Maryellen Haggard, USDA Forest Service, Leavenworth Ranger District, 600 Sherbourne, Leavenworth, Washington 98826

William L. Gaines,[1] USDA Forest Service, Wenatchee National Forest, 215 Melody Lane, Wenatchee, Washington 98801 Email: wgaines@fs.fed.us

Effects of Stand-Replacement Fire and Salvage Logging on a Cavity-Nesting Bird Community in Eastern Cascades, Washington

Abstract

We monitored the response of cavity-nesting species to three snag density treatments (high = 37-80 snags/ha, medium = 15-35 snags/ha, and low = 0-12 snags/ha) during two breeding seasons 4-5 yr post-fire and logging in Douglas-fir- ponderosa pine forests in the eastern Cascades, Washington. Snag surveys were used to describe habitat, and both breeding bird surveys and nest surveys were used to characterize the bird community. Stands with the medium snag density treatment had the highest abundance, species richness, and nesting population of cavity nesters. The reasons for this may be: 1) snags were not evenly distributed within a stand such that both clumped and dispersed snag density habitats were interspersed in this treatment, and 2) a greater proportion of ponderosa pine snags in medium density treatments may have attracted species that prefer ponderosa pine for nesting and foraging. Ponderosa pine was preferred for nest sites and large snags (> 48 cm dbh) provided nesting habitat for more species than smaller snags. However, smaller snags were used for nesting and foraging by some species.

Introduction

Snag abundance is a limiting factor for primary cavity excavators because they excavate a nest cavity each year (McClelland et al. 1979, Zarnowitz and Manuwal 1985, Bull et al. 1990). Primary cavity excavators are important members of forest ecosystems because the cavities they excavate may be used by secondary cavity nesters, including bats, American marten (*Martes americana*), many owl species, and other birds (Bevis 1994, Strangel 1994, Bull et al. 1997), and because they influence insect numbers (Mannan et al. 1980).

The snags retained during salvage logging following a fire can strongly influence the bird community (Blake 1982, Medin 1985). Designing salvage logging for snag retention is especially important in areas where there has been a stand-replacement fire. Snags in large burned areas have greater exposure to wind, causing them to fall at high rates. Morrison and Raphael (1993) found an 85% decrease in snag density (from 31.4 to 4.6 snags/ha) 18 to 23 yr following a fire in the Sierra Nevada.

The relationship between snag density and bird populations in areas of stand-replacement fires has not been well studied. Our objectives in this study were to:

(1) measure the abundance and species richness of cavity-nesting birds at different levels of snag retention, and (2) characterize nest trees, nest sites, and estimate the number of nests by primary and secondary cavity nesting birds.

Study Area

The study area was located on the eastern side of the Cascade Mountains in the Wenatchee National Forest. The study took place in areas that were affected by the high intensity stand-replacement Rat Creek fire of 1994 that burned on the Leavenworth Ranger District and adjacent private land. The landscape was dominated by ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*) plant associations (Lillybridge et al. 1995). Elevations ranged from 650 m to 1300 m. Average annual precipitation is from 25 to 50 cm, falling mostly as snow.

Methods

Stand Selection

Six stands (two replicates of three treatments) that were salvaged logged in 1996 were selected for monitoring of cavity-nesting bird communities (Figure 1). These stands were selected based upon those available following logging and those that met snag retention and site characteristic criteria.

[1]Author to whom correspondence should be addressed.

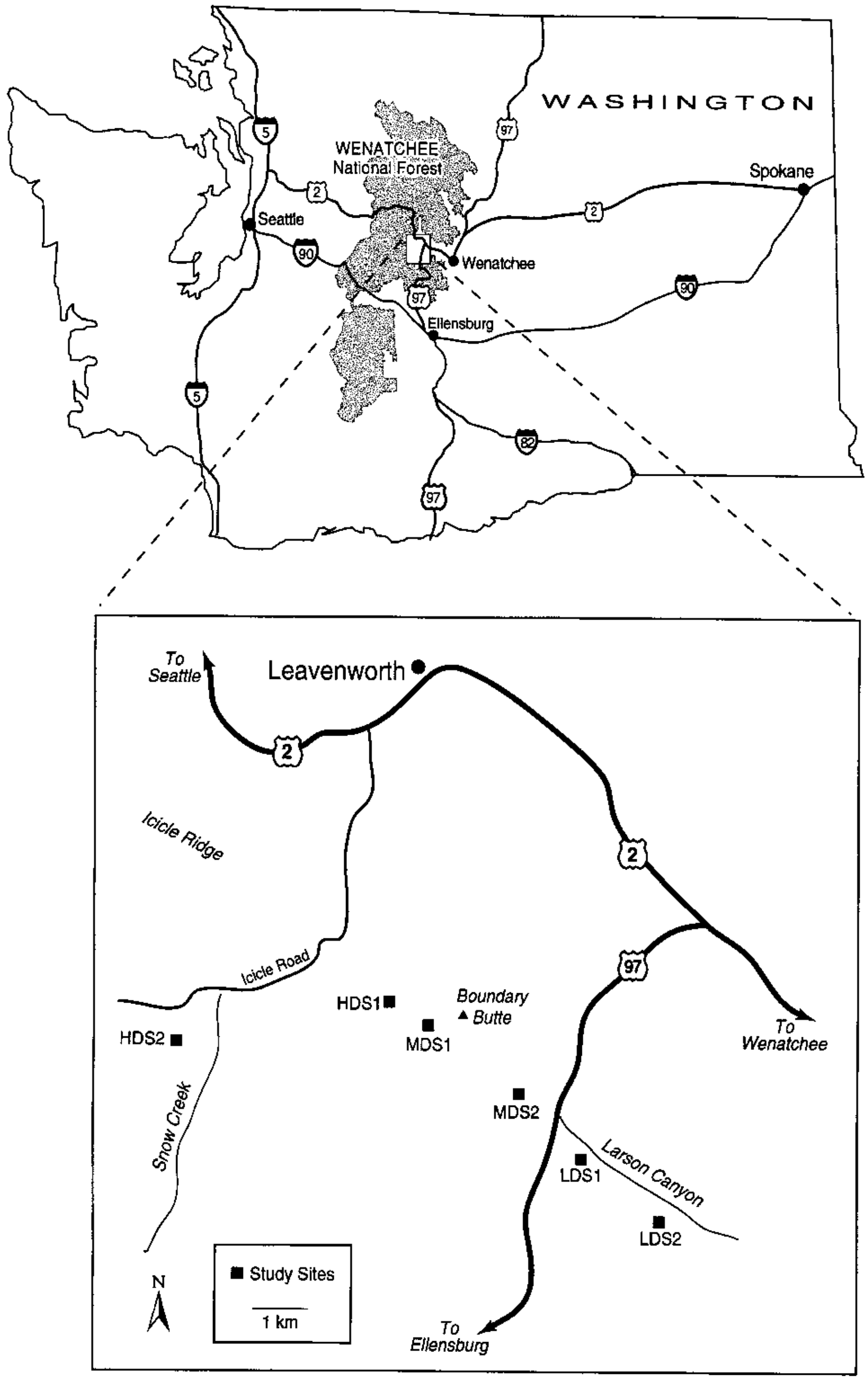

Figure 1. Location of study sites on the Wenatchee National Forest (Low Density = LD, Medium Density = MD, and High Density = HD).

Retention in the low treatment was 0-12 snags/ha. Medium retention treatment contained 15-35 snags/ha and high was characterized by 37-80 snags/ha. The six treated stands were in areas that burned with high-intensity stand-replacment fire. Each stand had a northerly aspect and was about 36.5 ha, with corrections made for topographic features. Slope averaged 40%, with elevations ranging 579-732 m.

Distance between stands was maximized to the extent possible. All but the low snag density treatments were in different drainages to increase the probability of sampling different bird populations. In the low snag density treatments, one stand was picked at the mouth of a canyon and the other near the top end of the same canyon to maximize the distance between them.

Snag Surveys

Snag density was recorded at each point-count station in two snag plots. One plot was established uphill and to the right and the other plot downhill and to the left of station center. Plot size varied with snag treatment: plots in low density measured 48 x 48 m; those in medium density measured 30 x 67 m; and those in high density measured 30 x 30 m. For each snag, tree species, dbh (diameter breast height), height, and decay stage (Cline et al. 1977) was recorded.

Breeding Bird Surveys

Seven fixed radius point-count stations were set up in each of the study stands, except for one low-density stand that only fit six stations, for a total of 41 stations. The point-count method was chosen because it is efficient and is the preferred method in rough terrain (Ralph et al. 1993). The radius for all point counts was 75 m and point-count stations were established using a systematic sampling design. The first station center was established 100 m from the edge of the treatment stand and subsequent centers were placed along a designated compass direction across slope with corrections for topography. The station centers were a minimum 225 m apart (Hutto et al. 1986, Ralph et al. 1993). In one high density and one low density stand a 100-m buffer was placed around small (<0.1 ha) green islands.

Bird abundance was surveyed using a fixed-radius counting method to provide a relative index of abundance of cavity-nesting species (Ralph et al. 1993). Bird counts were conducted during the breeding season mid-April–June, 1998 and 1999. Surveys were conducted within 30 min of sunrise and up to 5 hr following sunrise. Surveys were not conducted during periods of heavy rains or high winds. Surveys were a minimum of one week apart. All bird surveyors spent two weeks prior to initiation of point counts learning to identify birds in the study stands. Surveyors were trained to recognize birds visually, by vocalizations and drumming patterns, and flight characteristics.

Detection of woodpeckers during 10-min intervals at each count station were based on visual observation and calls (Hutto et al. 1986). For each point count, birds were classified as those within the 75-m circle, those beyond the 75-m circle, and those detected while walking between points (Manuwal and Carey 1991). Birds originally detected outside the 75-m circle that moved inside the 75-m circle were counted as being within the 75-m circle. Each point-count station was visited six times during the breeding season.

Nest surveys

Cavity nests were located through nest searches. Transects were walked through the entire stand and each snag ≥25 cm dbh was examined for evidence of a cavity. The smallest nest tree reported to be used by any cavity nester was 25 cm dbh (Scott 1978, Schroeder 1983). Fresh wood chips at the base of a cavity, and incubating behavior of adults or evidence of nestlings, were used as indicators of an active nest and were used to detect nest cavities (Zarnowitz and Manuwal 1985).

Four attributes of cavity snags were recorded: tree species, decay class (Cline et al. 1977), tree size, and surrounding spatial distribution. We compared the nest tree with other trees on paired plots. One plot was centered on the nest tree and the other plot was centered on a tree similar to the nest tree, but without a cavity, and at least 75 m away. The direction and distance from plot center, dbh, decay stage, and species of each snag within a 25-m radius of plot center were measured.

Data Analyses

All significance levels were set at $P = 0.05$. A one-way ANOVA followed by a Tukey test (Zar 1996) was used to evaluate snag densities by size class among treatments as a way of validating the implementation of the treatments. Snag size classes used for analyses were: <15 cm, 16-24 cm, and ≥25 cm. These sizes classes encompassed a range of nesting and foraging habitats used by cavity nesters (Bull et al. 1997). A G-test (Zar 1996) was used to compare the percentage of Douglas-fir and ponderosa pine snags in the different treatment areas.

A one-way ANOVA followed by a Tukey test (Zar 1996) was used to assess bird abundance among treatments. A G-test (Zar 1996) was used to determine whether cavity nesters were nesting in ponderosa pine snags in proportion to their availability on the landscape. Paired t-tests (Zar 1996) were used to compare site characteristics of nest trees with non-nest trees in paired plots. Paired t-tests were conducted for the following variables: % ponderosa pine and % Douglas-fir trees within 25 m of tree; mean dbh of surrounding trees out to 10 m; mean dbh of trees from 10-25 m; number of trees < and ≥ 25 cm within 10 m of plot center; number of trees < and ≥ 25 cm within 10-25 m of plot center; and number of trees out to 25 m at the same orientation as the nest cavity.

Results

Stand Treatment Characteristics

The number of snags ≥ 25 cm dbh and snags 16-24 cm dbh differed significantly ($P < 0.001$ and $P = 0.0058$) among the three treatment areas (Table 1). High standard error values reflect the heterogeneity of snags on the landscape.

The distribution of size classes was similar among treatment areas, although very large snags (>100 cm dbh) occurred only in high-density stands. The mean dbh of trees >15 cm dbh in low-density was 31.56 cm ± 17.68 cm; in medium-density 30.77 cm ± 7.04 cm; in high-density 37.55 cm ± 23.63 cm. Tree height distribution varied between treatments with the tallest trees occurring in stands with the highest densities of snags. The mean height of trees >15 cm dbh in low-density was 16.30 m ± 9.75 m; medium-density 17.58 m ± 7.97 m; high-density 21.28 m ± 8.90 m.

The predominant tree species in the study area were ponderosa pine and Douglas-fir. The frequency of ponderosa pine and Douglas-fir was significantly different among treatments for snags ≥ 25 cm dbh ($G = 40.24$, $DF = 2$, $P < 0.001$), and snags between 16 and 24 cm dbh ($G = 114.6$, $DF = 2$, $P < 0.001$). The percentage of ponderosa pine snags was lower than the percentage of Douglas-fir snags in all sites for snags >15 cm dbh. High density had 10% ponderosa pine and 89% Douglas-fir, medium density had 35% ponderosa pine and 62% Douglas-fir, and low density had 13% ponderosa pine and 87% Douglas-fir (Table 2).

Stage of snag decay did not vary among treatments since most trees were killed during the fire and case-hardened. Snags in stages 3 or 4 would have been present before the fire; all others were classified as decay stage 2.

Bird Abundance and Species Richness

Thirteen cavity-nesting species were observed on the study plots and species composition

TABLE 1. Snag densities in each treatment (low, medium, high) following stand replacement fire and salvage logging, Wenatchee National Forest, 1998.

Treatment and Plot Number	Snag Size ≤15 cm dbh Mean	SE	16-24 cm dbh Mean	SE	≥ 25 cm dbh Mean	SE
Low Density						
LDS1	118.9	2.85	9.0	0.72	9.0	1.58
LDS2	65.6	0.78	8.2	0.44	7.0	0.65
Medium Density						
MDS1	220.4	3.34	39.8	1.84	28.9	0.62
MDS2	138.7	2.90	28.2	1.37	29.3	0.71
High Density						
HDS1	282.4	2.31	74.1	2.49	82.8	1.13
HDS2	130.6	1.95	28.9	1.31	75.5	1.13

TABLE 2. Relative frequencies of snag species in each study stand, WNF, 1998. Other trees include alder and big leaf maple. PP = ponderosa pine, DF = Douglas-fir.

Treatment and Plot Number	Snag Size 16-24 cm dbh %PP	%DF	%Other	≥ 25 cm dbh %PP	%DF	%Other
Low Density						
LDS1	10	90	0	12	88	0
LDS2	8	92	0	23	77	0
Medium Density						
MDS1	35	53	12	53	47	0
MDS2	28	72	0	24	76	0
High Density						
HDS1	4	95	1	7	93	0
HDS2	7	90	3	23	77	0

TABLE 3. The mean number of birds/point count station in each of the treatments, Wenatchee National Forest, (1998-1999 averaged). Numbers in bold show significant differences (P = 0.05). P = primary cavity nester, S = secondary cavity nester.

Species	Low Density		Medium Density		High Density	
	LDS1	LDS2	MDS1	MDS2	HDS1	HDS2
White-headed woodpecker (*Picoides albolarvatus*) - P	0.09	0	0	0.17	0	0
Lewis' woodpecker (*Melanerpes lewis*) - P	1.84	1.59	0	1.42	0	0
Black-backed woodpecker (*Picoides arcticus*) - P	0	0	0.25	0.75	1.34	0.17
Hairy woodpecker (*Picoides villosus*) - P	0.75	2.09	2.50	2.50	3.09	3.83
Northern flicker (*Colaptes auratus*) - P	1.75	2.84	4.25	3.92	3.00	2.00
Western bluebird (*Sialia mexicana*) - S	**1.57**	**1.92**	0.75	1.50	0.67	0
Mountain bluebird (*Sialia currucoides*) - S	2.33	1.59	**3.25**	**3.67**	2.25	0.67
Red-breasted nuthatch (*Sitta canadensis*) - S	0.09	0.17	0.34	0.75	0.25	0
House wren (*Troglodytes aedon*) - S	0.92	1.50	2.00	1.92	1.25	0.42
European starling (*Sturnus vulgaris*) - S	0.09	0.92	0	4.17	0	0.17
American kestrel (*Falco sparverius*) - S	0.34	1.09	0.50	1.84	0	0.17
Brown preeper (*Certhia americana*)	0	0	0.09	0	0	1.25
Northern Pygmy owl (*Glaucidium gnoma*)	0	0	0	0	0	0.09

varied with snag density (Table 3). Species such as Lewis' woodpecker and western bluebird were most abundant in stands with low snag density. Northern flicker and mountain bluebird occurred in highest numbers in stands with medium density. Black-backed and hairy woodpecker were most common in stands with high snag density. Species richness of cavity-nesting species was highest in the medium-density treatment.

The mean number of cavity nesters was significantly different among treatments in 1998 ($F = 5.08$, $P = 0.033$), with the mean number of cavity nesters in medium snag density sites being higher than in the other sites. The number of cavity nesters did not differ significantly among the treatment areas in 1999 ($F = 3.75$, $P = 0.065$) although the trend was the same, with the highest number of birds in the medium-density treatment (Figure 2). In terms of individual species, the

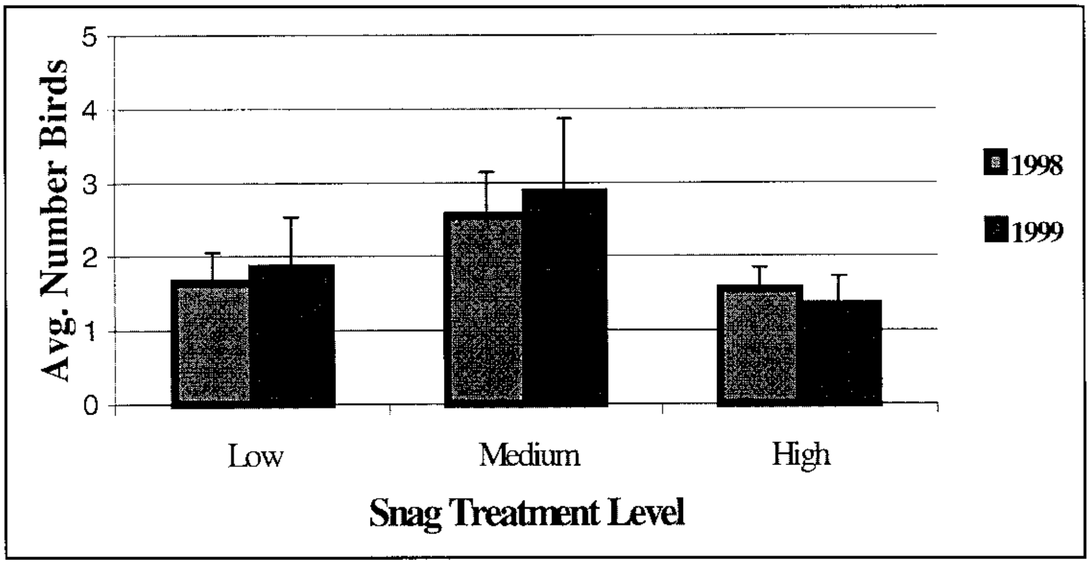

Figure 2. Mean number of cavity nesting birds in the three treatment areas: low, medium, and high snag density.

western bluebird was more abundant in low density treatments in 1998 (F = 4.08, $P = 0.03$) and the mountain bluebird occurred most often in stands with medium snag density in 1999 (F = 6.92, $P < 0.005$). No other significant differences in individual species abundance between treatments were observed.

Nest–Site Characteristics

We found a total of 114 nests. Northern flicker were the most common primary cavity excavators, while mountain bluebird were the most common secondary cavity nesters to nest on all sites. Northern flicker, western bluebird, mountain bluebird and American kestrel nested in all treatment areas, but had the most nests in stands with medium snag density. Hairy woodpecker also nested in all treatment areas, but had fewest nests in the low snag density. Black-backed woodpecker and house wren nested only in treatments with medium and high snag densities. Lewis' woodpecker was the only species to nest most often in low density treatments and did not nest in treatments with the high snag densities. Overall, medium snag density had the highest number of nests with eight species and 56 total nests (Table 4).

Approximately 66% of all nests were in ponderosa pine snags (Table 5). Cavity nesters used ponderosa pine snags for nesting significantly more often than expected (G = 216, DF = 1, $P < 0.001$). Secondary cavity nesters had a higher proportion of nests in Douglas-fir than the primary cavity excavators (woodpecker species).

TABLE 4. Number of active cavity nests of bird species in the treatments, WNF, 1998-1999 combined.

Species	Tree Density		
	Low	Medium	High
Northern flicker	4	12	6
Hairy woodpecker	3	6	6
Black-backed woodpecker	0	1	1
Lewis' woodpecker	10	4	0
Western bluebird	5	7	2
Mountain bluebird	7	12	5
House wren	0	12	7
American kestrel	1	2	1
TOTAL	30	56	28

The mean dbh of nest trees was smaller for secondary cavity nesters than for primary cavity excavators. Northern flicker nested in large trees (mean dbh of 64 cm) and American kestrel nested in small trees (mean dbh of 24 cm).

The height of nest trees and cavities ranged widely for all species. Mean tree height was 20.0 m (range = 2.2-37.5 m) and mean nest cavity height was 8.8 m (range = 1.5-25 m) for all nests. Sixty-nine percent of the nest trees had a broken top. Sample sizes were adequate to compare tree densities surrounding the nest tree with those of non-nest paired plots for the northern flicker, hairy woodpecker, and Lewis' woodpecker. Plots around northern flicker nest trees (N = 17) contained larger trees (mean dbh = 19.5 cm) within 10 m than in the plots surrounding the non-nest trees (mean dbh = 10 cm, $P = 0.011$). Areas within 10 m of northern flicker nest trees had more trees ≥ 25

TABLE 5. Characteristics of snags used as nest sites by seven species of cavity-nesting birds in ponderosa pine/Douglas-fir forests, WNF. Other (O) nest trees include cottonwood and alder.

Species	# Snags[1]	Tree species (no.)			Snag dbh (cm)		Broken top (%)	Tree height (m)		Cavity height (m)	
		PP	DF	O	Mean	Range		Mean	Range	Mean	Range
Northern flicker	17	14	3		64	38-117	65	19.3	2.4-37.2	9.2	1.8-23.9
Hairy woodpecker	13	11	1	1	56	28-86	62	19.8	7.3-37.5	5.9	2.0-13.7
Lewis' woodpecker	10	6	3	1	58	38-99	80	18.3	8.2-27.4	9.3	7.6-20.4
Black-backed woodpecker	2	2			50	48-51	50	21.3	19.2-23.5	3.0	2.3-3.7
Mountain bluebird	20	12	8		36	15-71	90	14.5	2.1-35.7	7.0	1.5-11.6
Western bluebird	11	5	6		42	18-74	64	19.1	4.6-33.5	10.2	1.5-15.2
House wren	18	8	9	1	42	18-93	67	18.9	4.3-35.4	8.5	1.5-25.0
American kestrel	4	2	1	1	24	18-30	75	29.0	23.0-36.0	17.5	5.2-23.9
Total or Grand Mean	95	60	31	4	46.5	15-117	69	20.0	2.1-37.5	8.8	1.5-25.0

[1]Numbers may not agree with those in Table 4 because some nest trees were used more than once.

cm dbh (mean = 2.5) than in non-nest plots (mean = 0.6, $P = 0.008$). The number of trees 16-24 cm dbh at a distance of 10-25 m from hairy woodpecker nest trees (mean = 52.4) was greater than for paired trees (mean = 28.2, $P = 0.034$). No significant differences between nest trees and paired non-nest trees were found for the number of trees < 25 cm within 10 m, the mean dbh of surrounding trees, the number of trees > 25 cm dbh 10-25 m from the tree, or the percentage of ponderosa pine or Douglas-fir within a 25 m radii.

We examined nests of woodpecker species and found no significant difference between the density of trees in the same orientation as the cavity opening and the density of trees elsewhere around the nest tree for northern flicker, hairy and Lewis' woodpecker. Hairy woodpecker nest trees had significantly more snags from 10-25 m in the same orientation as the cavity than the paired tree ($t = 2.99$, DF= 12, $P = 0.005$). There were no significant differences between the nest tree and the paired tree for Lewis' woodpecker ($t = 1.13$, DF= 9, $P = 0.145$) or northern flicker ($t = 0$, DF= 16, $P = 0.5$).

Mountain bluebird nested in cavities previously occupied by hairy woodpecker (4), northern flicker (4), and black-backed woodpecker (1). In three known cases, mountain bluebird nested in the same cavity in both 1998 and 1999. Western bluebird nested in cavities previously occupied by hairy woodpecker (5), northern flicker (1), mountain bluebird (3), and house wren (1). In only one instance did western bluebird occupy the same nest in both 1998 and 1999. House wren nested in hairy woodpecker (7) and black-backed woodpecker cavities (2). Two house wren pairs occupied the same cavities in both 1998 and 1999. American kestrel nested in old northern flicker cavities (2). In two instances, a cavity had three occupants in the two years. The occupants of one cavity changed from black-backed woodpecker to mountain bluebird to house wren. The occupants of the other cavity changed from hairy woodpecker to western bluebird to house wren.

Discussion

Species composition varied among treatments (Tables 3,4). Specifically, Lewis' woodpeckers occurred primarily in stands with low snag density, but also occurred in stands with a medium snag density. Black-backed woodpecker and brown creeper occurred in both high and medium snag densities, but neither was present in the low density. Mountain bluebird, northern flicker, and house wren occurred throughout, but were in greatest abundance in the stands with medium snag densities. Saab and Dudley (1998) studied stand-replacement fire and salvage logging and also reported changing species composition in stands with varying snag densities, however, overall densities of cavity-nesting birds were similar.

The density of cavity-nesting birds was not positively associated with the number of snags ≥ 25 cm dbh in this system. Evidence from other studies suggests that cavity-nesting birds select for more than the snag tree itself and avian assemblages may change in relation to the structure of the stand of snags (Raphael and White 1984, Shackelford and Conner 1997). For example, hairy woodpecker were closely associated with the presence of large-diameter snags and logs, while northern flicker were associated with increasing numbers of small-diameter snags (Shackelford and Conner 1997). Both small snags (<15 cm dbh) and large snags are important for foraging (Horton and Mannan 1988). Extensive foraging on small snags occurred in all treatment areas in this study.

The spatial structure of snags can also influence bird communities. Bird species composition may be determined by the degree of openness of a habitat. Logging can cause changes in bird species composition (Hagar 1960) because the openness presents new opportunities for aerial foragers (Franzreb and Ohmart 1978). Fire-altered habitat also leads to an increase in species that forage in low brush or open ground (Bock and Lynch 1970).

The size and distribution of snags in medium density treatments were conducive to a higher abundance of cavity-nesting species (Table 4). Medium density also had a greater number of ponderosa pine snags than the other treatments. The high proportion of ponderosa pine compared to Douglas-fir may have influenced the presence of species that prefer ponderosa pine for both nesting and foraging. However, the occurrence of unused large ponderosa pine snags in both low and high density treatments suggests that the presence of ponderosa pine snags alone may not result in an increased abundance of cavity-nesting birds.

The number of nests was highest in the medium snag density treatment (Table 4). We speculate that medium snag densities provided habitat for species that prefer open nesting habitat and those that prefer to nest in higher tree densities. For example, Lewis' woodpecker and American kestrel nest in open or semi-open sites; hairy woodpecker, black-backed woodpecker, and house wren nest in more dense tree stands (McClelland et al. 1979, Saab and Dudley 1998). Yet, all species were observed in the medium snag density treatments. Ponderosa pine was the preferred tree species for primary cavity nesters. Nests in Douglas-fir were most often occupied by secondary nesters and many Douglas-fir nest snags had old cavities or were dead before the fire.

In burned forests, large snags are often used for nesting (Raphael and White 1984, Hutto 1995, Saab and Dudley 1998) and cavity nesters chose large nest snags in this study as well (Table 5). Primary cavity-excavator species used larger-diameter nest trees than secondary cavity nesters. The difference might be because secondary cavity nesters typically nested in Douglas-fir snags, which had a smaller mean dbh than the ponderosa pine snags. The high number of small Douglas-fir trees in this study was due to several decades of fire exclusion (Harrod et al. 1999).

In this study, as in several others (McClelland et al. 1979, Mannan et al. 1980, Zarnowitz and Manuwal 1985, Welsh and Capen 1992, Bevis 1994, Hutto 1995, Saab and Dudley 1998), most nests were in broken top snags (Table 5). A broken top provides an avenue for heart-rotting fungi, which makes the snag more suitable for cavity excavation (McClelland et al. 1979). Broken top trees are especially important in burns because they provide nest sites for the first few years following a high-intensity fire when other trees are not easily excavated due to case-hardening (Saab and Dudley 1998).

Factors other than the suitability of the tree itself may play important roles in selection of the nest site (Welsh and Capen 1992, Vierling 1997). Forest stand characteristics are sometimes a better predictor of bird use than individual snag characteristics (Swallow et al. 1986). Saab and Dudley (1997) showed that the density of trees surrounding the nest tree of cavity-nesting birds was higher than the density of trees at random sites. In contrast, Lewis' woodpeckers avoid nesting in dense tree stands (Vierling 1997). In this study northern flickers chose nest trees with at least two large-diameter snags (≥ 25 cm) within 10 m, and hairy woodpeckers chose nest trees surrounded by a high density of small snags.

We found a number of unoccupied cavities suggesting that the availability of suitable nest sites may not be the only factor limiting populations of cavity-nesting birds (Ingold and Ingold 1984, Peterson and Gauthier 1985, Rendell and Robertson 1989). Cavities can remain unused if they fall within the territory of another individual or breeding pair that defends more than one cavity for roost sites (Peterson and Gauthier 1985, Rendell and Robertson 1989). Unused cavities may also be the result of a surplus of cavities rather than the result of interspecific or intraspecific competition (Ingold and Ingold 1984). In addition, the cavity entrance size or volume may make it unsuitable for some secondary-nesting species (Rendell and Robertson 1989). Even though there were unoccupied cavities, some nest cavities changed occupants three times during two years of observation. This pattern may be the result of temporal breeding differences between species and not the result of interspecific competition for nest sites (Ingold and Ingold 1984). For example, mountain bluebirds commonly used old hairy woodpecker cavities after hairy woodpecker young were fledged. It would be worthwhile to investigate this trend further by measuring specific cavity parameters and habitat variables between used and unused sites.

Management Implications

The results of this study have management implications for retaining snag habitat during salvage logging in dry forests on the east side of the Cascades following stand-replacement fire. Snag densities of 15-35 snags ≥ 25 cm dbh per hectare provided the highest abundance, species richness, and nesting populations of cavity nesters. Snags > 48 cm dbh provided nesting habitat for more species. An average of 21 snags > 48 cm dbh per hectare yielded highest nesting populations, supported multiple cavities, and were important for foraging. Smaller snags provided foraging and nesting habitat for some species. The treatment with highest bird abundance had 34 snags/ha in 16-24 cm dbh size class and 180 snags/ha in the < 15 cm dbh size class. Treatments with snags distributed in clumps and individually dispersed had the highest abundance and species richness of cavity nesting species.

This study also poses new questions. The highest bird abundance occurred in medium density stands, which were not only different in snag density, but also had the highest percentage of ponderosa pine, a favored nest tree. Future studies designed to look at the relationship between the availability of ponderosa pine and the breeding bird population would help to separate snag density effects and tree species effects. In addition, long term monitoring is necessary to understand the dynamics between snag deterioration rates and changes in bird assemblages following stand-replacement fires and salvage logging.

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