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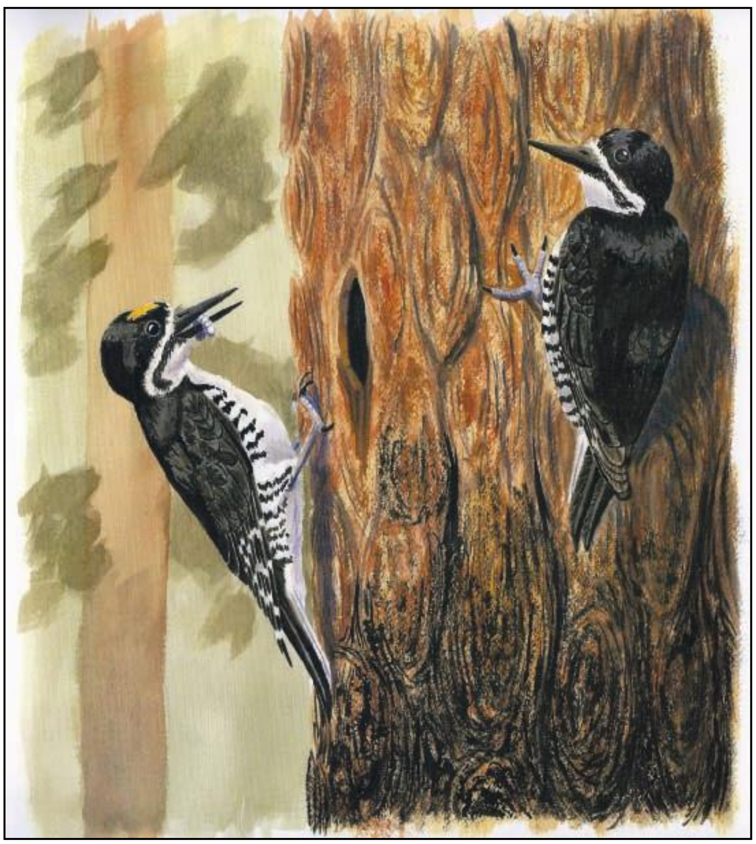
Occurrence Patterns of Black-backed Woodpecker in Unburned National Forest Land in the Sierra Nevada



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April 2012

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PRBO Conservation Science

Contribution Number 1872

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Executive Summary

The Black-backed woodpecker (*Picoides arcticus*) is currently under review for listing as a threatened or endangered species in the state of California and is designated as the Management Indicator Species for snags in burned National Forest land in the Sierra Nevada. While their association with burned forest has recently been clarified in the Sierra Nevada, their occurrence in unburned forest is not well understood.

As part of a region wide avian monitoring project, we documented Black-backed Woodpecker observations between 2009 and 2011 from 498 point count transects on ten National Forest units in the Sierra Nevada National Forest planning region. We used point counts and playbacks to detect woodpeckers in forest and shrub habitats at elevations between 1000 and 2800 m. We employed a Bayesian modeling approach - that closely followed a recent analysis for Black-backed Woodpecker in burned forest in the Sierra Nevada – to determine occupancy patterns in unburned forest. We included elevation, latitude, canopy cover, live tree basal area, and snag density as covariates on occupancy. To examine occupancy and habitat associations for unburned forest birds, after a preliminary analysis, we excluded transects that were within 2 km from areas that had burned since 2001. We identified this as the broad definition of unburned forest but also show occurrence results for what we define as a very conservative definition (>5 km from areas that burned since 1991).

When we included all transects with distance to burned areas as a covariate, occupancy was positively associated with transects less than 2 km and greater than 6 km from recent burns. Overall transect occupancy in unburned forest for the broad definition was 0.22 and point-level occupancy was 0.11. This point-level value was nearly half of what was estimated for burned forest in the Sierra Nevada. Occupancy at unburned forest locations had a strong positive association with the residuals of latitude on elevation, while snag density and other covariates were not significant predictors. We also explored general habitat preferences by calculating selection ratios among habitat types. Black-backed woodpeckers showed evidence of preference for red fir (*Abies magnifica*) and lodgepole pine (*Pinus contorta*) forest, used white fir, Jeffrey, and eastside pine in proportion to availability, and avoided Sierra mixed conifer and Ponderosa pine forest. Using occupancy results we estimate there are between 1398 – 6899 Black-backed Woodpecker uniquely occupied sites on unburned National Forest land in the Sierra Nevada.

Introduction

Black-backed Woodpeckers (*Picoides arcticus*) are widely distributed across the boreal region in Canada (Hoyt and Hannon 2002, Tremblay et al. 2009), and they reach the southernmost limit of their range in the Sierra Nevada (Dixon and Saab 2000). Their association with relatively high severity burned forest habitats throughout its range is well established (Blackford 1955, Murphy and Lehnhausen 1998, Hutto 1995, Saracco et al. 2011 and others). As this habitat is rare, highly dynamic, and influenced by fire suppression and salvage logging; there is increasing concern about its management and conservation in California. This concern has been illustrated recently with the selection of Black-Backed Woodpecker by the US Forest Service as an indicator for snags in burned forest in the Sierra Nevada (USFS 2008), and its consideration for listing as threatened or endangered by the California Department of Fish and Game (Hanson & Cummings 2010, CDFG 2012).

While the Black-backed Woodpecker is often considered a burned forest habitat specialist, anecdotal observations and a smattering of records from formal surveys suggest it does occur in the Sierra Nevada outside of burned areas (Grinnell and Miller 1944, PRBO data, K. Purcell pers.comm). However, there is little quantitative information about its occurrence in unburned forest. To address this shortcoming in knowledge about the life history of Black-backed Woodpeckers we investigated their distribution and habitat associations across National Forest land in the Sierra Nevada using occupancy models.

Methods

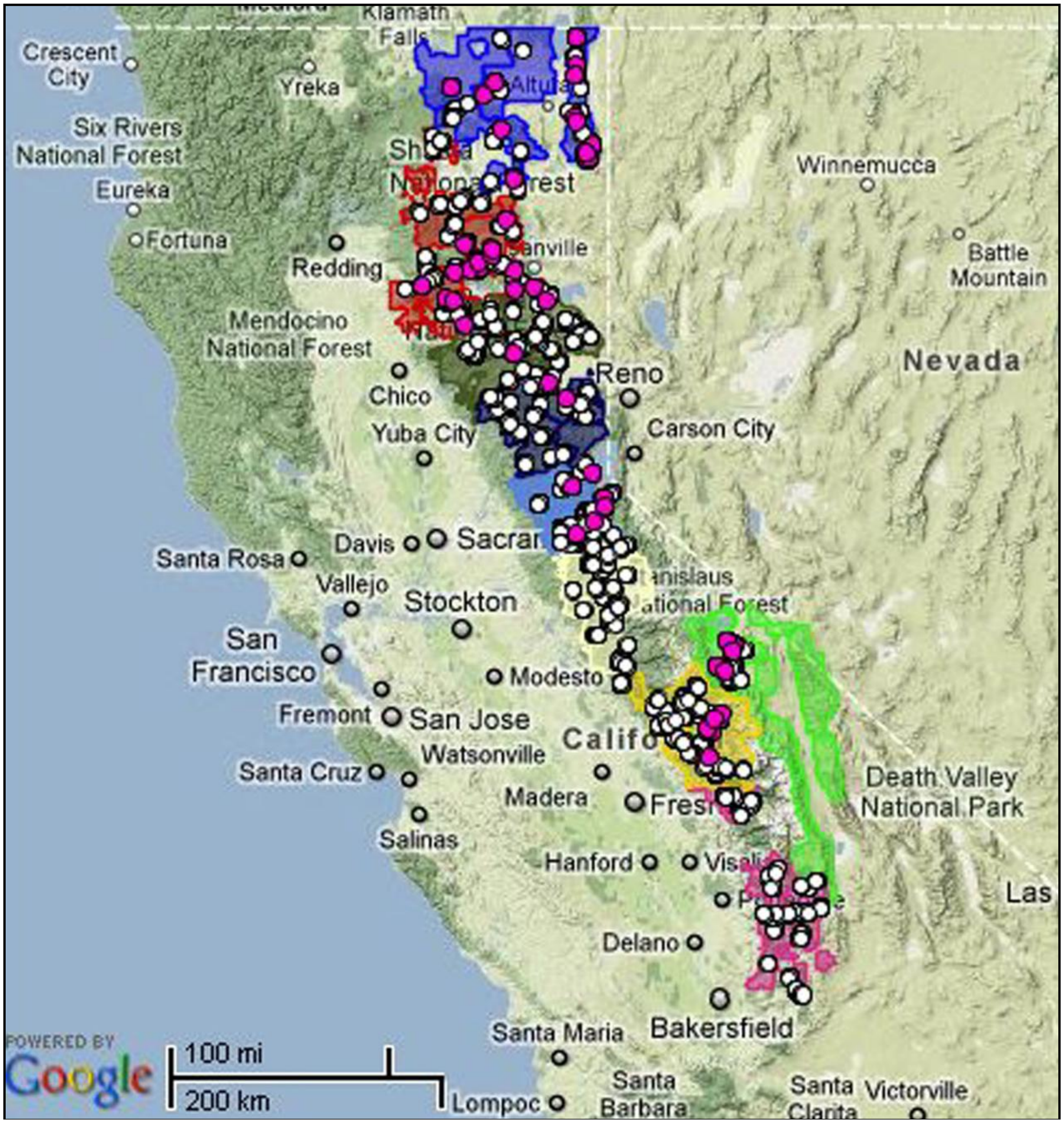
Study Location

We surveyed for Black-backed Woodpecker across nine National Forests and the Lake Tahoe Basin Management Unit in the Sierra Nevada Forest Planning area (USFS 2004a). This area extends from the Modoc National Forest near the Oregon border to the Sequoia National Forest east of Bakersfield (Figure 1). Sample locations ranged in elevation from 1000 – 2800 m and were limited to areas within 1 km of accessible roads and slopes less than 35%.

Sample Design

We used sampling locations established in 2009 and 2010 as part of the PRBO & USDA Forest Service (USFS) Sierra Nevada Management Indicator Species project (Roberts et al.

Figure 1. The location of PRBO Management Indicator Species study sites where Black-backed Woodpecker surveys were conducted from 2009 - 2011 in the Sierra Nevada. Pink circles represent point count stations where Black-backed Woodpecker were detected and white where they were not. National Forests are denoted by unique colors starting from the north, they are Modoc, Lassen, Plumas, Tahoe, Eldorado, Stanislaus, Inyo, Sierra and Sequoia. Note this map encompasses all sites surveyed including the 198 transects less than 2 km from areas that burned since 2001.



2011). This study was designed to estimate trends in the distribution of Hairy Woodpecker, Mountain Quail, and Fox Sparrow across National Forest lands in the Sierra Nevada. We used a generalized random-tessellation stratified (GRTS) sampling scheme to distribute transects across the sampling frame to avoid clustering in any given area (one particular forest for example) while remaining random at the local level to avoid bias due to natural spatial patterns of habitat and physiognomic conditions (Theobald et al. 2007). The spatial pattern of GRTS samples are therefore both balanced (at large scales, in this case the entire study area) and random (at small scales, in this case at approximately the National Forest Ranger District scale). GRTS is an efficient design for monitoring programs aimed at identifying trends of species with widely differing population metrics (Carlson and Schmiegelow 2002).

The set of potential sampling locations was built from a tessellation generated in ArcGIS 9 (ESRI 2006), consisting of a grid of cells with a random origin covering the entire study area. We did not choose to stratify by geographical location (e.g. latitude bands) or by jurisdictional boundaries other than Forest Service ownership, nor did we define *a priori* a target number of survey locations within different National Forests. Thus, we used the GRTS algorithm to select survey locations with equal weight across the entire study area, resulting in the placement of survey locations proportional to the amount and spatial distribution of suitable habitat. We assembled a vegetation layer of over 40 different California Wildlife Habitat Relationship (CWHR) land cover types (USFS 2004b) and removed non-forested habitat types such as meadow, foothill chaparral, oak woodland, alpine, and juniper. At each location we established two transects in adjacent 1 km grid cells consisting of 4 point count stations at 250 m in the cardinal directions from a fifth point in the center. This resulted in a sample of 2500 points on 500 point count transects distributed as 250 spatially balanced pairs.

Survey Methods

At each of the five point count stations within a transect we conducted a standardized unlimited distance point count survey (Ballard et al. 2003; Ralph et al. 1995) where a single observer estimates the distance to the location of each individual bird they detect during a five minute time span from a fixed location. At the center point of each transect, we conducted a five minute playback survey for Hairy Woodpecker and Mountain Quail. In 2011, immediately following this playback survey, we also conducted a playback survey for Black-backed

Woodpecker following the protocol developed by the Institute for Bird Populations for monitoring this species in burned forests of the Sierra Nevada (Saracco et al. 2011). This survey was 6-minutes long with three increments of 30 second broadcasts followed by 1.5 minutes of listening. All observers underwent an intensive, three week training period focused on bird identification and distance estimation prior to conducting surveys. Laser rangefinders were used to assist in distance estimation at every survey point. Counts began around local sunrise, were completed within five hours, and did not occur in inclement weather.

Survey effort varied each year due to access restrictions (e.g., snow, river crossings) and variation in field effort. In 2009, we visited 415 transects and returned to 60% for a second visit, in 2010 we visited 464 transects and returned to 58% and in 2011 we visited 472 transects and returned to 47%. Of the 500 total transects, we have not been able to reach two of them because of late-season snowpack, all others have been visited at least once

Vegetation Surveys

We collected vegetation survey data between 2009 and 2011 within a 50 m radius plot centered at each point count station following the relevé protocol outlined in Stine et al. (2005). We measured a variety of forest structural conditions including vegetation cover, basal area, canopy tree diameter, and counted number of snags (see Roberts et al. 2011 for more detailed methods). We used the California Wildlife Habitat Relationships (CWHR) system to classify the dominant habitat type at each point (Mayer and Laudenslayer 1988). To create transect-level habitat values for inclusion in occupancy estimates we averaged the point-level measurements.

Analysis

In order to evaluate the distribution of Black-backed Woodpecker on unburned forest in the Sierra Nevada we used occupancy models (MacKenzie et al. 2006). Occupancy models can account for imperfections in the detection process, variable sampling efforts across time and space, and can include covariates on both probability of detection and occurrence to provide insight into patterns of activity and habitat associations. To facilitate the comparison of our results with those of our partners in Sierra Nevada Black-backed Woodpecker monitoring, we designed our occupancy models following the methods reported in Saracco et al. (2011).

We initially examined the effect of distance to burned areas on occupancy. To do this, we built occupancy models at both the point and transect scale for all transects and included standardized distance to fire boundary and the squared standardized distance to fire boundary (which returned high values for sites near and far from fire boundaries) as covariates on occupancy.

Using the results of the distance from fire analyses, we sought to distinguish the woodpecker detections that were associated with areas burned in wildfires from those in unburned forest. To do so, we defined our area of interest (unburned forest) using both spatial and temporal conditions. Black-backed Woodpecker can forage over relatively large distances, including up to several kilometers outside of the burned areas they nest in (Siegel et al. 2012), but the suitability of burned habitat for this species clearly declines five to seven years after fire (Saab et al.2007, Saracco et al. 2011). Thus, for the majority of analyses we defined unburned forest as all survey points that were greater than 2 km from areas that burned in a wildfire since 2001. However, for some analyses we also provide comparison results from sites that were at least 5 km from areas that burned since 1991 (last 20 years). We refer to these two definitions as the broad (2 km, 10 years) and conservative (5 km, 20 years) definitions of unburned forest throughout the report. We did not adjust time since fire for each survey year, thus transects surveyed in 2009 and 2010 were only 8 and 9 years post-fire for the broad definition and 18 and 19 years post-fire for the conservative definition. We used Spatial Analyst in ArcGIS10 (ESRI 2011) to calculate the distance from field point count locations to fire perimeters from the California Fire Perimeters GIS layer (CalFire 2010) after we removed all fire polygons with dates older than 2001 for broad definition, or 1991 for conservative. Though we refer to these as broad and conservative definitions of unburned forest, in reality we consider both to be rather conservative. A total of 300 transects were located more than 2 km from areas that burned in the last 10 years; and 83 transects were more than 5 km from areas that burned in the last 20 years.

We built occupancy models using only 2011 data and the broad definition of unburned forest (more than 2 km from fires that burned since 2001). We limited the analysis to 2011 data as it was the only year we conducted Black-backed Woodpecker playback surveys. These surveys, and presumably, a heightened recognition of the species calls by our observers, resulted in substantially larger sample size than the previous two years combined.

Models were built with data at two scales; individual point count stations vs. the aggregates of 5 point count stations in each transect. In both cases we considered the passive point counts as separate survey visits from playback surveys, leading to a maximum of four survey occasions (up to two visits and up to two survey types) in the detection histories for each site. The playback surveys actually included two separate playback events; the five minute Hairy Woodpecker/Mountain Quail playback, followed by the six minute Black-backed Woodpecker playback. Detections from the Hairy Woodpecker/Mountain Quail survey were included in the playback detections in order to minimize false absences. Including these playbacks resulted in the addition of three point count stations that otherwise would have been classified as unoccupied. At the point scale, the four outer point count locations received a maximum of two passive point count surveys over two visits, while at the center point count location up to two passive surveys and two playbacks were possible. For the transect scale we combined all five of the passive point count surveys into a single count, and again considered the playback surveys as separate. The effective area sampled on the passive surveys (five point count locations) at the transect scale is larger than the playback surveys (a single point count location). The time of surveys is also different, with five, five-minute passive point counts (25 minutes total at the transect scale) compared to11 minutes of playback surveys. However, the playback surveys have been shown to significantly increase detection probability compared to individual passive point count surveys (Saracco et al. 2011). As such we would expect detection probability to reflect the sum of these time and area surveyed effects.

We followed closely the methods described in Saracco et al. (2011) to design occupancy analyses, and ran the models with WinBUGS (Spiegelhalter et al. 2003) using the R2WinBUGS package (Sturtz et al. 2005) in R (R Development Core Team 2009). All counts were converted to detection/non-detection (1 or 0) during each survey visit at each site. Occupancy was modeled as a Bernoulli process estimating the true occupancy state of each field site (point or transect). Both occupancy and probability of detection were defined by logit-linear models. Probability of detection was a function of an intercept term (logit-transformed probability of detection for a single passive survey) plus a term reflecting the covariate of survey type (passive [0] vs. playback [1]). Occupancy probability was a function of an intercept term (logit-transformed probability of occupancy for an average survey location with mean covariate values) plus terms for covariates of natural log of number of snags per acre (>30 cm dbh) and the residuals from a linear regression of elevation on latitude. Covariate values for transect scale models were simply the averaged point scale measurements.

We included the following additional site and visit-level covariates in occupancy model iterations: percent tree cover, live tree basal area, date of visit, and time of day as covariates on detection probability; and CWHR habitat type, ranger district (as a measure of spatial autocorrelation), latitude, percent canopy cover, and residuals from a linear regression of basal area on canopy cover as covariates on occupancy. All numerical covariates were standardized to a mean of zero and standard deviation of 1. None of the coefficients on these covariates were identified as significant, and including more than two terms on either occupancy or detection often resulted in non-convergence or instability of the WinBUGS model simulations. The final models including elevation and snag density as covariates on occupancy were chosen based on model convergence diagnostics and AIC (these data are not included in this report). WinBUGS models were simulated over three chains for at least 100,000 iterations with a burn-in of 80,000 and thinned by 4. In each case acceptable convergence was achieved with BGR statistic of 1.0 ± 0.1 on each model term.

We evaluated selection for habitat types within both the broad and conservative definitions of unburned forest at the point count scale using selection ratios following Manly et al. (2010). We used vegetation data collected at point count locations to classify habitat into several conifer types based on the California Wildlife Habitat Relationships system (Mayer and Laudenslayer 1988) and examined selection for habitat types with at least one Black-backed Woodpecker detection. We computed selection ratios by dividing the proportion of used transects in each habitat type by the availability of that habitat in comparison to all others. If habitats were used in proportion to their availability, they would have a selection ratio of 1.0. A selection ratio >1 indicated preference, while a value <1 implied avoidance. We first used a global test to evaluate if the pattern of habitat use was different from the pattern of available habitats. If we found evidence of selection ($P < 0.05$), we further interpreted the selection ratios for each habitat using simultaneous 95% Bonferroni confidence interval calculated over all habitats. Due to small sample size all confidence intervals included 1 for all habitat types but they provide an indication of habitat selection and avoidance by this species. Habitat selection was analyzed using program R (R Development Core Team 2009) and the package 'adehabitat' (Calenge 2006).

Results

Black-backed Woodpeckers were detected on 40 out of 472 transects surveyed in 2011. Of these 40 transects 28 had detections from passive point counts and an additional 12 transects had detections only from playback surveys. Including detections from passive point counts and Hairy Woodpecker/Mountain Quail playback surveys in 2009 and 2010, Black-backed Woodpeckers were detected on a total of 52 out of 498 transects surveyed (Figure 1; see Appendix 1 for detection history). Black-backed Woodpeckers were present on 10% (30 out of 300) of transects that fell within the broad definition of unburned forest and 17% (14 out of 83) of transects that met the conservative definition. Black-backed Woodpeckers were also detected on 11% (22 out of 198) of transects that fell within our definition of burn-influenced forest (less than 2 km from fire in the past 8-10 years, according to survey year).

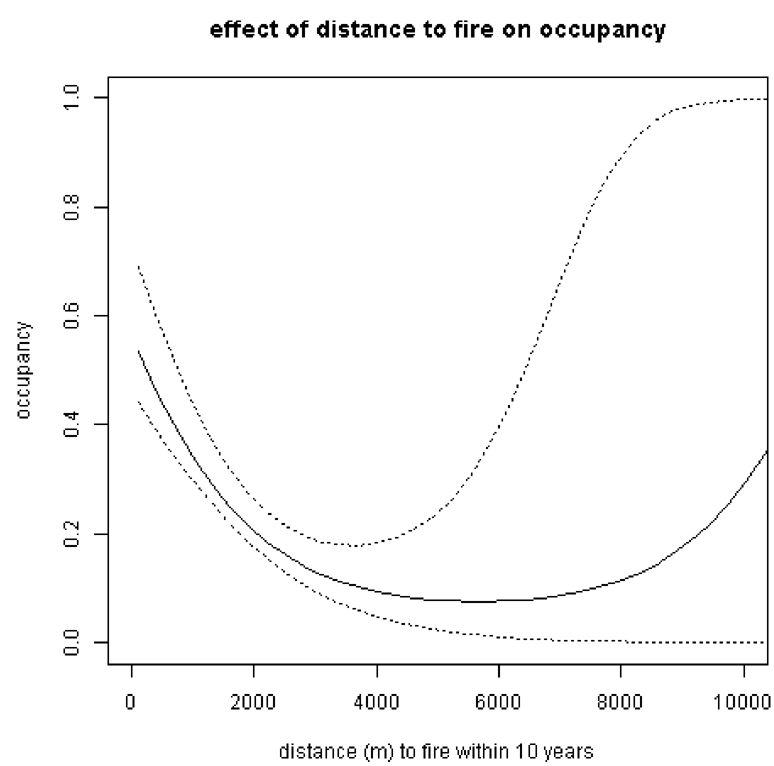
Table 1. The percent and total number (in parenthesis) of transects where Black-backed Woodpeckers were detected from 2009 – 2011 for each National Forest in the Sierra Nevada region. Data are shown for each definition of unburned forest as well as for "burn-influenced" transects (less than 2 km from fires burned since 2001) for comparison.

	Unburned Forest		
Forest	Broad	Conservative	Burn-Influenced Forest
Modoc	12% (5)	11% (1)	42% (8)
Lassen	16% (8)	31% (5)	21% (6)
Plumas	0	0	18% (3)
Tahoe	4% (1)	0	4% (1)
Tahoe Basin	0	0	100% (2)
Eldorado	7% (2)	0	6% (1)
Inyo	46% (6)	75% (3)	9% (1)
Stanislaus	0	0	0
Sierra	15% (8)	23% (5)	0
Sequoia	0	0	0
Sierra Nevada Total	10% (30)	17% (14)	11% (22)

Black-backed Woodpecker detections were distributed across unburned forest on seven of the ten National Forest units we sampled (Table 1). The greatest proportion of transects with detections were on the Inyo National Forest followed by the Sierra and Lassen. The Plumas, Tahoe Basin, Stanislaus, and Sequoia had no unburned forest detections across the three years of our study, but woodpeckers were detected on burn-influenced transects in the Tahoe Basin and Plumas National Forest. Black-backed Woodpeckers were detected on a greater proportion of unburned transects than burn-influenced on the Inyo (46% vs. 9%) and Sierra National Forests (15% vs. 0%).

There was a significant effect of distance from areas that burned since 2001 in Black-backed Woodpecker occurrence in the Sierra Nevada (Table 2). At both the point count station and transect scales the effect of distance to fire was negative indicating that Black-backed Woodpecker occupancy was higher near these burned areas. In contrast, the association with the quadratic term was positive indicating that occupancy was higher at sites far from fires as well (Figure 2). This effect was consistent between point and transect level scales though considerably stronger at the point count station scale.

Figure 2. Black-backed Woodpecker transect scale (1km^2) occupancy (with 95% confidence intervals) in relation to distance from areas that had burned in the previous 10 years across National Forest land in the Sierra Nevada in 2011.



At the point scale, estimated occupancy in unburned forest from our sample was 0.11 (95% CI = 0.05-0.22). At "average" sites (with mean values for all covariates) it was 0.05 (95% CI = 0.01-0.11). Detection probability at the point scale for passive surveys alone was 0.18 (95% CI = 0.07-0.36), playback surveys was 0.32 (95% CI = 0.12-0.57), and combined was 0.44 (95% CI = 0.20-0.70).

At the transect scale estimated occupancy from our sample was 0.22 (95% CI = 0.12-0.42), while at "average" sites it was 0.11 (95% CI = 0.04-0.29). Detection probability at the transect scale (five point count stations combined) for passive surveys was 0.35 (95% CI = 0.16-0.59), for playback surveys was 0.16 (95% CI = 0.06-0.30), and combined was 0.45 (95% CI = 0.22-0.70).

Table 2. Coefficient estimates, standard deviations, and lower and upper 95% confidence intervals for point and transect-scale occupancy models. Four total models were developed at two scales, transect and point, with or without locations less than 2 km from fires within 10 years. Covariates include: survey type for detection probability (*p*), and snags (natural log of counts per point) and elevation (residuals from a regression on latitude) for occupancy (*psi*).

Unburned Forest (>2km from fire within 10 years)

	Point scale				*Transect scale*			
	Estimate	SD	Lower	Upper	Estimate	SD	Lower	Upper
p intercept	-2.31	0.48	-3.29	-1.40	-1.46	0.48	-2.41	-0.56
Survey type	1.50	0.46	0.60	2.42	-0.31	0.41	-1.14	0.48
psi intercept	-3.18	0.53	-4.20	-2.10	-2.16	0.58	-3.23	-0.90
Snags	-0.18	0.32	-0.80	0.44	-0.40	0.54	-1.68	0.44
Elevation	1.78	0.43	1.03	2.76	2.12	0.79	1.06	4.16

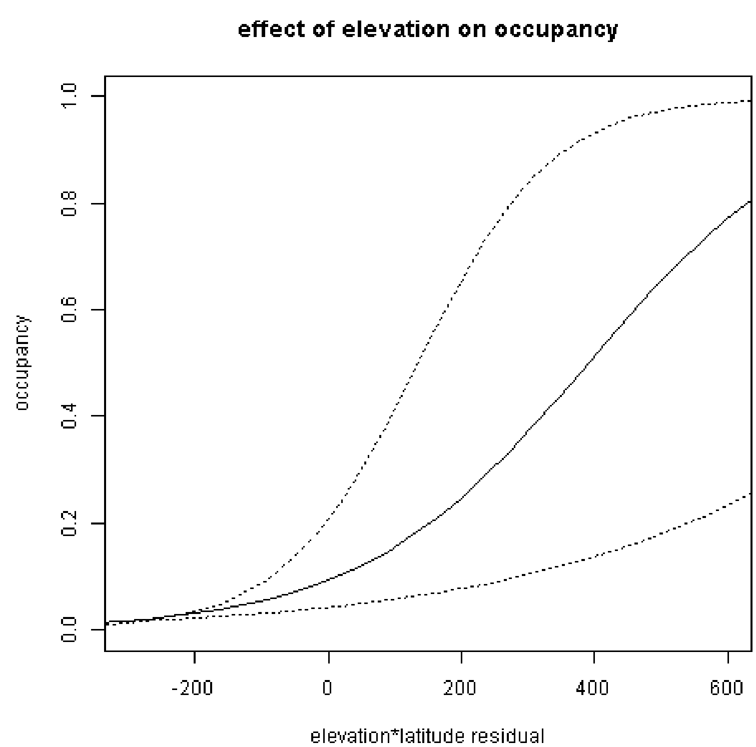
All forest (regardless of distance to fire)

	Point scale				*Transect scale*			
	Estimate	SD	Lower	Upper	Estimate	SD	Lower	Upper
p intercept	-2.35	0.37	-3.10	-1.67	-1.02	0.34	-1.72	-0.38
Survey type	1.69	0.34	0.99	2.34	-0.26	0.30	-0.86	0.33
psi intercept	-2.63	0.37	-3.31	-1.84	-2.07	0.32	-2.66	-1.39
Snags	0.11	0.22	-0.31	0.54	-0.01	0.23	-0.47	0.43
Elevation	1.22	0.28	0.74	1.81	1.29	0.35	0.71	2.10
Distance to fire	-1.50	0.54	-2.64	-0.52	-1.16	0.61	-2.42	-0.04
Dist.fire^2	1.21	0.48	0.35	2.26	0.77	0.56	-0.25	1.99

For all the models we examined, at both point and transect scales, number of snags was a non-significant covariate on occupancy and coefficient estimates were near zero (Table 2). The residual of elevation on latitude was a strongly positive effect in each model, and at both scales the coefficients were larger on the unburned forest models (Table 2). This indicates Black-backed Woodpeckers in our sample tended to occur on our higher elevation transects, especially for those transects not associated with fires (Figure 2). Elevation of Black-backed Woodpecker unburned forest detections averaged 2494 m ± 29 (SE) in the central and southern Sierra (Eldorado, Inyo and Sierra National Forests) and 1975 m ± 58 (SE) in the northern Sierra and southern Cascades (Modoc, Lassen and Tahoe National Forests).

The effect of survey type on probability of detection was significantly positive (i.e. playback surveys improved detectability) at the point scale, but survey type was not significant at the transect scale (Table 2). In fact the coefficient for survey type was slightly negative for both transect scale models, indicating that a single playback survey has slightly lower detectability than five passive point counts.

Figure 3. Occupancy vs. the residuals of elevation*latitude for the transect-scale occupancy model including only locations more than 2 km from areas that burned within 10 years.



At the broad scale, Black-backed Woodpecker point-level unburned forest detections were distributed across eight different CWHR habitat types (Figure 4). The greatest number of detections were in red fir (RFR; 32%) followed by lodgepole pine (LPN; 19%). Eastside pine (EPN), Jeffrey pine (JPN), Sierra mixed conifer (SMC), and white fir (WFR) each accounted for 11% of detections. Ponderosa pine (PPN; 3%) and montane chaparral (MCP; 2%) accounted for the remaining detections. Selection ratios indicated that Black-backed Woodpeckers were not using habitat types in proportion to their availability (global test P = 0.006; Figure 5). Due to small sample sizes, p-values for each separate CWHR habitat type were all greater than the Bonferroni-adjusted p-value of 0.006 and most confidence intervals overlapped zero. But the overall pattern showed that Black-backed Woodpeckers were likely selecting for lodgepole pine and red fir forest, as these two types comprised 22% of all point count stations but included 51% of points with detections. They used Jeffrey pine, eastside pine, white fir, and montane chaparral in proportion to their availability and likely avoided Sierra mixed conifer and Ponderosa pine. These patterns were similar for the conservative definition but the global test indicated that relationships were not significant (P = 0.14), due to limited sample size.

For the broad definition, Black-backed Woodpecker unburned forest detections were distributed across eight different CWHR habitat types (Figure 4). The greatest number of detections were in red fir (RFR; 32%) followed by lodgepole pine (LPN; 19%). Eastside pine (EPN), Jeffrey pine (JPN), Sierra mixed conifer (SMC), and white fir (WFR) each accounted for 11% of detections. Ponderosa pine (PPN; 3%) and montane chaparral (MCP; 2%) accounted for the remaining detections. Selection ratios indicated that Black-backed Woodpeckers were not using habitat types in proportion to their availability (global test $P = 0.006$) and selected for lodgepole pine and red fir forest (P < 0.05; Figure 5). They used Jeffrey pine, eastside pine, white fir, and montane chaparral in proportion to their availability. They avoided Sierra mixed conifer and Ponderosa pine. These patterns were similar for the conservative definition but due to small sample sizes, relationships were not significant (P = 0.14).

Figure 4. The distribution of Black-backed Woodpecker point scale detections among CWHR habitat types compared to total point count stations across 10 National Forest units in the Sierra Nevada from 2009 – 2011. Distribution is shown for both broad and conservative definitions of unburned habitat.

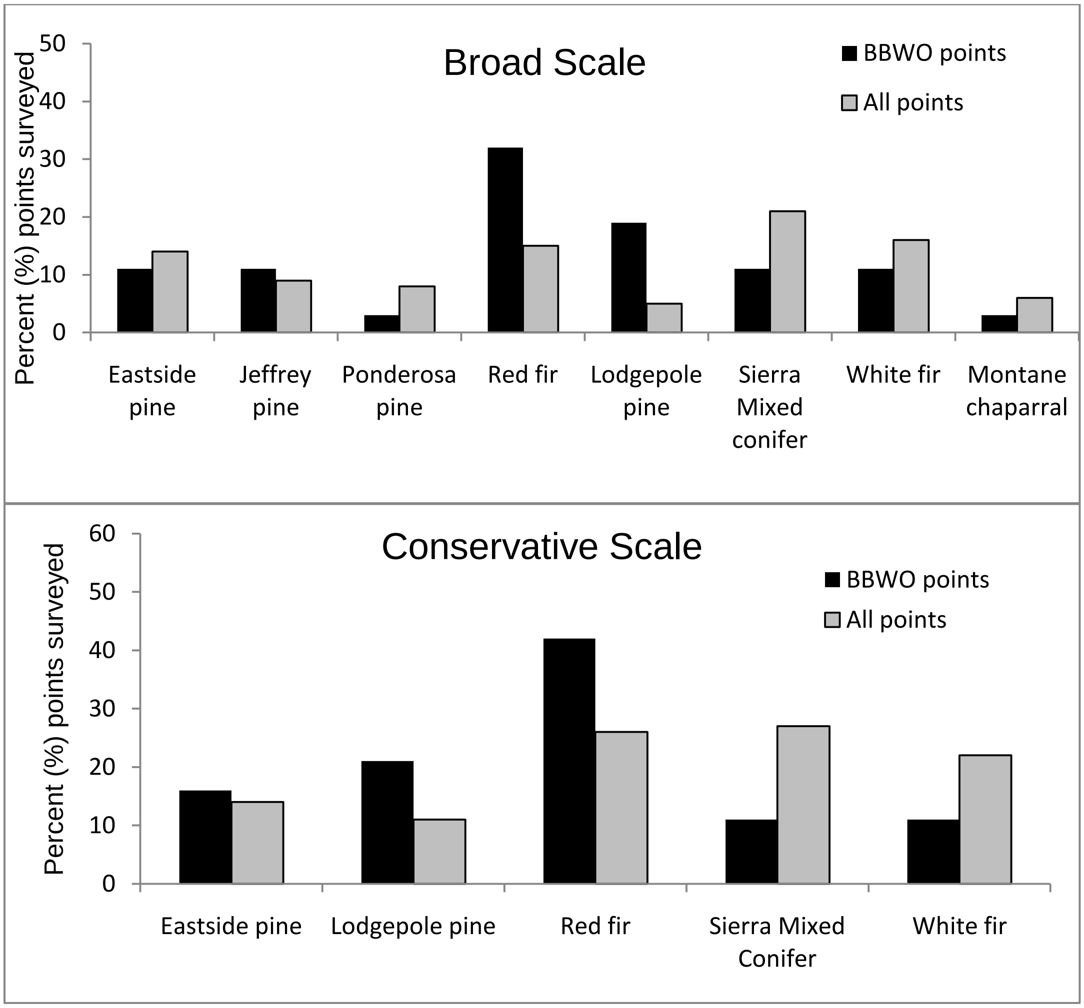
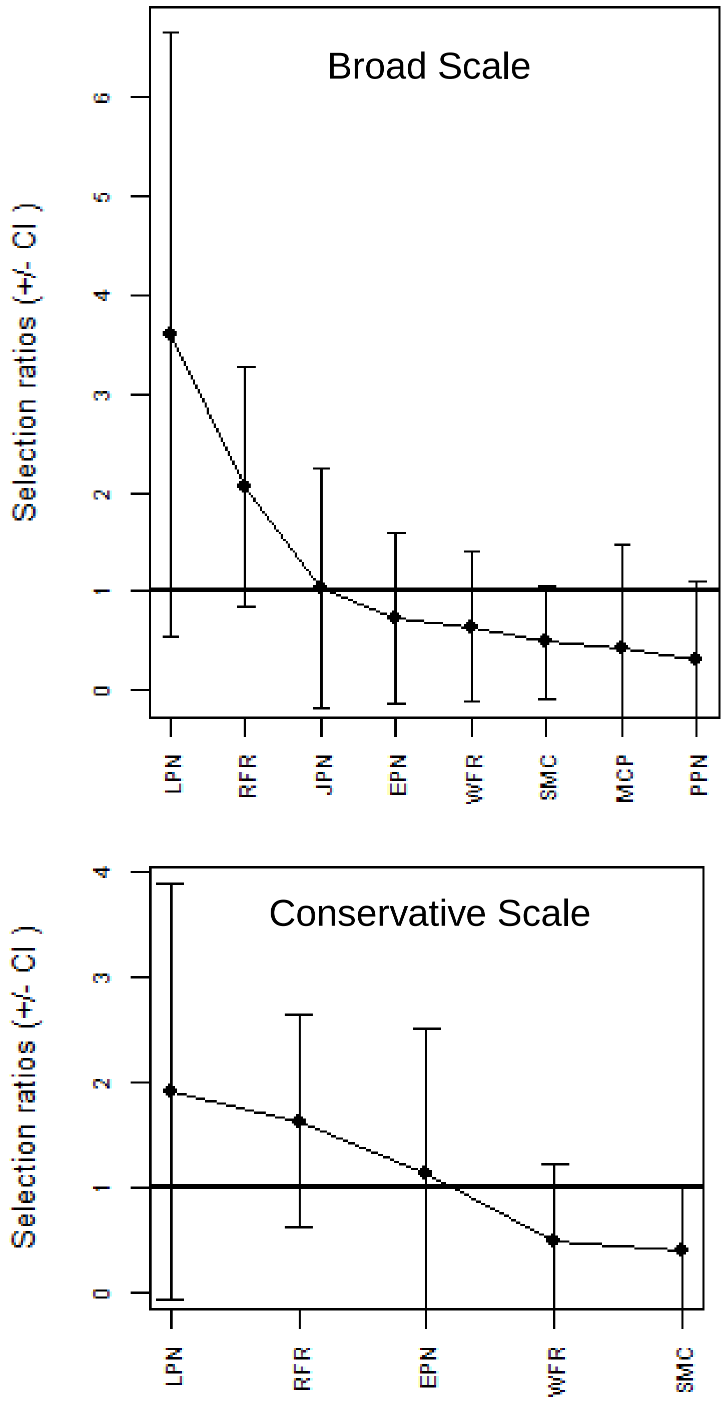


Figure 5. Black-backed Woodpecker habitat selection ratios and 95% confidence intervals distributed across eight CWHR habitat types for the broad definition of unburned forest and five types for the conservative definition. Habitat types include LPN = lodgepole pine, RFR = red fir, JPN = Jeffrey pine, EPN = eastside pine, WFR = white fir, SMC = Sierra mixed conifer, MCP = montane chaparral and PPN = Ponderosa pine.



Discussion

Our results indicate there is a substantial presence of Black-backed Woodpecker outside of areas burned in recent wildfire across the Sierra Nevada. These "green forest" occurrences are characterized by higher elevations and red fir, lodgepole pine, and to a lesser extent Jeffrey and eastside pine forest. The affinity for red fir and lodgepole pine is consistent with descriptions of this species distribution in unburned forest in California by Grinnell and Miller (1944).

In unburned boreal forest in Canada, they were found in old-growth spruce forest with many snags and downed logs (Hoyt and Hannon 2002, Tremblay et al. 2009) and in Oregon, they selected for old growth lodgepole pine forest (Goggans et al. 1989). However, in these and other studies, authors concluded that Black-backed Woodpeckers were most commonly associated with recently burned areas (Hutto 1995, Murphy and Lehnhausen 1998, Kotliar et al. 2002, Smucker et al. 2005, Hutto 2008).

Using an approach similar to Saracco et al. (2011), we estimated that Black-backed Woodpecker occupancy in unburned forest was about half of that found for areas that had recently burned at moderate to high severity in the Sierra Nevada National Forests (0.05 vs. 0.10). Although the confidence intervals around our estimate were relatively large, these results do support the idea that Black-backed Woodpeckers are considerably more abundant in recently burned areas in the Sierra Nevada than in unburned. However, they do appear to be more prevalent in unburned habitat here than has been reported elsewhere in the species range (Hutto 1995, Murphy and Lehnhausen 1998, Hutto 2008), and that has been speculated for the Sierra Nevada (Hanson and North 2008, Hanson and Cummings 2010).

Occupancy was higher closer to burns but also increased once distance from fire exceeded approximately 6 km. Though our results were at a considerably smaller scale, this is the same effect observed in a boreal forest population (Hoyt and Hannon 2002). They hypothesized that this was the result of woodpeckers occurring within some minimum distance of burned areas (50 km in their study), detecting the recent burns and emigrating from the unburned forest into burned areas. Our results suggest that the depressed occupancy zone surrounding recent fires is far smaller in the Sierra Nevada than the 50 km they observed. A second hypothesis for explaining a positive relationship between occupancy and distances far from fires could be a function of the distribution of the preferred habitats of Black-backed Woodpeckers. Both red fir and lodgepole pine forest types occur at higher elevations and have longer fire return intervals compared to the lower elevation conifer forest types in the Sierra Nevada (Taylor 1993, Taylor 2000, Stephens et al. 2007). Thus these higher elevation forest types would, on average, occur further from recent fires than lower elevation forest types.

We found no evidence of a relationship between Black-backed Woodpecker occupancy and snag densities. Our sampling scale (50 m radius plot), may not have adequately characterized snag densities within the relatively large home range of the species or at an appropriate spatial scale. Areas of high snag density are likely to be clumped across the landscape and the scale of our vegetation surveys is not amenable to identifying and tracking these uneven distributions at the scale of a woodpecker home range. In a similar process, beetle infestations are typically clumped on the landscape, and may be a key resource for Black-backed Woodpeckers (Murphy and Lehnhausen 1998, Hoyt and Hannon 2002). Research has shown that this species will travel long distances to reach unburned forest areas within their home range that have old growth forest characteristics (e.g., dead and dying trees; Dudley and Saab 2007, Tremblay et al. 2009, Siegel et al. 2012). Additionally, it is possible that Black-backed Woodpecker occurrence may be more closely tied to dying trees infested by beetles in unburned forest. Our definition of snags only included totally dead trees. Further investigation into this species' foraging ecology and diet in unburned forest in the Sierra Nevada is needed to better understand their distribution as efforts to reduce tree die offs associated with beetle outbreaks and the spread of wood-boring beetles could have negative impacts on the species.

Caveats and Limitations

While this study provides new and important information about the occurrence patterns and habitat associations of Black-backed Woodpeckers in the Sierra Nevada, there are several limitations that should be mentioned. Though our survey effort was very large, the detection probability and relative uncommonness of the species resulted in a small sample size and thus considerably wide confidence intervals around our occupancy estimates. Our study was limited to National Forest land and areas within 1 km of accessible roads. Thus, high elevation sites are probably not equally represented in our sample. Especially in the southern Sierra, high elevation lodgepole pine and red fir forest are more prevalent in National Parks that we did not sample and roadless National Forest wilderness areas that we clearly under-sampled. These high elevation forests may represent the most densely occupied unburned habitats for Black-backed Woodpecker.

We also advise caution in extrapolating these results beyond National Forest lands in the Sierra Nevada. Management practices in National Parks and on private timber land can vary substantially from National Forest and could influence the occurrence patterns of this species. Based on our understanding of the species in unburned forest we suggest that National Parks; where more late seral habitat exists, beetle infestations are not managed, and considerable amount of high elevation habitat exists; may provide important habitat for this species in the Sierra Nevada.

We provided an estimate of occupancy for a hypothetical transect with the average covariate values for comparison with Saracco et al. (2011) but the proportion of survey transects occupied is best determined by estimating occupancy probability for each transect independently and taking the average of those values. Thus the 0.22 estimate is most appropriate as the average transect value does not indicate the proportion of survey transects that were occupied by Black-backed woodpeckers in our 2011 sample. The overall occupancy estimate is much higher than the average transect estimate, suggesting that the majority of occupied transects are clustered in one extreme of the range of covariate values, in this case on the higher elevation sites as shown in Figure 3.

Our analysis only excluded areas that were affected by wildfire but may have included areas that were subjected to prescribed fire over the last decade. Recent evidence suggests this species will utilize areas that burned in lower severity prescribed fire (V. Saab pers. comm, R.Burnett pers. obs.) and these areas may represent a small portion of our estimate of the "unburned" portion of the Sierra Nevada population. Because only a tiny fraction of our 4.5 million acre sampling frame was subjected to prescribed fire over the last decade, we suggest it could only explain a fraction of the observations in "unburned" habitat. However, the utility of prescribed fire in creating habitat for this species in the Sierra Nevada warrants further study.

While this study illustrates there is a sizeable portion of the Sierra Nevada Black-backed Woodpecker population that occurs away from burned forest, the importance of these individuals to the overall Sierra Nevada population viability is unknown. An understanding of population growth rates in unburned forest, home range size, and movement between burned and unburned habitats throughout their lifetime is needed to help guide management of this species in the

Sierra Nevada. With previous studies showing Black-backed Woodpecker diet composed primarily of wood-boring beetles (Dixon and Saab 2000), studies of their diet and association with beetle outbreaks in unburned forest might help clarify their habitat associations and reliance on beetles away from burned areas. We have anecdotal observations of this species nesting primarily in live lodgepole pine trees but a greater understanding of their nest site selection in unburned forest would also be useful for developing management strategies for this species outside of burned areas.

Acknowledgements

We'd like to thank Diana Craig, USDA Forest Service Region 5 Wildlife Ecologist, for all of her leadership and assistance in making this project possible and successful. We are also especially thankful to all the staff on the forests and ranger districts throughout the Sierra Nevada that have been invaluable to the success of this project. Of particular note are Peggy O'Connell, Claudia Funari, Dawn Lipton and Diana Cole of Eldorado National Forest; Coye Burnett, Jennifer Hensel, and Mark Williams of Lassen National Forest; Marty Yamagiwa of Modoc National Forest; Tina Mark and Marilyn Tierney of Tahoe National Forest; Crispin Holland of Stanislaus National Forest; Greg Schroer, Anae Otto and Kim Sorini of Sierra National Forest and Emilie Lang, Jeff Cordes, Steve Anderson and Robin Galloway of Sequoia National Forest. We thank the field crews from 2009 and 2010 but especially the 2011 field crew for their dedication to conducting a large amount of Black-backed Woodpecker playback surveys: PRBO staff members Brent Campos, Ken Etzel, Kristin Sesser, Jim Tietz and seasonal field biologists Mary Clapp, Lidia D'Amico, Patrick Furtado, Dan Lipp, Michelle McGee, Jeff Moker, Lauren Morgan-Outhisack, Julia Polasik, Josh Stagner and Nate Turner.

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Appendix 1. Detection history (number by year and visit) of Black-backed Woodpeckers at point count transects on Sierra Nevada National Forests 2009 - 2011. Numbers in bold with PB denote playback-only transect-level detections. 'NA' means the transect was not visited and '0' means a Black-backed Woodpecker was not detected. Distance to fire (m) is shown for both 10 and 20 years post-fire, as of the 2011 fire season.

	Number of individuals detected							
	2009		2010		2011			
Transect	visit 1	visit 2	visit 1	visit 2	visit 1	visit 2	10 year fire distance (m)	20 year fire distance (m)
EL06A	0	0	0	NA	0	2	0	0
EL31B	NA	NA	1	0	0	0	2165	2165
EL35B	NA	NA	1	NA	0	0	12671	4078
IN01C	0	0	NA	NA	0	2	7042	6549
IN05B	0	0	0	0	0	**1 (PB)**	3283	3283
IN05C	NA	NA	0	1	**1 (PB)**	0	2170	2170
IN06A	0	0	0	0	**1 (PB)**	NA	6299	6299
IN06B	1	0	0	0	0	NA	5827	5827
IN14A	0	0	1	NA	0	NA	131	131
IN16A	NA	NA	0	0	1	NA	3547	2773
LA04A	0	NA	0	1	0	NA	297	297
LA12B	0	NA	0	0	1	NA	18	18
LA16A	0	0	0	1	0	NA	2587	2587
LA22B	1	0	0	NA	0	1	351	351
LA33A	NA	NA	0	NA	**1 (PB)**	0	7268	7268
LA35B	NA	NA	0	0	0	1	2299	2299
LA36B	NA	NA	0	NA	1	0	3876	3876
LA37A	NA	NA	0	0	0	1	1612	1612
LA38A	NA	NA	0	NA	1	0	5687	5687
LA40A	NA	NA	0	NA	**1 (PB)**	0	6356	6356
LA40B	NA	NA	0	NA	1	0	6513	6513
LA41A	NA	NA	0	1	0	NA	7040	7040
LA43B	NA	NA	0	1	0	NA	1643	1643
LA44A	NA	NA	0	0	0	1	0	0
MO02A	2	0	NA	NA	0	0	3898	3898
MO04A	0	0	0	0	1	0	4677	4677
MO08B	0	NA	0	0	0	1	171	171
MO09B	0	NA	0	0	**2 (PB)**	NA	1672	1672
MO12A	0	0	0	0	1	NA	1921	1921
MO16A	0	NA	NA	NA	2	1	418	418
MO17A	0	0	NA	NA	2	NA	3530	3530
MO18A	0	0	1	0	0	NA	1667	1667
MO18B	0	0	0	0	1	NA	862	862
MO19B	0	NA	NA	NA	**1 (PB)**	0	1991	1991
MO30A	0	NA	0	1	0	0	5787	5787
MO37A	NA	NA	0	0	1	1	0	0
MO37B	NA	NA	0	1	0	1	0	0
MO39B	NA	NA	0	0	2	NA	2031	2031
PL05A	0	NA	NA	NA	**1 (PB)**	NA	0	0
PL37A	0	NA	0	0	0	**1 (PB)**	74	74

Appendix 1. Continued.

	Number of individuals detected							
	2009		2010		2011			
Transect	visit 1	visit 2	visit 1	visit 2	visit 1	visit 2	10 year fire distance (m)	20 year fire distance (m)
PL52A	NA	NA	0	NA	1	NA	1282	0
SI01C	NA	NA	0	NA	1	1	12280	10322
SI14B	0	0	1	NA	**1 (PB)**	1	14075	9506
SI21C	NA	NA	1	NA	0	**1 (PB)**	2784	2784
SI33B	0	0	0	NA	1	NA	2055	2055
SI46B	0	0	0	NA	1	NA	11981	11981
SI58A	NA	NA	1	NA	0	0	11786	11365
SI63A	NA	NA	0	NA	NA	2	4069	4069
TA08C	NA	NA	0	NA	0	**2 (PB)**	1631	1631
TA28A	0	0	0	0	1	NA	2410	2410
TB01A	1	1	NA	NA	2	1	535	535
TB01B	1	0	NA	NA	1	2	37	37

Appendix 2. An estimate of Black-backed Woodpecker numbers in unburned areas across National Forest land in the Sierra Nevada Planning Area.

Introduction

We recognized the importance of these data to the current environment surrounding the decision to list Black-backed Woodpecker as a California state threatened or endangered species (Hanson and Cummings 2010). To facilitate this debate we attempted to extrapolate the results of our occupancy and habitat selection analyses to all unburned habitats across the Sierra Nevada National Forests as an attempt to generate an estimate of the total number of Black-backed Woodpeckers. Our general approach here is to take a conservative interpretation of our occupancy estimates as applied to the likely density of territories across unburned forest, as many of these parameters are unknown, in order to build an estimate of the number of Black-backed Woodpecker pairs in our study area.

Methods

To extrapolate our occupancy model results across unburned areas in the Sierra Nevada National Forests we estimated occupancy values in relation to elevation (this relationship is shown in Figure 3) for all areas in our original Management Indicator Species project sampling frame (Roberts et al. 2011), but we excluded all 1km^2 grid cells whose center were within 2 km of areas that have burned since 2001. Thus, all portions of grid cells included were at least 1.5 km from these burned areas. The resulting sampling frame included 18,494 1 km^2 grid cells (approximately 4.6 million acres) covering all unburned forest and chaparral habitat within the Sierra Nevada National Forests. Stratifications originally used to develop this sampling frame include elevation (1000 – 2800 m) and habitat type (all forest types and montane chaparral). Both of which were used in limiting our 18,494 km^2. Our sampling frame was also limited to areas within 1 km of roads and slopes less than 35%. However, some of our point count locations did occur on slopes greater than 35% and more than 1 km from roads even though the transect scale (averaged) values were within the stratification bounds. Thus we have limited survey data from steep slopes and areas far from roads, but we feel they warrant inclusion in this calculation and assume that they impose minimal bias.

For each 1 km^2 grid cell we calculated the elevation*latitude residual and predicted an occupancy estimate plus 95% confidence interval values based on a fitted model derived from

Figure 3. We then calculated the average occupancy across all grid cells in the sampling frame and then multiplied that averaged occupancy estimate (and upper and lower bounds of the confidence interval) by the total number of grid cells in the sampling frame.

Results & Discussion

Our estimate of elevation*latitude adjusted occupancy of unburned habitat in Sierra Nevada National Forests is 0.215 (95% CI = 0.076 - 0.373). Those numbers apply to a sampling frame of 18,494 1km^2 grid cells (about 4.5 million acres). If we assume each 1km^2 could be occupied (i.e. a territorial bird or pair from one grid cell does not exclude occupancy of the adjacent grill cells by other birds) then we would estimate 3980 grid cells were occupied by unique Black-backed Woodpeckers in areas at least 1.5km from areas that burned since 2001 on Sierra Nevada National Forests (95% CI: 1398 – 6899 territories).

Several of the key assumptions required to derive this estimate are worthy of further discussion. Current estimates of Black-backed Woodpecker home range size in burned and unburned habitat varied widely, with averages across studies ranging from 0.45 km^2 – 4.29 km^2 (see Siegel et al. 2012 Table 8 for summary). Not all of these studies were conducted during the nesting period. If estimated density is determined to be lower than the one pair possible per square kilometer we assumed, then our population estimates can be adjusted accordingly. However, our estimate also assumes only one territory is possible per km^2 grid cell and some of these cells could contain more than one territory. Several of our transects had multiple detections - presumably at least some were of different birds - and home ranges in fire areas in the Sierra Nevada frequently overlap (Siegel et al. 2012). By excluding all the area within at least 1.5 km that had burned since 2001 we removed 6235 square kilometers or approximately 25% of the forested Sierra Nevada National Forest sampling frame. Assuming at least a portion of the birds occurring in these areas reside entirely outside of the areas that burned, the estimate would be larger. With our data it is not possible to determine what portion of these estimated 3980 occupied sites contain breeding pairs versus unpaired birds, hence the use of the term occupied site versus territories or breeding pairs. Also, as stated in the body of this report we have no way to determine the viability of the unburned forest portion of the population and how they disperse or immigrate/emigrate from one to the other. Finally, these estimates are from on one year of data (2011) and extrapolations were based on a fairly small sample size; hence the rather larger range in the confidence intervals. An additional year of data collection should help refine these estimates.