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Authors: Hanson, Chad T., and North, Malcolm P.

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POSTFIRE WOODPECKER FORAGING IN SALVAGE-LOGGED AND UNLOGGED FORESTS OF THE SIERRA NEVADA

CHAD T. HANSON[1,3] AND MALCOLM P. NORTH[2]

[1]*Agricultural Experiment Station, Department of Plant Sciences, College of Agricultural and Environmental Sciences, One Shields Avenue, University of California at Davis, Davis, CA 95616*
[2]*USDA Forest Service, Pacific Southwest Research Station, Sierra Nevada Research Center, 1731 Research Park Dr., Davis, CA 95616*

Abstract. In forests, high-severity burn patches—wherein most or all of the trees are killed by fire—often occur within a mosaic of low- and moderate-severity effects. Although there have been several studies of postfire salvage-logging effects on bird species, there have been few studies of effects on bird species associated with high-severity patches in forests that have otherwise burned at lower severities. From 2004 to 2006, we investigated the foraging presence or absence of three woodpecker species, the Black-backed (*Picoides arcticus*), Hairy (*P. villosus*), and White-headed (*P. albolarvatus*) Woodpeckers, within four different forest habitat conditions in Sierra Nevada conifer forests: unburned; moderate-severity and unlogged; high-severity and unlogged; and high-severity and logged. We found Black-backed Woodpecker foraging was restricted to unlogged high-severity patches. Hairy Woodpeckers foraged most in unlogged high-severity patches, and White-headed Woodpeckers showed no significant difference in presence among conditions. These results suggest that unlogged, high-severity forest is important habitat for the Black-backed and Hairy Woodpeckers.

Key words: *foraging, high-severity fire, salvage logging, Sierra Nevada, stand-replacement fire, woodpeckers.*

Forrajeo de Pájaros Carpinteros en Bosques Quemados Con y Sin Extracción de Madera en la Sierra Nevada

Resumen. En ambientes boscosos, a menudo se encuentran parches que han sido severamente quemados (donde la mayoría o todos los árboles mueren a causa del fuego) inmersos en un mosaico de lugares en los que la severidad del fuego ha sido baja o moderada. Aunque existen varios estudios acerca de los efectos de la extracción de madera posterior al fuego sobre especies de aves, ha habido pocos estudios acerca de los efectos sobre especies de aves asociadas con parches severamente afectados por el fuego en bosques que, en general, han sido quemados con una severidad relativamente menor. Entre 2004 y 2006, investigamos la presencia o ausencia de tres especies de pájaros carpinteros (*Picoides arcticus*, *P. villosus* y *P. albolarvatus*) alimentándose en ambientes de cuatro condiciones distintas en bosques de coníferas de la Sierra Nevada: no quemados, con quemas de severidad moderada y sin extracción de madera, con quemas de alta severidad y sin extracción de madera, y con quemas de alta severidad y extracción de madera. Encontramos que el forrajeo de *P. arcticus* estuvo restringido a parches con quemas de alta severidad y sin extracción de madera, mientras que *P. villosus* se encontró principalmente en este ambiente. La presencia de *P. albolarvatus* no mostró diferencias entre los distintos ambientes. Estos resultados sugieren que los bosques con quemas de alta severidad en los que no se extrae madera son un hábitat importante para *P. arcticus* y *P. villosus.*

Dynamic, nonequilibrium forces such as wildland fire have strong influences on ecosystems by changing the structure, size, and heterogeneity of patches (O'Neill et al. 1986, Kotliar and Wiens 1990, Wu and Loucks 1995, White and Jentsch 2001), and by influencing wildlife habitat and biodiversity (Connell 1978, Smucker et al. 2005). Ecologists have suggested that an important measure of a disturbance is whether it is within the natural range of variability that historically shaped an ecosystem (White and Jentsch 2001). Although species numbers may be high in intermediate levels of disturbance (Connell 1978), highly endemic species, which are often rare, may require at least some relatively high disturbance intensity to perpetuate the environment with which they evolved (Hutto 1995).

Historically, Sierra Nevada forests were characterized by frequent, low-severity fire in lower-elevation forests dominated by pine (*Pinus* spp.; McKelvey et al. 1996, Skinner and Chang 1996, Agee and Skinner 2005) and more infrequent, high-severity events at higher elevations (>2300 m) such as in lodgepole pine (*Pinus contorta*) forests (Skinner and Chang 1996). Between these zones, in mixed-conifer forests, many studies have documented a fire regime of moderately frequent low-intensity fire (McKelvey et al. 1996, Skinner and Chang 1996). Moderate- and high-severity fires, however, did occur in many western midelevation forests (Leiberg 1902, Show and Kotok 1924, Baker and Ehle 2001, Nagel and Taylor 2005). The extent and frequency of these fire events is often difficult to identify because there are few surviving scarred trees, and tree regeneration may occur continually over decades, obscuring any tree age cohort structure. Understanding current densities and habitat use of species associated with high-severity events can provide insight into the role of high-severity fire within the historical range of disturbance variability for midelevation Sierran forests.

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[3]E-mail: cthanson@ucdavis.edu

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There is perhaps no vertebrate species more strongly representative of snag habitat produced when most or all trees are killed by fire than the Black-backed Woodpecker (*Picoides arcticus*; Hutto 1995, Hanson 2007). This species is a designated management indicator species, potentially acting as a bellwether for the viability of other species associated with postfire snag habitat (U.S. Department of Agriculture 2004), which has high levels of native-species richness for both higher plants and vertebrates (Noss et al. 2006). In the northern Rocky Mountains, the Black-backed Woodpecker is largely restricted to recent severely burned, unlogged forest (Hutto 1995, 2006, Caton 1996). Similar research has not been conducted in the Sierra Nevada.

Historical, qualitative records of Black-backed Woodpeckers suggest they were "quite numerous" in Sierra Nevada mixed-conifer forests (Cooper 1870), but by the 1920s had become "rare" (Dawson 1923, Grinnell and Storer 1924). In the Rockies, the Black-backed Woodpecker appears to require a minimum high-severity patch size of 12–25 ha (Saab et al. 2002), use snag dominated habitat for only 5–7 years postfire (Saab et al. 2004), and rely upon a constantly replenished supply of this ephemeral habitat as new fires occur (Hutto 1995). Other strong excavators, such as the Hairy (*P. villosus*) and White-headed (*P. albolarvatus*) Woodpeckers are associated with burned forest as well, but the strength and nature of their association are less clear (Saab et al. 2002, 2004).

The purpose of this study was to investigate whether current management prescriptions for "salvage" logging, involving postfire removal of all but 3–6 large (generally >50 cm in diameter at breast height [dbh]) snags per acre (7.5–15 per ha) in severely burned forest, could reduce foraging habitat quality for these woodpecker species (U.S. Department of Agriculture 2001, 2004), using an analysis of presence-or-absence data.

METHODS

The study sites included the 2001 Star fire area, which encompassed approximately 6750 ha on the Tahoe and Eldorado National Forests (all data were gathered on the Tahoe National Forest); the 2001 Stream fire area, which covered approximately 1670 ha on the Plumas National Forest; and the 2003 Kibbie Complex fire area, which covered approximately 2715 ha on Yosemite National Park and the Stanislaus National Forest (all data were gathered on the Stanislaus National Forest; Fig. 1). These fires were selected because they were large, patchy, and occurred primarily in mixed-conifer and true fir (*Abies* spp.) forest at elevations ranging from 1400 to 2200 m in the Sierra Nevada. Mixed-conifer forests in the Sierra Nevada are dominated by white fir (*A. concolor*), ponderosa pine (*Pinus ponderosa*), incense-cedar (*Calocedrus decurrens*), Douglas-fir (*Pseudotsuga menziesii*), and sugar pine (*Pinus lambertiana*); true fir stands are comprised of white and red fir (*A. magnifica*; Barbour and Minnich 2000).

A portion of each fire area was logged after the fires, with at least 7.5–15 large snags per hectare retained under current management guidelines (and some additional smaller snags retained due to unmerchantability). The U.S. Forest Service mapped burn severity and logging units in each fire area. The burn severity maps were derived from aerial photography conducted by the interagency Burned Area Emergency Rehabilitation teams.

Within the Star, Stream, and Kibbie fire areas, we stratified sample locations into four categories: unburned, moderate severity and unlogged, high severity and unlogged, and high severity and logged. To avoid mixing postburn forest conditions, we included only patches >12 ha with one burn condition, using U.S. Forest Service burn severity maps as a guide.

There was an overall total of 9 replicate patches each for unburned and high-severity and logged conditions, 8 replicates for the moderate-severity and unlogged condition, and 10 replicates for the high-severity and unlogged condition, for a total of 36 patches in the entire study (Fig. 1). The unbalanced designed occurred because one patch that appeared to be of moderate severity was later determined to be of high severity, once tree mortality data were gathered.

Between mid-June and late-July in 2004 through 2006, we recorded the presence or absence observed for the Black-backed, White-headed, and Hairy Woodpeckers along 1400 m transects, beginning 100 m from the patch edge and moving through the center of each of the 36 patches, changing direction when edges were reached. In each transect, we stopped every 200 m (estimated by pacing) to record presence or absence for an 8 min survey period until eight such survey periods were completed for each of the 36 patches. There was equal survey effort among the 36 patches.

In each 8 min survey period, we recorded visual detections of Black-backed, White-headed, and Hairy Woodpeckers within approximately 50 m of the investigator. No data were recorded within less than 100 m of the edge of each of the 36 patches, or in patches <12 ha in size (Saab et al. 2002). No transects were repeated within a patch. The time of day for censusing transects was mixed such that no habitat condition received proportionally more morning or afternoon data collection than another. Surveys were conducted between 06:00 and 15:00 PST. We calculated the proportion of the eight survey periods in which presence was observed for each replicate patch to produce one data point for each of the three species in each patch.

To minimize potential for overlap of woodpecker home ranges and establish spatial independence of data points, all patches included in the study were at least 400 m from another patch (600 m between sample locations given each patch's edge buffer). This distance should be sufficient to insure independent samples of Black-backed Woodpeckers in burned forests (Hoyt and Hannon 2002); however, data on Hairy Woodpecker home range size is lacking (Jackson et al. 2002), and the White-headed Woodpecker in Oregon may have some home-range overlap at this distance (although populations in the Sierra Nevada have a higher density and therefore possibly a smaller home range size [Garrett et al. 1996]).

In each patch, we recorded snag density in each of the three size classes and mortality proportions of all trees ≥25 cm dbh in each of twelve 0.01 ha plots. Trees were classified as snags if they had no remaining green foliage. We treated the 12 plots within each patch as subsamples of the patch. Plots were spaced by 70 m, estimated by pacing, along transects through the center of each patch, changing transect direction when patch edges were reached. We included only "recent" snags (those retaining their bark and fine twigs [Thomas et al. 1979]) because research (Hutto 1995, Saab et al. 2002, 2004) and personal observation suggest that the three woodpecker species forage primarily on recently dead trees, and because the focus of the study was the relationship between fire-caused mortality and foraging.

STATISTICAL ANALYSES

We analyzed differences in presence among habitat conditions for each species with a nonparametric Kruskal-Wallis one-way analysis of variance, using SAS (SAS Institute 2001), because the data were not normally distributed. In the analyses, the proportion of survey periods with observed presence for each of the three species in each patch was the dependent variable, habitat

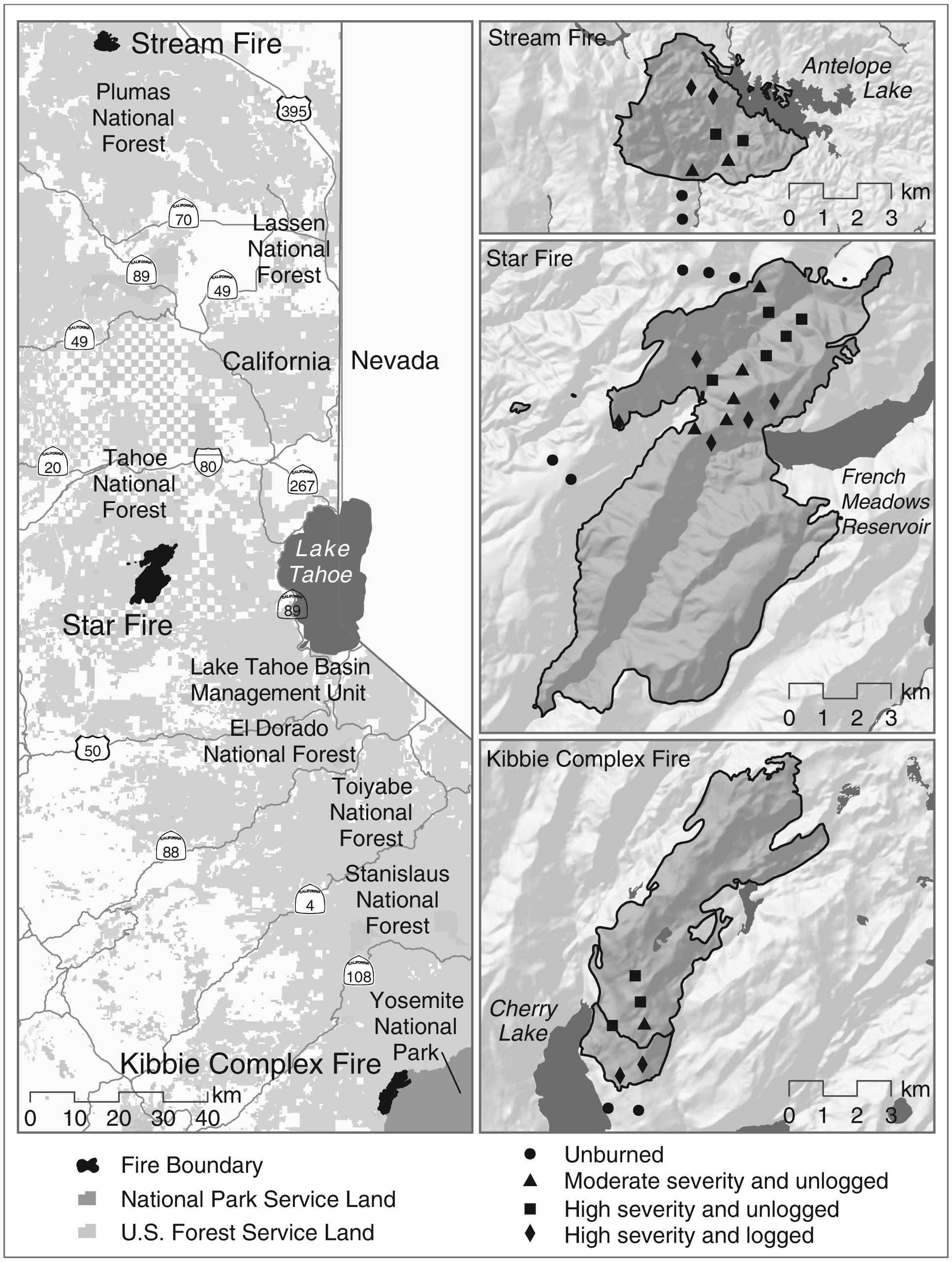

FIGURE 1. Star, Stream, and Kibbie Complex fire areas, and patch locations for foraging presence or absence observations (2004–2006) of the Black-backed, White-headed, and Hairy Woodpeckers, in the Sierra Nevada mountains, California.

condition ($n = 4$) was the discrete independent variable, and each patch was treated as an experimental unit. We made pairwise comparisons among habitat conditions for each species following the methods of Siegel and Castellan (1988) for multiple pairwise comparisons in a Kruskal-Wallis test with unequal sample sizes. Results for this analysis are reported as χ^2 values since the Kruskal-Wallis test is well-approximated by the χ^2 distribution when there are more than three groups and when there are more than five observations per group (Siegel and Castellan 1988). We report results as significant at $\alpha = 0.05$, but also note where differences were detected at $\alpha = 0.10$.

RESULTS

The Star, Stream, and Kibbie fires occurred in predominantly dense, mature and old-growth forest, producing high snag densities. Mortality ranges were 0%–16%, 39%–72%, 92%–100%, and 92%–100% for the unburned, moderate-severity and unlogged, high-severity and unlogged, and high-severity and logged conditions, respectively. In high-severity and logged patches, 27% of all snags 25–49 cm dbh had been removed, and 74% of all snags ≥50 cm dbh had been removed. Density of snags 25–49 cm dbh was greatest in high-severity and logged, and high-severity

TABLE 1. Mean snag density (number per ha ± SD) in four habitat conditions within the Star, Stream, and Kibbie fire areas in the Sierra Nevada mountains of California in a study of foraging presence differences among the Black-backed, White-headed, and Hairy Woodpeckers. Snag densities are based upon twelve 0.01 ha plots along transects in each of the 36 patches, for a total of 432 plots. Severity refers to the level of tree mortality resulting from wildland fire. Mortality ranges were 0%–16%, 39%–72%, 92%–100%, and 92%–100% for the unburned, moderate-severity and unlogged, high-severity and unlogged, and high-severity and logged conditions, respectively.

Habitat condition	Number of patches	Snags 25–49 cm dbh	Snags ≥50 cm dbh
Unburned	9	13.9 ± 10.2	7.4 ± 11.4
Moderate severity and unlogged	8	110.8 ± 76.8	53.4 ± 35.5
High severity and unlogged	10	127.5 ± 63.3	124.2 ± 63.3
High severity and logged	9	169.4 ± 116.4	18.5 ± 7.3

and unlogged conditions, while density of snags ≥50 cm dbh was greatest in the high-severity and unlogged condition and lowest in unburned and high-severity and logged condition (Table 1).

The Black-backed Woodpecker foraged exclusively in high-severity and unlogged patches ($\chi^2_3 = 18.1$, $P < 0.001$; Table 2). There were no significant differences in foraging among habitat conditions for the White-headed Woodpecker ($\chi^2_3 = 1.4$, $P = 0.72$). For the Hairy Woodpecker, there was a significant effect of habitat condition ($\chi^2_3 = 10.9$, $P = 0.01$). A pairwise analysis of Hairy Woodpecker foraging among the different habitats found significantly more foraging in the high-severity and unlogged condition than in the unburned condition ($P < 0.05$), and more foraging in the high-severity and unlogged condition than in the high-severity and logged condition ($P < 0.10$; Table 2). Of all foraging observations, 97%, 81%, and 92% occurred on snags, as opposed to live trees, for the Black-backed, White-headed, and Hairy Woodpeckers, respectively.

TABLE 2. Foraging presence (mean proportion of survey periods with detections) among four habitat conditions for Black-backed, White-headed, and Hairy Woodpeckers in the Stream, Star, and Kibbie fire areas of the Sierra Nevada mountains, California (2004–2006). Severity refers to the level of tree mortality resulting from wildland fire. Values within a column with different superscripts are significantly different at $\alpha = 0.05$, except where otherwise noted.

Habitat condition	Black-backed Woodpecker ($\chi^2_3 = 18.1$, $P < 0.001$)	White-headed Woodpecker ($\chi^2_3 = 1.4$, $P = 0.72$)	Hairy Woodpecker ($\chi^2_3 = 10.9$, $P = 0.01$)
Unburned	0.00[1]	0.07[1]	0.03[1]
Moderate severity and unlogged	0.00[1]	0.08[1]	0.09[1,2]
High severity and unlogged	0.09[2]	0.05[1]	0.25[2]
High severity and logged	0.00[1]	0.03[1]	0.07[1,a]

[a] For the Hairy Woodpecker, at $\alpha = 0.10$, foraging presence was significantly higher in the high-severity and unlogged condition than it was in the high-severity and logged condition ($P = 0.08$).

DISCUSSION

These results suggest that the three woodpecker species represent a continuum along which snag habitat in unlogged high-severity burn forests becomes increasingly important, from White-headed, to Hairy, to Black-backed Woodpecker, respectively. Previous research has predicted that White-headed Woodpeckers would disfavor high-severity burn patches (Saab and Dudley 1998), though we did not find significantly higher or lower White-headed Woodpecker presence in high-severity patches. Our findings are consistent with Hairy and Black-backed Woodpecker studies in other regions, which have found strong but not exclusive associations between the Hairy Woodpecker and unlogged high-severity areas (Hutto 1995, Smucker et al. 2005, Saab et al. 2007, Vierling et al. 2008), and essentially exclusive associations between the Black-backed Woodpecker and this habitat type when it is available (Hutto 1995, Murphy and Lehnhausen 1998, Hoyt and Hannon 2002, Smucker et al. 2005). Previous research has also found these species to be positively associated with higher fire severity, and increasing snag density and diameter (Russell et al. 2007), as well as higher prefire canopy cover for Black-backed Woodpeckers (Russell et al. 2007). Our results are broadly consistent with these findings.

Previous studies indicate that the Black-backed Woodpecker in particular may be able to effectively use snag-forest habitat for approximately 5–8 years postfire, or less, after which snag attrition, declines in beetle larvae, and recolonization of nest predators into the burn area begin to render territories unsuitable (Hutto 1995, Murphy and Lehnhausen 1998, Hoyt and Hannon 2002, Saab et al. 2004). It may take longer for nest predators to recolonize large snag-dominated forest patches compared to small ones, allowing relatively longer woodpecker occupancy (Saab et al. 2004). Given the ephemeral nature of snag patches and the need for a constantly replenished supply of this habitat type (Hutto 1995, Murphy and Lehnhausen 1998, Saab et al. 2007), it will be important to gain more precise knowledge of temporal thresholds associated with Black-backed Woodpecker use of particular snag patches.

In this study, large-snag retention (18 per ha) in the high-severity and logged condition was higher than minimum prescriptions of 7.5–15 per ha on U.S. Forest Service lands (U.S. Department of Agriculture 2001, 2004) due to the fact that some additional snags, generally in the 50–60 cm dbh size range, were retained because they were deemed to be unmerchantable. Even with this above-minimum level of large-snag retention, foraging presence was significantly reduced for two of the three woodpecker species relative to the high-severity and unlogged condition.

Logistic regression modeling in the northern Rocky Mountains, based upon nesting presence or absence, found nest-site selection for Black-backed Woodpeckers to be strongly associated with high density of small snags within 11.3 m of the nest tree (Saab et al. 2002, 2004). This has led some land managers to conclude that a high-quality Black-backed Woodpecker territory consists of dense stands of small, young fire-killed trees. The results of our study, however, indicate why it is important to distinguish nest-site characteristics from foraging habitat (Hutto 2006). The Black-backed Woodpecker did not forage in the high-severity and logged condition, despite high densities of small snags.

MANAGEMENT IMPLICATIONS

The strength of the association of Black-backed Woodpeckers with unlogged postfire snag conditions makes it a useful indicator species for wildlife associated with this habitat (Hutto 1995, 2006, Noss et al. 2006). Other indicator species include Mountain Bluebird (*Sialia currucoides*), a bird that uses nest cavities excavated in previous years by Black-backed Woodpeckers, which create new nest cavities each year (Hutto 1995, Dixon and Saab 2000).

Researching the habitat-quality and quantity needs of species such as the Black-backed Woodpecker may yield useful insights into the natural range of variability for high-severity fire, and aid land managers in setting appropriate parameters for fire-caused mortality and heterogeneity. Currently, average annual fire extent remains heavily suppressed in California's forests relative to pre-1850 levels, and increased use of wildland fire use has been recommended to bring fire extent closer to historic levels (Stephens et al. 2007).

Some studies have concluded that high-severity fire must have been historically rare or have occurred only in small patches in mixed-conifer forests of the Sierra Nevada, given relatively frequent fire return intervals (McKelvey et al. 1996, Skinner and Chang 1996). Yet, the foraging preference of the Black-backed Woodpecker for snag-forest habitat and historical records indicating that this now-rare species was once common (Cooper 1870) suggest high-severity burns occurred with enough frequency for some species to evolve a strong habitat association with them. Determining the Black-backed Woodpecker's optimal habitat patch size, distribution, and stand structure would improve management of this important postfire condition.

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