaf trees (e.g., *Populus* spp., *Quercus* spp., *Acer* spp.) in the sub-canopy. At higher elevations (2,400–3,000 m), ponderosa pine is no longer present, and mixed-conifer forests grade into spruce-fir forests consisting of Engelmann spruce (*Picea engelmanni*), corkbark fir (*Abies lasiocarpa*), white fir, and Douglas-fir (Moir 1993). Trembling aspen occurs as a seral species in most montane forest types, where it can occur as a subdominant tree in conifer forests, or as monotypic stands embedded within a matrix of conifer forests.

Some birds characteristic of mixed-conifer in the Southwest are Northern Goshawk, Mexican Spotted Owl, Broad-tailed Hummingbird, Northern Flicker, Hairy Woodpecker, Williamson's Sapsucker, Cordilleran Flycatcher, Steller's Jay, Mountain Chickadee, Red-breasted Nuthatch (*Sitta canadensis*), Golden-crowned Kinglet (*Regulus satrapa*), Hermit Thrush, Plumbeous Vireo, Warbling Vireo (*Vireo gilvus*), Yellow-rumped Warbler, Grace's Warbler, Olive Warbler, Red-faced Warbler (*Cardellina rubifrons*), Dark-eyed Junco, and Western Tanager. Birds of special management concern include Northern Goshawk, the threatened Mexican Spotted Owl, Williamson's Sapsucker, Olive-sided Flycatcher, Dusky Flycatcher (*Empidonax oberholseri*), and Red-faced Warbler.

Fire in Mixed-Conifer Forests

In lower elevation mixed-conifer forests, the historical fire regime was very similar to that occurring in ponderosa pine, in that most events were low-severity ground fires (Grissino-Mayer et al. 1995, Moir et al. 1997). In contrast, many fires that occurred at higher elevations within mixed-conifer and spruce-fir forests were stand-replacing, providing opportunities for establishment of aspen. Since it is a seral species, aspen will persist as long as disturbance continues. In the absence of disturbance, conifers will eventually overtop and outcompete aspen for light and nutrients.

Fire Effects on Mixed-Conifer Forests Birds

We found few studies from the Southwest that specifically address the response of birds to fire in mixed-conifer forests. What little we can suggest is extrapolated from studies in the Sierra Nevada (Bock and Lynch 1970, Raphael et al. 1987) or Rocky Mountains (Hutto 1995, Kotliar et al. 2002). Certainly, fire provides opportunities for a number of species that occur in much lower numbers in unburned forest. Bock and Lynch (1970) found that 28% of 32 regularly breeding species occurred only in burned forest, and 19% only in unburned forest; overall, species richness was highest in the burned forest. Species restricted to burned forest included Willamson's Sapsucker, Olive-sided Flycatcher, House Wren, Mountain Bluebird (*Sialia currucoides*), Lazuli Bunting (*Passerina amoena*), Green-tailed Towhee, Chipping Sparrow, and Brewer's Sparrow; those restricted to unburned forest were Hermit Thrush, Golden-crowned Kinglet, Plumbeous Vireo, and Nashville Warbler (*Vermivora ruficapilla*).

Hutto (1995) identified 15 species, primarily woodpeckers, flycatchers, and seedeaters, that were more abundant in postfire, mixed-conifer forest in the Rocky Mountains. Of species mostly confined to recent postfire conditions, four also occur in the Southwest: Olive-sided Flycatcher, American Three-toed Woodpecker (*Picoides dorsalis*), Clark's Nutcracker (*Nucifraga columbiana*), and Mountain Bluebird. Species found more frequently in areas 10–40 yr postfire included Common Nighthawk (*Chordeiles minor*), Calliope Hummingbird (*Stellula calliope*), Northern Flicker, Orange-crowned Warbler (*Vermivora celata*), and Chipping Sparrow. The American Robin, Yellow-rumped Warbler, and Dark-eyed Junco were detected in all early and mid-successional forest studies that Hutto (1995) reviewed.

Kotliar et al. (2002) summarized results from 11 published and unpublished studies in conifer forests of the western US, where severe, stand-replacement wildfire had occurred within 10 yr of data collection. Of these, only one (Johnson and Wauer 1996) occurred in the Southwest. The studies occurred in various forest types, although mixed-conifer appeared best represented in their sample. Kotliar et al. (2002) found that 9 of 41 species were more abundant in recently burned forests, including American Three-toed Woodpecker, Black-backed Woodpecker (*Picoides arcticus*), Northern Flicker, Hairy Woodpecker , Olive-sided Flycatcher, Mountain Bluebird, Western Wood-Pewee, House Wren, and Tree Swallow (*Tachycineta bicolor*). All of these except the Black-backed Woodpecker are found commonly in the Southwest.

Clearly, wildfire in mixed-conifer forests creates habitats and provides resources that otherwise would not be available for a variety of birds in these ecosystems. However, not all species are favored by fire. Some, such as the Mexican Spotted Owl, require older forests that result from years of fire exclusion (May and Gutiérrez 2002).

Following fire, many mixed-confer forests transition into aspen. Given fire suppression, aspen has less opportunity to become established, and existing stands succeed to mixed-conifer. Aspen forest is a dwindling forest type in the Southwest that often supports more species than surrounding conifer forests, thereby contributing to greater landscape diversity (Finch and Reynolds 1987, Griffis 1999). Management priorities should emphasize maintaining and restoring aspen forests on the landscape.

More field research specific to southwestern conditions needs to be conducted to understand fire effects on birds in mixed-conifer forests. Clearly, the various successional stages of mixed-conifer forests support distinctive avifaunas, and thus all succcessional stages should be represented in appropriate quantities in the landscape (Kotliar et al. 2002). This requires management that emulates natural fire regimes to the extent possible (Kotliar et al. 2002). At lower elevations, this would require reducing ladder fuels and increasing fine fuels needed to carry ground fire. Potential tools to achieve these conditions include reductions in grazing pressures, thinning, and prescribed fire.

At higher elevations, fire management might entail a combination of prescribed and natural fire, with well-planned fuel breaks consisting of topographic or vegetation barriers that impede fire spread. Fire management at higher elevations is best achieved with a mosaic of long-unburned stands mixed with other areas that are burned with varying frequencies and intensities. The resulting landscape should possess the heterogeneity to provide habitat for numerous species.

Future research should focus on the effects of past management so we have a basis for ensuring viable populations of species native to mixed-conifer forests. As management options are developed, they should be applied within an adaptive management framework that monitors the response of bird populations and communities to treatments, to enable adjustments to management through time. Research should be structured in such a way to address questions at the appropriate scale in time and space. Wildfire in mixed-conifer forest results in a shifting mosaic of seral stages through time. To understand the dynamics of wildfire, research cannot be restricted to short-term studies but must continue for decades. Similarly, research cannot be restricted to small plots, but must be extended to landscapes to better understand relationships at the scale at which disturbance regimes manifest themselves.

In summary:

1. Ground fires once maintained low-elevation southwestern mixed-conifer forests in a relatively open condition, whereas higher-elevation forests experienced stand-replacement burns that created heterogeneous landscapes, including openings for aspen regrowth.
2. Historical reductions in fire frequencies caused low-elevation forests to become dense, and all southwestern mixed-confer forests to experience occasional large stand-replacement fires.
3. Few studies have been done of avian responses to fire in southwestern mixed-conifer forests; however, studies in this habitat in the Sierra Nevada and Rocky Mountains indicate that each type of mixed-conifer forest supports a distinctive avifauna, from unburned mature forests, to aspen groves that follow stand-replacement fires, to open park-like forests maintained by ground fires.
4. Research goals should be to learn more about habitat requirements of birds in southwestern mixed-conifer forests, by conducting long-term studies at appropriate landscape scales.
5. Management goals should be to return low elevation forests to the historic relatively open condition, and to create high-elevation mosaics of unburned forests and those burned with varying frequencies and intensities, especially including those that provide opportunities for aspen.

RIPARIAN WOODLANDS

Riparian woodlands follow stream and river channels that cross all the southwestern ecosystems discussed previously in this chapter. Dominant native trees in southwestern riparian woodlands include cottonwood (*Populus* spp.), sycamore (*Platanus wrightii*), willow (*Salix* spp.), ash (*Fraxinus velutina*), walnut (*Juglans* spp.), mesquite, and a variety of others that can be locally common at different elevations (Johnson and Jones 1977, Patten 1998, Cartron et al. 2000).

Southwestern riparian woodlands support an abundance and variety of breeding birds greater than the relatively arid ecosystems adjacent to them. Riparian avifaunas include some of the highest bird densities ever reported, and many species that are rare or missing elsewhere in the region (Carothers et al. 1974, Strong and Bock 1990, Rosenberg et al. 1991, Nabhan 2000). Low and mid-elevation gallery forests of large mature trees are particularly important for both breeding and migratory birds (Bock and Bock 1984, Szaro and Jakle 1985, Skagen et al. 1998, Powell and Steidl 2000). Riparian species that appear most frequently on state and regional Partners in Flight priority lists include Common Black-Hawk (*Buteogallus anthracinus*), Yellow-billed Cuckoo (*Coccyzus americanus*), Elegant Trogon (*Trogon elegans*), Bell's Vireo (*Vireo bellii*), Lucy's Warbler (*Vermivora luciae*), and Abert's Towhee (*Pipilo aberti*), along with the endangered Southwestern Willow Flycatcher (*Empidonax trailii extimus*; Sedgwick 2000).

FIRE IN RIPARIAN WOODLANDS

The frequencies and effects of prehistoric wildfires in southwestern riparian woodlands are very poorly understood (Dwire and Kauffman 2003). While such fires usually are assumed to have been rare (Busch 1995), most riparian corridors cross upland ecosystems that burned relatively frequently, and dominant native trees such as cottonwood and willow have shown considerable ability to resprout after fire (Ellis 2001). Much more certain is that the frequency and especially the intensity of fires have increased historically. While livestock grazing may have reduced fuels somewhat, two other factors have combined to make these ecosystems more likely to experience intense fire: the spread of exotic saltcedar trees (*Tamarix ramosissima*); and increasing aridity resulting from reduced flows and altered flooding regimes (Busch and Smith 1995, Ellis et al. 1998).

Fire Effects on Riparian Woodlands Birds

We found no studies describing the response of birds to fire in southwestern riparian habitats. However, we do not recommend prescribed burning as a research or management priority. Recent fires have been highly destructive of most native riparian vegetation, while facilitating the spread of saltcedar, which fails to provide habitat for many native birds (Rosenberg et al. 1991, Busch 1995). Research and management efforts should be directed at finding ways to control saltcedar, and to restore flow and flood patterns conducive to reproduction in the native trees, especially cottonwood, willow, and sycamore.

In summary:

1. Southwestern riparian woodlands support an extraordinary variety and abundance of birds, many of which have a high conservation priority.
2. Many of these ecosystems have been altered historically by water impoundments and diversions that reduce flows, change flood regimes, encourage the spread of exotic saltcedar, and increase the frequency and intensity of fire.
3. Research and management priorities should not involve fire, but should be directed at returning flood regimes that favor native trees such as cottonwood, willow, and sycamore that in turn provide critical habitat for many southwestern birds.

RESEARCH AND MANAGEMENT RECOMMENDATIONS

We have described habitat-specific research and fire management issues in the preceding sections of this review. In summary, we do not recommend application of prescribed fire in Sonoran, Mojave, or Chihuahuan deserts, and associated xeric desert grasslands, or in southwestern riparian woodlands. Major threats to these ecosystems are the increased fuel loads caused by invasions of exotic grasses and trees, and the resulting increase in wildfire frequency and intensity. Managers and researchers must find ways to reverse these invasions, for the sake of southwestern desert and riparian woodland ecosystems and their associated avifaunas.

Wildfire doubtless once played a highly significant role in (1) sustaining mesic desert grasslands in a relatively shrub-free state, (2) maintaining structural heterogeneity of interior chaparral, (3) limiting the distribution and density of pinyon-juniper woodland, (4) maintaining oak, pine, and low-elevation mixed-conifer ecosystems as open stands of relatively mature trees, and (5) opening dense stands of high-elevation, mixed-conifer forests and providing opportunities for aspen regrowth. Whenever possible, prescribed fire should be applied to mimic these effects. This will have the double benefit of reducing fuels and the risks of large wildfires, and sustaining habitats upon which many southwestern birds depend.

Successful implementation of prescribed burning programs in southwestern ecosystems will not be easy. In formerly open woodlands, such as pine and oak, the challenge will be to keep fire on the ground where it can open the forest floor without harming the mature trees. In higher-elevation mixed-conifer forests, where stand-replacement fires were a part of the natural ecosystem dynamic, the challenge will be to create landscapes with sufficient fuel breaks so that prescribed fire can be contained in a desired area.

Finally, it is important to recognize that certain kinds of birds require or prefer unburned areas, even in ecosystems that have a long evolutionary association with fire. That is why burning all of any particular landscape would be just as undesirable as preventing fire altogether. For every sparrow that depends upon the seeds produced by recently burned desert grassland, there is another that requires heavy grass cover that a fire temporarily destroys. For every bluebird that prefers an open pine forest, there is a towhee that does best where understory foliage is dense. For every sapsucker that nests in fire-dependent aspen, there is a Mexican Spotted Owl that prefers a mature stand of mixed-coniferous forest. In all of these cases, the overall objective of management must be to maintain landscape-level mosaics of stands in various stages of postfire ecological succession, including some areas long spared from fire.

Given the prevalence and ecological importance of fire in the Southwest, there have been remarkably few studies of the effects of fire on southwestern birds, especially of prescribed burning and for ecosystems other than ponderosa pine (Table 1). Also scarce are studies about birds outside the breeding season, or on demographic attributes other than abundance, such as nesting success. Most of our conclusions and recommendations about fire and birds in the Southwest are based on extrapolations from known fire effects on vegetation and generally understood habitat requirements of particular bird species. We believe most of our conclusions are reasonable, but they would be strengthened and doubtless greatly refined by the results of more replicated, large-scale, properly controlled field studies. It always appears self-serving when scientists call for more research, but in this case the need is self-evident. Given increased public awareness and concern about the destructive aspects of wildfire in the Southwest, there is a real danger that fire prevention and suppression policies will be implemented that are as ecologically unfortunate as those of the past century.

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