prbo

Plumas-Lassen Administrative Study
2009 Avian Monitoring Report

February 2010

Ryan D. Burnett, Paul Taillie, and Nathaniel Seavy
PRBO Conservation Science

Contribution Number 1726

Executive Summary

In 2009 the avian module of the Plumas-Lassen Administrative Study (PLAS) expanded to address important questions related to post-fire habitat and its management. The primary objective of this new part of the study is to assess the influence of post-fire conditions on spatial and temporal variation in bird abundance, and to use this information to inform forest management practices that can maintain avian diversity across multiple spatial scales. We began sampling three areas affected by fire within the boundaries of the original PLAS study: the Storrie, Moonlight, and Cub fires.

Avian species richness and total bird abundance were higher in green forest than all fire areas combined though a similar number of species were detected in fire areas as in green forest. The highest total bird abundance recorded in 2009 in our study area and highest species richness in any fire area was found in high severity areas of the Storrie fire – nine years after it burned.

The abundance of avian species in post-fire habitat was considerably different than green forest in the study area. Eight species were significantly more abundant in post-fire habitat whereas eleven were in green forest of the PLAS. Hairy Woodpecker - a Management Indicator Species in the Sierra Nevada – and White-headed Woodpecker were significantly more abundant in post-fire habitat compared to green forest. Black-backed Woodpecker were only detected within fifty meters of observes in the Moonlight fire though we have observed them in both the Cub and Storrie fire and rarely in the PLAS green forest.

A number of cavity nesting species showed a preference for certain tree species and large diameter trees. All cavity nesting species we studied showed a preference for decayed snags which were not readily available in both of the younger fires (Cub and Moonlight) regardless of the severity at which a plot burned. Nesting densities of cavity nesting species increased as the area of the plot with greater than 50% overstory tree mortality increased.

In the Sierra Nevada considerable debate surrounds the management of post-fire habitat. As the area affected by wildfire appears to be increasing after nearly a century of suppressed fire activity, a greater understanding of the value of these habitats and the critical habitat elements required by the unique and relatively diverse avian community will be important to sustaining biological diversity in the Sierra Nevada. Post-fire habitats are necessary components of the Sierra Nevada ecosystem that support a unique, diverse, and abundant avian community that should be considered when managing these areas.

Post-Fire Habitat Management Recommendations

- Restrict all activities that may disturb breeding birds to the non-breeding season (August - April)
- Consider post-fire habitat as important component of the ecosystem necessary for maintaining biological diversity in the Sierra Nevada
- Consider the area of a fire that burned in high severity, as opposed to the area of the entire fire, when determining what percentage of the fire area to salvage log
- Consider the landscape context (watershed, ranger district, forest, ecosystem) and availability of different habitat types when planning post-fire management actions
- Manage a portion of post-fire areas for large patches (minimum of 50 acres) of high severity habitat
- Retain high severity areas in locations with higher densities of larger diameter trees and existing snags with relatively high levels of decay
- Manage a portion of post-fire areas for early successional shrub and herbaceous dominated habitats and natural regeneration of conifers
- Retain snags in salvaged areas greater than green forest standards of 4 snags per acre
- Retain some patches of high severity fire adjacent to intact green forest patches as the juxtaposition of unlike habitats is positively correlated with a number of avian species including declining species such as Olive-sided Flycatcher, Western Wood-Pewee, and Chipping Sparrow
- Manage post-fire areas for diverse and abundant understory plant community including shrubs, grasses, and forbs. Understory plant communities provide a unique and important resource for a number of species in a conifer dominated ecosystem
- Retain snags (especially large pine trees that decay slowly) in areas being replanted as they can provide the only source of snags in those forest patch for decades to come and we have found that scattered large snags in plantations surrounded by forest are readily used by cavity nesting birds

Introduction

The primary objective of the landbird module of the Plumas-Lassen Administrative Study is to assess the impact of forest management practices in sustaining a long-term ecologically stable forest ecosystem at the local and landscape scales. We know the avian community in the Sierra Nevada is comprised of species that are associated with a wide range of forest seral stages, vegetative composition, and structures. This vegetation, and hence avian diversity, is constantly changing as a result of natural disturbances (primarily fire) that create a dynamic and diverse ecosystem. Therefore, it is imperative for managers to consider how natural disturbance events interact temporally and spatially with management actions, and how ecological integrity can be achieved in an inherently dynamic system.

In the Sierra Nevada, there is a pressing need to understand the nexus of silvicultural practices, wildfire, and fuels treatments in order to maintain forested ecosystems that are ecologically diverse and resilient. In the context of a century of fire suppression, at the core of the debate over how to manage Sierra forests is the debate over how to most appropriately manage areas where natural disturbances have been disrupted. Forest Service managers need a better understanding of the suitability of habitat created through fire suppression, fuel treatments (DFPZ, groups, mastication), and wildfire and post wildfire management.

The challenge of integrating wildfire and forest management into wildlife conservation is not unique to the Sierra Nevada. Because large, infrequent disturbances are responsible for long-lasting changes in forest structure and composition (Foster et al. 1998), they are recognized as a critical element of bird community dynamics (Brawn et al. 2001). In many regions of western North America, fires burn with considerable spatial and temporal variability (Agee 1993), creating complex mosaics of vegetation patches. In these systems, changes in bird abundance are often linked to post-fire vegetation characteristics and landscape composition (Saab et al. 2002, Huff et al. 2005, Smucker et al. 2005).

In addition to fire suppression, there are a number of management activities that influence post-fire vegetation characteristics and landscape composition in working forests. These activities include salvage-logging, the mechanical mastication and herbicidal treatments to reduce broadleaf shrubs, and planting of conifer species that are favored by forestry. As a result, management activities may have profound influences on post-fire conditions- locally and across the landscape.

Beginning in 2009 the avian module of the Plumas-Lassen Administrative Study (PLAS) expanded to address important questions related to post-fire habitat and its management. The primary objective of this new part of the study is to assess the influence of post-fire conditions on spatial and temporal variation in bird abundance, and to use this information to inform forest management practices that can maintain avian diversity across multiple spatial scales. We began sampling three areas affected by fire within the boundaries of the original PLAS study: the Storrie Fire that burned in the Fall of 2000, the Moonlight Fire that burned in the Fall of 2007, and the Cub Fire that burned in the Summer of 2008. Each of these fires burned at similar elevations and through primarily mixed conifer and true fir vegetation communities but with varying intensity patterns. This report provides results from the first year of fire monitoring and uses ongoing monitoring of unburned or “green” forest in the study area to provide context.

Methods

Study Location

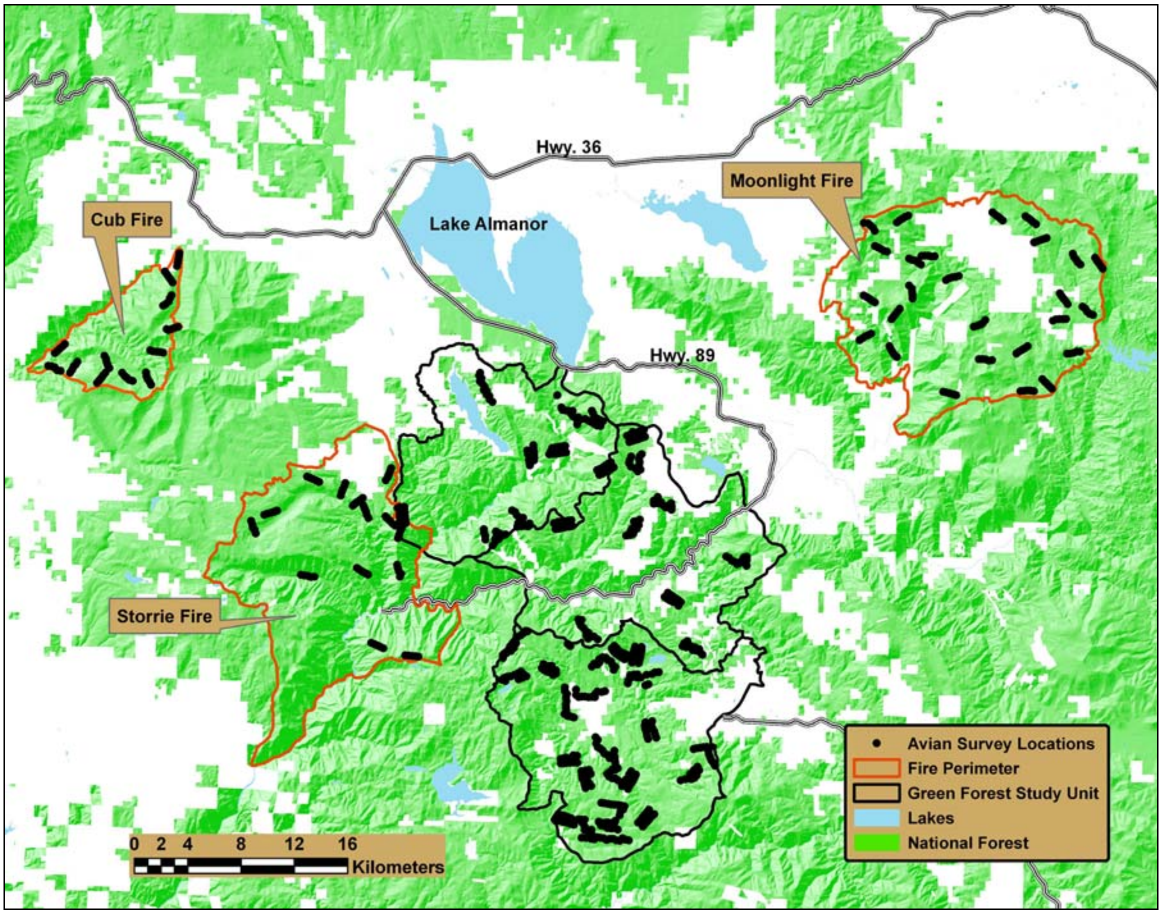
The Plumas-Lassen Area Study avian module study encompasses portion of the Mount Hough Ranger District of Plumas National Forest and the Almanor Ranger District of Lassen National Forest in the Sierra Nevada Mountains of Northeastern California (Figure 1). In 2009 we added three separate burned areas to our study within this same area. The elevations of sites surveyed ranged from 1126 – 1998m with a mean of 1658 in the Cub fire, 1199 – 2190m with a mean of 1779 in the Moonlight Fire, 1107 – 2011m with a mean of 1528 in the Storrie fire, and 1094 – 1902m with a mean of 1483 at the existing PLAS green forest sites.

Site Selection

A total of 52 transects (260 stations) were established across the three fires. Twenty-six transect were surveyed in the Moonlight fire, 12 in the Cub Fire, and 13 in the Storrie Fire. Site selection for PLAS green forest study sites followed a similar random selection protocol except each transect contained 12 points instead of five and approximately 25% of transects were systematically established in areas where treatments were planned (many now implemented). The PLAS site selection protocol for the unburned “green forest” sample is described in detail in the study plan and previous annual reports (Stine et al. 2005, Burnett et al. 2009).

Random starting points for each fire transect were generated in ArcGIS 9.2 within the boundaries of each fire. The sampling area was limited to forest service land and sites with a slope of less than 40 degrees to allow access and safe navigation on foot in a timely manner. We maintained a minimum distance between transect starting points of 1500m to ensure transects would not overlap and maximize a spatial balance within the sampling frame of each fire. Four more points were added to the starting point on a random compass bearing at 250m spacing resulting in a 1km long five point transect.

Figure 1. The location of PRBO study sites in the Plumas-Lassen study area in 2009.



As we attempted to implement our sampling protocol logistical constraints necessitated minor deviations from the methods described above in order to establish the minimum number of transects desired for each fire. In the Storrie Fire, two transects that were in remote areas (ST8 and ST7) and accessible only by the Pacific Crest Trail were moved from the random location to the trail or adjacent to the trail due to rugged un-navigable terrain. In three cases of extreme topography (two in Cub Fire and one in Storrie Fire; CB13, CB14, and ST12) we moved the transect to a more navigable location in the same general area. Five originally selected transects (ST1, ST2, ST3, ST5, and ST11) were dropped after field crews were unable to safely access or navigate them and replaced with new transects that were in locations of known accessibility. Finally there were five transects (ML8, CB4, CB6, CB15, and ST14) that were dropped completely as we selected a few extra transects in each fire assuming some would have to be dropped. As a result of these terrain limitations, fairly large sections of the Cub and especially the Storrie fire were not surveyed (see Figures 1 & 2).

Figure 2. Location of PRBO point count locations overlaid on composite burn index fire severity maps for each of three fires in the study area. Red = high intensity, Orange = moderate, Lime = low intensity, and green is low to unburned.

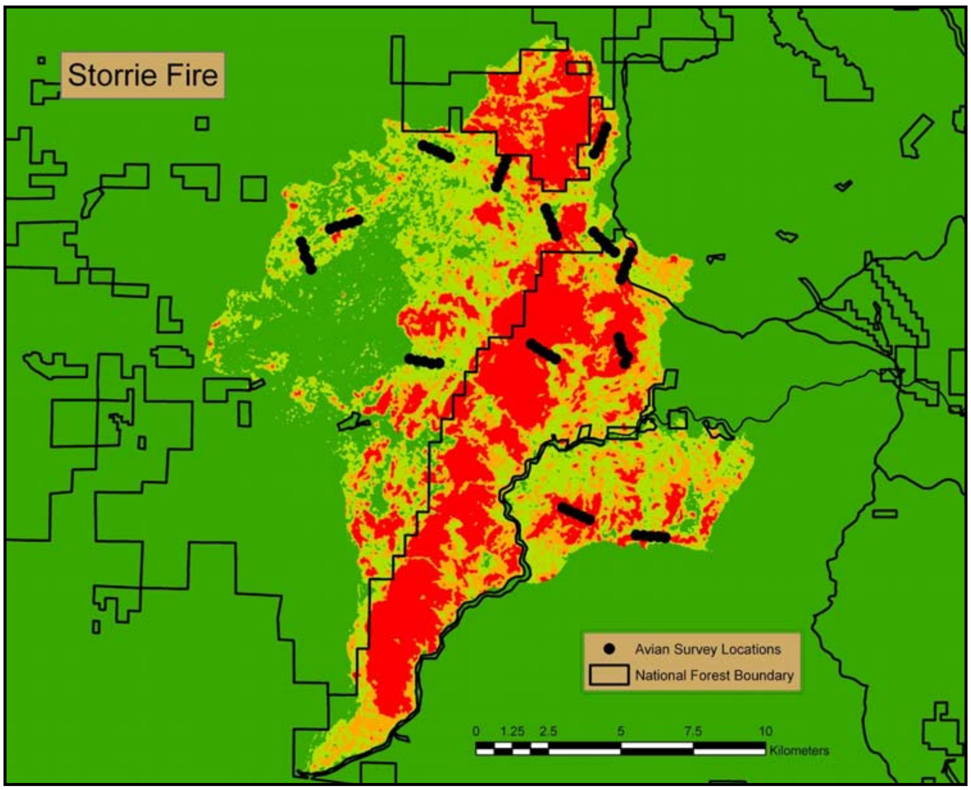
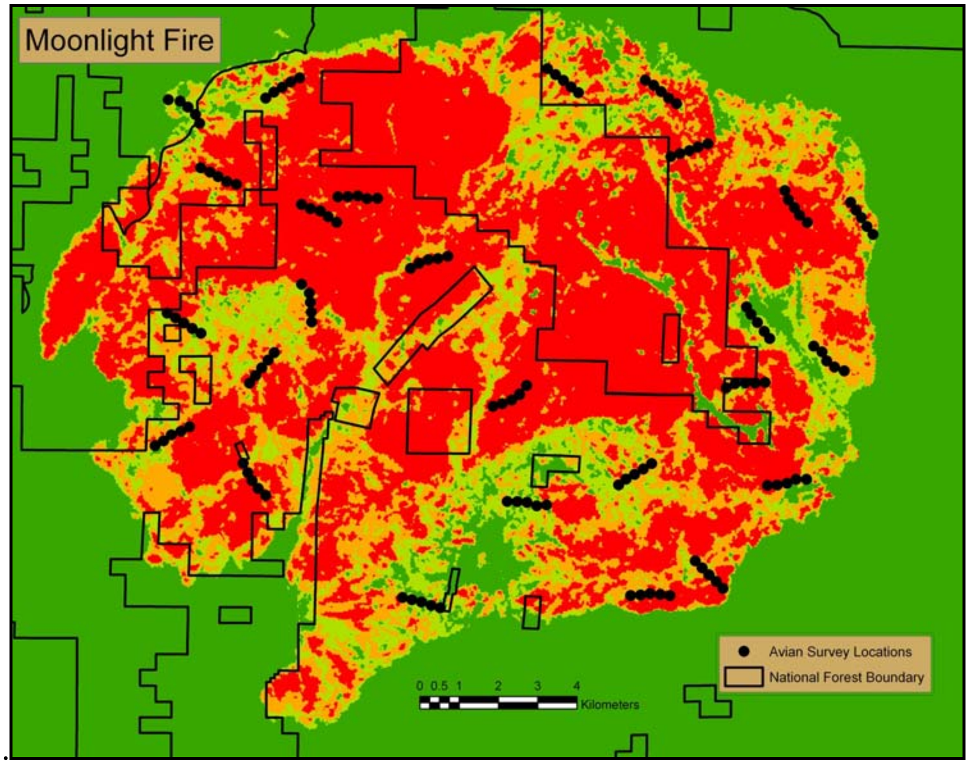
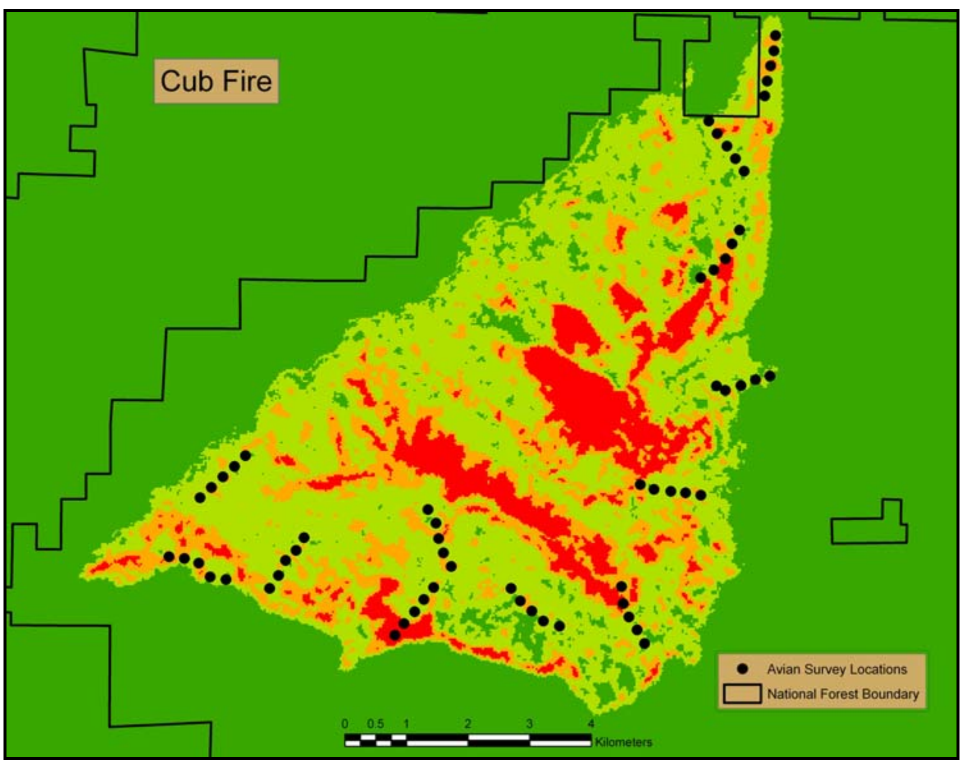


Figure 2 continued.





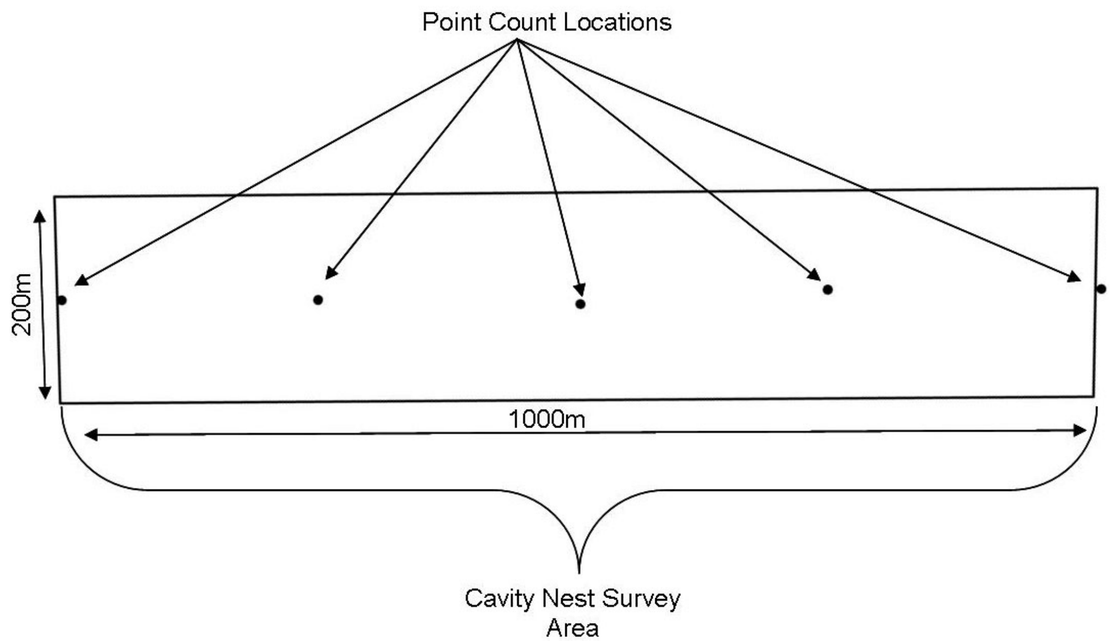
Bird community surveys

The avian community was sampled using a five minute exact distance point count census (Reynolds et al. 1980, Ralph et al. 2005). In this method points are clustered in transects, but data are only collected at the individual stations. All birds detected at each station during the five-minute survey were recorded according to their initial distance from the observer. The method of initial detection (song, visual, or call) for each individual was also recorded. 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 four hours, and did not occur in inclement weather. Each transect was visited twice during the peak of the breeding season from mid May through the first week of July (Appendix C).

Cavity nest surveys

In addition to the point count census, at each fire transect a 20ha area (200m x 1000m rectangle) was surveyed for nests of cavity-nesting birds following the protocol outlined in "A field protocol to monitor cavity-nesting birds" (Dudley and Saab 2003). After the point count census was complete, the nest survey was conducted for between two and four hours depending on the habitat and terrain and time spent waiting to confirm a cavities status. All nest surveys were completed by noon. The primary search method for finding nests was bird behavior though once suspicious birds were located observers often conducted a systematic search of snags in the vicinity. Once a potential nest was found it was observed from a distance for a maximum of 20 minutes to confirm the cavity was an active nest. If that cavity was confirmed active a variety of characteristics of both the nest tree and the cavity were recorded. These characteristics included diameter at breast height (DBH), tree height, cavity height, tree decay class, and the orientation of the cavity opening. For tree decay, we used a qualitative scale of decay ranging from one to eight one being a live, intact tree and eight a severely decayed stump (see Figure 7). If the observer was unable to confirm the cavity was active, its location was recorded to aid nest searchers during the second visit. Only confirmed active nests were used in analysis presented herein.

Figure 3. PRBO Northern Sierra post-fire habitat survey plots.



Vegetation surveys

Vegetation data was collected in all post-fire plots (with the exception of two in Moonlight) in 2009. We measured vegetation characteristics within a 50 m radius plot centered at each point count station following the relevé protocol outlined in the original PLAS bird module study plan (Stine et al. 2005). On these plots we measured shrub cover, live tree cover, and herbaceous cover as well as the relative cover of each species in the shrub and tree layers through ocular estimation. We also collected basal area of live trees and snags using a 10-factor basal area key. To estimate the density of snags across the plot, we recorded data (e.g. DBH, species, height, decay) on every snag within 11.3m of the center of the point count. In addition to the point count stations, we selected five random points in every plot, and collected the same snag data within 11.3m. At the center of this random plot, a tree was chosen at random to serve as the control for the nest tree. The same descriptive characteristics that were collected for nest trees were also collected for these random trees at the center of the random snag plots.

Analysis

A per point index of abundance (detections within 50m of observer summed across two visits) at all 260 point count station was calculated for 28 species that occurred in at least one of the study areas. The species selected are comprised of all of the California Partner's in Flight Coniferous Forest Focal species, (CALPIF 2002), for which we had adequate detections to conduct meaningful analysis, as well as three woodpecker species, and a suite of other species that were among the most abundant in the study area or showed some large differences between post-fire habitat and green forest.

In order to quantify the overall songbird community in the study areas we used three different metrics, the Shannon Index of species diversity, species richness, and total bird abundance. The Shannon index used a transformation of Shannon's diversity index (or H', Krebs 1989) denoted N_1 (MacArthur 1965). The transformation expresses the data in terms of number of species and thus is more easily interpreted. Expressed mathematically:

$$N_1 = e^{H'} \text{ and } H' = \sum_{i=1}^{i=S} (p_i)(\ln p_i)(-1)$$

Where S = total species richness and p_i is the proportion of the total numbers of individuals for each species (Nur et al. 1999). High Shannon index scores indicate both high species richness and more equal distribution of individuals among species. Species richness is defined simply as the number of species detected within 50m of each point summed across the two visits and total bird abundance is the sum of all species detected per visit within 50m of observers. All species that do not breed or naturally occur in the study area and those that are not adequately sampled using the point count method including waterfowl, shorebirds, and raptors were excluded from each calculation. In addition, we calculated these metrics for each fire according to fire severity-as determined from on the ground vegetation surveys-and defined by percent overstory tree mortality. High severity was classified as sites with greater than 50% tree mortality and moderate to low severity being less than 50% tree mortality. These metrics were investigated for each fire and the Plumas Lassen Administrative Study green forest sample (Table 2).

Results

Bird community composition

A total of 97 species were recorded during point count censuses in the study area in 2009: 59 species on the 60 stations in the Cub fire, 72 species on the 130 Moonlight stations, 61 species on the 65 Storrie stations, and 78 species on the 468 PLAS green forest stations. Once species not adequately sampled using the point count method were removed (see paragraph above), there were 55 species in the Cub, 64 in the Moonlight, 55 in Storrie, and 61 in PLAS green forest. No species were unique to the Cub fire, seven species (Ash-throated Flycatcher, Canyon Wren, Cedar Waxwing, Clark's Nutcracker, Gray Flycatcher, Pygmy Nuthatch, and White-crowned Sparrow) were unique to the Moonlight fire, four species (Blue-gray Gnatcatcher, Chestnut-backed Chickadee, Vesper Sparrow, and Western Bluebird) were unique to the Storrie fire, and four species (Brewer's Blackbird, Red-winged Blackbird, Swainson's Thrush, and Western Meadowlark) were unique to the PLAS green forest sample.

Of the 28 species investigated, the index of abundance was highest in one of the fires for 21 of the species and higher in green forest for seven of the species. When all fires were combined, 16 species (8 significant) were more abundant in fire areas compared to 12 (11 significant) in green forest. The species with the highest index of abundance in the Cub fire were Mountain Chickadee, Red-breasted Nuthatch, Oregon Junco, and Audubon's Warbler and Hermit Warbler. In the Moonlight fire the most abundant were Lazuli Bunting, Oregon Junco, Dusky Flycatcher, Fox Sparrow, and Western Tanager. In the Storrie fire they were Lazuli Bunting, Oregon Junco, Fox Sparrow, Spotted Towhee, and MacGillivray's Warbler. In the PLAS green forest study area they were Hermit Warbler, Nashville Warbler, Audubon's Warbler, Dusky Flycatcher, and Oregon Junco.

Hairy Woodpecker - a Management Indicator Species in the Sierra Nevada – and White-headed Woodpecker were significantly more abundant in post-fire habitat compared to green forest. Black-backed Woodpecker were only detected within fifty meters of observes in the Moonlight fire though we have observed them in both the Cub and Storrie fire and rarely in the PLAS green forest. Lewis' Woodpecker, which we have never detected in the PLAS green forest study area, was fairly common in both the Moonlight and Storrie Fire areas.

Western Wood-Pewee, Mountain Bluebird, American Robin, Lazuli Bunting, Chipping Sparrow, and Cassin's Finch were all significantly more abundant in post-fire areas than PLAS green forest sites. Hammond's Flycatcher, Dusky Flycatcher, Cassin's Vireo, Mountain Chickadee, Red-breasted Nuthatch, Nashville Warbler, Audubon's Warbler, Golden-crowned Kinglet, Black-headed Grosbeak, Western Tanager, and Hermit Warbler were all significantly more abundant in PLAS green forest than all fire areas combined. For many of these species there abundance varied between each of the fires and many of these effects were significant (Table 1).

Table 1. An index of the abundance (detections within 50m of observers per station summed across 2 visits) for 28 species in each of three burned areas and the adjacent unburned Plumas-Lassen Area Study (PLAS) in 2009. Species are listed in taxonomic order and means are presented with standard errors.

Species	CUB	MOONLIGHT	STORRIE	PLAS
Calliope Hummingbird	0.00	0.11 (.03)	0.08 (.03)	0.05 (.01)
Hairy Woodpecker	0.15 (.06)	0.35 (.07)	0.12 (.05)	0.05 (.01)
White-headed Woodpecker	0.28 (.09)	0.11 (.04)	0.11 (.04)	0.04 (.01)
Black-backed Woodpecker	0.00	0.05 (.02)	0.00	0.00
Olive-sided Flycatcher	0.05 (.03)	0.05 (.02)	0.03 (.02)	0.03 (.01)
Western Wood-Pewee	0.05 (.03)	0.14 (.04)	0.20 (.08)	0.05 (.01)
Hammond's Flycatcher	0.27 (.07)	0.22 (.05)	0.03 (.02)	0.41 (.03)
Dusky Flycatcher	0.30 (.09)	0.72 (.09)	0.23 (.06)	0.69 (.05)
Cassin’s Vireo	0.03 (.02)	0.03 (.02)	0.08 (.04)	0.36 (.03)
Warbling Vireo	0.23 (.09)	0.18 (.06)	0.09 (.06)	0.14 (.02)
Mountain Chickadee	0.78 (.14)	0.41 (.08)	0.29 (.08)	0.66 (.05)
Red-breasted Nuthatch	0.68 (.10)	0.16 (.04)	0.34 (.08)	0.56 (.04)
Brown Creeper	0.35 (.08)	0.17 (.04)	0.32 (.11)	0.19 (.02)
Golden-crowned Kinglet	0.27 (.09)	0.12 (.04)	0.17 (.06)	0.59 (.04)
Mountain Bluebird	0.02 (.02)	0.17 (.05)	0.02 (.02)	0
American Robin	0.08 (.04)	0.17 (.04)	0.34 (.09)	0.10 (.02)
Nashville Warbler	0.12 (.06)	0.15 (.04)	0.34 (.10)	0.78 (.05)
Audubon's Warbler	0.58 (.11)	0.37 (.06)	0.29 (.08)	0.69 (.05)
Hermit Warbler	0.37 (.09)	0.30 (.07)	0.15 (.05)	1.26 (.06)
MacGillivray's Warbler	0.17 (.05)	0.21 (.06)	0.40 (.09)	0.33 (.03)
Western Tanager	0.22 (.07)	0.46 (.07)	0.14 (.06)	0.56 (.04)
Black-headed Grosbeak	0.08 (.04)	0.04 (.02)	0.20 (.07)	0.19 (.03)
Lazuli Bunting	0.02 (.02)	0.79 (.11)	0.83 (.21)	0.04 (.01)
Spotted Towhee	0.15 (.07)	0.07 (.03)	0.52 (.14)	0.13 (.02)
Chipping Sparrow	0.00	0.25 (.05)	0.23 (.08)	0.06 (.01)
Fox Sparrow	0.17 (.07)	0.46 (.10)	0.69 (.19)	0.43 (.06)
Oregon Junco	0.60 (.11)	0.77 (.10)	0.72 (.13)	0.69 (.04)
Cassin’s Finch	0.02 (.02)	0.09 (.03)	0.06 (.06)	0.02 (.01)

The Shannon index of diversity ranged from 5.77 in PLAS to 4.56 in the Cub Fire (Table 2). Similarly, species richness ranged from 6.37 in PLAS to 4.92 in the Cub Fire. Total bird abundance ranged from 5.08 in PLAS to 3.55 in the Cub Fire. Comparing these metrics by fire severity between each fire all three indices were higher in low severity areas of the Cub and Moonlight fires and higher in high severity areas of the Storrie fire (Figure 4). Species richness was highest in green forest of the PLAS and high severity areas of the Storrie fire, Shannon diversity was highest PLAS green forest, and total bird abundance was highest in the high severity areas of the Storrie fire.

Table 2. The mean per point Shannon diversity and species richness indices for the three fires and the Plumas Lassen Administrative Study in 2009 with standard error.

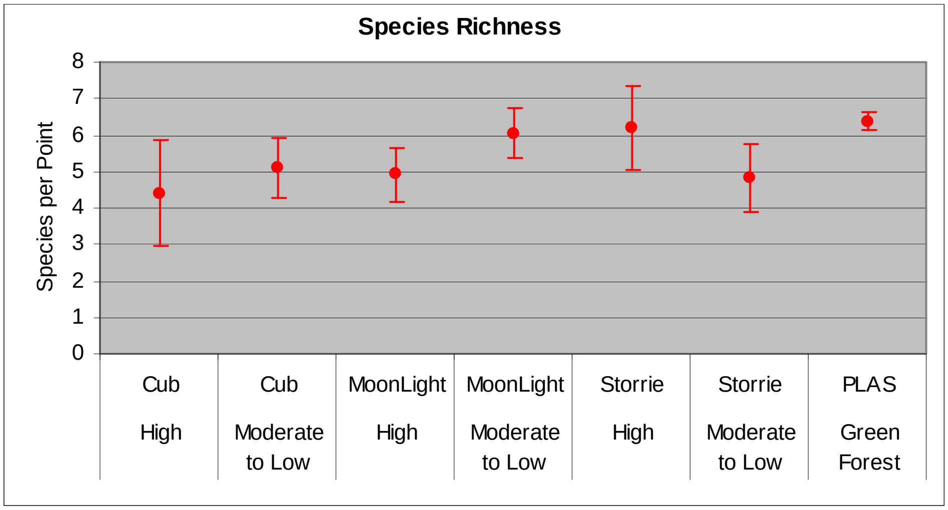
Metric	CUB	MOONLIGHT	STORRIE	PLAS
Diversity	4.56 (.31)	4.94 (.22)	4.77 (.30)	5.77 (.11)
Richness	4.92 (.34)	5.39 (.25)	5.38 (.35)	6.37 (.12)
Total Bird Abundance	3.55 (.28)	4.12 (.35)	4.58 (.35)	5.08 (.12)

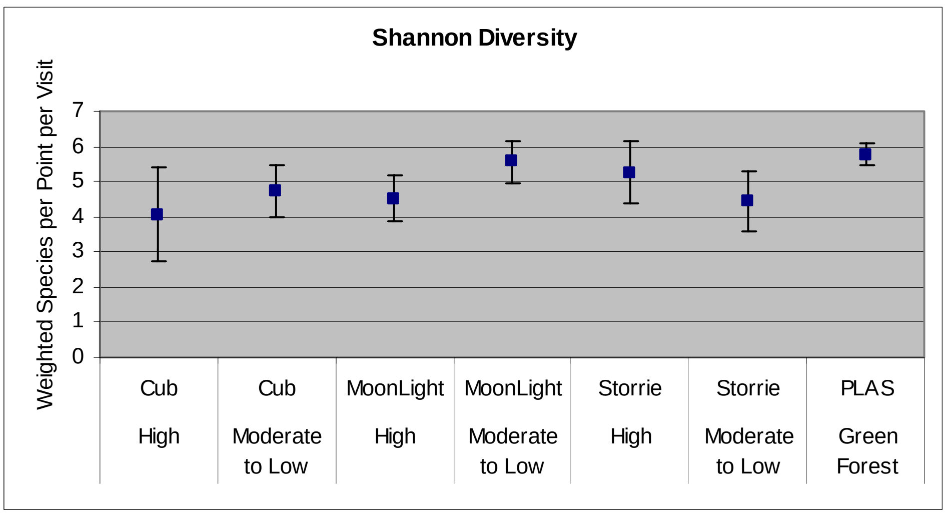
Cavity nest characteristics

A total of 64 active cavity nests were confirmed in 2009. The nest trees selected were quite variable in both size and species. The diameter at breast height (DBH) ranged from 12cm (4.7 inches) to 130cm (51.2 inches) and the height off the ground ranged from 2 to 31 meters. Nests were located in at least nine different tree species and we compared use of nest trees versus their availability across each of the three fires for all bird species combined (Figure 5). 38% of nests were found in true fir (primarily white fir) while it comprised 51% of the available trees, 17% were in Douglas Fir compared to 6% of available, 14% were in yellow pine compared to 13% of available, 6% were in aspen compared to 1% of available, 5% were in black oak compared to 4% of available, 2% were in incense cedar compared to 7% of available, and no nests were found in sugar pine though it comprised 4% of the available. For 16% of the nests and 13% of the random "nests" we were unable to identify the nest tree to species.

Some bird species showed a preference for tree species selected. White-headed Woodpecker (4 out of 10) and Mountain Bluebird (3 out of 10), nested in Yellow Pine (ponderosa or Jeffrey) more than its availability with 35% of their nests in these species while it comprised only 13% of the available nest trees. Red-breasted Sapsucker nests were only found in true Fir, Douglas fir, or Quaking Aspen. Hairy Woodpeckers nested primarily in Fir (both Douglas and true) with 8 out 10 nests in fir.

Figure 4. Avian community indices by burn severity at three fires in 2009 and green forest in the adjacent Plumas-Lassen Administrative Study area with 95% confidence intervals High severity = >50% overstory tree mortality and Moderate to Low severity = <50%.





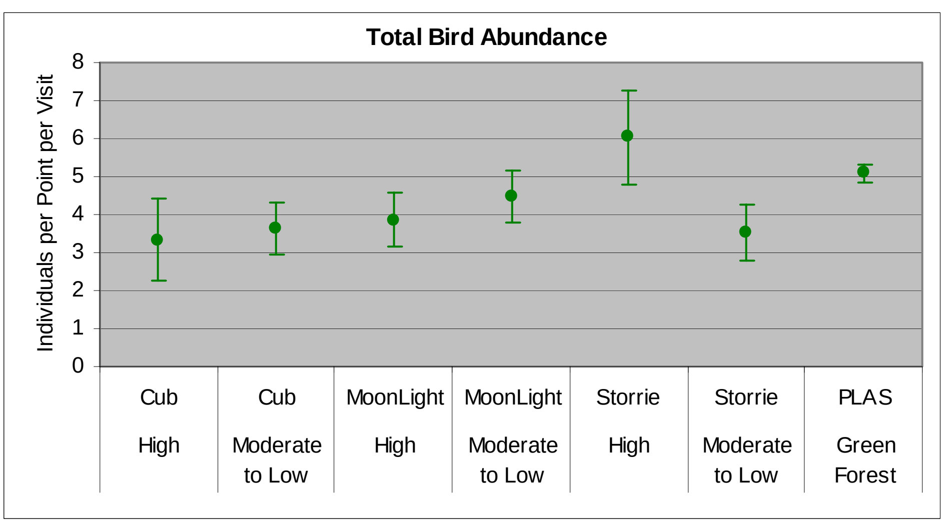
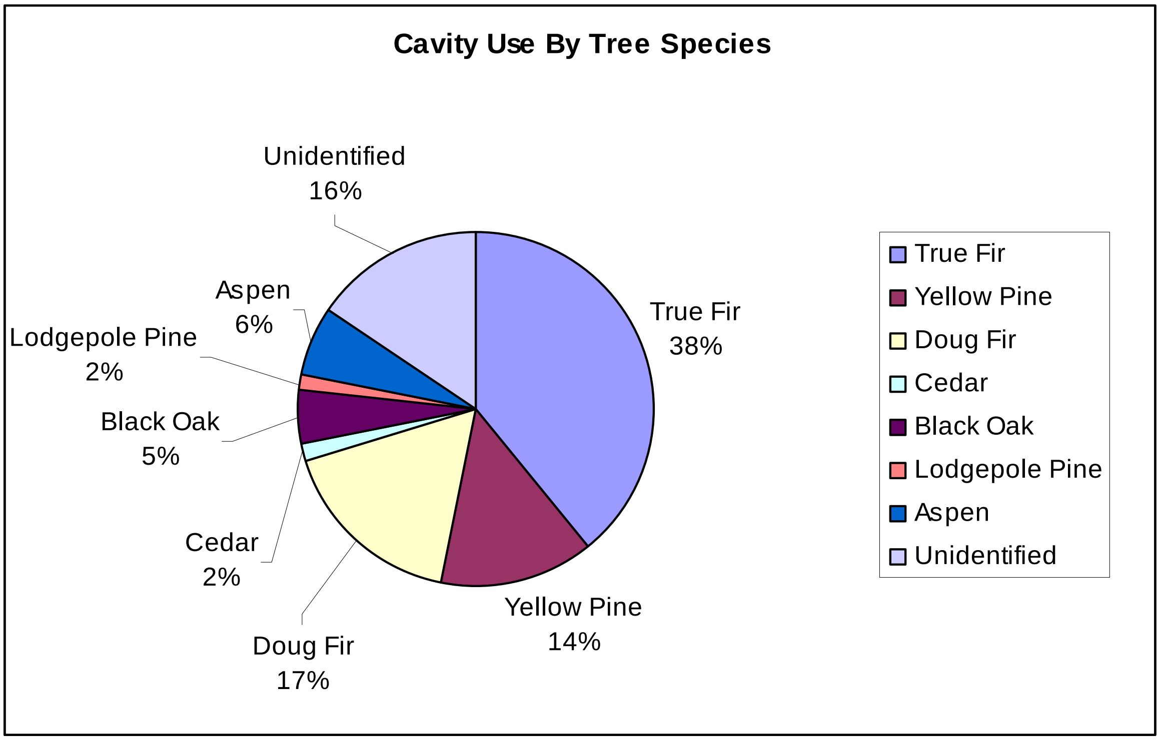
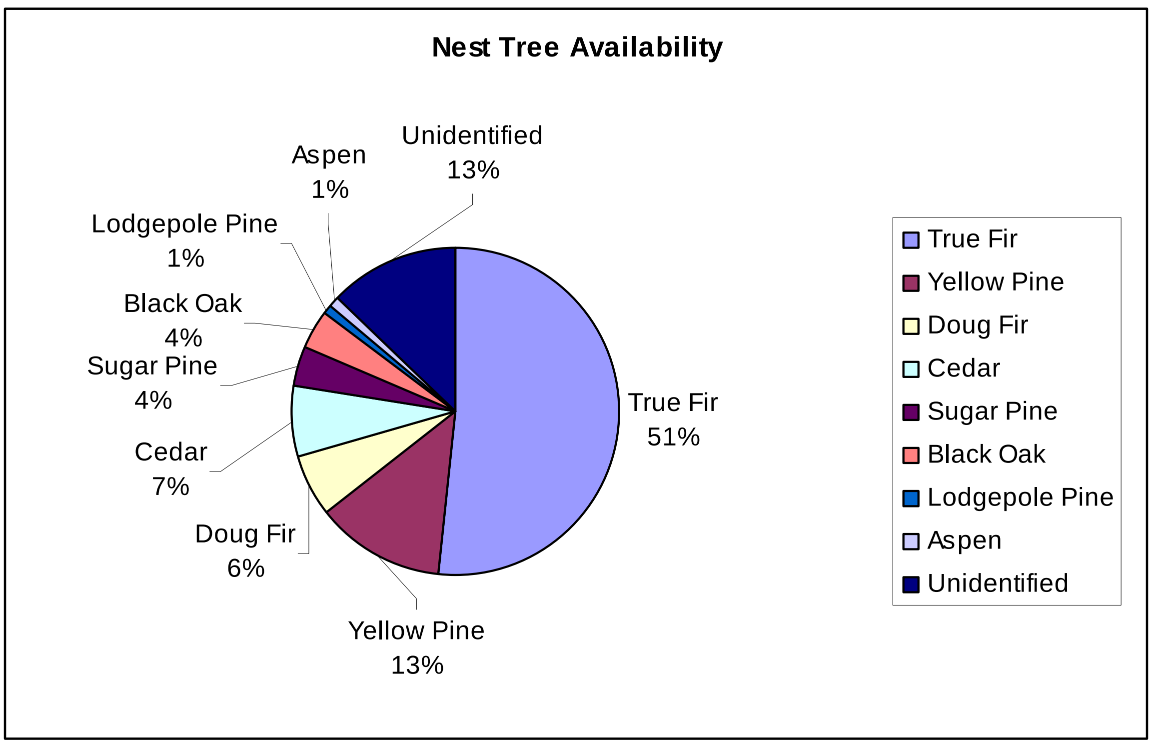


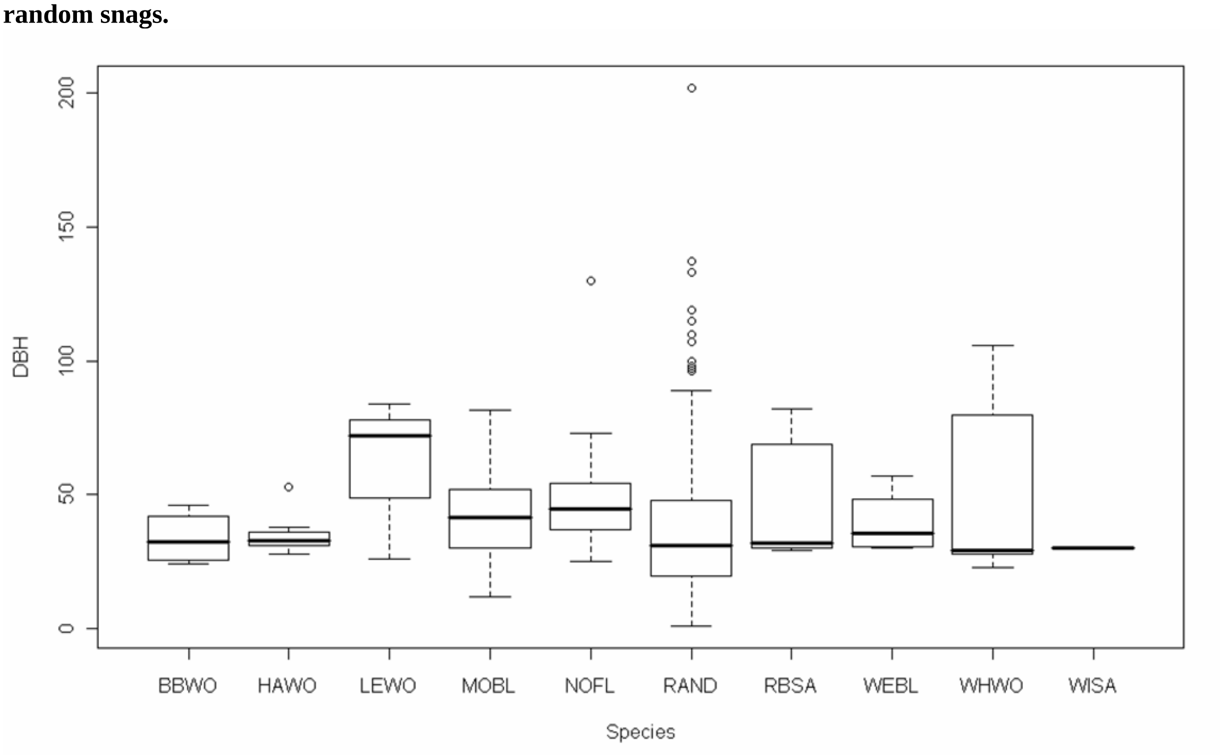
Figure 5. Avian cavity nest tree use compared to availability in the Cub, Moonlight, and Storrie Fires in 2009. Ponderosa and Jeffrey pine are combined under Yellow Pine and Red and White fir are combined under True Fir as snags of these species were difficult to determine to species.





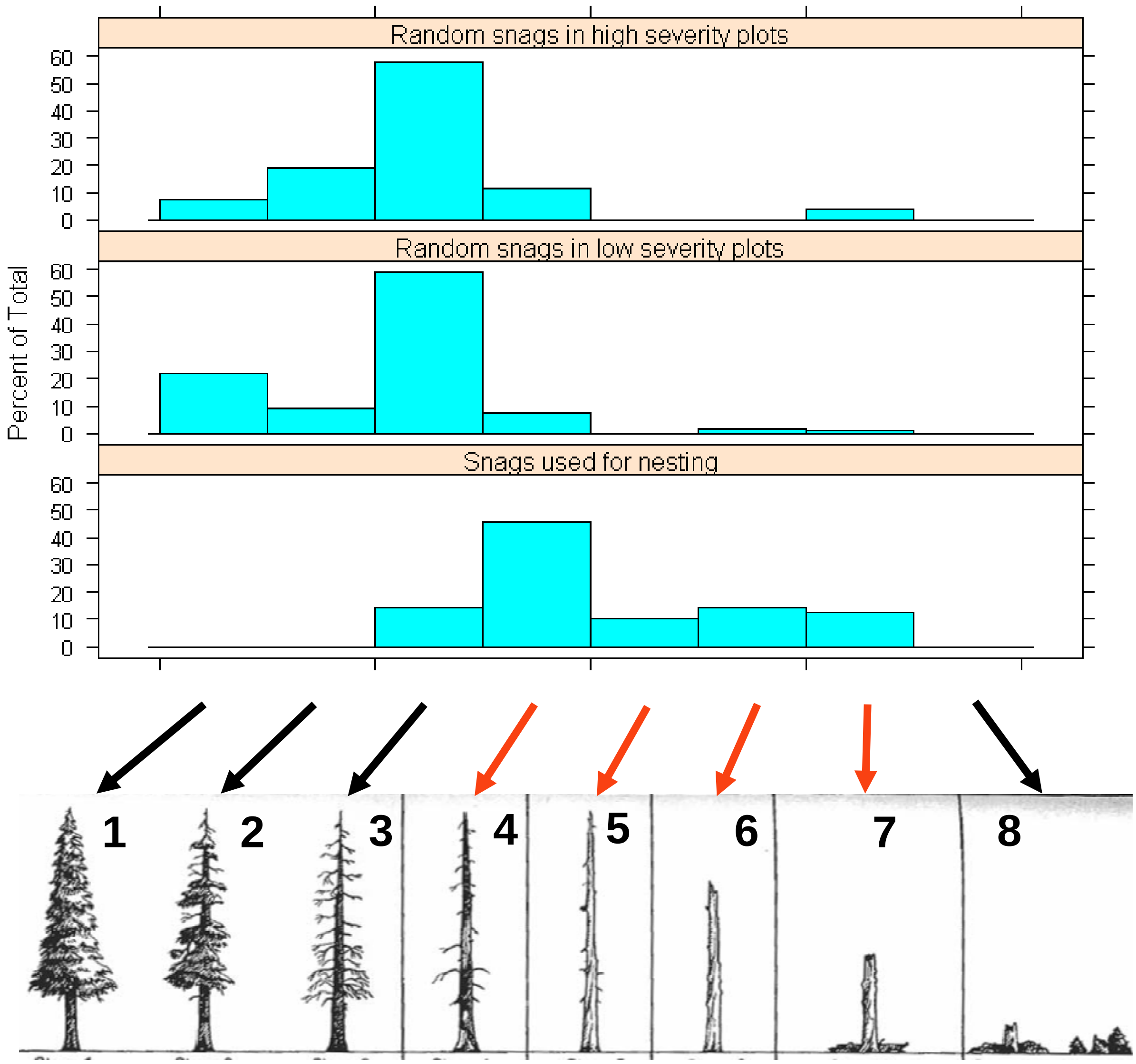
Almost all nests were in snags larger than 25cm DBH and typically in snags larger than the average snag size available. The size of trees used was quite variable and patterns were evident by species (Figure 6). Lewis' Woodpecker, Mountain Bluebird and Northern Flicker tended to select for considerably larger DBH nest trees compared to what was available while the remaining species used trees slightly larger than the average available. We found nests in trees with a DBH as small as 12cm (Mountain Bluebird) - and as large as 230cm (Northern Flicker).

Figure 6. The DBH of nest trees according to bird species with the random "nest" trees shown as species RAND. (BBWO – Black-backed Woodpecker, HAWO – Hairy Woodpecker, LEWO – Lewis's Woodpecker, MOBL – Mountain Bluebird, NOFL – Northern Flicker, RBSA- Red-breasted Sapsucker, WEBL - Western Bluebird, WHWO – White-headed Woodpecker, WISA – Williamson's Sapsucker). The diameter or snags used by cavity-nesting birds was almost always larger than 25 cm in diameter and typically larger than random snags.



There were two different patterns that emerged in terms of decay class, those bird species that preferred slightly decayed trees and those that preferred very decayed trees. However, all species selected for trees that were a higher decay class than was available (Figure 7). Only five nests were in trees with intact tops, four in trees with forked tops, one in a pile of logs at a landing, the other 54 were in trees with broken tops. The average decay class of nest trees for Black-backed Woodpecker, Hairy Woodpecker, Northern Flicker, Red-breasted Sapsucker and Williamson's Sapsucker were all between four and five. Whereas the average decay class for Lewis' Woodpecker, Mountain Bluebird, Western Bluebird, and White-headed Woodpecker were all greater than five (Figure 3). The average decay class of all trees available was three. The number of available snags in the decay classes selected for by cavity nesting birds did not vary between high severity (>50% overstory tree mortality) and moderate to low severity areas of the two recent fires (Cub and Moonlight; Figure 7).

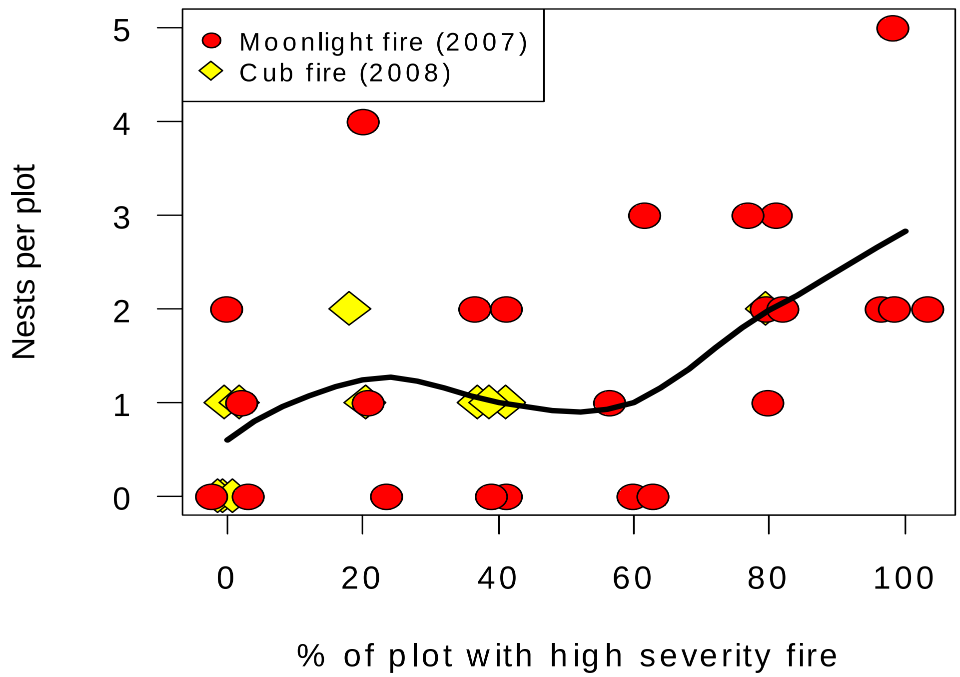
Figure 7. The distribution of decay classes in random snag plots in low-moderate and high severity fire areas compared to the distribution of snags by decay class where active nests were found in the Cub and Moonlight fires in 2009. Snags used for nesting were usually more decayed than the random sample of snags in high and low severity areas.

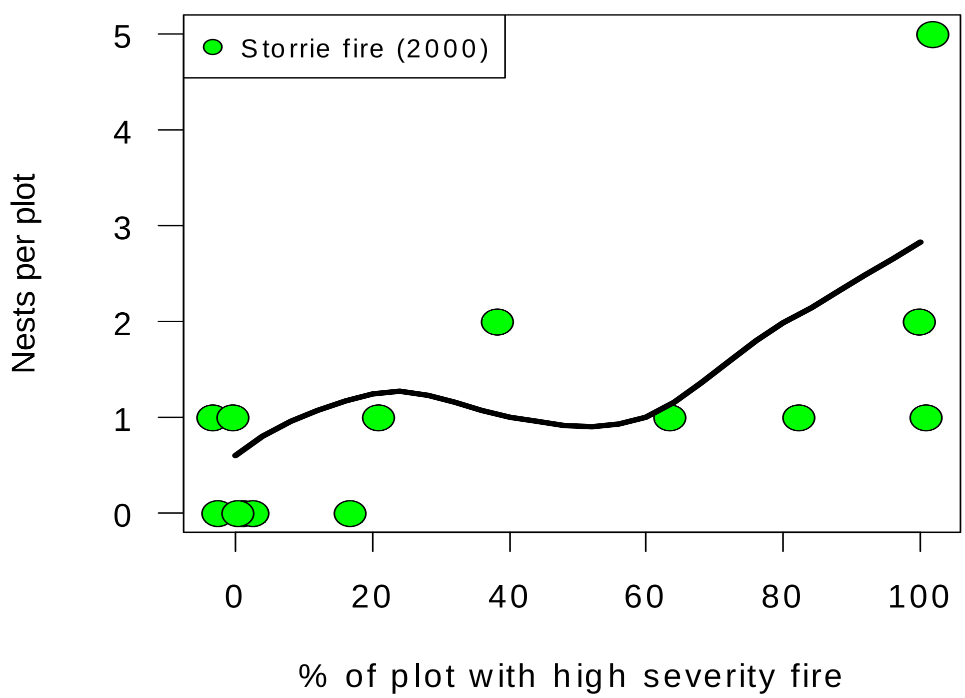


Nest Densities

Nest densities were highest in the Moonlight Fire and lowest in the Cub fire though the difference between any of the fires was not statistically significant (*P* = 0.3). Four out of the five plots with nest densities greater then two per plot were in the Moonlight fire with one in the Storrie Fire. Nest density did vary with respect to fire severity across the three fires and the effect was not linear (Figure 8). Nest densities were lowest in plots with no high severity fire, increased with modest amounts of high severity fire but varied little between 20% and 60% high severity. Once the amount of the plot that was high severity was over 60% the density of cavity nests increased substantially.

Figure 8. The number of cavity nests per plot in relation to the percent of the plot categorized as high severity based on vegetation surveys at point count stations in 2009 with fitted trend line. Trend line in Storrie fire graph is that predicted for the Cub and Moonlight fires for comparison. High severity was defined as overstory tree mortality greater than 50%.





Discussion

Overview

Post-fire habitat in the Plumas-Lassen study area supports a unique and moderately diverse bird community - compared to green forest in the region - including a number of rare and declining species. The disparity between green forest and burned avian assemblages was greatest between the two fires with the most high severity habitat (Storrie and Moonlight). However, all of the twenty most abundant bird species found in PLAS green forests were also detected in all three burned areas. Avian species associated with larger patches of mature green forest (e.g. Pileated Woodpecker, Hermit Thrush, Hammond's Flycatcher, Golden-crowned Kinglet, and Hermit Warbler) were detected in each of the fire areas suggesting these burned areas still contain enough green forest to support these species. Factors such as tree species, tree size, high severity patch size, and especially decay class influenced cavity nesting species nest tree choice and likely their densities across the three burned areas. High severity fire does not result - in the first two years following fire – in snags with the preferred decay condition used by cavity nesting species. Thus, pre-fire snag densities appear an important consideration for determining the occupancy of sites by cavity nesting birds immediately following fire. Post-fire habitat should be managed as a unique component in the Sierra Nevada as part of a balanced ecosystem approach in order to sustain biological diversity.

Avian Community Composition Burned vs. Green Forest

The difference in avian species diversity and total bird abundance between green forest and post-fire habitat in our study area was not clear cut. Per point species diversity and total bird abundance was generally greater in unburned forest than post-fire habitat. However, more total species were detected in the Moonlight fire which covers a much smaller geographic area and had far fewer sampling locations than the PLAS green forest. Green forest in our study area likely have greater structural diversity and total foliage volume at the point level which can support a greater diversity of species (McCarthur et al. 1966, Verner and Larson 1989), while post-fire habitats in our study area appear more heterogeneous on a landscape scale. Therefore, whether green forest or post-fire habitat supports greater avian diversity depends on the resolution at which the question is considered.

Further, when sites were stratified by fire severity, we found avian species richness in high severity areas in the oldest fire (Storrie) was equal to green forest and the total bird abundance was significantly greater at the point scale. Thus, our results suggest that within our study area, areas burned by wildfire, especially those with older high severity patches, may in some cases support equal or greater landbird diversity and total bird abundance at the point or patch scale which is consistent with what others have found in the region (Bock and Lynch 1970, Raphael et al. 1987, Fontaine et al. 2009).

While post-fire habitats clearly support a number of avian species, its most important attribute may be the unique species - those uncommon or rare in green forest - that are abundant in post-fire habitat. A few of these species (e.g. Chipping Sparrow, Western Wood-Pewee) are experiencing significant population decreases in the Sierra Nevada (Sauer et al. 2008).

The value of post-fire habitat for many species extends well beyond the first few years following fire. The abundance of some bark foraging birds has been shown to decline approximately five years after fire (Saab et al. 2004, Saab et al. 2009), presumably as a result of a decline in wood boaring beetle abundance (McCullough et al. 1998), and possibly as mammalian nest predators recolonize burn areas (Saab and Vierling 2001). However, as successional processes bring about change to burned areas the suitability of habitat is likely to increase for a number of aerial foraging cavity nesting species such as bluebirds, Lewis' Woodpecker, and swallows (Hobson and Schieck 1999, Saab et al. 2007) as well as shrub-dependent species such as Fox Sparrow and Mountain Quail (Bock and Lynch 1970, Raphael et al. 1987). In our study area, Fox Sparrow was more abundant in green forest than either the Cub or Moonlight fires but 1.6 times less abundant in green forest than in the Storrie fire. We observed similar patterns for several other shrub-dependent species including MacGillivray's Warbler and Spotted Towhee. As large patches of dense shrub cover develop in high severity patches of the Moonlight and Cub fires the abundance of many shrub dependent species will likely increase. The dense, relatively large patches of shrub habitat that develop following moderate to high severity fire support a number of species and, when interspersed with areas of green forest, are a key component for maximizing avian diversity in post-fire environments.

The abundance of different foraging guilds varied considerably between burned and unburned forest in our study area similar to patterns documented elsewhere in the western mountains (Bock and Lynch 1970, Raphael et al. 1987, Hutto 1995, Fontaine et al. 2009). Generally, we found foliage gleaning birds were more abundant in unburned forest and bark gleaning, aerial insectivores, and shrub and ground foraging species were more abundant in post-fire habitat. However, very few foliage gleaning birds present in green forest were absent from fire areas but a few in the fire associated guilds were absent from green forest (Lewis' Woodpecker, Black-backed Woodpecker, and Mountain Bluebird). In addition, a number of species quite common in post-fire areas were exceedingly rare in green forests of the PLAS. Lazuli Bunting, a species associated with shrubs and herbaceous understory vegetation, was the most abundant bird in the Moonlight fire, where it was 21 times more abundant than in the PLAS green forest. Two mature forest foliage gleaning birds, Hermit Warbler and Golden-crowned Kinglet, were five and four times more abundant respectively in green forest in 2009 compared to the Moonlight and Storrie fires. There is little question that these fires have resulted in a significant decrease in the suitable habitat and thus populations of many green forest species in these fire areas but, in 2009, almost all green forest associated species found in the PLAS were still occupying habitat within both of these fires. Thus, the needs of mature green forest species species should be considered in post-fire management.

Cavity Nesting Densities and Nest Snag Characteristics

The importance of post-fire habitats for cavity nesting and bark foraging birds is well established (Raphael et al. 1987, Hutto 1995, Saab and Dudley 1998). However, little information exists for the Sierra Nevada describing the important characteristics in post-fire snag-dominated habitats that determine the density and diversity of cavity nesting species. Our results here provide some of the first detailed information for a whole suite of cavity nesting species in post-fire habitat in the Sierra Nevada.

Almost all species selected for more decayed trees and generally used the existing pre-fire snags in the recent burns. In at least the first two years following fire, the majority of available snags were not in the decay classes selected for by cavity nesting species regardless of fire severity. This suggests that in post-fire habitat the presence of existing snags is critical for providing suitable nesting substrate until fire killed trees obtain a greater amount of decay which aligns well with what Hutto (1995) found in the Northern Rockies. This lack of suitable nest substrate is a likely the reason for the observed peak in woodpecker density four to five years after a fire (Saab et al. 2004), even though wood boring beetle abundance may peak sooner (McCullough et al. 1998). Thus, the necessary tree decay for suitable nesting substrate may not be obtained until after food availability has begun to wane. Maximizing habitat suitability for bark foraging-cavity nesting birds appears a function of managing for sufficient snag densities in green forest prior to fire.

The density of snags and size of high severity patches has been shown to influence the density of cavity nesting species in post-fire habitat (Saab et al. 2004, Dudley and Saab 2007, Hutto 2006). Nest densities in all three fires in our study appeared increase with the proportion of the plot that burned with high severity. This pattern continues to support the hypothesis that cavity nesting birds favor larger patches of high fire severity. Our plots were 20ha (49 acres), which probably represents a minimum patch size of high severity to maintain. However, more detailed analysis has suggested a minimum 200ha of high severity high snag density (>250 snags/acre) habitat is a minimum patch size for species such as Black-backed Woodpecker (Dudley and Saab 2007). Further investigation using GIS based analysis of patch size in future years will provide a greater understanding of the size and overall importance of landscape scale patterns on species associated with post-fire habitat.

In addition to managing large areas with high snag densities for cavity nesting and foraging species, when considering replanting patterns patch size is also important for shrub dependent species. Fox Sparrow, average territory size in the Northern Sierra is between two and three hectares (PRBO unpublished data), and their abundance precipitously increases as the area within a 500 m radius (78.5 ha, 196 acre) is comprised of greater amounts of shrub habitat (Howell and Burnett *In review*).

Interestingly, we found a similar pattern of high severity burn area and nest density in the nine year post-burn habitat of the Storrie fire as in the Moonlight and Cub fires. With only one year of data sample sizes are relatively low to discern a clear pattern but, we found that at least some areas of the Storrie fire that burned at high severity are still supporting relatively high densities of many cavity nesting birds. This suggest post-fire treatments being planned and carried out in the Storrie fire should still consider the needs of species dependent upon relatively large high severity and high snag density patches.

Conclusions

In the Sierra Nevada considerable debate surrounds the management of post-fire habitat. After nearly a century of fire suppression policies in the Sierra Nevada, the area affected by wildfire each year appears to be increasing back towards pre-suppression levels (Miller et al. 2007). Thus, there is a growing need to understand the value of the habitats created by wildfire and the critical elements required by the unique and relatively diverse avian community in the Sierra Nevada. It is clear from our first year of monitoring three burned areas that post-fire habitat, especially high severity areas, are an important component of the Sierra Nevada ecosystem.

Wildfires provide a unique opportunity to mold a landscape into the forest composition that will exist there for the decades to come. However, post-fire areas are not blank slates or catastrophic wastelands; they are a unique component of the ecosystem that supports a diverse and abundant avian community that should be considered in planning post-fire management. The results from this ongoing study, especially with several more years of monitoring, can provide some important information on factors influencing the unique bird assemblages in post-fire habitat in order to ensure their needs are met while meeting other post-fire objectives.

In future years we will conduct a more detailed analysis of fire severity at different scales and using standard measures used to classify burn severity (e.g. composite burn index). Additionally, we will use available remotely sensed data on burn severity and possibly LiDAR data to better understand the importance of severity class, patch size, and snag densities for the various species associated with post-fire habitat. Finally, we will compare bird assemblages within fuel reduction treatments in green forest, post-fire treatments, and untreated post-fire habitat to determine the effects of various treatments on a broad range of avian species to provide insight for a balanced approach to management of these forest ecosystems.

Literature Cited

Agee, J.K. 1993. Fire ecology of Pacific Northwest Forests. Island Press. Washington, D.C.

Bock, C. E. and J. F. Lynch.1970. Breeding bird populations of burned and unburned conifer forest in the Sierra Nevada.Condor 72:182-189.
Agee, J.K. 1993. Fire ecology of Pacific Northwest Forests. Island Press. Washington, D.C.

Brawn, J.D., S.K. Robinson, and F.R. Thompson. 2001. The role of disturbance in the ecology and conservation of birds. Annual Review of Ecological Systems 32, 251-276.

Burnett, R.D., N.Nur, and C.A.Howell. *In review*. Implications of spotted owl management for landbirds in the Sierra Nevada, CA, USA. Forest Ecology and Management.

Dudley, J.G. and V.A. Saab. 2007. Home range size of Black-backed Woodpeckers in burned forests of Southwestern Idaho. Western North American Naturalist 67: 593-600.

Fontaine, J., D. Donato, D. Robinson, B. Law, and J. Kaufman. Bird communities following high-severity fire: Response to single and repeat fires in a mixed-evergreen forest, Oregon, USA. Forest Ecology and Management 257: 1496-1504.

Howell, C.A. and R.D. Burnett. *In review*. Landscape effects on songbird abundance in the Northern Sierra Nevada, USA. Forest Ecology and Management.

Huff, M.H., N.E. Seavy, J.D. Alexander, and C.J. Ralph. 2005. Fire and birds in maritime pacific northwest. Studies in Avian Biology 30:46-62.

Hutto, R.L. 1995. Composition of bird communities following stand-replacement fires in Northern Rocky Mountain (U.S.A.) conifer forests. Conservation Biology 9:1041-1058.

Hutto, R.L. 2006. Towards meaningful snag management guidelines for postfire salvage logging in North American conifer forests. Conservation Biology 20: 984-993.

Hutto, R.L. 2008. The ecological effects of high severity fire: some like it hot. Ecological Applications 18:1827-1834.

MacArthur, R., H. Recher, and M. Cody. 1966. On the relation between habitat selection and species diversity. Amer. Natur. 100: 319-332.

McCullough, D.G., R.A. Werner, and D. Neumann. 1998. Fire and insects in northern and boreal forest ecosystems of North America. Annual Review of Entomology 43:107-127.

Ralph, C.J., S. Droege, and J.R. Sauer. 1995. Managing and monitoring birds using point counts: standards and applications. In C. J. Ralph, J. R. Sauer and S. Droege (eds.), Monitoring Bird Populations by Point Counts. USDA Forest Service Publication, Gen. Tech. Rep. PSW-GTR-149, Albany, CA .

Raphael, M.G., M.L. Morrison, and M.P. Yoder-Williams. 1987. Breeding bird populations during twenty five years of post-fire succession in the Sierra Nevada. The Condor 89, 614-626.

Reynolds, R.T., J.M. Scott, and R.A. Nussbaum. 1980. A variable circular plot method for estimating bird numbers. Condor 82:309:313.

Saab, V. and K. Vierling. 2001. Reproductive success of Lewis' Woodpecker in burned pine and cottonwood riparian forests. Condor 103: 491-501.

Saab, V., R. Brannon, J. Dudley, L. Donohoo, D. Vanderzanden, V. Johnson, and H. Lachowski. 2002. Selection of fire-created snags at two spatial scales by cavity-nesting birds. Gen. Tech. Rep. PSW-GTR-181. http://www.fs.fed.us/psw/publications/documents/gtr-181/062_Saab.pdf

Saab, V., J. Dudley, W. Thompson. 2004. Factors influencing occupancy of nest cavities in recently burned forests. Condor 106: 20-36.

Saab, V. R. Russell, and J. Dudley. 2009. Nest-site selection by cavity-nesting birds in relation to postfire salvage logging. Forest Ecology and Management 257: 151-159.

Sauer, J. R., J. E. Hines, and J. Fallon. 2008. The North American Breeding Bird Survey, Results and Analysis 1966 - 2007. Version 5.15.2008. USGS Patuxent Wildlife Research Center, Laurel, MD.

Smucker, K.M., R.L. Hutto, and B.M. Steele. 2005. Changes in bird abundance after wildfire: importance of fire severity and time since fire. Ecological Applications 15:1535-1549.

Stine, P., Landram, M., Keane, J., Lee, D., Laudenslayer, B., Weatherspoon, P., and Baldwin, J. 2002. Fire and fuels management, landscape dynamics, and fish and wildlife resources: An integrated research plan for the Herger-Feinstein Quincy Library Group Pilot Study Area. http://www.fs.fed.us/psw/programs/snrc/forest_health/plas_studyplan.pdf

Verner, J. and T.A. Larson. 1989. Richness of breeding bird species in mixed-conifer forest of the Sierra Nevada, California. Auk 106:447-463.

Appendix A. Outreach and Publications

In Press
Nesting Ecology of Yellow Warblers in Montane Chaparral Habitat in the Northern Sierra Nevada – Western North American Naturalist

In Revision
Landbird community composition in the context of Spotted Owl management in the Sierra Nevada – resubmitting summer 2010.

In prep
Short-term response of avian species to fuel treatments in the Sierra Nevada – draft submitting for publication spring 2010.

Presentations
Short-term response of avian species to fuel treatments in the Sierra Nevada – oral presentation at the Annual PLAS symposium Quincy, CA April 2009

Managing post-fire habitat for birds in the Sierra Nevada – poster presentation – Pre and Post-Wildfire Forest Management for Ecological Restoration and Fire Resiliency Conference – Sacramento, CA 2/10/10.

PRBO's Sierra Nevada Program – Management Indicator Species Online Tools – Regional Biologist Training – Susanville, CA. 2/2/10

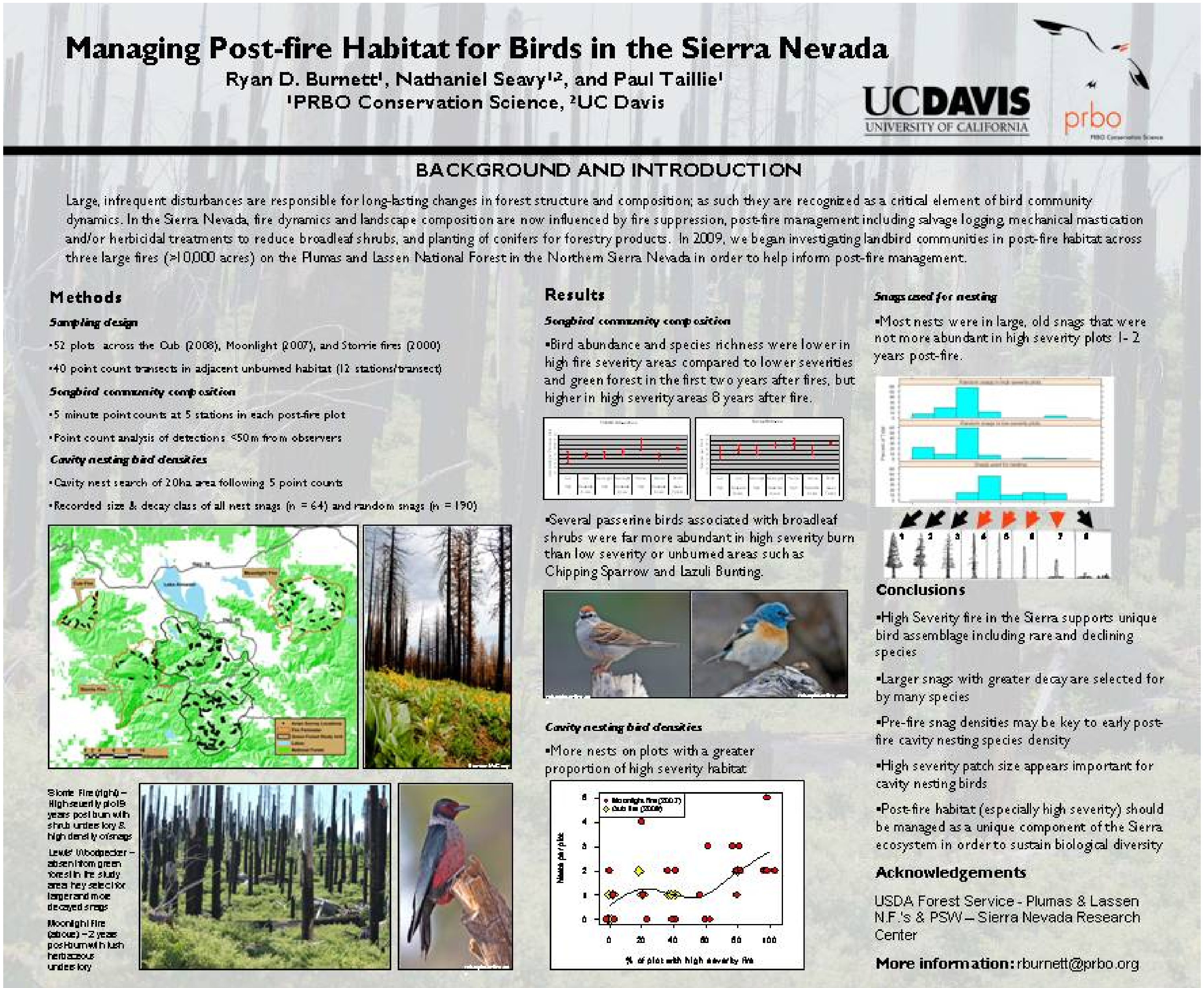
Forest Management, Fire, and Climate Change in the Sierra Nevada – PRBO Board of Directors and Friends Holiday meeting – San Francisco, CA – 12/9/09

Other Outreach
"Birds in the Park" – presentation on managing coniferous forest for birds and bird banding demonstration in collaboration with Lassen Volcanic National Park – over 200 park visitors participated 7/20/08.

"Habitat for Birds and Humanity" – Sierra Institute for Community and Environment sponsored field trip. – 6/28/2009

Participated in several Lassen National Forest field trips to discuss fuel reduction projects.

Appendix B. Managing Post-fire Habitat for Birds in the Sierra Nevada Poster



Appendix C. PRBO's Plumas-Lassen Study sites with dates surveyed in 2009.

Transect	Transect Code	1st Visit	2nd Visit
Cub 01	CB01	5/28/2009	6/23/2009
Cub 02	CB02	5/28/2009	6/23/2009
Cub 03	CB03	6/1/2009	6/24/2009
Cub 05	CB05	6/1/2009	6/24/2009
Cub 07	CB07	6/3/2009	6/25/2009
Cub 08	CB08	6/2/2009	6/24/2009
Cub 09	CB09	6/2/2009	6/25/2009
Cub 10	CB10	6/2/2009	6/25/2009
Cub 11	CB11	6/2/2009	6/25/2009
Cub 12	CB12	6/2/2009	6/24/2009
Cub 13	CB13	6/13/2009	6/29/2009
Cub 14	CB14	6/9/2009	6/24/2009
Moonlight 01	ML01	5/28/2009	6/17/2009
Moonlight 02	ML02	5/26/2009	6/18/2009
Moonlight 03	ML03	5/28/2009	6/19/2009
Moonlight 04	ML04	5/27/2009	6/22/2009
Moonlight 05	ML05	5/26/2009	6/17/2009
Moonlight 06	ML06	5/31/2009	6/20/2009
Moonlight 07	ML07	6/1/2009	6/22/2009
Moonlight 09	ML09	6/1/2009	6/20/2009
Moonlight 10	ML10	5/31/2009	6/20/2009
Moonlight 11	ML11	5/27/2009	6/22/2009
Moonlight 12	ML12	5/27/2009	6/23/2009
Moonlight 13	ML13	5/27/2009	6/22/2009
Moonlight 14	ML14	6/1/2009	6/22/2009
Moonlight 15	ML15	5/27/2009	6/20/2009
Moonlight 16	ML16	5/25/2009	6/19/2009
Moonlight 17	ML17	5/30/2009	6/19/2009
Moonlight 18	ML18	5/28/2009	6/19/2009
Moonlight 19	ML19	5/28/2009	6/19/2009
Moonlight 20	ML20	5/29/2009	6/20/2009
Moonlight 21	ML21	5/29/2009	6/23/2009
Moonlight 22	ML22	5/29/2009	6/23/2009
Moonlight 23	ML23	5/26/2009	6/18/2009
Moonlight 24	ML24	6/1/2009	6/20/2009
Moonlight 25	ML25	5/26/2009	6/19/2009
Moonlight 26	ML26	5/27/2009	6/22/2009
Moonlight 27	ML27	5/26/2009	6/17/2009
Storrie 01	ST01	6/17/2009	6/26/2009
Storrie 02	ST02	6/15/2009	7/1/2009

Transect	Transect Code	1st Visit	2nd Visit
Storrie 03	ST03	6/15/2009	7/1/2009
Storrie 04	ST04	6/9/2009	6/29/2009
Storrie 05	ST05	6/12/2009	6/30/2009
Storrie 06	ST06	6/3/2009	6/29/2009
Storrie 07	ST07	6/13/2009	7/1/2009
Storrie 08	ST08	6/16/2009	6/30/2009
Storrie 09	ST09	6/8/2009	7/1/2009
Storrie 10	ST10	6/8/2009	6/26/2009
Storrie 11	ST11	6/15/2009	6/27/2009
Storrie 12	ST12	6/10/2009	6/29/2009
Storrie 13	ST13	6/8/2009	6/27/2009
Storrie 15	ST15	6/9/2009	6/25/2009
Unit 2 13	213	5/22/2009	6/18/2009
Unit 2 14	214	5/23/2009	6/15/2009
Unit 2 22	222	5/25/2009	6/16/2009
Unit 2 24	224	5/22/2009	6/18/2009
Unit 3 13	313	5/25/2009	6/16/2009
Unit 3 22	322	5/25/2009	6/16/2009
Unit 4 13	413	5/20/2009	6/11/2009
Unit 4 14	414	5/19/2009	6/17/2009
Unit 4 22	422	5/20/2009	6/23/2009
Unit 4 24	424	5/18/2009	NS
Black Hawk Creek 1	BLH1	5/20/2009	6/10/2009
Butt Valley Reservoir 3	BVR3	5/19/2009	6/13/2009
Caribou 2	CAR2	5/30/2009	6/26/2009
Caribou 3	CAR3	5/30/2009	6/26/2009
DFPZ Unit 4 01	D401	5/19/2009	6/11/2009
DFPZ Unit 4 02	D402	5/16/2009	6/5/2009
DFPZ Unit 4 03	D403	5/18/2009	6/12/2009
DFPZ Unit 4 04	D404	5/18/2009	6/8/2009
DFPZ Unit 4 05	D405	5/16/2009	6/6/2009
DFPZ Unit 4 07	D407	5/18/2009	6/5/2009
DFPZ Unit 4 08	D408	5/23/2009	6/11/2009
Halsted Flat 3	HAL3	5/18/2009	6/6/2009
Lower Knox Flat 1	LKF1	5/20/2009	6/12/2009
Lower Knox Flat 3	LKF3	5/20/2009	6/16/2009
Miller’s Fork 1	MIF1	5/23/2009	6/11/2009
Miller’s Fork 2	MIF2	5/25/2009	6/11/2009
Miller’s Fork 3	MIF3	5/19/2009	6/11/2009
Meadow Valley 1	MVY1	5/16/2009	6/5/2009
Meadow Valley 2	MVY2	5/23/2009	6/17/2009
Ohio Creek 2	OHC2	5/22/2009	6/18/2009

Transect	Transect Code	1st Visit	2nd Visit
Pine Leaf Creek 1	PLC1	5/16/2009	6/5/2009
Seneca 1	SEN1	5/22/2009	6/18/2009
Silver Lake 1	SIL1	5/30/2009	6/26/2009
Silver Lake 2	SIL2	5/30/2009	6/26/2009
Silver Lake 3	SIL3	5/19/2009	6/15/2009
Snake Lake 2	SNK2	5/18/2009	6/6/2009
Snake Lake 3	SNK3	5/16/2009	6/6/2009
Soda Creek 1	SOD1	5/21/2009	6/12/2009
Soda Creek 2	SOD2	5/21/2009	6/12/2009
Spanish Creek 2	SPC2	5/20/2009	6/10/2009