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EFFECTS OF PRESCRIBED FIRE ON WINTER ASSEMBLAGES OF BIRDS IN PONDEROSA PINE FORESTS OF NORTHERN ARIZONA

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ABSTRACT—Studies of birds in winter are rare in wildlife ecology despite winter being a critical time for birds. We examined winter assemblages of birds in ponderosa pine (*Pinus ponderosa*) forests of northern Arizona following prescribed fire. We conducted point counts on two study sites in northern Arizona from mid-October to mid-March 2004–2006. Each site had one unit treated by prescribed fire a full growing season before the point counts began, paired with control unit(s) of similar structure. We detected 39 species during the survey. Nine species comprised 81% of all detections; eight of these were year-round residents of the area. Dark-eyed juncos (*Junco hyemalis*) were the most numerous, comprising 23% of all detections. Assemblages were similar between treatments (Sorenson similarity index = 0.85) and years (Sorenson similarity index = 0.85), and rank abundance of species between burn and control units were correlated (Spearman's $\rho = 0.83$). Therefore, assemblages of birds in winter were similar among areas treated by prescribed fire and unburned areas of ponderosa pine forests in northern Arizona.

RESUMEN—Estudios de aves durante el invierno son raros en la ecología de la vida silvestre, a pesar de que el invierno es una época crítica para las aves. Examinamos los ensamblajes invernales de aves en bosques de pino ponderosa (*Pinus ponderosa*) en el norte de Arizona después de un incendio prescrito. Llevamos a cabo conteo de puntos en dos sitios de estudio en el norte de Arizona desde mediados de octubre hasta mediados de marzo durante 2004–2006. Cada sitio tuvo una sola unidad tratada con fuego controlado en una temporada completa de crecimiento antes de que los conteos de puntos se empezaran, pareada con unidad(es) de control de estructura similar. Detectamos 39 especies durante el período de muestreo. Nueve especies comprendieron el 81% de todas las detecciones; ocho de estas fueron residentes permanentes del área. Juncos ojo oscuro (*Junco hyemalis*) fueron los más numerosos, comprendiendo 23% de todas las detecciones. Los ensamblajes fueron similares entre tratamientos (índice de similitud de Sorenson = 0,85) y entre años (índice de similitud de Sorenson = 0,85), y las abundancias de especies por rango entre unidades quemadas y de control estuvieron correlacionadas (ρ de Spearman = 0,83). De esta manera, los ensamblajes invernales de aves fueron similares entre áreas tratadas con fuego prescrito y áreas no quemadas de bosques de pino ponderosa en el norte de Arizona.

Although most studies of avian ecology occur during the breeding season, winter is important to population ecology of birds. Survival in winter can affect populations, because birds that survive winter may reproduce the following breeding season (Fretwell, 1972; Kreisel and Stein, 1999). Habitat required for breeding might not be the same as habitat that provides food and shelter from harsh conditions in winter (Fretwell, 1972; Grubb, 1975, 1977; Connor, 1979; Graber and Graber, 1983; Morrison et al., 1986). Food generally is limited in winter; as insects are less abundant and many plants are dormant during this time. As a result, food is distributed patchily and birds become opportunistic in their foraging ecology (Beal, 1911; Otvos, 1965; Willson, 1971; Crockett and Hansley, 1978; Brawn et al., 1982; Morrison et al., 1986; Szaro et al., 1990).

For many forests, including ponderosa pine (*Pinus ponderosa*) forests in northern Arizona, fire was a natural disturbance of the system until fire-suppression efforts began in the early 20th century. Frequent, low-intensity fires were part of the ecology and evolutionary history of ponderosa pine forests (Cooper, 1960; Covington and Moore, 1994; Swetnam and Baisan, 1996; Moir et

TABLE 1—Description of study units in the Birds and Burns Network of the Coconino and Kaibab national forests, Arizona, including treatment (burn and control), area (ha), number of trees surveyed, average (±*SE*) diameter at breast height (cm), and average (±*SE*) height of tree (m).

	Kaibab National Forest				Coconino National Forest			
			Diameter at breast height	Height of tree			Diameter at breast height	Height of tree
Treatment	Area	*n*	$\bar{x} \pm SE$	$\bar{x} \pm SE$	Area	*n*	$\bar{x} \pm SE$	$\bar{x} \pm SE$
Burn	369	758	33.7 ± 0.5	13.7 ± 0.2	405	1940	23.1 ± 0.2	12.7 ± 0.1
Control	487	872	33.3 ± 0.4	11.3 ± 0.1	404	1567	24.5 ± 0.3	10.9 ± 0.1

al., 1997). Managers are attempting alternative forest-management strategies that include using prescribed burns in an effort to return fire to the landscape. As such, it will be important to understand effects of these treatments on birds wintering in areas where managers are using this tool.

A few studies have examined effects of wildfire on wintering birds in coniferous forests (Blake, 1982; Kreisel and Stein, 1999; Bock and Block, 2005; Covert-Bratland et al., 2006). Prescribed fire could have different effects on wintering birds than wildfire, yet only one study has examined effects of prescribed fire on wintering birds in a coniferous forest (King et al., 1998). Therefore, we compared assemblages of wintering birds in ponderosa pine forests recently treated by prescribed fire with untreated controls to determine whether prescribed fire affects composition and abundances of species during the first few winters following prescribed treatments.

MATERIALS AND METHODS—*Study Area*—We located study sites in the Coconino and Kaibab national forests in northern Arizona, as part of the Birds and Burns Network. Ponderosa pine was the dominant overstory species on both study sites, with Gambel oak (*Quercus gambelii*) contributing to the canopy on study units in Coconino National Forest. Pinyon pine (*Pinus edulis*), one-seed juniper (*Juniperus monosperma*), and alligator juniper (*J. deppeana*) occurred on control units in Kaibab National Forest, but contributed little to the canopy. Alligator juniper was on both units in Coconino National Forest. Open patches of grassland on both sites were dominated by bunchgrasses, including Arizona fescue (*Festuca arizonica*) and blue gramma (*Bouteloua gracilis*). Topography on the study site in Coconino National Forest varied from flat to steep hills, with elevations of 2,070–2,160 m. The study site in Kaibab National Forest was flat, with elevations of 2,100–2,300 m.

Each study site in the forests had a burned treatment unit paired with control unit(s) of similar structure (Table 1). We chose treatment units in consultation with district fire managers on each forest. We then placed control units in representative areas with similar structure within 1 km of the treatment unit where no management (e.g., thinning or prescribed burn) was planned. It was not possible to randomize location of each treatment unit; however, we made efforts to ensure all sampling occurred at randomly placed stations within units. We used a systematic random-sampling design for placement of point-count stations. We randomized placement of the first point, assigning remaining points using a Geographical Information System algorithm (Dickson, 2006).

Personnel of the United States Forest Service administered prescribed fires during autumn 2003 on the treatment unit in Coconino National Forest and on the treatment unit in Kaibab National Forest during

TABLE 2—Measurements of fire activity from prescribed fires on each burn unit and burn units combined on the Coconino and Kaibab national forests, Arizona.

National forest	Dates burned	Maximum height of char on bole (m)	Percentage of needles scorched	Percentage of bole charred
Kaibab	27 October 2003 6 November 2003 25 March 2004	2.6 ± 0.11	17.6 ± 1.05	85.8 ± 1.01
Coconino	15 September 2003 18 September 2003 19 September 2003	0.7 ± 0.02	2.3 ± 0.29	56.9 ± 1.00
Combined	—	1.2 ± 0.04	6.6 ± 0.39	65.0 ± 0.81

TABLE 3—Species detected during point counts from mid-October to mid-March 2004–2006, including incidental species (i) only detected beyond 100-m radius of point-count stations. Species, scientific name, foraging group, number of detections, percentage of total detections, year(s) detected, and treatment(s) detected are listed. Incidental species and those that are the only representative of their foraging group were not assigned to foraging groups analyzed in rank order of abundance.

Common name	Taxon	Foraging group	Number of detections (within 100 m)	Percentage of total detections (n = 4,639)	Year(s) detected	Treatment(s) detected
Bald eagle	*Haliaeetus leucocephalus*	—	i	—	Both	Control only
Northern goshawk	*Accipiter gentiles*	—	i	—	1	Burn only
Red-tailed hawk	*Buteo jamaicensis*	—	2	0.04	Both	Both
Swainson's hawk	*Buteo swainsoni*	—	i	—	1	Burn only
Wild turkey	*Meleagris gallopavo*	—	3	0.06	Both	Both
Mourning dove	*Zenaida macroura*	—	1	0.02	2	Burn only
Long-eared owl	*Asio otus*	—	1	0.02	2	Control only
Great horned owl	*Bubo virginianus*	—	1	0.02	1	Burn only
Northern pygmy-owl	*Glaucidium gnoma*	—	1	0.02	1	Burn only
Northern flicker	*Colaptes auratus*	Bark-foraging/sapsucking	62	1.34	Both	Both
Williamson's sapsucker	*Sphyrapicus thyroideus*	Bark-foraging/sapsucking	11	0.24	Both	Both
Red-naped sapsucker	*Sphyrapicus nuchalis*	Bark-foraging/sapsucking	7	0.15	Both	Both
Downy woodpecker	*Picoides pubescens*	Bark-foraging/sapsucking	2	0.04	1	Burn only
Hairy woodpecker	*Picoides villosus*	Bark-foraging/sapsucking	160	3.45	Both	Both
Three-toed woodpecker	*Picoides tridactylus*	Bark-foraging/sapsucking	9	0.19	Both	Both
Steller's jay	*Cyanocitta stelleri*	Generalist	176	3.79	Both	Both
Clark's nutcracker	*Nucifraga columbiana*	—	i	—	2	Burn only
Pinyon jay	*Gymnorhinus cyanocephalus*	Generalist	28	0.60	Both	Control only
American crow	*Corvus brachyrhynchos*	Generalist	2	0.04	Both	Control only
Common raven	*Corvus corax*	Generalist	50	1.08	Both	Both
Violet-green swallow	*Tachycineta thalassina*	—	8	0.17	1	Both
Mountain chickadee	*Poecile gambeli*	Gleaning insectivore	405	8.73	Both	Both
Bushtit	*Psaltriparus minimus*	Gleaning insectivore	78	1.68	Both	Both
Brown creeper	*Certhia americana*	Bark-foraging/sapsucking	133	2.87	Both	Both
White-breasted nuthatch	*Sitta carolinensis*	Bark-foraging/sapsucking	406	8.75	Both	Both
Red-breasted nuthatch	*Sitta canadensis*	Bark-foraging/sapsucking	2	0.04	2	Burn only

TABLE 3—Continued.

Common name	Taxon	Foraging group	Number of detections (within 100 m)	Percentage of total detections (n = 4,639)	Year(s) detected	Treatment(s) detected
Pygmy nuthatch	*Sitta pygmaea*	Bark-foraging/sapsucking	678	14.62	Both	Both
Golden-crowned kinglet	*Regulus satrapa*	Gleaning insectivore	34	0.73	Both	Both
Ruby-crowned kinglet	*Regulus calendula*	Gleaning insectivore	220	4.74	Both	Both
Western bluebird	*Sialia mexicana*	Gleaning insectivore	508	10.95	Both	Both
Mountain bluebird	*Sialia currucoides*	Gleaning insectivore	1	0.02	1	Control only
Townsend's solitaire	*Myadestes townsendi*	Gleaning insectivore	10	0.22	Both	Both
American robin	*Turdus migratorius*	Gleaning insectivore	84	1.81	1	Both
Yellow-rumped warbler	*Dendroica coronata*	Gleaning insectivore	32	0.69	Both	Both
Olive warbler	*Peucedramus taeniatus*	Gleaning insectivore	16	0.34	Both	Both
Dark-eyed junco	*Junco hyemalis*	Seed-eating	1,065	22.96	Both	Both
Cassin's finch	*Carpodacus assinii*	—	i	—	Both	Both
Red crossbill	*Loxia curvirostra*	Seed-eating	38	0.82	Both	Both
Pine siskin	*Carduelis pinus*	Seed-eating	32	0.69	Both	Both

autumn 2003 and spring 2004 (Table 2). Fire prescriptions were characterized as broadcast burns with expected behaviors of fire to be low-to-moderate intensity (Dickson, 2006). Fires were heterogeneous in nature, ranging from areas not burned to areas with burns severe enough to kill trees. We measured maximum height of char on bole, percentage of circumference of bole that was charred at the base, and percentage of needles scorched, because these are measures of fire that fire managers can incorporate into fire prescriptions. Average ($\pm SE$) maximum height of char on bole for burn units was 1.2 m $\pm$ 0.04. Average percentage circumference of bole that was charred at the base was 65.0 $\pm$ 0.81 and average percentage of needles scorched was 6.6 $\pm$ 0.39. Measurements for individual burn units are included in Table 2. Nevertheless, these values represent low-severity fire that had little post-treatment effect on structure of the forest.

Field Methods—We conducted point counts in winter (Reynolds et al., 1980) at 170 point-count stations in northern Arizona during the first 2 winters following treatments. The study site in Coconino National Forest had 40 point-count stations each in burn and control units. The study site in Kaibab National Forest had 40 point-count stations in the burn unit and 50 point-count stations between two control units. Each station was ca. 300 m apart and $\geq$200 m from edges of units. At each station, we recorded number of individuals and distance to each individual for all birds observed during a 5-min survey period. Point counts began $\leq$30 min of sunrise and concluded within 5 h. We did not count in windy (i.e., >28 km/h) or wet (more than a light snow) conditions. We visited all stations eight times (4/season) between mid-October and mid-March, 2004–2006, with a single observer per visit.

We assigned all species detected within 100 m of a point-count station to one of four foraging groups (foraging group must include >1 species). We also recorded incidental observations (i.e., observed in a unit but not within 100 m of any point-count station). Foraging groups included seed-eating, bark-foraging/sapsucking, gleaning insectivores, and generalists (see Table 3 for species-specific assignments to groups).

Statistical Analyses—We used a similarity index and a test of rank order of abundance to describe patterns in assemblages of wintering birds. We used an uncorrected index of abundance because we were examining patterns of abundance and not proposing actual estimates of abundance. We investigated similarity in assemblages of wintering birds between treatments (pooling across years) and years (pooling across treatments) using the Sorenson similarity index, $C = 2j/(a + b)$; where j = number of species common to both treatment units or years, a = total number of species detected in burn units or year 1, and b = total number of species detected in control units or year 2 (Magurran, 1988). The similarity index equals a number between 0 and 1, with higher values representing greater similarity.

We used rank order of abundance to represent structure of assemblages for each year and treatment. We ranked species in order of abundance, based on number of individual detections. We calculated Spearman's rank-order correlation coefficient (Spearman's

ρ; Conover, 1999) using SPSS 15.0 for Windows (SPSS, Inc., Chicago, Illinois). A higher value of Spearman's ρ represents a higher correlation in rank order of species between treatments and years. For example, Spearman's ρ = 1.00 will have species ranked in the same order for each treatment or year.

Results—We detected 39 species of birds during winters of 2004–2006 (Table 3). Nine species comprised 81% of observations. In descending order, these were dark-eyed junco (*Junco hyemalis*), pygmy nuthatch (*Sitta pygmaea*), western bluebird (*Sialia mexicana*), white-breasted nuthatch (*Sitta carolinensis*), mountain chickadee (*Poecile gambeli*), ruby-crowned kinglet (*Regulus calendula*), Steller's jay (*Cyanocitta stelleri*), hairy woodpecker (*Picoides villosus*), and brown creeper (*Certhia americana*). All of these species, except for ruby-crowned kinglet, are year-round residents of ponderosa pine forests in northern Arizona.

Assemblages were similar in composition and structure among years and between treatments. Using the Sorenson similarity index (C) to examine all non-incidental species detected during point counts, similarity between treatments and years was $C = 0.85$. We detected similar patterns when examining individual foraging groups. Seed-eating birds had $C = 1.00$ between treatments and $C = 0.80$ among years. Gleaning insectivores had $C = 0.95$ between treatments and $C = 0.89$ among years. Bark-foraging/sapsucking birds had $C = 0.89$ for both treatment and year. Generalists had $C = 0.85$ between years, however, $C = 0.66$ between treatments because we detected two species, pinyon jay (*Gymnorhinus cyanocephalus*) and American crow (*Corvus brachyrhynchos*), in control units only.

We also examined how rank order of abundance of species in each treatment differed among years for all non-incidental species. In burn units, Spearman's $\rho = 0.69$ ($P < 0.01$). Spearman's $\rho = 0.70$ ($P < 0.01$) in control units. Because there was no yearly difference, we combined years for a Spearman's $\rho = 0.83$ ($P < 0.01$) correlation between treatments. Individual foraging groups differed among years in each treatment. Seed-eating birds had Spearman's $\rho = 0.50$ ($P = 0.67$) among years in burn units and Spearman's $\rho = 1.00$ in control units. This group had Spearman's $\rho = 0.50$ ($P = 0.67$) between treatments for both years combined. Generalists had Spearman's $\rho = 1.00$ in burn units and control units among years, and Spearman's $\rho = 0.63$ ($P = 0.37$) between treatments. Gleaning insectivores had Spearman's $\rho = 0.47$ ($P = 0.17$) in burn units, Spearman's $\rho = 0.28$ ($P = 0.43$) in control units, yet Spearman's $\rho = 0.91$ ($P < 0.01$) between treatments. Bark-foraging/sapsucking birds had Spearman's $\rho = 0.95$ ($P < 0.01$) in the burn units, Spearman's $\rho = 0.96$ ($P < 0.01$) in the control units, and Spearman's $\rho = 0.92$ ($P < 0.01$) between treatments.

We also compared composition and structure of assemblages of birds between burn units to determine whether intensity of fire had an effect. The Sorenson similarity index was $C = 0.78$ between burn units and Spearman's $\rho = 0.79$ ($P < 0.01$). Order of abundance for individual foraging groups in each burn unit were all correlated (bark-foraging/sapsucking–Spearman's $\rho = 0.97$ ($P < 0.01$); gleaning insectivore–Spearman's $\rho = 0.76$ ($P = 0.03$); generalist–Spearman's $\rho = 1.00$) except seed-eating, which had Spearman's $\rho = 0.50$ ($P = 0.67$).

Discussion—Assemblages of birds in northern Arizona were similar in composition and structure among treatments and years during the first 2 winters following low-intensity prescribed fire. Differences in assemblages of wintering birds might depend on type of fire, i.e., whether wildfire (high-intensity) or prescribed fire (low-to-moderate intensity). Blake (1982) compared assemblages of wintering birds in areas burned by wildfire and unburned areas in northern Arizona. In his study, hairy woodpeckers were more common in burned areas. Our results were the same although our prescribed fires were lower intensity than many wildfires. Blake (1982) also reported that species that search crevices in bark for insects, such as nuthatches, were more common in unburned sites in winter; however, nuthatches had similar abundances in burned and unburned areas in our study. This pattern could be the result of low-intensity prescribed fire not altering structure of forest stands as much as high-intensity wildfire.

Number of species detected in undisturbed sites in ponderosa pine forests during winter varies between studies. Our study and Bock and Block (2005) detected a similar number of species wintering in unburned areas (31 and 26, respectively). However, Haldeman et al. (1973) recorded only 18 species wintering in undisturbed sites in ponderosa pine forests of

northern Arizona. Pygmy nuthatch was the most common species reported by Haldeman et al. (1973) and the second-most common species behind dark-eyed juncos in our study. However, common species were generally the same for each study, including mountain chickadee, pygmy and white-breasted nuthatch, dark-eyed junco, western bluebird, hairy woodpecker, northern flicker, and Steller's jay.

Of 39 species we detected, 25 were common between treatment and years (Table 3). However, some species were only present in 1 year or treatment. For example, violet-green swallows (*Tachycineta thalassina*) had returned from migration before counts ended the first year. We had 13 species only detected in one treatment (five in control, eight in burn). These species were represented mostly by raptors (three), owls (three), and corvids (three). Of these, only pinyon jays were detected more than twice (Table 3). Therefore, less-abundant species may be present in only one treatment, producing diversity while maintaining composition and structure of assemblages. As such, creating a mosaic of burned and unburned areas will enhance species diversity in ponderosa pine forests.

Although there was some variability among foraging groups, assemblages of birds were similar between unburned areas and areas treated with prescribed fire, between each burn unit, and among years during winters initially following prescribed fire. Therefore, managers that use low-severity prescribed fires in ponderosa pine forests of northern Arizona might not be altering structure of the forest enough to impact assemblages of wintering birds during the first few years following prescribed fire.

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