Research Article

Distribution and Relative Abundance of Forest Birds in Relation to Burn Severity in Southeastern Arizona

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Abstract

*The frequency of wild and prescribed fires in montane forests of the southwestern United States has increased after a century of fire suppression and subsequent fuels accumulation. To assess the effects of recent fires (median time since fire = 6 yr) on the montane forest bird community, we surveyed birds in 8 Sky Island mountain ranges in southeastern Arizona, USA, and examined how the distribution (i.e., presence–absence) of 65 species and relative abundance of 16 species correlated with evidence of severe and less severe fire at >1,500 survey points. We detected associations between fire and bird presence–absence for 17% of the 65 species analyzed and between fire and bird relative abundance for 25% of the 16 species analyzed. Most species (73%) were positively associated with burned areas and displayed stronger associations (i.e., more extreme odds ratios) with survey points that had evidence of severe as opposed to less severe fire. Positive associations with severe fire were strong (>3 to 1 odds) for western wood-pewee (*Contopus sordidulus*) and house wren (*Troglodytes aedon*), and negative associations with severe fire were strong for warbling vireo (*Vireo gilvus*) and red-breasted nuthatch (*Sitta canadensis*). Although recent fires appear to have had a positive effect on the distribution and relative abundance of several montane forest bird species in the region, these species are not the open-woodland birds that we would have expected to have benefited from fire based on previous research. Nevertheless, our results confirm associations between fire and bird presence–absence and relative abundance reported previously for 7 species of birds. Our results also provide new information for Grace's warbler (*Dendroica graciae*) and greater pewee (*C. pertinax*), 2 species for which fire data were formerly lacking. Managers can use these data to make and test predictions about the effects of future fires, both severe and less severe, on montane forest birds in the southwestern United States.* (JOURNAL OF WILDLIFE MANAGEMENT 70(4):1005–1012; 2006)

Key words

Arizona, birds, burn severity, forest fire, fire suppression, J. T. Marshall Jr.

Many species of montane forest birds in the southwestern United States, especially those inhabiting pine–oak woodland and ponderosa pine (*Pinus ponderosa*) forest, evolved in areas that historically experienced recurrent (generally ≥1 fire every decade), low- to moderate-severity surface fires (Ganey et al. 1996, Swetnam and Baisan 1996). However, during the last century, grazing of surface fuels by introduced livestock and widespread fire suppression have greatly reduced the frequency of surface fires in these forest ecosystems (Allen 1996, Pyne 1996). This change in fire frequency has altered the structure and composition of montane forest in the Southwest, including forests in the Sky Island mountain ranges of southeastern Arizona, USA. In the Sky Islands, many forests that were formerly park-like (i.e., open canopy with grassy understory) now contain dense thickets of young trees and large quantities of downed branches (Marshall 1957, 1963; Pyne 1996).

The increase in understory fuel loads has resulted in a recent increase in the frequency of large, often severe, wildfires in the region (Swetnam et al. 1999). In response, land management agencies have used low-severity prescribed fires to reduce the risk of future wildfires (U.S. Department of the Interior 1995). Most of these wild and prescribed fires have occurred during the 1990s (see results). Despite this recent increase in the frequency of fires, few studies have examined the effects of fire on the unique avian communities that inhabit the Sky Island Mountains of the southwestern United States (but see Horton 1987, Short 2002). Furthermore, no studies have examined how severe wildfires affect populations of montane forest birds in the region (i.e., previous studies have focused on the effects of lower-severity prescribed fires). Yet, differences in the severity and frequency of fires may help to explain observed differences in the distribution and abundance of forest bird species among Sky Island mountain ranges.

Indeed, Marshall (1957, 1963) speculated that differences in the distribution and abundance of pine–oak woodland birds between adjacent Sky Islands in Arizona and Mexico might be explained in part by differences in fire regimes between the 2 areas. In general, wildfires have been suppressed during the last century in southeastern Arizona but have burned unabated (until recently) in adjacent mountain ranges in Mexico. Not surprisingly, Marshall (1963) found that species that prefer brushy, dense woodlands, such as black-throated gray warbler (*Dendroica nigrescens*) and Scott's oriole (*Icterus parisorum*), were more abundant in southeastern Arizona, whereas species that prefer open woodlands (Appendix), such as American kestrel (*Falco sparvarius*) and chipping sparrow (*Spizella passerina*), were more abundant just south of the U.S. border. If fire suppression has reduced the distribution and abundance of birds that inhabit open forests in the southwestern United States, we might expect to see an increase in these species as recent wild and prescribed fires reopen forests in the region.

Because of the recent increase in fire frequency in the Southwest, we need more information on the effects of fire on montane forest birds to better manage this unique avian community. Examining

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Table 1. Number of routes surveyed in 8 mountain ranges in southeastern Arizona, USA (Apr–Jul 2000) and number of survey points along these routes that had evidence of recent fire in 3 general classes of burn severity (BS; no fire [0], less severe fire [1], and severe fire [2])[a].

Mountain range	Survey routes	Survey points		
		0	1	2
Chiricahua	28	486	101	23
Huachuca	19	228	48	16
Santa Catalina	12	130	39	18
Rincon	10	55	84	47
Santa Rita	6	72	1	0
Pinaleno	4	68	22	2
Galiuro	3	38	4	0
Santa Teresa	2	30	1	0
Total	84	1,107	300	106

[a] Less severe fire = burn severity index classes 0.5 to 2 and severe fire = burn severity index classes 2.5 to 4 (see Methods for complete description of burn severity index).

the effects of fire on birds using an experimental approach is logistically difficult and feasible only for evaluating effects of low- to moderate-severity prescribed fires (Ganey et al. 1996). Yet, fire affects birds differently depending on the severity of the burn (Hejl 1994). Hence, we need to examine the effects of fire on birds across a range of burn severities. Montane forests in southeastern Arizona provide an ideal setting for this research because recent wild and prescribed fires in the region have created a mosaic of postburn conditions (Allen 1996). For example, the 11,000-ha Rattlesnake wildfire (Chiricahua Mountains; Jun 1994) burned severely in mixed-conifer and ponderosa pine forests at higher elevations but burned less severely in pine–oak woodland at lower elevations.

We took advantage of this variation in burn severities by surveying breeding birds in burned and unburned forests in all higher-elevation Sky Island mountain ranges in southeastern Arizona, USA, from April to July 2000. Specifically, we examined how the distribution (i.e., presence–absence) of 65 bird species correlated with evidence of recent fires at >1,500 survey points. In addition, we examined how evidence of recent fires at survey points was associated with relative abundance for a subset of 16 species for which we detected sufficient variation in relative abundance. Our goal was to provide managers with information with which to make and test predictions about the effects of future fires (of varying severities) on the distribution, abundance, and persistence of montane forest birds in the region.

Study Area

We surveyed montane forest birds in 8 Sky Island mountain ranges in southeastern Arizona: the Chiricahua, Huachuca (Cochise County), Santa Rita (Santa Cruz County), Santa Catalina, Rincon (Pima County), Galiuro, Pinaleno, and Santa Teresa (Graham County) mountains. The Sky Islands are characteristic of a basin and range topography with high-elevation (2,280–3,267 m) mountain ranges separated by low-elevation (762–1,372 m) desert basins. Climate throughout much of the region is arid or semi-arid, but montane forests in the Sky Islands are substantially cooler and wetter than surrounding deserts. Annual precipitation varies among mountain ranges (average of approx. 80 cm in the Santa Catalina Mountains), and most precipitation falls during a brief summer season of localized thunderstorms and during a longer winter season of widespread frontal storms.

Within the 8 Sky Island mountain ranges, we conducted our study primarily in pine–oak woodland but also in ponderosa pine and mixed-conifer forests between 1,450 and 2,900-m elevation on lands administered by the United States Forest Service, United States National Park Service, and United States Department of Defense (see Conway and Kirkpatrick 2001). Common tree species in the study area included Apache pine (*P. englemannii*), Chihuahua pine (*P. leiophyllus*), ponderosa pine, southwestern white pine (*P. strobiformis*), white fir (*Abies concolor*), Douglas fir (*Pseudotsuga menziessi*), Arizona sycamore (*Plantanus wrightii*), alligator juniper (*Juniperus deppeana*), and several species of oak (*Quercus* spp.).

Methods

Survey Routes

We established 1,513 survey points along 84 survey routes ($\bar{x} = 18$; range = 5 to 40 survey points/route; Table 1) as part of a larger study to determine the distribution and abundance of buff-breasted flycatchers (*Empidonax fulvifrons*) in the region (Conway and Kirkpatrick 2001). We created survey routes by pacing 200 m between adjacent survey points along canyon bottoms, ridges, trails, and dirt roads, and we used a Global Positioning System receiver to record the location and elevation (m) of each survey point. We used 100-m intervals between survey points on 2 of our 84 survey routes (total of 23 survey points) to coincide with survey point locations of previously established buff-breasted flycatcher survey routes (Martin 1997).

To determine the extent, severity, and age of recent wild and prescribed fires, we referenced U.S. Forest Service records from 1988 to 2000 for the Coronado National Forest. However, specific data for recent fires were often missing or incomplete. Therefore, we established routes with limited knowledge of the local fire history, even though we knew that many of our survey routes would be located within the perimeters of several recent wild and prescribed fires (e.g., 1995 Shovel wildfire, Santa Catalina Mountains; 1996 Clark Peak wildfire, Pinaleno Mountains; and 1998 Chiminea prescribed burn, Rincon Mountains).

Following the completion of our bird surveys in 2000, we acquired additional information (e.g., newly digitized fire perimeters from old Forest Service and National Park Service paper maps) on the extent and age of recent fires that allowed us to estimate the time since fire for 82% of the burned survey points along our survey routes. These data represent the best information currently available on the extent and age of recent fires in southeastern Arizona, USA.

Bird Surveys (2000)

For each of the 84 survey routes, we conducted a single survey from sunrise to 4 hours after sunrise, 18 April–11 July 2000, using a 3-minute survey period and an unlimited radius count at each survey point. To reduce observer bias, we trained the 3 surveyors prior to the start of the field season in the lab and in the field to identify Arizona breeding birds by sight and especially by sound (the vast majority of our bird detections were aural). We also trained surveyors in the identification of different burn severity classes (see below). We did not conduct surveys on days with precipitation or with wind speeds >19 km/hour. Upon arriving at a survey point, observers recorded all visual and aural detections of birds during the 3-minute survey period.

Burn Severity Index

In addition to recording bird detections, observers scanned approximately 100 m on either side of the transect and used the following index of burn severity to quantify visual evidence of the effects of recent fire at each survey point:

0. No evidence of recent fire
1. Evidence of low-severity surface fire (e.g., fire-charring roughly 0–0.3 m above ground on a few trees)
2. Evidence of moderate-severity surface fire (e.g., fire-charring roughly 0.3–1.5 m above ground on most trees; a few small oaks or pines killed in understory)
3. Evidence of severe surface fire (e.g., fire charring often >1.5 m above ground on trees; almost all understory oaks or pines killed [some oaks re-sprouting]; a few large trees killed [burned snags or fallen trunks])
4. Evidence of severe crown fire (e.g., all above-ground vegetation killed with some re-growth from roots and/or seeds)

This visual assessment of burn severity is similar to the system used by the National Park Service to estimate burn severity in forests immediately following fire (U.S. Department of the Interior 2003). For our index, we concentrated on height of charring and gross changes in forest structure resulting from fire because these visual assessments of fire severity persist after a fire has passed through a forest (E. Margolis, University of Arizona, personal communication). We recorded burn severity separately on each side of the survey transects because burn severity sometimes differed from one side to the other. At these survey points, we calculated a single measure of burn severity by averaging the burn severity values recorded on both sides of the survey transect.

Bird Surveys (2004)

We analyzed data collected during additional bird surveys in 2004 to address 2 issues. We were concerned that detection probability of birds might have differed between burned and unburned survey points during our 2000 bird surveys, which may have biased our results (Pendleton 1995). In addition, we were worried that birds detected >100 m from our survey points in 2000 (the max. distance for which we quantified visual evidence of the effects of recent fire) were actually in another burn severity category. To address these issues, we used data from bird surveys conducted from 21 April to 9 July 2004 along 57 of the 84 survey routes that we originally surveyed in 2000 (C. Kirkpatrick, University of Arizona, unpublished data).

Similar to our 2000 bird surveys, we completed one survey per route from sunrise until 4 hours after sunrise and used a 3-minute survey period to record all visual and aural detections of birds at each survey point. Unlike our 2000 bird surveys, however, we recorded the distance to each bird (measured to nearest 5-m interval with aid of a laser rangefinder) and the time that each bird was first detected during the survey. Thus, we were able to estimate the average detection distance for each species. In addition, we were able to model the decline in detections of new birds as a function of time, which allowed us to compare detection functions for birds detected at survey points with and without evidence of recent fire.

Statistical Analyses

Before conducting analyses of our 2000 bird survey data, we eliminated species that were known to be migrating through the area (e.g., hermit warbler [*Dendroica occidentalis*]) and species detected primarily as flyovers (e.g., white-throated swift [*Aeronautes saxatalis*] and broad-tailed hummingbird [*Selasphorus platycercus*]). Because we used a slightly different method to survey for buff-breasted flycatchers, we report results for this species elsewhere (Conway and Kirkpatrick, in press).

We took 2 approaches to test for associations between birds and fire at survey points. First, we used logistic regression (SAS PROC LOGISTIC) to examine whether bird presence–absence was associated with burn severity for 65 bird species. Second, we used ordinal logistic regression (SAS PROC LOGISTIC) to examine whether bird relative abundance was associated with burn severity for a subset of 16 bird species. We examined associations between relative abundance and burn severity only for species for which we observed sufficient variation in relative abundance (i.e., we detected ≥2 individuals of the species at a relatively large number [>20%] of survey points).

We treated presence–absence and relative abundance data as categorical and ordinal dependent variables, respectively, in the regression models. For our ordinal regression models, we included 3 relative abundance categories for each of the 16 species: 1) no birds, 2) 1 bird, and 3) several birds (≥2 birds detected at survey point). We lacked sufficient numbers of detections at survey points to model these relative abundance data continuously using linear regression (even using a Poisson model). Hence, logistic ordinal regression was the most appropriate method for the analysis of our relative abundance data.

For the logistic and ordinal logistic regression models, we evaluated overall model fit using a goodness-of-fit test to assess whether the independent variables, taken as a whole, had an effect on the dependent variable. We treated burn severity as a categorical independent variable and collapsed values for the burn severity index recorded at each survey point into 3 general categories prior to analysis to increase the power of our tests: 1) no evidence of fire (burn severity index class 0), 2) evidence of less severe fire (burn severity index classes 0.5 to 2), and 3) evidence of severe fire (burn severity index classes 2.5 to 4). To control for the effect of elevation (and indirectly forest type), we included elevation as a covariate in the regression models and restricted data for each species to the elevational range (minus outliers) in which we observed the species.

We included route as a categorical independent variable in the regression models to control for the lack of independence between survey points along survey routes. If route was not a significant factor ($P > 0.10$), we eliminated this variable from the regression model and re-ran the analysis to improve our parameter estimates. We adjusted the contrast coding to compare 1) the proportion of survey points with or without birds at survey points with severe fire versus survey points with no evidence of fire, and 2) the proportion of survey points with or without birds at survey points with less severe fire versus survey points with no evidence of fire. Because a large percentage (32%) of burned survey points were located in the Rincon Mountains (Table 1), we reanalyzed the data without Rincon Mountain data for species that initially showed biologically significant associations with recent fire (see below) to test the robustness of our results.

We based our conclusions on the combined evidence of *P*-values from statistical hypothesis testing and magnitudes of differences (odds ratios) generated from parameter estimation. An odds ratio of 1.0 indicates no difference between the proportion of survey points with or without birds across different burn severities, and an odds ratio close to zero or substantially >1.0 indicates a large difference. For bird species in which presence–absence or relative abundance was positively associated with burn severity, we considered an odds ratio ≥1.5 (i.e., approx. 50% increase) to indicate a biologically significant effect. For bird species in which presence–absence or relative abundance was negatively associated with burn severity, we considered an odds ratio ≤0.66 (i.e., approx. 50% decrease) to indicate a biologically significant effect.

Results

We observed evidence of fire on 69% of our 84 survey routes and at 27% of our 1,513 survey points. At an additional 2% of our survey points, we saw evidence of older fires (e.g., single burned log or snag but no other evidence of fire in area). We classified these points as fire class 0 because they did not fit into our classification of recent fire. When we collapsed our burn severity index values into 3 general burn severity categories, we had 1,107 survey points with no evidence of fire, 300 survey points with evidence of less severe fire, and 106 survey points with evidence of severe fire (Table 1).

We were able to estimate the time since fire for 332 (82%) of the 406 burned survey points. Of these 332 burned survey points, 76% were last burned between 1990 and 1998, 10% were last burned between 1980 and 1989, 5% were last burned between 1970 and 1979, and 8% were last burned prior to 1969. Mean time since fire was 10 years (SD = 12.6), and median time since fire was 6 years (range 2–47). Seventy-six percent of these survey points were burned by wildfires, and 24% were burned by prescribed fires.

Although we did not measure vegetation characteristics at survey points, we observed that the forest canopy was typically more open at survey points with evidence of severe fire compared to survey points with evidence of less severe or no fire. However, density of understory vegetation at survey points appeared to differ widely across burn severity classes (likely due to either the prefire forest structure or the time since recent fire for regrowth of understory vegetation).

Bird Surveys (2000)

At 1,513 survey points, we detected 10,473 individuals of 97 species. The most widely distributed species were spotted towhee (*Pipilo maculatus*; detected at 37% of survey points), black-headed grosbeak (*Pheucticus melanocephalus*; 30% of survey points), American robin (*Turdus migratorius*; 24% of survey points), dusky-capped flycatcher (*Myiarchus tuberculifer*; 24% of survey points), red-faced warbler (*Cardellina rubrifrons*; 24% of survey points), Mexican jay (*Aphelocoma ultramarina*; 21% of survey points), western tanager (*Piranga ludoviciana*; 20% of survey points), yellow-eyed junco (*Junco phaeonotus*; 20% of survey points), hermit thrush (*Catharus guttatus*; 18% of survey points), and cordilleran flycatcher (*Empidonax occidentalis*; 17% of survey points).

The most abundant species, in terms of average number of birds detected at survey points with ≥1 bird, were Mexican jay ($\overline{x} = 2.2$; range 1–10 birds per point), bushtit (*Psaltriparus minimus*; $\overline{x} = 1.9$; range 1–12 birds per point), Cassin's kingbird (*Tyrannus vociferans;* $\overline{x} = 1.8$; range 1–4 birds per point), bridled titmouse (*Baeolophus wollweberi*; $\overline{x} = 1.4$; range 1–5 birds per point), yellow-eyed junco ($\overline{x} = 1.4$; range 1–4 birds per point), western wood-pewee ($\overline{x} = 1.3$; range 1–3 birds per point), American robin ($\overline{x} = 1.3$; range 1–3 birds per point), spotted towhee ($\overline{x} = 1.3$; range 1–3 birds per point), black-headed grosbeak ($\overline{x} = 1.3$; range 1–4 birds per point), and house wren ($\overline{x} = 1.3$; range 1–4 birds per point).

We found biologically significant associations between bird presence–absence and burn severity for 11 of the 65 species we analyzed (Table 2). Overall model fit was significant (χ^2 *P* value < 0.05) for the 11 regression models. Species positively associated with evidence of severe fire (i.e., burn severity index classes 2.5 to 4), in order of decreasing strength of associations, were western wood-pewee, house wren, white-breasted nuthatch (*Sitta carolinensis*), Virginia's warbler (*Vermivora virginiae*), hairy woodpecker (*Picoides villosus*), Grace's warbler, and greater pewee. Species positively associated with evidence of less severe fire (i.e., burn severity index classes 0.5 to 2), in order of decreasing strength of associations, were yellow-rumped warbler (*Dendroica coronata*), greater pewee, house wren, hairy woodpecker, Grace's warbler, white-breasted nuthatch, and Virginia's warbler (Table 2).

Species negatively associated with evidence of severe fire, in order of decreasing strength of associations, were red-breasted nuthatch and warbling vireo (Table 2). Species negatively associated with evidence of less severe fire, in order of decreasing strength of associations, were red-breasted nuthatch and spotted towhee. We were unable to detect positive or negative associations between bird presence–absence and fire for the remaining 50 species analyzed. However, sample sizes were small (<10 detections total) for many of these species.

We found biologically significant associations between bird relative abundance and burn severity for 4 of the 16 species we analyzed (Table 3). Overall model fit was significant (χ^2 *P* value < 0.05) for the 4 regression models. Species positively associated with evidence of severe fire, in order of decreasing strength of associations, were western wood-pewee, house wren, and spotted towhee. House wrens were also positively associated with areas with evidence of less severe fire. Species negatively associated with evidence of fire were warbling vireo (severe fire) and spotted towhee (less severe fire). We were unable to detect associations between recent fire and bird relative abundance for acorn woodpecker, Cassin's kingbird, Mexican jay, Stellar's jay (*Cyanocitta stelleri*), bridled titmouse, pygmy nuthatch (*Sitta pygmaea*), bushtit, American robin, red-faced warbler, black-headed grosbeak, yellow-eyed junco, and hepatic tanager (*Piranga flava*).

By and large, our results were consistent for most species when

Table 2. Number of survey points in 3 general classes of burn severity (BS; no fire [0], less severe fire [1], and severe fire [2])[a] at which we detected or did not detect birds at 1,513 survey points[b] in 8 mountain ranges in southeastern Arizona, USA (Apr–Jul 2000). Results of logistic regression analyses show associations between bird presence–absence and survey points with evidence of severe and less severe fire compared to survey points with no evidence of recent fire. Estimated distance (m; mean, range, and % detections <100 m) of birds from survey points recorded during surveys conducted Apr–Jul 2004.

		n		Coefficient		Odds ratio				Distance		
Species	BS	Birds	No birds	*b*	SE	Exp *b*	95% CI	Wald χ^2	*P*	$\bar{x}$	Range	% <100 m
Hairy woodpecker[c]	0	29	879							37	15–70	100
	1	21	273	0.51	0.31	1.7	0.9–3.0	2.8	0.097			
	2	11	95	0.80	0.41	2.2	1.0–4.7	4.2	0.039			
Greater pewee[c,d]	0	49	824							69	25–200	88
	1	29	216	0.64	0.26	1.9	1.1–3.2	5.9	0.015			
	2	13	75	0.74	0.37	2.1	1.0–4.3	4.1	0.044			
Western wood-pewee[d,e]	0	175	857							41	10–135	99
	1	34	202	0.36	0.36	1.4	0.7–2.9	1.0	0.319			
	2	18	61	1.51	0.56	4.5	1.5–13.5	7.3	0.007			
White-breasted nuthatch[e]	0	168	932							46	15–100	100
	1	54	244	0.40	0.25	1.5	0.9–2.4	2.6	0.105			
	2	26	80	1.06	0.39	2.9	1.3–6.2	7.3	0.007			
Red-breasted nuthatch[c]	0	59	798							57	25–120	96
	1	10	279	−1.27	0.36	0.3	0.1–0.6	12.3	≤0.001			
	2	4	102	−1.30	0.54	0.3	0.1–0.8	5.9	0.015			
House wren[c]	0	68	960							30	5–85	100
	1	47	249	0.54	0.22	1.7	1.1–2.6	6.2	0.013			
	2	33	73	1.26	0.26	3.5	2.1–5.8	23.8	≤0.001			
Warbling vireo[c]	0	73	817							39	10–80	100
	1	27	265	−0.33	0.25	0.7	0.4–1.2	1.7	0.191			
	2	6	100	−1.00	0.45	0.4	0.2–0.9	5.0	0.025			
Grace's warbler[e]	0	167	862							36	5–220	99
	1	62	235	0.49	0.25	1.6	1.0–2.7	3.8	0.052			
	2	19	87	0.80	0.41	2.2	1.0–5.0	3.7	0.054			
Yellow-rumped warbler[c,d]	0	35	884							35	10–120	99
	1	38	257	0.76	0.26	2.2	1.3–3.6	8.7	0.003			
	2	10	96	0.22	0.38	1.2	0.6–2.6	0.3	0.574			
Virginia's warbler[c,f]	0	70	993							66	20–200	88
	1	29	258	0.38	0.25	1.5	0.9–2.4	2.3	0.129			
	2	17	88	0.87	0.32	2.4	1.3–4.5	7.3	0.007			
Spotted towhee[e]	0	433	629							36	5–150	99
	1	81	194	−0.44	0.24	0.6	0.4–1.0	3.3	0.069			
	2	48	57	0.30	0.36	1.3	0.7–2.7	0.7	0.407			

[a] Less severe fire = burn severity index classes 0.5 to 2 and severe fire = burn severity index classes 2.5 to 4 (see Methods for complete description of burn severity index).
[b] Survey points restricted for each species to the elevational range (minus outliers) in which we detected the species.
[c] We removed the variable *route* from this analysis because it was not significant ($P > 0.10$) in initial model.
[d] Bird distribution associated with survey points with evidence of recent fire using data from all mountain ranges (results shown) but not when data from Rincon Mountains excluded from analysis.
[e] We retained the variable *route* in this analysis because it was significant ($P < 0.10$) in initial model.
[f] *P* value marginally significant ($0.10 < P < 0.15$) but odds ratio above a priori cutoff (≥1.5) for a biologically significant association.

we excluded data from the Rincon Mountains from our presence–absence and relative abundance logistic regression analyses. However, 2 species (greater pewee and yellow-rumped warbler) that initially showed biologically significant associations with recent fire did not show biologically significant associations when we re-ran analyses without data from the Rincon Mountains.

Bird Surveys (2004)

We found that detection functions were similar for birds detected at burned versus unburned survey points when we analyzed data from our 2004 bird surveys ($n = 5{,}681$ detections of 66 species). As the 3-minute survey progressed, the percentage of new birds detected during each of 3 1-minute intervals declined from 54% to 25% to 21% at unburned survey points and from 53% to 24% to 23% at burned survey points, suggesting that we detected the same proportion of birds during surveys in both burned and unburned areas in 2004 and (by inference) in 2000.

Most birds that we detected were relatively close to the survey point during our 2004 surveys. Mean detection distances ranged between 30 and 69 m for the 11 bird species that exhibited biologically significant associations with fire (Table 2). Moreover, most of the detections for these 11 species were <100 m from the survey point (Table 2), suggesting that the majority of birds detected in 2004 and (by inference) in 2000 were associated with the burn severity category that we recorded within the 100-m radius around each survey point.

Discussion

In general, recent fires (including severe wildfires) in the Sky Islands of southeastern Arizona, USA, appear to have had a

Table 3. Results of ordinal logistic regression analyses showing associations between bird relative abundance and survey points with evidence of recent fire (burn severity [BS] = less severe [1] and severe [2])[a] compared to survey points with no evidence of recent fire at 1,513 survey points[b] in 8 mountain ranges in southeastern Arizona, USA, Apr–Jul 2000.

Species	BS	Coefficient		Odds ratio		Wald	
		b	SE	Exp *b*	95% CI	χ^2	*P*
Western wood-pewee[c]	1	0.31	0.35	1.4	0.7–2.7	0.8	0.380
	2	1.71	0.52	5.5	1.9–15.6	10.6	0.001
House wren[d]	1	0.52	0.21	1.7	1.1–2.6	6.5	0.011
	2	1.29	1.5	3.6	2.2–6.0	25.7	≤0.001
Warbling vireo[d]	1	−0.37	0.25	0.8	0.4–1.5	2.2	0.139
	2	−1.03	0.45	0.3	0.1–0.8	5.3	0.021
Spotted towhee[c,e]	1	−0.42	0.22	0.6	0.4–1.0	3.6	0.058
	2	0.46	0.33	1.6	0.8–3.0	2.0	0.154

[a] Less severe fire = burn severity index classes 0.5 to 2 and severe fire = burn severity index classes 2.5 to 4 (see Methods for complete description of burn severity index).

[b] Survey points restricted for each species to the elevational range (minus outliers) in which we detected the species. See Table 1 for number of survey points with (and without) birds by burn severity.

[c] We retained the variable *route* in this analysis because it was significant ($P < 0.10$) in initial model.

[d] We removed the variable *route* from this analysis because it was not significant ($P > 0.10$) in initial model.

[e] *P* value marginally significant ($0.10 < P < 0.15$) but odds ratio above the a priori cutoff (≥1.5) for a biologically significant association.

positive effect on the distribution and relative abundance of montane forest birds in the region. We found that most bird species (73%) showed positive as opposed to negative associations with recently burned areas. In addition, we found that most bird species showed stronger associations (either positive or negative) to recently burned areas with evidence of severe as opposed to less severe fire, a pattern that has been reported for other forest bird communities in the western United States (Hejl 1994, Hutto 1995). These mixed responses of birds to fires of varying severities underscore the importance of examining the influence of burn severity in fire effects studies.

Although our data are correlative in nature, many of our findings are corroborated by results from previous studies. For example, previous studies have reported negative associations with fire for red-breasted nuthatch (Taylor and Barmore 1980, Bock and Bock 1983, Raphael and White 1984) and warbling vireo (Dieni and Anderson 1999) and positive associations with fire for hairy woodpecker (Taylor and Barmore 1980, Raphael et al. 1987, Johnson and Wauer 1996), western wood-pewee (Granholm 1982, Raphael et al. 1987, Short 2002; but see Dieni and Anderson 1999), house wren (Raphael et al. 1987, Johnson and Wauer 1996), white-breasted nuthatch (Short 2002), and yellow-rumped warbler (Apfelbaum and Haney 1981, Bock and Bock 1983, Hutto 1995). We are the first to report positive associations with fire for greater pewee and Grace's warbler, 2 species that prefer open pine forests in the Southwest (Chace and Tweit 1999, Stacier and Guzy 2002).

On the surface, our findings for Virginia's warbler (positive association with less severe and severe fire) appeared to contradict results from previous fire studies that show sharp declines in Virginia's warblers immediately after fire (Horton 1987, Johnson and Wauer 1996). However, Virginia's warblers are known to return to burned areas in years following fire as the density of understory vegetation increases (Johnson and Wauer 1996). Median time since fire was 6 years, and no fires occurred immediately (i.e., 1–2 yr) prior to the start of our study. Thus, the positive association that we observed between Virginia's warblers and burned areas likely reflects a positive association between Virginia's warblers and recovering understory vegetation as time since fire increased.

Spotted towhees prefer scrubby vegetation, and fires are thought to present a temporary setback for this species until subsequent seral development attracts more individuals to a burned area (Greenlaw 1996). We found that spotted towhees were positively associated with areas with evidence of severe fire. However, we also observed that spotted towhees were negatively associated with areas with less severe fire. We have no explanation for this apparent contradiction other than spotted towhees may benefit from severe fires that affect the structure of both the forest understory and overstory but not from less-severe fires that affect only the structure of the forest understory. A complete understanding of how fire affects bird distribution and relative abundance requires conducting postfire bird surveys through time at the same locations to track vegetation succession and determine the number of years postfire that produce suitable (or optimal) conditions for each species in a community (Raphael et al. 1987).

Marshall (1963) speculated that fire suppression in southeastern Arizona had resulted in a decrease in the distribution and abundance of 15 bird species (Appendix) associated with open pine–oak woodland in the region. For at least some of these species, we had expected to see positive associations between bird presence or relative abundance and areas with evidence of recent fire. Yet, we found that none of the 15 open-woodland species showed positive associations with burned areas. In fact, we found that most of these species were rare or absent during our surveys (Appendix), suggesting that recent fires have not yet benefited these open-woodland species. Assuming Marshall's (1963) contention is correct, we believe that many of these open-woodland species continue to be excluded from much of the region because either 1) the severity or frequency of recent fires has not been conducive to restoring montane forests to their formerly open, park-like condition, or 2) there has been insufficient time since the reintroduction of fire (median time since fire was only 6 yr for our burned survey points) to allow for the recolonization of these open-woodland species to burned areas in southeastern Arizona, USA.

In summary, our results substantiate associations between fire and bird presence–absence and relative abundance for 7 species of birds reported in other correlative fire studies. Our results also provide new information for 2 species (Grace's warbler and greater pewee) whose breeding ranges in the United States are restricted to the Southwest and for which fire data were formerly lacking. Moreover, our study is the first to quantify the effects of different burn severities on birds in the region. Although our results suggest that recent wild and prescribed fires appear to have had a positive effect on the distribution and relative abundance of several montane forest bird species in the region, these species are not the open woodland birds that we would have expected to benefit from fire based on Marshall's (1963) conclusions. It appears that the effects of a century of fire suppression continue to influence the distribution of many species of montane forest birds in southeastern Arizona, USA.

Management Implications

Additional research is needed to examine the reproductive success of species within burned areas because the mere presence or increased abundance of a species within a burn does not necessarily indicate that the area represents high-quality habitat for the species (Van Horne 1983). Research is also needed to investigate the immediate (approx. 1–2 yr after fire) and longer-term (approx. >20 yr after fire) responses of bird populations to fire in southeastern Arizona, USA. Finally, research is needed to determine the effect of the most severe wildfires (i.e., burn severity index class 4) on montane forest birds in southeastern Arizona, USA. Our sample size of points for this burn severity class was small because recent class 4 wildfires have occurred primarily at elevations >2,600 m in areas that we did not survey extensively.

Our results provide managers with information that can be used to make and test predictions about the effects of future wild and prescribed fires (of varying severities) on montane forest birds in the southwestern United States. Ideally, these predictions will be tested with the following approaches: 1) long-term studies using randomized experimental designs to investigate effects of low-severity prescribed fires, and 2) Before-After-Control-Impact designs (Underwood 1994) to investigate the effects of more severe wildfires in areas that have established bird monitoring plots (e.g., Santa Catalina Mountains). The numerous, large wildfires that burned in the southwestern United States from 2002 to 2004 should provide additional opportunities to examine the effects of fire, especially severe fire, on montane forest birds in the region.

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Literature Cited

Allen, L. S. 1996. Ecological role of fire in the Madrean province. Pages 5–10 *in* P. F. Ffolliot, L. B. DeBano, M. B. Baker, Jr., G. J. Gottfried, G. Solis-Garza, C. B. Edminster, D. G. Neary, L. S. Allen, and R. H. Hamre, technical coordinators. Effects of fire on Madrean province ecosystems. U.S. Forest Service General Technical Report RM-GTR-289, Washington, D.C., USA.

Apfelbaum, S., and A. Haney. 1981. Bird populations before and after wild fire in a Great Lakes USA pine forest. Condor 83:347–384.

Bock, C. E., and J. H. Bock. 1983. Response of birds and deer mice to prescribed burning in ponderosa pine. Journal of Wildlife Management 47: 836–840.

Chace, J. F., and R. C. Twight. 1999. Greater pewee (*Contopus pertinax*). Number 450 *in* A. Poole and F. Gill, editors. The birds of North America. The Academy of Natural Sciences, Washington, D.C., USA.

Conway, C. J., and C. Kirkpatrick. 2001. Population status, detection probability, and effects of fire on buff-breasted flycatchers. Arizona Game and Fish Department, Phoenix, USA.

Conway, C. J., and C. Kirkpatrick. In press. Effect of forest fire suppression on buff-breasted flycatchers. The Journal of Wildlife Management.

Dieni, J. S., and S. H. Anderson. 1999. Effects of recent burning on breeding bird community structure in aspen forests. Journal of Field Ornithology 70: 491–503.

Ganey, J. L., W. M. Block, and P. F. Boucher. 1996. Effects of fire on birds in Madrean forests and woodlands. Pages 146–154 *in* P. F. Ffolliot, L. B. DeBano, M. B. Baker, Jr., G. J. Gottfried, G. Solis-Garza, C. B. Edminster, D. G. Neary, L. S. Allen, and R. H. Hamre, technical coordinators. Effects of fire on Madrean province ecosystems. U.S. Forest Service General Technical Report RM-GTR-289, Washington, D.C., USA.

Granholm, S. L. 1982. Effects of surface fires on birds and their habitat in coniferous forests of the Sierra Nevada, California. Dissertation, University of California, Davis, USA.

Greenlaw, J. S. 1996. Spotted towhee (*Pipilo maculates*). Number 263 *in* A. Poole and F. Gill, editors. The birds of North America. The Academy of Natural Sciences, Washington, D.C., USA.

Hejl, S. J. 1994. Human-induced changes in bird populations in coniferous forests in western North America during the past 100 years. Studies in Avian Biology 15:232–246.

Horton, S. P. 1987. Effects of prescribed burning on breeding birds in a ponderosa pine forest, southeastern Arizona. Thesis, University of Arizona, Tucson, USA.

Hutto, R. L. 1995. Composition of bird communities following stand-replacement fires in northern Rocky Mountain (U.S.A.) conifer forests. Conservation Biology 9:1041–1058.

Johnson, T. H., and R. H. Wauer. 1996. Avifaunal response to the 1977 La Mesa fire. Pages 70–94 *in* C. D. Allen, technical coordinator. Fire effects in southwestern forests. Proceedings of the second La Mesa Fire symposium. U.S. Forest Service General Technical Report RM-GTR-286, Washington, D.C., USA.

Marshall, J. T., Jr. 1957. Birds of pine–oak woodland in southern Arizona and adjacent Mexico. Pacific Coast Avifauna 32.

Marshall, J. T., Jr. 1963. Fire and birds in the mountains of southern Arizona. Proceedings of the Tall Timbers Fire Ecology Conference 2:135–141.

Martin, J. A. 1997. Distribution, abundance, and habitat characteristics of the buff-breasted flycatcher in Arizona. Thesis, University of Arizona, Tucson, USA.

Pendleton, G. W. 1995. Effects of sampling strategy, detection probability, and independence of counts on the use of point counts. Pages 131–134 *in* C. J. Ralph, J. R. Sauer, and S. Droege, editors. Monitoring bird populations by point counts. U.S. Forest Service General Technical Report PSW-GTR-149, Washington, D.C., USA.

Pyne, S. J. 1996. Nouvelle southwest. Pages 9–16 *in* W. Covington and P. K. Wagner, editors. Conference on adaptive ecosystems restoration and management: restoration of cordilleran conifer landscapes of North America. U.S. Forest Service General Technical Report RM-GTR-278, Washington, D.C., USA.

Raphael, M. G., and M. White. 1984. Use of snags by cavity nesting birds in the Sierra Nevada. Wildlife Monographs 86.

Raphael, M. G., M. L. Morrison, and M. P. Yoder-Williams. 1987. Breeding bird populations during twenty-five years of post-fire succession in the Sierra Nevada. Condor 89:614–626.

Short, K. C. 2002. The effects of low-severity prescribed fires on vegetation, arthropods, and breeding birds in southwestern Ponderosa Pine forests. Dissertation, University of Montana, Missoula, USA.

Stacier, C. A., and M. J. Guzy. 2002. Grace's warbler (*Dendroica graciae*). Volume 677 *in* A. Poole and F. Gill, editors. The birds of North America. The Academy of Natural Sciences, Washington, D.C., USA.

Swetnam, T. W., C. D. Allen, and J. Betancourt. 1999. Applied historical ecology: using the past to manage the future. Ecological Applications 9: 1189–1206.

Swetnam, T. W., and C. H. Baisan. 1996. Fire histories of montane forests in Madrean borderlands. Pages 15–36 *in* P. F. Ffolliot, L. B. DeBano, M. B.

Baker, Jr., G. J. Gottfried, G. Solis-Garza, C. B. Edminster, D. G. Neary, L. S. Allen, and R. H. Hamre, technical coordinators. Effects of fire on Madrean province ecosystems. U.S. Forest Service General Technical Report RM-GTR-289, Washington, D.C., USA.

Taylor, D. L., and W. J. Barmore. 1980. Post-fire succession of avifauna in coniferous forests of Yellowstone and Grand Teton National Parks, Wyoming. Pages 130–145 *in* R. M. DeGraaf, editor. Workshop proceedings: management of western forests and grasslands for nongame birds. U.S. Forest Service General Technical Report INT-86, Washington, D.C., USA.

Underwood, A. J. 1994. On beyond BACI: sampling designs that might reliably detect environmental disturbances. Ecological Applications 4:3–15.

U.S. Department of the Interior. 1995. Federal fire management policy. Washington, D.C., USA.

U.S. Department of the Interior. 2003. National Park Service Fire monitoring handbook. National Interagency Fire Center, Boise, Idaho, USA.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. Journal of Wildlife Management 47:893–901.

Associate Editor: Greenberg.

Appendix. Birds identified by Marshall (1963) as being associated with open pine–oak woodland in southeastern Arizona, USA, and percentage of 1,513 survey points at which we detected these species in 8 mountain ranges in southeastern Arizona, USA, Apr–Jul 2000.

Species	%
American kestrel	0.0
Montezuma quail (*Cyrtonyx montezumae*)	0.6
Greater roadrunner (*Geococcyx californianus*)	0.5
Screech owls (*Megascops* spp.)[a]	0.0
Common nighthawk (*Chordeiles minor*)[a]	0.0
Cassin's kingbird	2.8
Purple martin (*Progne subis*)	0.0
Violet-green swallow (*Tachycineta thalassina*)	2.9
Western bluebird (*Sialia mexicana*)	1.2
Eastern bluebird (*Sialia sialis*)	0.3
American robin	24.0
Curve-billed thrasher (*Toxostoma curvirostre*)	0.0
Canyon towhee (*Pipilo fuscus*)	0.1
Yellow-eyed junco	19.5
Chipping sparrow	0.5

[a] Marshall (1957) conducted bird surveys throughout the day and was more likely to detect nocturnal and crepuscular species than we were during our morning bird surveys.