Selection of Fire-created Snags at Two Spatial Scales by Cavity-nesting Birds[1]

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Abstract

We examined the use of snag stands by seven species of cavity-nesting birds from 1994-1998. Selection of snags was studied in logged and unlogged burned forests at two spatial scales: microhabitat (local vegetation characteristics) and landscape (composition and patterning of surrounding vegetation types). We modeled nest occurrence at the landscape scale by using Landsat Thematic Mapper imagery. At both spatial scales, we observed a continuum in habitat use with the extremes represented by black-backed and Lewis's woodpeckers. A range of habitat conditions characteristic of black-backed and Lewis's woodpeckers would likely incorporate habitat features necessary for nest occurrence of other members in the cavity-nesting bird community.

Introduction

Forests affected by wildfire, and subsequent salvage logging, became increasingly prevalent in the early 1990s across much of the inland West. Many cavity-nesting birds are associated with burned forests, but little is known about their habitat selection in post-fire conditions (Hutto 1995, Kotliar and others [In press], Saab and Dudley 1998). Virtually nothing is known about the influence of landscape patterns on nest-site selection in burned forests (Kotliar and others [In press]).

Species of cavity-nesting birds respond variably to post-fire salvage logging (Caton 1996, Hitchcox 1998, Kreisel and Stein 1999, Saab and Dudley 1998). Cavity nesters, however, often nest (Saab and Dudley 1998) and forage (Kreisel and Stein 1999) in patches of higher snag densities than that expected based on availability of snags. In salvaged forests of western Idaho, snags generally were retained in uniform distributions (equal numbers of snags per hectare), while within those burned forests,

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we previously reported that cavity-nesting birds used clumps (stands) of snags for their nest sites (Saab and Dudley 1998). We suggested that salvage prescriptions could be improved to favor cavity-nesting birds by changing the distribution of snags retained (from uniform to clumped), even when the same number of snags are harvested.

In this paper, we examine the use of snags by cavity-nesting birds at both the microhabitat and landscape scales within burned forests. A landscape-level analysis is necessary to estimate the area (size) and distribution of snag stands selected by cavity nesters. A large-scale analysis, however, is difficult in burned forests because snag stands are not easily detected with remote sensing. We have three related questions that address the area and distribution of snag stands. First, is pre-fire vegetation classification a reasonable index to post-fire stands of snags at the microhabitat scale? Second, using pre-fire vegetation classification, what are the characteristics of snag stands surrounding nest sites at the landscape scale? Lastly, are patterns of nest-site selection at the landscape scale consistent with patterns at the microhabitat scale? Information developed from this study is intended to provide guidelines for post-fire, snag management that accommodates cavity-nesting birds at two habitat scales: microhabitat (nest site) and landscape (composition and patterning of surrounding vegetation cover types).

Study Area

The study areas are in the Foothills and Star Gulch fires on the Boise National Forest in southwestern Idaho (Elmore, Ada, and Boise Counties). Elevation ranges from 1,100 meters to 2,400 meters. The Foothills fire was a moderate to high-intensity crown fire during August/September 1992 that burned 104,328 hectares. Prior to the fire, about a third of the burn was forested and the remainder was shrub steppe. The Star Gulch Fire occurred in August 1994 and burned 12,350 hectares at various intensities, creating a patchy mosaic of green and burned forest. Because of the nature of these fires, most standing trees were snags.

Pre-fire overstory vegetation was dominated by ponderosa pine *(Pinus ponderosa)* community types at lower elevations and on southerly aspects, whereas Douglas-fir *(Pseudotsuga menziesii)* community types dominated at higher elevations and on northerly aspects.

We selected at least two replicates each in unlogged and logged treatments. Seven study sites averaged 680 hectares in size, based on the area treated, and were used to monitor cavity-nesting birds and vegetation in post-fire conditions. One unlogged and four logged study sites were used in the Foothills study area, while two unlogged study sites were located in the Star Gulch study area.

Salvage logging prescriptions on the Foothills Fire varied by aspect and management for big game security cover (Saab and Dudley 1998). Based on the average densities of standing snags in unlogged units, about 50 percent of smaller snags (> 23 centimeters to ≤ 53 centimeters diameter breast height [dbh]) and 70 percent of larger snags (≥ 53 centimeters dbh) were harvested in the salvage-logged units (Saab and Dudley 1998). Densities of small snags averaged 43 per hectare and large snags averaged 5 per hectare in logged units, whereas densities in unlogged units averaged 81 per hectare for small snags and 17 per hectare for large snags.

Methods

Nest Monitoring and Microhabitat Measurements

Nest surveys for nine cavity-nesting birds *(table 1)* were conducted by walking 200 meter-wide belt transects during May through June 1994-1998. Transect length averaged 1.6 kilometers and number of transects per study site varied from 26 to 43. Nests were monitored every 3 to 4 days to determine status and fate. Methods for vegetation measurements and nest monitoring followed those described for BBIRD (Martin and Guepel 1993, Ralph and others 1993) with some modifications. The number and dbh of all snags > 23 centimeters were recorded within 11.3 meter-radius plots (0.04 hectare) centered at each nest tree. The same data were recorded at 89 non-nest random locations (40 in unlogged and 49 in logged treatments). Each nest tree and the center of each random location were geographically referenced by using a global positioning system (GPS), and data were exported into the geographic information system, ARC-INFO (Anonymous 1998).

Table 1—*Number of nests and non-nest random points monitored in burned ponderosa pine/Douglas-fir forests of western Idaho, 1994-1998.*

Species	Logged	Unlogged	Total
American Kestrel *(Falco sparverius)*	80	20	100
Lewis's Woodpecker *(Melanerpes lewis)*	305	50	355
Hairy Woodpecker *(Picoides villosus)*	46	135	181
White-headed WP *(Picoides albolarvatus)*	4	10	14
Black-backed WP *(Picoides arcticus)*	6	29	35
Northern Flicker *(Colaptes auratus)*	87	101	188
Western Bluebird *(Sialia mexicana)*	130	60	190
Mountain Bluebird *(Sialia currucoides)*	60	132	192
European Starling *(Sturnus vulgaris)*	31	0	31
Nest Total	749	537	1,286
Non-nest Random Points	49	40	89

Vegetation Classification and Landscape Measurements

Vegetation classification was derived from two Landsat Thematic Mapper (TM) images. Each TM pixel covers a 30-meter by 30-meter area. A pre-fire classification was mapped from a September 1991 image, and post-fire conditions were mapped from a September 1995 image. Aerial photography (1:16000) from July 1988 and August 1996 were used to assist in the classification process.

The vegetation classification had two components: (1) cover type, and (2) crown closure for each cover type. Decision rules for assigning cover types were derived from the Southwest and Central Idaho Ecogroups, who mapped 8 million hectares in southwestern Idaho (Redmond and others 1998). Cover types for our study included ponderosa pine, Douglas-fir, and a mix of ponderosa pine and Douglas-fir. The crown closure classes we used were: low (> 10 to ≤ 40 percent), moderate (> 40 to ≤ 70 percent), and high (> 70 percent). Ninety-eight training sites were visited in the field to calibrate the classified images.

Landscape measurements were determined from ARC-INFO files by using the landscape metrics software FRAGSTATS (McGarigal and Marks 1995). Landscape analyses were conducted only for black-backed and Lewis's woodpeckers because at the microhabitat scale, these species represented different ends of a continuum in habitat use (see Saab and Dudley 1998). Landscape variables were measured within a 1,000-meter radius of nest trees and random points, an area (314 hectares) that encompasses the home range sizes of most songbirds (Hansen and Urban 1992) and some woodpecker species in the Pacific Northwest of U.S. (Dixon and Saab 2000), Goggans and others 1989, Garrett and others 1996).

The resolution of TM imagery was too coarse for identifying stands of snags in the post-fire image. To describe stand area and distribution of snags and other landscape patterns, we developed a vegetation map by combining pre- and post-fire classifications. We used pre-fire cover type/crown closure as an index to post-fire composition and stand area of snags, based on nine cover type/crown closure classes: ponderosa pine/low, moderate, and high crown closure; Douglas-fir/low, moderate, and high crown closure; and ponderosa pine-Douglas-fir/low, moderate, and high crown closure. Based on earlier microhabitat findings (Saab and Dudley 1998), we wanted to know if high and moderate snag densities in burned forests at black-backed and Lewis's woodpecker nest sites, respectively, would correspond to high and moderate crown closure in pre-fire conditions.

For a measure of distribution of snag stands surrounding each nest and random point, we calculated the mean nearest neighbor and mean proximity index (McGarigal and Marks 1995) of like stands (same cover type/crown closure) for each of three cover types in moderate and high crown closures. Nearest neighbor was the mean distance (meters) to the nearest like stand, regardless of stand area, within the 1,000 meter-radius landscape circle. The mean proximity index considered the distance (meters) to and area (hectares) of like stands. This index measured both the degree of cover type isolation and the degree of fragmentation of the corresponding cover type within the 1,000 meter-radius landscape (McGarigal and Marks 1995).

Analyses

At the microhabitat scale, type III sums of squares, analysis of variance (ANOVA; Anonymous 1996) was used to test for non-random selection of snag densities by comparing densities at nest sites with random sites. Differences in habitat measurements for microhabitat and landscape variables were considered significant at $p < 0.05$. Means are followed by $\pm$ one standard error (SE).

For landscape analyses, we adopted the approach recommended by Burnham and Anderson (1998), i.e., we developed a "global" logistic regression model containing various landscape predictor variables that may have had important influences on nest occurrence of black-backed and Lewis's woodpeckers. Three global models were developed: nest occurrence of black-backed woodpecker vs. random points in unlogged units, nest occurrence of Lewis's woodpecker vs. random points in unlogged units, and nest occurrence of Lewis's woodpecker vs. random points in logged units. We were unable to model the response of black-backed woodpeckers to landscape features in logged units because of a small sample of nests (n = 6). Global models were tested for goodness of fit using the Hosmer and Lemeshow (1989) test. From the global model for each set of comparisons, we generated a subset of candidate models that contained various combinations of variables we deemed biologically relevant.

We used the Akaike's Information Criterion (AIC; Akaike 1973) to rank candidate models and assess their relative plausibility given the data. AIC operates on the principle of parsimony (Box and Jenkins 1970), where the highest ranked models are those that best fit the data with the fewest parameters. The principle of parsimony states that there is an ideal point in the balance between increasing the number of parameters to decrease bias and decreasing the number of parameters to increase precision. We used PROC LOGISTIC in SAS (Anonymous 1996) to produce AIC values for all sets of candidate models. Once we selected the best candidate model based on the highest AIC value, standardized estimates derived from logistic regression were used to evaluate the relative importance of each landscape predictor variable to nest occurrence (cf. Manly and others 1993).

Results

Microhabitat

To date, microhabitat data have been analyzed for 1994-1996 (625 nests, 89 random sites). Based on these data, seven species selected nest sites with significantly higher snag densities than that measured at random sites in both logged (d.f. = 7, F = 7.2, $p < 0.001$) and unlogged (d.f. = 7, F = 4.6, $p < 0.001$) treatments *(fig. 1)*. Snag densities were highest at black-backed woodpecker nest sites and lowest at random sites. Among cavity nesters, snag densities were lowest at Lewis's woodpecker nest sites, yet densities were still higher than those in the random unlogged controls. This suggests that cavity nesters as a group selected clumps (stands) of snags rather than uniformly-spaced snags (Saab and Dudley 1998).

Based on 1994-1995 data, we reported that cavity-nesting birds used larger diameter snags more than in proportion to availability (Saab and Dudley 1998). Among the woodpecker species, Lewis's woodpecker selected the largest diameter snags, whereas black-backed woodpecker used the smallest diameter snags. This pattern has continued through 1998: snag diameters were smallest for black-backed woodpecker and largest for Lewis's woodpecker *(fig. 2)*.

Landscape

All global models adequately fitted the data (Hosmer and Lemeshow goodness of fit test, $p > 0.5$). The selected model for black-backed woodpecker in unlogged units included 15 predictor variables *(table 2)*. Statistically significant predictors were proximity of stands characterized by burned, ponderosa pine/high crown closure; proximity; and area of burned, Douglas-fir/high crown closure stands; and area of burned, Douglas-fir/low crown closure stands. Standardized estimates derived from logistic regression indicate the strength and nature of the relationship between the predictor variables and the response variable. The strongest positive standardized estimates indicated that area and proximity of burned, Douglas-fir/high crown closure stands were the best predictors of black-backed nest sites in unlogged landscapes, whereas one would be unlikely to find a nest in close proximity of burned ponderosa pine/high crown closure or in stands of Douglas-fir/low crown closure *(table 2)*.

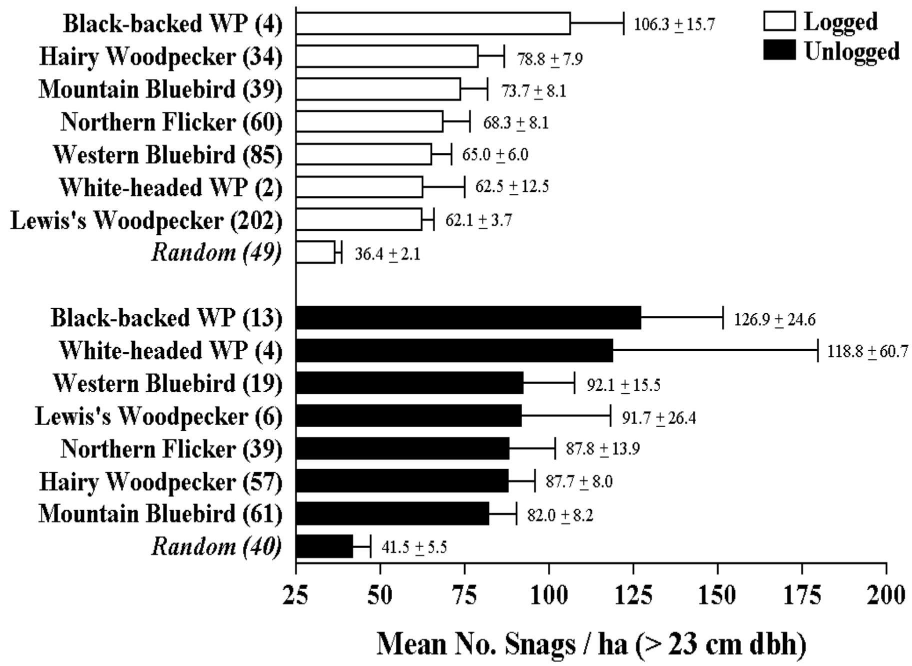

Figure 1—Mean number of snags (> 23 cm dbh) per hectare (+ 1 SE) surrounding nest trees and random trees based on microhabitat measurements during 1994-1996. Sample size for each species is stated in parentheses.

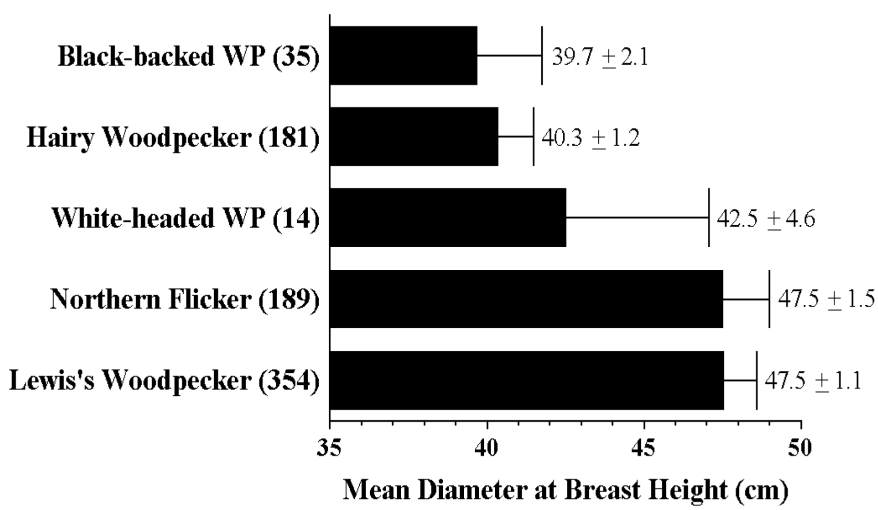

Figure 2—Mean diameter (± 1 SE) at breast height of nest trees during 1994-1998. Sample size for each species is stated in parentheses.

Table 2—*Selected models and coefficients derived from logistic regression for predictors of nest occurrence for black-backed woodpecker (unlogged) and Lewis's woodpecker (unlogged and logged).*

Variable	Parameter estimate	SE	Chi-square	P	Standardized estimate
Unlogged					
Black-backed Woodpecker (n=29 nests) vs. Random (n=40 points)					
Intercept	3.44	4.46	0.60	0.440	
Proximity Index-Ponderosa Pine High CC[2]	**-2.14**	**0.79**	**7.27**	**0.007**	**-2.55**
Proximity Index-Ponderosa Pine Moderate CC	0.02	0.10	0.05	0.820	0.13
Proximity Index-Doug-Fir High CC	**0.34**	**0.13**	**6.60**	**0.010**	**2.27**
Proximity Index-Doug-Fir Mod CC	0.27	0.69	0.16	0.690	0.22
Proximity Index-Ponderosa/Doug-Fir High CC	-3.33	1.83	3.31	0.070	-1.46
Proximity Index-Ponderosa/Doug-Fir Moderate CC	-1.83	1.08	2.82	0.090	-1.09
Stand Area-Ponderosa Pine High CC	-0.49	0.29	2.97	0.080	-2.21
Stand Area-Ponderosa Pine Moderate CC	-0.16	0.17	0.80	0.370	-1.26
Stand Area-Ponderosa Pine Low CC	0.21	0.12	2.84	0.090	1.64
Stand Area-Doug-Fir High CC	**0.47**	**0.21**	**4.90**	**0.030**	**4.64**
Stand Area-Doug-Fir Moderate CC	0.61	0.34	3.04	0.080	1.36
Stand Area-Doug-Fir Low CC	**-1.09**	**0.49**	**5.03**	**0.030**	**-11.7**
Stand Area-Ponderosa Pine/Doug-Fir High CC	0.56	0.59	0.87	0.350	0.84
Stand Area-Ponderosa Pine/Doug-fir Low CC	-0.03	0.17	0.03	0.860	-0.18
Distance to High or Moderate CC	-0.02	0.02	0.54	0.460	-0.24

Variable	Parameter estimate	SE	Chi-square	P	Standardized estimate
Unlogged					
Lewis's Woodpecker (n=50 nests) vs. Random (n=40 points)					
Intercept	6.63	7.00	0.90	0.340	
Nearest Neighbor-Ponderosa Pine Moderate CC	-0.13	0.08	2.38	0.120	-0.83
Nearest Neighbor-Doug-Fir Moderate CC	-0.01	0.07	0.03	0.860	-0.05
Nearest Neighbor-Ponderosa/Doug-Fir Moderate CC	0.001	0.05	0.00	0.990	0.009
Proximity Index-Ponderosa Pine Moderate CC	**0.12**	**0.06**	**4.03**	**0.040**	**0.77**
Proximity Index-Doug-Fir Moderate CC	0.4	0.49	0.66	0.420	0.31
Proximity Index-Ponderosa/Doug-Fir Moderate CC	-0.1	0.57	0.03	0.870	-0.05
Stand Area-Ponderosa Pine Moderate CC	**-0.22**	**0.11**	**3.83**	**0.050**	**-1.74**
Stand Area-Ponderosa Pine Low CC	0.13	0.09	2.05	0.150	0.87
Stand Area-Doug-Fir Moderate CC	-0.06	0.18	0.09	0.760	-0.11
Stand Area-Doug-Fir Low CC	-0.11	0.09	1.43	0.230	-1.08
Stand Area-Ponderosa Pine/Doug-fir Mod CC	0.14	0.22	0.45	0.500	0.49
Stand Area-Ponderosa Pine/Doug-fir Low CC	-0.03	0.08	0.11	0.740	-0.17
Distance to High or Moderate CC	-0.03	0.02	3.38	0.070	-0.43

(*table 2* continued)

Variable	Parameter estimate	SE	Chi-square	P	Standardized estimate
Logged					
Lewis's Woodpecker (n=305 nests)					
vs. Random (n=49 points)					
Intercept	3.26	1.40	5.36	0.020	
Nearest Neighbor-Ponderosa Pine High CC	**-0.03**	**0.01**	**7.50**	**0.006**	**-0.27**
Nearest Neighbor-Ponderosa Pine/Doug-Fir High CC	-0.003	0.00	1.60	0.200	-0.16
Stand Area-Ponderosa Pine High CC	**0.12**	**0.06**	**3.71**	**0.050**	**0.51**
Stand Area-Ponderosa Pine Moderate CC	0.04	0.05	0.48	0.490	0.22
Stand Area-Ponderosa Pine Low CC	-0.02	0.02	1.19	0.280	-0.24
Stand Area-Doug-Fir High CC	-0.02	0.02	0.78	0.390	-0.19
Stand Area-Doug-Fir Moderate CC	-0.04	0.07	0.27	0.600	-0.11
Stand Area-Doug-Fir Low CC	0.02	0.03	0.26	0.600	0.07
Stand Area-Ponderosa Pine/Doug-Fir High CC	**-0.37**	**0.09**	**16.04**	**0.001**	**-0.66**
Stand Area-Ponderosa Pine/Doug-fir Mod CC	**0.39**	**0.15**	**6.90**	**0.009**	**1.2**
Stand Area-Ponderosa Pine/Doug-fir Low CC	-0.09	0.06	2.27	0.130	-0.45

[1] The highest standardized estimates are in bold, indicating the most important predictors of nest occurrence.
[2] CC = Crown closure. Cover types were in burned conditions. Variables represent mean values.

One goal of the multivariate analysis is to statistically adjust the estimated effects of each predictor variable in the model for differences in the distributions of and associations among the other predictor variables (Hosmer and Lemeshow 1989). When adjusting for other variables in the model, stand area of burned, Douglas-fir/high crown closure was the most important variable in predicting the presence of black-backed woodpecker nests *(table 2)*. Probability of nest occurrence was most consistently high for black-backed woodpecker when stand area of Douglas-fir/high crown closure was between 30 and 50 hectares *(fig. 3)*. In landscapes where stand area was outside of this range, other landscape features necessary for nesting black-backed woodpeckers were likely reduced in availability or absent. Nests were not present where stand area was less than 12 hectares, and probability was highly variable when stand area was between 12 and 25 hectares or when area was greater than 55 hectares *(fig. 3)*. The average stand area within landscapes surrounding black-backed nests was 37.16 hectares ± 3.41, whereas average stand area at random points was 24.87 hectares ± 3.7 *(fig. 4)*. The stand area for all species of cavity nesters was between the areas measured for black-backed and Lewis's woodpeckers *(fig. 4),* a pattern similar to that reported at the microhabitat scale *(figs. 1, 2)*.

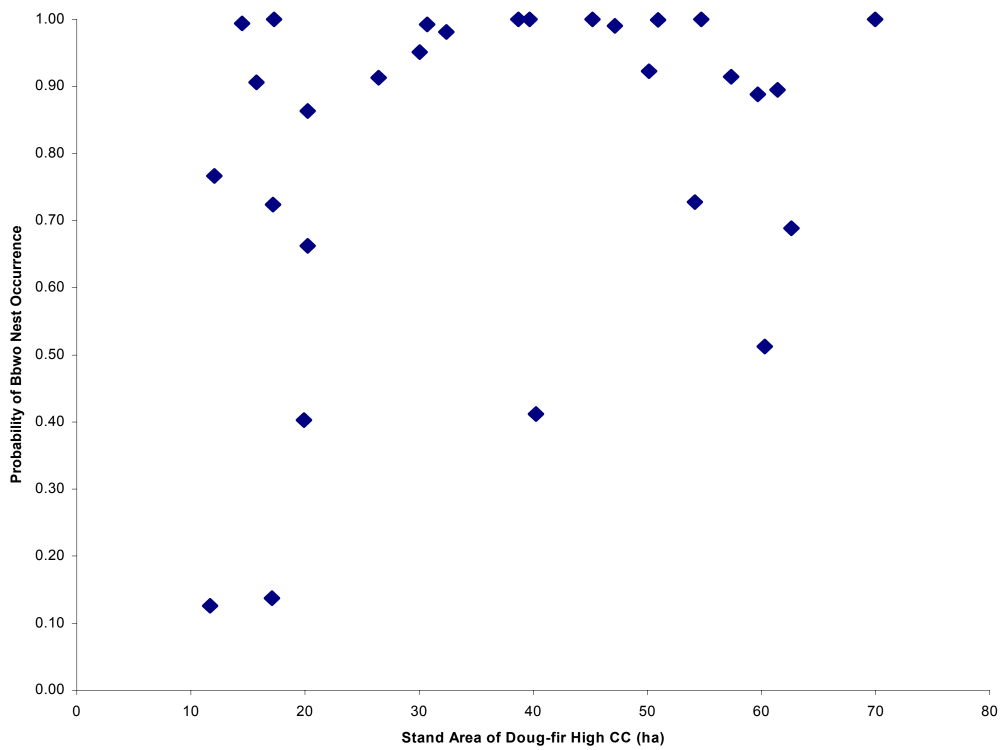

Figure 3—Scatter plot of the probability of black-backed woodpecker nest occurrence with stand area of burned, Douglas-fir/high crown closure areas. The scatter plot was adjusted for other landscape variables in the predictive model.

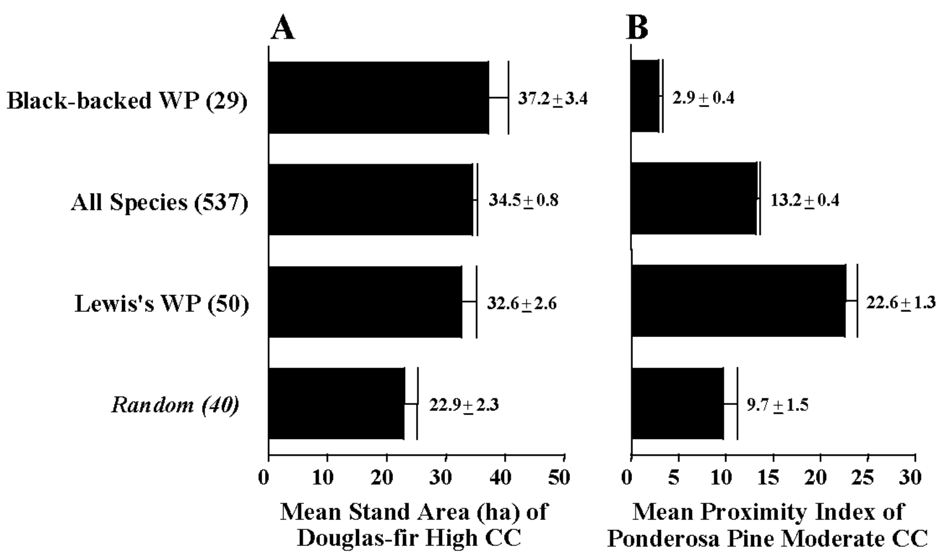

Figure 4—Based on measurements taken within landscape circles (1,000 meter-radius circle) surrounding nest and random points. (A) Mean area of stands (± 1 SE) characterized as burned, Douglas-fir/high crown closure, and (B) Mean proximity index (± 1 SE) of burned, ponderosa pine/moderate crown closure. Sample size for each species is stated in parentheses.

The selected model for Lewis's woodpecker in unlogged units included 13 landscape predictor variables *(table 2)*. The only statistically significant predictor of their nest occurrence was the proximity of burned stands characterized by ponderosa pine moderate crown closure, while area of these stands was nearly significant at $p = 0.05$. Standardized estimates revealed that the strongest relationship between Lewis's woodpecker and the predictor variables was a negative one with area of burned, ponderosa pine/moderate crown closure stands *(table 2)*. The mean area of these stands was 33.56 hectares ± 1.53 within nest landscapes, and 25.41 hectares ± 2.67 within random landscapes. The positive relationship with proximity of this cover type suggests that burned, ponderosa pine/moderate crown closure stands were in close proximity of one another within landscapes surrounding Lewis's woodpecker nests *(fig. 4)*. This variable was not important to black-backed woodpeckers or all species combined. Once again, measurements revealed a similar pattern as that reported at the microhabitat scale: Lewis's woodpecker was at one end of the continuum of habitat use and black-backed woodpecker at the other end *(fig. 4)*.

Eleven landscape predictor variables were included in the selected model for Lewis's woodpecker within logged units *(table 2)*. Statistically significant predictors and the nature of the relationship with Lewis's woodpecker were:

- Nearest neighbor of burned, ponderosa pine high crown closure stands, negative relationship.
- Area of burned, ponderosa pine high crown closure stands, positive relationship.
- Area of burned, ponderosa pine/Douglas-fir high crown closure, negative relationship.
- Area of burned, ponderosa pine/Douglas-fir moderate crown closure, positive relationship.

Based on standardized estimates, area of ponderosa/Douglas-fir moderate crown closure stands (mean = 6.63 hectares ± 0.16) was the most important variable in predicting nest occurrence of Lewis's woodpecker in logged units. Thus, regardless of cover type or treatment, moderate crown closure in a burned condition was the most important characteristic of a landscape feature in predicting the presence of a Lewis's woodpecker nest. The negative relationship with nearest neighbor of burned, ponderosa pine/high crown closure and the positive relationship with stand area of the same cover type/crown closure indicates that the close distribution (mean nearest neighbor = 61.9 meters ± 0.75) and large area (mean = 15.82 hectares ± 0.47) of these stands was also important for their nest site selection.

Discussion

At the microhabitat scale, habitat use by black-backed and Lewis's woodpeckers was represented by different ends of a continuum. Compared to other cavity-nesting birds and random sites, black-backed woodpeckers selected nest sites with the highest densities of snags of relatively small diameters, whereas Lewis's selected nest sites with moderate densities of snags of large diameters. The microhabitat selection by black-backed woodpeckers that we observed in western Idaho is similar to that reported elsewhere in the Northern Rocky Mountains. Black-backed woodpeckers have consistently selected unlogged conditions of high snag densities for both nesting and foraging habitat (Caton 1996, Hitchcox 1996, Hoffman 1997, Hutto 1995, Kreisel and Stein 1999). Perhaps high snag densities provide greater foraging opportunities for this species (Saab and Dudley 1998) that feeds primarily on bark (Scolytidae) and wood-boring (Cerambycidae) beetles (Dixon and Saab 2000). In contrast, Lewis's woodpecker favors open woodlands, especially burned pine forests (Tobalske 1997, Saab and Vierling 2001). Unlike most woodpecker species, Lewis's woodpeckers are primarily aerial flycatchers during the breeding season. This species is thought to do well in burned forests because of the relatively open canopy that allows for shrub development and associated arthropod prey (Bock 1970), good visibility, and perch sites for foraging (Linder and Anderson 1998), and space for foraging maneuvers (Saab and Dudley 1998).

Pre-fire crown closure of live trees may serve as an index to post-fire stand densities of snags. One might expect that unburned stands of Douglas-fir with a high crown closure could result in burned high densities of snags with relatively small diameters. This was consistent with black-backed woodpecker nest-site selection at both the microhabitat and landscape scales in burned forests of western Idaho. Likewise, one might expect that unburned moderate crown closure stands of ponderosa pine and Douglas-fir could result in burned moderately dense stands of snags with relatively large diameters. This characterized nest-site selection by Lewis's woodpecker at the microhabitat and landscape scales. Patterns in nest-site selection at the landscape scale were consistent with patterns in nest-site selection at the microhabitat scale. Following the microhabitat data, landscapes used by nesting black-backed woodpeckers represented one end of a habitat continuum, while landscapes used by Lewis's woodpeckers represented the other extreme.

Because pre-fire vegetation classification was a reasonable approximation of post-fire stands of snags, we used Landsat TM images of pre- and post-fire conditions to characterize the area and spatial distribution of snags surrounding nest sites. In unlogged burned conditions, black-backed woodpeckers selected landscapes where large stands of Douglas-fir/high crown closure occurred in closer proximity than in landscapes surrounding random points. Lewis's woodpeckers chose burned landscapes where relatively small stands of ponderosa pine/moderate crown closure were in close proximity compared to average, unlogged conditions.

In logged areas, moderate crown closure was again an important feature of landscapes surrounding Lewis's woodpecker nests. Stand area, however, was smaller on average in logged compared to unlogged units. The close distribution and large stand area of ponderosa pine/high crown closure was another important characteristic of landscapes surrounding nests of Lewis's woodpecker in logged conditions. Stands of burned, ponderosa pine/Douglas-fir with moderate crown closure were the best predictor of Lewis's woodpecker nests.

Management Implications

The continuum of habitat use by black-backed and Lewis's woodpeckers reported for the microhabitat scale was consistent at the landscape scale. This suggests that management for cavity nesters should be considered not only at the local, stand level but also at larger spatial scales. At both scales, we found that a range of habitat conditions characteristic of black-backed and Lewis's woodpeckers would likely incorporate habitat features necessary for nest occurrence of other members in the cavity-nesting bird community.

Our data suggest that pre-fire vegetation classification can be used to develop design criteria for cavity-nesting birds in post-fire salvage logging projects. We can manage for a diversity of species across burned landscapes by maintaining a continuum of habitat features. Unlogged landscapes with large, dense stands of Douglas-fir snags in close proximity to one another were typical of black-backed woodpeckers. Partially logged landscapes were favored by Lewis's woodpeckers, although they selected unlogged conditions for nesting habitat as well. Burned landscapes used by nesting Lewis's woodpeckers were primarily composed of closely distributed, small to medium-sized stands of ponderosa pine/moderate crown closure.

Our future work will be focused on examining the relationships between pre-fire crown closure (from remote sensing) and post-fire snag densities and diameters (from our microhabitat measurements). Determining these relationships will assist not only in developing design criteria for post-fire salvage logging but also in generating stand exam information based on remote sensing data. Future work also will include developing probabilities of nest occurrence for each species using landscape variables and examining the influence of landscape variables on nest success.

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