Point Blue Conservation Science

# Avian Monitoring of the Freds and Power Fire Areas

2014 Annual Report

April 2015

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Cover photo*: Lewis's Woodpecker (*Melanerpes lewis), *a rare woodpecker across the Sierra Nevada landscape, can be found nesting in both the Freds and Power Fires. Photos by Tom Grey and Richard Aracil, respectively.*

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## EXECUTIVE SUMMARY

In this report we present our 2014 activities and preliminary results of avian monitoring in post-fire habitats of the Freds and Power fires. We compared data collected within the fires to locations outside of burned areas on adjacent National Forest lands and were able to detect significant differences in abundance for individual bird species between burned and unburned areas. In addition, we compared metrics of abundance and richness for three avian guilds relative to levels of fire severity and post-fire management actions, including salvage logging and reforestation. We also completed avian monitoring in the 2008 Government Fire on the Tahoe National Forest but do not present results in this report. We added Government Fire to our post-fire monitoring sample to better represent younger fires with less management activities.

**2014 Activities**

- We established and surveyed point count locations in the Freds Fire (94 point count stations on 9 transects) that overlapped the Region 5 Vegetation Ecology Program Common Stand Exam plots.
- We established and surveyed point count locations in the Power Fire (148 point count stations on 15 transects) that overlapped regeneration plots established by the Region 5 Ecology program.
- We collected vegetation/habitat data at 109 point count stations located in the Power Fire footprint.
- We established and surveyed point count locations in the Government Fire, located on Tahoe National Forest and burned in 2008 (129 point count stations on 26 transects).

**Post-Fire Habitat Management Recommendations**

Recommendations are a synthesis of our results, scientific literature, and expert opinion from 15 years of studying birds in the Sierra Nevada. Some of these are hypotheses that should be tested and further refined to ensure they are achieving the desired outcome of sustaining biological diversity in the Sierra Nevada.

*General*

- Whenever possible restrict activities that depredate breeding bird nests and young to the non-breeding season (August–April).
- Consider post-fire habitat as an important component of the Sierra Nevada ecosystem because it maintains biological diversity.

- Consider the area of a fire that burned at high severity, as opposed to the area of the entire fire, when determining what percentage of the fire area to salvage log. Consider the natural range of variability for high severity patch size, as not all of these areas should be targeted for salvage logging.
- Consider the landscape context (watershed, forest, and ecosystem) and availability of different habitat types when planning post-fire management actions.
- Approach post-fire management through a climate-smart lens - use the past to inform but plan for the future – find solutions that promote resiliency and foster adaptation.
- Use existing climate predictions of vegetation communities to guide reforestation locations and species mixes. Favor fire-tolerant species and consider whether lower elevations on south-facing slopes should be planted with conifers.
- Monitor, evaluate, be patient, strategic, and constrained in aiding the recovery of a post-fire landscape.

*Snags*

- Manage a substantial portion of post-fire areas for large patches (20–300 acres) burned at high severity as complex early seral forest for wildlife.
- Retain high severity burned habitat in locations with higher densities of medium to larger diameter trees.
- Retain high severity patches in areas where pre-fire snags are abundant as these are the trees most readily used in the first three years after a fire by cavity nesting birds.
- Retain snags in salvaged areas in far greater densities than green forest standards and retain snags in dense clumps.
- Snag retention immediately following a fire should aim to achieve a range of snag conditions from heavily decayed to recently dead in order to ensure a long lasting continuous source of suitable cavity and foraging trees.
- When reducing snags in areas more than five years post-fire, snag retention should favor large pine and Douglas fir, but decayed snags of all species with broken tops should be retained in recently burned areas.
- Consider that snags in post-fire habitat are still being used by a diverse and abundant avian community well beyond the 5 to 10 year horizon of Black-backed Woodpecker use.

- 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 patches for decades to come.
- Consider retaining smaller snags in heavily salvaged areas to increase snag densities because a large range of snags sizes are used by a number of species for foraging and nesting from as little as 6 inches DBH. Though, most cavity nests were in snags over 15 inches DBH.

*Early Successional Habitat*

- 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 conifer dominated ecosystems.
- Most shrub patches should be at least 10-15 acres and shrub cover should average over 50% across the patch acreage. Within the shrub patch, manage for denser clumps (>70%) in order to support area-sensitive species such as Fox Sparrow.
- Retain natural oak regeneration with multiple stems as these dense clumps create valuable understory bird habitat in post-fire areas 5–15 years after the fire.
- In highly decadent shrub habitat consider burning or masticating half the area (in patches) in one year and burning the remaining area several years later once fuel loads have been reduced.
- Maximize the use of prescribed fire to create and maintain chaparral habitat and consider a natural fire return interval of 20 years as the targeted re-entry rotation for creating disturbance in these habitat types.

*Shaping Future Forest*

- Limit replanting of dense stands of conifers in areas with significant oak regeneration and when replanting these areas use conifer plantings in clumps to enhance the future habitat mosaic of a healthy mixed conifer hardwood or pine-hardwood stand.
- Consider managing smaller burned areas (<5000 acres) and substantial portions of larger fires exclusively for post-fire resources for wildlife especially when there have been no other recent fires (within the last 10 years) in the adjoining landscape.
- Retain patches of high severity burned areas adjacent to intact green forest patches as the juxtaposition of unlike habitats is positively correlated with a number of avian

species, including those declining such as Olive-sided Flycatcher, Western Wood-Pewee, and Chipping Sparrow.

- Incorporate fine scale heterogeneity in replanting by clumping trees with unplanted areas interspersed to create fine scale mosaics that will invigorate understory plant communities, increase, natural recruitment of shade intolerant tree species and help reduce future fire risk.
- Plant a diversity of tree species where appropriate, as mixed conifer stands generally support greater avian diversity than single species dominated stands in the Sierra Nevada.
- Consider staggering plantings across decades and leaving areas to naturally regenerate in order to promote uneven-aged habitat mosaics at the landscape scale.
- Consider fuels treatments to ensure the fire resiliency of remnant stands of green forest within the fire perimeter. These areas increase avian diversity within the fire and the edges between unlike habitats support a number of species (e.g. Olive-sided Flycatcher).
- Avoid planting conifer species in or adjacent (depends on the size of riparian corridor) to riparian areas, primarily in the floodplain, to avoid future shading of riparian deciduous vegetation from the south or west and desiccation of these areas.
- Consider replanting riparian tree species (cottonwood, willow, alder, aspen) in riparian conservation areas affected by stand replacing fire where natural regeneration is lacking.

## INTRODUCTION

After nearly a century of successful fire suppression (Calkin et al. 2005), the subsequent densification of Sierra Nevada forests and accumulation of fuels (Sugihara et al. 2005), has led to increasingly large and severe wildfires across the range (Miller and Safford 2012; Steel et al. 2015). With the important role of fire as a primary driver of ecosystem form and function, there is a substantial need to understand the value of habitats created and altered by wildfire and how post-fire habitats are used by the unique avian community that occupy them. In the Sierra Nevada, considerable debate surrounds the management of post-fire habitat. Management actions in post-fire habitat affect the forest composition and structure that could persist for decades. Thus, it is necessary to carefully consider the species using post-fire habitat under different management prescriptions soon after fire and post-fire. With an increasing emphasis on ecological restoration to improve ecosystem resilience and the delivery of ecosystem services, there is also a need to use monitoring to minimize tradeoffs, seek complementarities among values, and optimize benefits among objectives (Hutto and Belote 2013).

Until recently there has been little study of bird communities in post-fire areas in the Sierra Nevada. Starting in 2009 Point Blue (formerly PRBO) Conservation Science began studying bird communities within burned areas in the Lassen and Plumas National forests and in 2014 expanded into the Eldorado National Forest on the Freds and Power Fires. In 2014, we also established bird monitoring within the 2008 Government Fire (also known as the American River Complex Fire) on Tahoe National Forest and the 2013 Rim Fire on Stanislaus National Forest. By expanding the work we began in the northern Sierra and including fires of different age, severity and management throughout the Sierra Nevada, we have increased our ability to detect differences in avian trends in relation to these variables. While we have provided a considerable amount of new information to help guide the management of burned areas, especially recently burned areas, many uncertainties remain. For example, snag retention in salvaged areas and reforestation remain significant parts of the ongoing debate over managing landscapes following large fires and our findings will help inform the future design of such management actions.

The 2004 Freds and Power fires afforded several opportunities to increase our knowledge of the effects of fire and post-fire management on Sierra Nevada avian communities. Both fires were 10 years old as of 2014 and have experienced varying levels of salvage logging and reforestation across portions of the burned area. Previous studies of the effects of salvage logging on forest avian communities have largely focused outside of the Sierra Nevada and often only on relatively short-term effects (e.g. Hutto and Gallo 2006, Saab et al. 2007, Cahall and Hayes 2008, Kronland and Restani 2011, Rost et al. 2013), yet in some forested ecosystems salvage logging can reduce snag abundance for over 50 years following harvest (Lindenmayer et al. 1997). To our knowledge there are currently no studies looking at salvage logging effects on avian communities in the Sierra Nevada a decade or more following fire. This and subsequent reports on avian monitoring in burned areas of the Eldorado National Forests will therefore help fill an important gap in our knowledge of ecological restoration following fire in this ecosystem.

In this report, we assess the effects of fire, degree of fire severity, and two post-fire management actions on birds ten years following two major fires in the central Sierra mixed-conifer zone. The findings presented here compliment a growing body of research into the effects of fire and post-fire management on montane and forest bird communities. Their value for management will increase as we continue data collection and analysis in subsequent years.

# METHODS

## Study Location

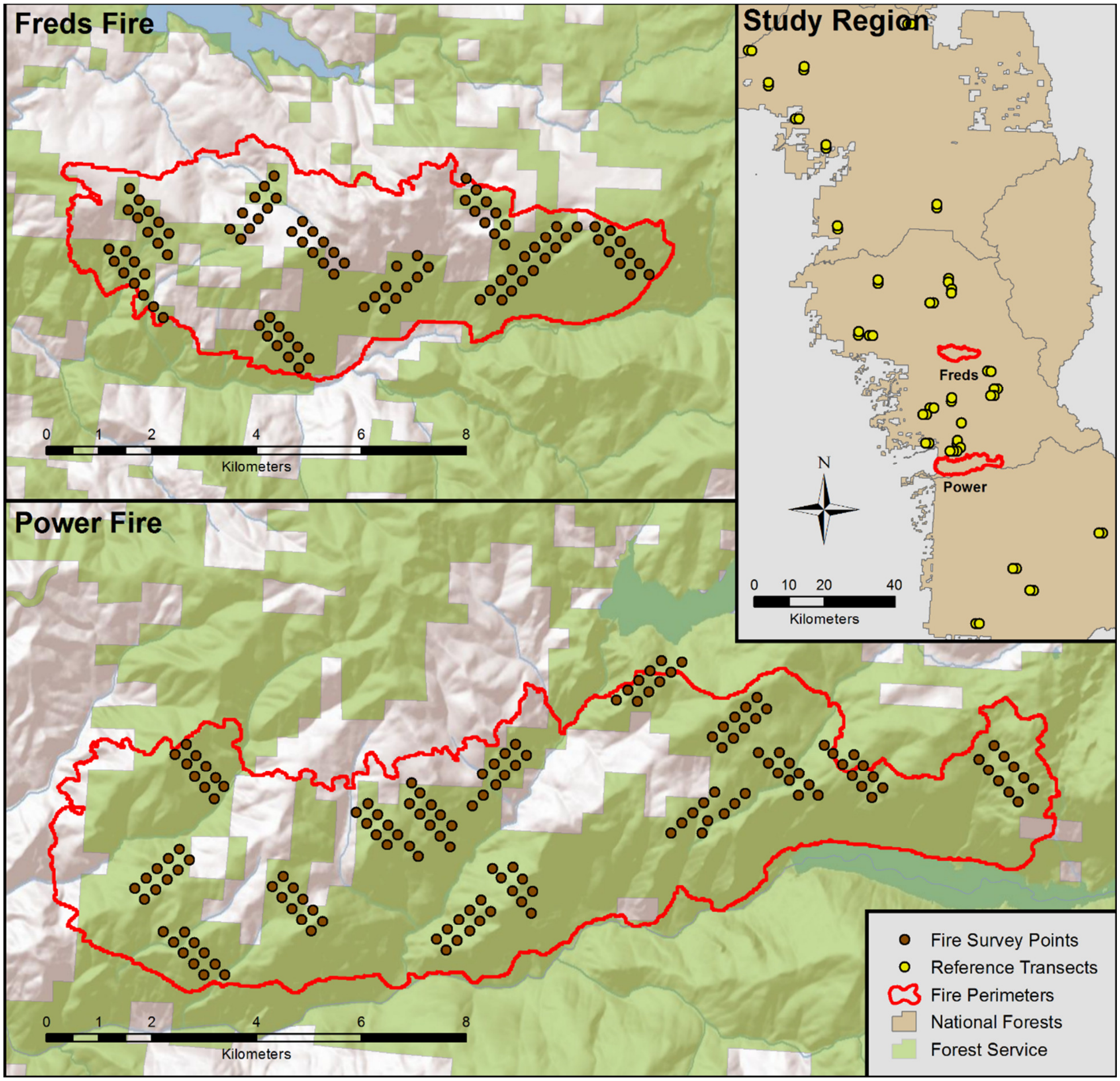
The study area includes the Freds Fire, located on Placerville Ranger District, and the Power Fire, located on the Amador Ranger District. Both districts are part of the Eldorado National Forest in the Sierra Nevada Mountains of California (Figure 1). Both fires burned during October 2004 and were predominantly on the south-facing side of river canyons; the Freds Fire burned along the South Fork American River canyon and the Power Fire burned along the Mokelumne River canyon. The elevations of avian monitoring locations in the Freds Fire ranged from 1315 – 2089 m (mean = 1720 m; $N$ = 94) and from 1120 – 2016 m (mean = 1611 m; $N$ = 148) in the Power Fire.

For analyses comparing burned to unburned forest, we included unburned locations from the Sierra Nevada Management Indicator Species bioregional monitoring program (Roberts et al. 2011). We chose points within Eldorado, Stanislaus and Tahoe National Forests on the west-slope of the Sierra Nevada with a maximum elevation of 2150 m located outside of areas that burned within the last 20 years. The elevations of unburned forest monitoring locations ranged from 1018 – 2121 m (mean = 1602 m; $N$ = 280; Figure 1: reference transects) and were located in similar pre-fire habitat types as burned transects and similar slope conditions. Reference transects were chosen randomly in respect to aspect. Because both fires burned in predominant southwest-facing river canyons, reference transects may be biased towards northern aspects.

## Sampling Design

Point count transects were established so as to take advantage of previous and ongoing vegetation surveys conducted by the US Forest Service Region 5 and UC Davis scientists. Where possible, survey points were located coincident with previously sampled Common Stand Exam (CSE; Freds Fire), or regeneration (Power Fire) plots. These vegetation plots were established along either a 400 m (CSE) or 200 m (regeneration) grid. CSEs were conducted in Freds fire during 2009, 2012 and 2013 (Bohlman and Safford 2014), and will be conducted in the Power fire during 2014-2016 (Clark Richter, *personal communication*). Regeneration surveys were conducted in Power Fire during 2009 (Welch and Safford 2010).

**Figure 1.** Study area maps and survey locations




To maximize the number of points surveyed in a morning, bird transects were typically comprised of 10 points made up of two parallel five-point sub-transects and were located within one kilometer of a road. These transects were placed at a diagonal along the vegetation plot grids making point count locations approximately 283 m apart. Each transect was located a minimum of 500 m from any other transect. Although both Freds and Power fires burned across a variety of terrain and across multiple landownerships, our transects were largely limited to Forest Service land, slopes with a maximum of 35 degrees and did not require any major stream crossings. Knowing that actual terrain can often be more hazardous than it appears using remotely sensed imagery and digital elevation models alone, we initially established more transects than could have been sampled safely. In a GIS we established 10 transects (100 points) for Freds Fire and 17 transects (170) for Power Fire. Following field reconnaissance, one Freds transect and two Power transects were discarded due to overly difficult or treacherous terrain. Occasionally individual points were moved slightly and rarely points were removed all together for the same reason. Thus, our sample design was done in a semi-systematic fashion resulting in a likely under-sampling of extremely steep slopes. Inferences drawn from these data are best applied to Forest Service lands with low to moderate slopes. A list of UTM coordinates for Freds and Power fire points can be found in Appendix A.

### Point Count Surveys

Surveyors conducted standardized five-minute exact-distance point counts (Ralph et al. 1995) at each point count station. With the aid of rangefinders, surveyors estimated the exact distance to each individual bird. The initial detection cue (song, visual, or call) for each individual was also recorded. Counts began around local sunrise, were completed within four hours, and did not occur in inclement weather. Surveyors received two weeks of training to identify birds and estimate distances and passed a double-observer field test. The majority of transects were visited twice during the peak of the breeding season from mid-May through the end of June. Due to logistic constraints, 14 points (out of 96) were only visited once in Freds Fire and two points (out of 148) were only visited once in Power Fire.

### Vegetation/Habitat Surveys

We collected vegetation data at 109 of the 148 point count survey locations in the Power Fire following a relevé protocol. These data along with coincident common stand exam data at some points (Bohlman and Safford 2014; Clark Richter *personal communication*) will be used in future analyses to inform models of habitat selection, habitat suitability, detection probability, and avian abundance. We plan to finish vegetation surveys in the Power and Freds fire during the 2015 field season.

### Analysis: General Procedures with Point Count Data

We restricted the analysis of our point count data to a subset of the species encountered. We excluded: (1) all birds >100 m from the observer, (2) species flying over the sampling locations but not actively using the habitat, (3) species that do not breed in the study area, and (4) those species that are not adequately sampled using the point count method (e.g., waterfowl, raptors, waders; Appendix B). Several of our analyses are further restricted to different species guilds whose habitat requirements we believe represent different spatial attributes, habitat characteristics, and management regimes representative of a healthy system. For the majority of analyses, we used two metrics to investigate the bird community: abundance and species richness. Abundance is defined as the mean number of individuals detected per point count survey. Bird species richness is defined as the mean number of species detected per survey.

### Analysis: Unburned vs. Burned Forest

We examined the differences in abundance and species richness between unburned forest (from the Sierra Nevada Management Indicator Species bioregional monitoring program) and burned forests (all points within Freds and Power fires, regardless of fire severity or post-fire management) by building a generalized linear mixed model with Poisson error structure and logarithmic link function using the package lme4.0 version 1.1-7 (Bates et al. 2011) in program R version 3.1.2 (R Core Team 2013). Our sample unit was a single point count visit and the dependent variable was the total sum of all individuals (abundance) or the total count of species present (species richness). Point count station was used as a random effect on the intercept parameter, with multiple visits to a single station representing repeated samples. The single fixed effect in these models was a categorical variable with three levels for location: unburned forest, Freds Fire and Power Fire.

To examine the effect of fire on abundance (number of individuals) for individual species, we used hierarchical N-mixture models, which uses multiple-visit data to estimate abundance and detection probability. Because rare and reclusive species are often difficult to model, we modeled only those species with raw (unadjusted for detectability) mean abundance of >0.10/point in either fires or unburned forest. By explicitly incorporating detection probability in the modeling process, we can account for imperfect detection (i.e., false absences), and through the use of covariates we can assess the relationship of environmental variables with both detectability and abundance. For these models, we used the pcount function in the package unmarked (Fiske and Chandler 2011) in Program R version 2.15.2 (R Core Team 2013). The sample unit of the analysis was a point count station ($N$ = 522). We used a Poisson distribution for each species' abundance model. Covariates on abundance included elevation, slope, solar radiation index (Keating et al. 2007) and a categorical variable with three levels for location (Freds Fire, Power Fire and unburned forest). Covariates on detection probability included a binary variable for burned/unburned status, such that detection probability was calculated separately for burned and unburned areas, because ability to detect species and individuals can differ between open chaparral and forest in burned and unburned areas, respectively. Model predictions of mean abundance for Freds Fire, Power Fire and unburned forests were calculated by holding all other covariates at their mean values and varying the location. Thus we present only the marginal effect of fire while implicitly accounting for any effects due to elevation, slope and solar radiation.

## Analysis: Fire Severity & Post-fire Management

We employed 32 bird species to evaluate the effects of burn severity and post-fire management (Table 1). We began with 53 species that are adequately sampled using our standardized point count method (Ralph et al. 1995). We then used multiple criteria to identify species. We used our local knowledge (Burnett et al. 2011, 2012; Campos and Burnett 2014), the Sierra Nevada avian literature (Bock and Lynch 1970, Bock et al. 1978, Beedy 1981, Raphael et al. 1987) and other published information (e.g., Birds of North America accounts [Poole 2005]) which detail the habitat associations of these species. We then selected the species closely aligned with three broad forest conditions in the Sierra Nevada: early successional, mid to late-successional open canopy forest, and late-successional mature to dense forest. The guilds represent three structural forest conditions that are created by fire or lack of fire: (1) early successional conditions created by recent stand-replacing fire, (2) open and edge conditions created by heterogeneous and frequent low to moderate severity fire, and (3) dense and mature conditions created primarily by long-term fire exclusion. We selected a total of 12 species for the early-successional guild, 12 species for the open forest guild, and 10 species for the mature dense forest guild (Table 1). The open forest and early-successional guilds shared two species: Chipping Sparrow and MacGillivray's Warbler. The species selected included year-round residents, short-distance migrants, and Neotropical migrants.

**Table 1.** List of species in the early successional, open and edge, and mature and dense avian guilds. Scientific names can be found in Appendix B. Species are listed in taxonomic order.

| Early Successional | Open and Edge | Mature and Dense |
|---|---|---|
| Mountain Quail | Western Wood-Pewee | Pileated Woodpecker |
| Hairy Woodpecker | Olive-sided Flycatcher | Hammond's Flycatcher |
| Dusky Flycatcher | Warbling Vireo | Pacific-slope Flycatcher |
| Western Bluebird | Townsend's Solitaire | Cassin's Vireo |
| House Wren | American Robin | Red-breasted Nuthatch |
| Yellow Warbler | Nashville Warbler | Brown Creeper |
| MacGillivray's Warbler | Black-throated Gray Warbler | Golden-crowned Kinglet |
| Lazuli Bunting | Yellow-rumped Warbler | Pacific Wren |
| Spotted Towhee | MacGillivray's Warbler | Hermit Thrush |
| Green-tailed Towhee | Black-headed Grosbeak | Hermit Warbler |
| Fox Sparrow | Western Tanager | |
| Chipping Sparrow | Chipping Sparrow | |

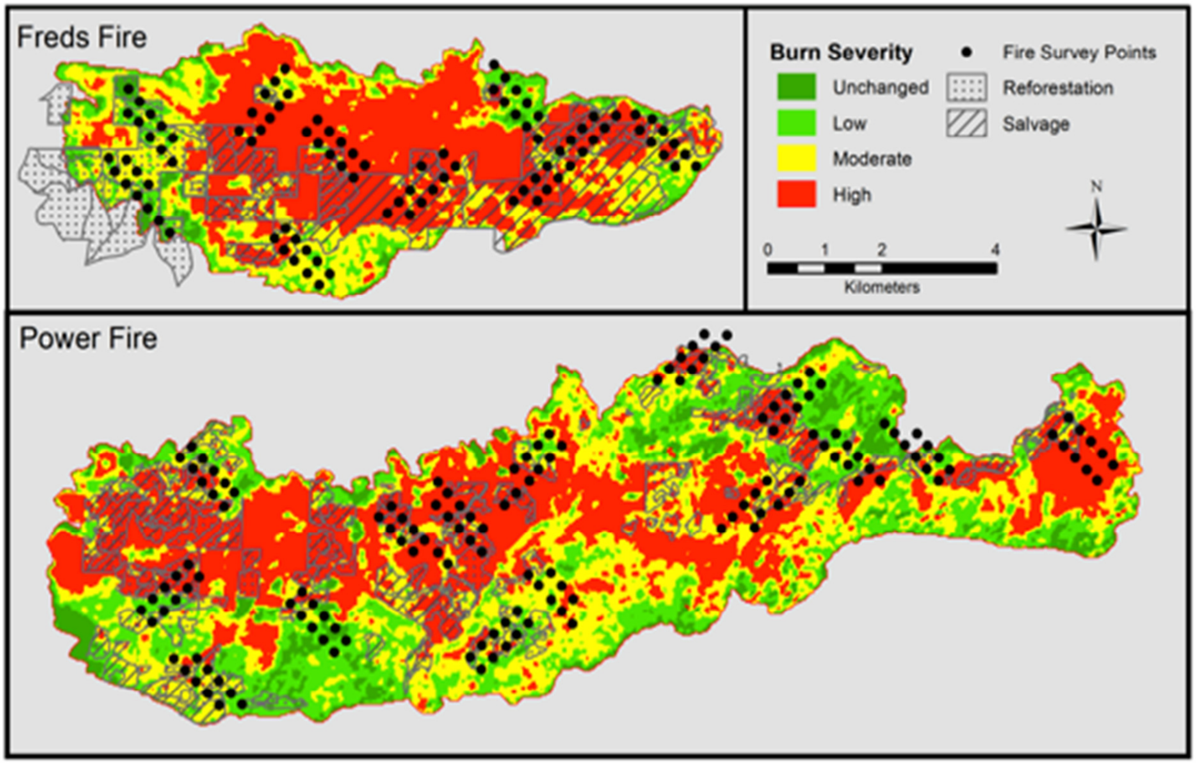
To classify burn severity (Table 2, Figure 2) we utilized a geodatabase maintained by the forest service for fires greater than 500 acres in size in California (available online at http://www.fs.usda.gov/wps/portal/fsinternet/main/r5/landmanagement/gis). Severity classifications were conducted using LANDSAT-TM satellite imagery and the Relativized differenced Normalized Burn Ratio (RdNBR). RdNBR data were converted to units of the composite burn index (CBI; Key and Benson 2006), a field-based measure of fire severity (Miller and Thode 2007).

**Table 2:** Fire severity categories as defined by Miller and Thode (2007) with percentage of Freds and Power fire avian monitoring point count stations that fell within each category.

| Category | Description | Freds Fire | Power Fire |
|---|---|---|---|
| Unchanged | Indistinguishable from pre-fire conditions | 3% | 9% |
| Low | Little mortality of structurally dominant vegetation | 18% | 17% |
| Moderate | Mixture of effects ranging from unchanged to high | 39% | 31% |
| High | Vegetation has high to complete mortality (>95%) | 40% | 43% |

We used the Region 5 Forest Service Activity Tracking System (FACTS) database (available online at http://www.fs.usda.gov/detail/r5/landmanagement/gis) to classify points in both fires as salvage logged or untreated, and as actively reforested or left for natural regeneration. Salvage logging occurred at 53% of Freds Fire points and 28% of Power Fire points (Figure 2). However, 87% of Freds Fire points that burned at high severity were salvage logged compared to only 39% of Power Fire points. Reforestation (predominantly pine plantations) occurred at 49% of Freds Fire total points (58% of the salvaged points) and 28% of Power Fire points (81% of salvaged points) Vegetation surveys at Power Fire closely corroborated the FACTS database, but these surveys were not completed at Freds Fire and thus we relied solely on the accuracy of the FACTS database.

**Figure 2.** Fire severity levels and post-fire management actions in Freds and Power fires.




To estimate the effect of fire severity, salvage, the interaction between these two variables and the effect of reforestation on the three species guilds, we built generalized linear mixed models with Poisson error structure and a logarithmic link function using the package lme4.0 version 1.1-7 (Bates et al. 2011) in program R version 2.15.2 (R Core Team 2011). Our sample unit was a single point count visit and the dependent variable was the total sum of all individuals of a particular guild (abundance) or the total count of guild species present (species richness). Point count station and fire location (Freds or Power) was included as a random effect on the intercept parameter. We fit 2 models where (1) fire severity was a categorical fixed effect [unburned, low, moderate, high], and (2) fire severity, salvage status (binary variable), the interaction between these two variables, and reforestation status (binary variable) as fixed effects. Sample sizes were not sufficient to examine an interaction between salvage logging and reforestation (see Table 3 for sample sizes for each model). For the first model, we excluded all burned points that had been treated (i.e., salvage-logged or replanted) so as to focus solely on the effect of fire severity ten years post-fire. For the second model, we included only those points that burned at moderate and high severity, since salvage logging and reforestation activities primarily took place in areas that burned at these severities. We report model mean predictions for abundance and species richness with 95% confidence intervals (CI).

**Table 3.** Number of points (*N*) according to fire severity, salvage logging status and reforestation status for the fire severity model (Model 1) and the post-fire management model (Model 2).

| | Variable | Levels | Sample size (*N*) | |
|---|---|---|---|---|
| Model 1 | Fire Severity | Unburned Forest | 296 | |
| | | Low | 32 | |
| | | Moderate | 43 | |
| | | High | 50 | |
| Model 2 | | | Salvage Logging | |
| | | | Yes | No |
| | Fire Severity | Moderate | 30 | 54 |
| | | High | 53 | 47 |
| | Reforestation | Yes | 52 | 14 |
| | | No | 25 | 93 |

## Data Management and Access: Sierra Nevada Avian Monitoring Information Network

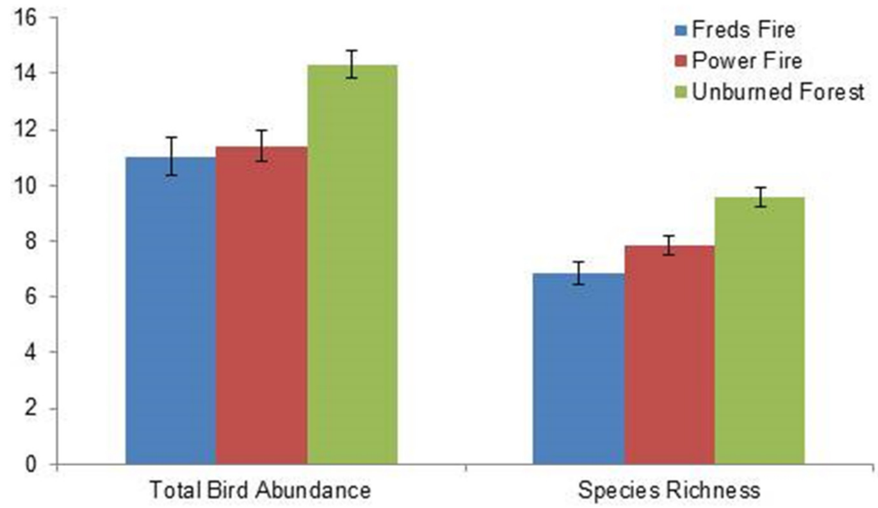
All avian data from this project is stored in the California Avian Data Center and can be accessed through the Sierra Nevada Avian Monitoring Information Network web portal (http://data.prbo.org/apps/snamin). At this website, species lists, interactive maps of study locations, as well as calculations of richness, density, and occupancy can be generated as selected by the user. Survey locations can be downloaded in various formats for use in GPS, GIS, or online mapping applications. Non-avian data (e.g., site narratives, vegetation, photos) are stored on Point Blue's server.

# RESULTS

## Unburned vs. Burned Forest

A total of 72 bird species were detected in Freds Fire, 74 in Power Fire and 78 in unburned forest (see Appendix B for complete list of species, scientific names and mean number of detections per visit). Model predictions of total bird abundance were highest in unburned forest with a mean of 14.3 individuals per point (CI: 13.8 – 14.9, $P < 0.0001$). Predictions of species richness were also highest in unburned forest with a mean of 9.6 species per point (CI: 9.3 – 9.9, $P < 0.0001$). Abundance was similar ($P = 0.44$) between Freds (mean = 11.0, CI: 10.4 – 11.7) and Power fires (mean = 11.4, CI: 10.9 – 12.0), although species richness was significantly higher in Power Fire (mean = 7.8, CI: 7.5 – 8.2; $P < 0.0001$) as compared to Freds Fire (mean = 6.8, CI: 6.4 – 7.3, Figure 3). Several species associated with arid habitats, including Rock Wren, Canyon Wren, Black-chinned Sparrow, Brewer's Sparrow, Western Meadowlark, Lawrence's Goldfinch, and cavity nesters including American Kestrel, Lewis's Woodpecker, Pygmy Nuthatch, and Mountain Bluebird, were all present in burned areas but absent in unburned forest.

**Figure 3**. Predicted mean bird abundance and species richness across Freds and Power fires and adjacent unburned forest. Bars indicate 95% confidence intervals.




Abundance models predicted that of the 36 species with sufficient sample sizes, 13 were more abundant in burned areas, seven were more abundant in unburned areas and 16 species showed no statistical difference (Table 3). Detection probabilities varied significantly between burned and unburned forests for seven of 36 species; five of the seven species had higher detection probabilities in unburned forest, with the remaining two species showing an opposite pattern (detection probabilities for all species in the fires and unburned forests can be found in Appendix C). Some cavity nesters (Acorn Woodpecker, House Wren, and Bewick's Wren), shrub nesting species associated with chaparral, (Yellow Warbler, MacGillivray's Warbler, Green-tailed Towhee, Spotted Towhee, Fox Sparrow and Lazuli Bunting), and species associated with open and edge habitats, (Western Wood-Pewee, Chipping Sparrow and Lesser Goldfinch) were more abundant in the fire areas as compared to unburned forest. The species with higher abundance in unburned forest were primarily closed-canopy nesters and foragers, including Hammond's Flycatcher, Cassin's Vireo, Red-breasted Nuthatch, Golden-crowned Kinglet and Hermit Warbler. Two of the species in our open forest and edge guild, Yellow-rumped Warbler and Black-throated Gray Warbler, were more abundant in unburned forest.

Eighteen of the 36 species analyzed showed significant differences in abundance between Freds and Power fires. For species with higher abundance in burned areas, only Western Wood-Pewee and Bewick's Wren had higher abundance in Power Fire as compared to Freds Fire. Several species, including Acorn Woodpecker, Rock Wren, Yellow Warbler, MacGillivray's

Warbler, Green-tailed Towhee, Lazuli Bunting and Lesser Goldfinch all had higher abundance in Freds Fire as compared to Power Fire. For the species showing higher abundance in unburned forest, an opposite pattern occurred where six of seven species showed higher abundance in Power Fire compared to Freds Fire. For the 16 species that showed similar abundance between the fires and unburned forest, only three species showed a difference between fires. White-headed Woodpecker and Warbling Vireo reached their lowest abundance in Freds Fire but had similar abundance in Power Fire and unburned forest. Brown Creeper had similar abundance between Freds Fire and unburned forest but reached its highest abundance in Power Fire.

**Table 3.** Estimated abundance (± SE) within 100 m of a point count station for 36 species in the Freds and Power fires and adjacent unburned forest. Species with significantly higher abundance inside or outside burned areas (P<0.05) are organized as such and asterisks following species name indicate different abundance between fires (*$P$ <0.05, **$P$ <0.01).

| ***Higher Abundance Inside Burn*** | Freds Fire | Power Fire | Unburned Forest |
|---|---|---|---|
| Acorn Woodpecker** | 0.41 ± 0.19 | 0.10 ± 0.06 | 0.02 ± 0.01 |
| Western Wood-Pewee** | 1.60 ± 0.54 | 2.82 ± 0.86 | 0.69 ± 0.34 |
| House Wren | 1.49 ± 0.26 | 1.71 ± 0.25 | 0.02 ± 0.01 |
| Bewick's Wren** | 0.24 ± 0.13 | 1.04 ± 0.38 | 0.23 ± 0.28 |
| Rock Wren* | 0.12 ± 0.08 | 0.04 ± 0.02 | 0.00 ± 0.00 |
| Yellow Warbler** | 0.97 ± 0.22 | 0.28 ± 0.07 | 0.22 ± 0.10 |
| MacGillivray's Warbler** | 2.32 ± 0.60 | 1.53 ± 0.38 | 1.34 ± 0.42 |
| Green-tailed Towhee** | 1.96 ± 0.25 | 1.37 ± 0.18 | 0.40 ± 0.19 |
| Spotted Towhee | 3.18 ± 0.43 | 2.58 ± 0.32 | 1.10 ± 0.28 |
| Chipping Sparrow | 0.86 ± 0.34 | 0.80 ± 0.27 | 0.19 ± 0.09 |
| Fox Sparrow | 2.07 ± 0.24 | 2.29 ± 0.23 | 1.50 ± 0.23 |
| Lazuli Bunting** | 3.40 ± 0.51 | 2.57 ± 0.38 | 0.21 ± 0.04 |
| Lesser Goldfinch** | 0.86 ± 0.33 | 0.14 ± 0.07 | 0.12 ± 0.18 |
| ***Higher Abundance Outside Burn*** | | | |
| Hammond's Flycatcher** | 0.00 ± 0.00 | 0.58 ± 0.32 | 0.98 ± 0.34 |
| Cassin's Vireo** | 0.27 ± 0.12 | 0.76 ± 0.25 | 1.42 ± 0.27 |
| Red-breasted Nuthatch** | 0.58 ± 0.24 | 1.81 ± 0.68 | 3.86 ± 0.45 |
| Golden-crowned Kinglet** | 0.13 ± 0.05 | 0.35 ± 0.09 | 1.82 ± 0.30 |
| Yellow-rumped Warbler** | 0.75 ± 0.30 | 1.34 ± 0.51 | 2.31 ± 0.41 |
| Hermit Warbler* | 0.14 ± 0.06 | 0.35 ± 0.09 | 3.46 ± 0.42 |
| Black-throated Gray Warbler | 0.09 ± 0.05 | 0.12 ± 0.05 | 0.66 ± 0.20 |
| ***No Difference Between Burned and Unburned*** | | | |
| Mountain Quail | 1.37 ± 0.30 | 1.02 ± 0.23 | 0.77 ± 0.35 |
| Hairy Woodpecker | 1.25 ± 0.60 | 1.25 ± 0.56 | 1.25 ± 0.48 |
| White-headed Woodpecker* | 0.55 ± 0.26 | 1.02 ± 0.39 | 1.00 ± 0.11 |
| Northern Flicker | 1.48 ± 0.36 | 2.03 ± 0.36 | 1.23 ± 0.61 |
| Olive-sided Flycatcher | 0.79 ± 0.30 | 0.80 ± 0.29 | 0.56 ± 0.33 |
| Dusky Flycatcher | 0.94 ± 0.29 | 1.16 ± 0.31 | 1.51 ± 0.16 |
| Warbling Vireo** | 0.30 ± 0.14 | 0.77 ± 0.29 | 0.71 ± 0.19 |
| Stellar's Jay | 2.00 ± 0.30 | 1.89 ± 0.26 | 2.03 ± 0.28 |
| Mountain Chickadee | 1.53 ± 0.37 | 1.90 ± 0.42 | 2.48 ± 0.31 |
| Brown Creeper** | 0.51 ± 0.17 | 1.20 ± 0.33 | 0.67 ± 0.17 |
| American Robin | 1.39 ± 0.42 | 1.55 ± 0.42 | 1.23 ± 0.45 |
| Nashville Warbler | 1.29 ± 0.39 | 1.58 ± 0.43 | 1.92 ± 0.24 |
| Dark-eyed Junco | 1.15 ± 0.33 | 1.47 ± 0.35 | 1.60 ± 0.19 |
| Western Tanager | 1.65 ± 0.35 | 1.76 ± 0.33 | 2.11 ± 0.25 |
| Black-headed Grosbeak | 1.34 ± 0.25 | 1.12 ± 0.16 | 0.94 ± 0.09 |
| Purple Finch | 0.00 ± 0.00 | 0.06 ± 0.02 | 0.39 ± 0.17 |

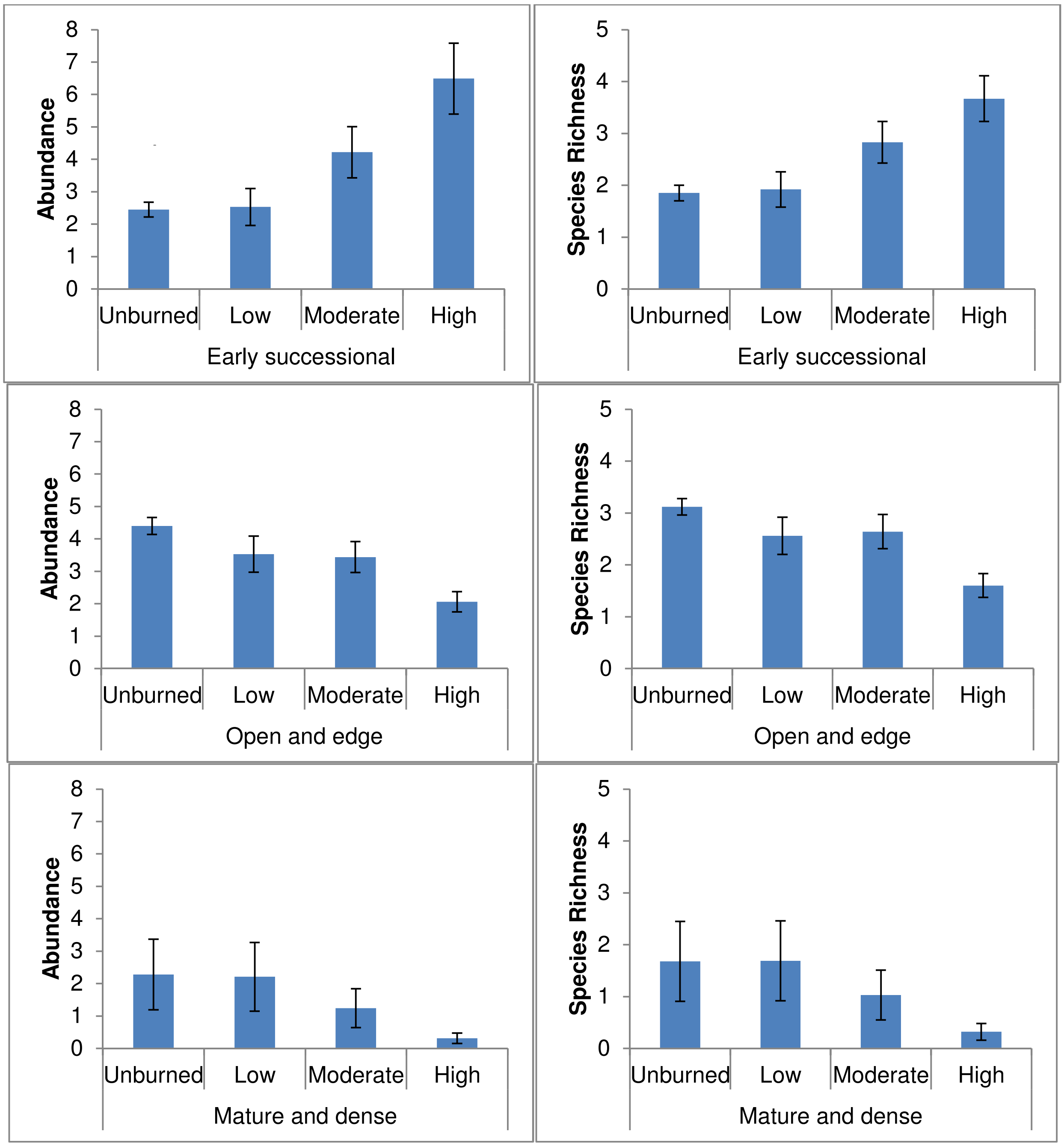
### Fire Severity & Post-fire Management

The influence of fire severity (in the absence of salvage logging or reforestation) varied between species guilds (Figure 4). The abundance and richness of the early successional guild increased significantly as fire severity increased, from a predicted mean of 2.5 individuals (CI: 2.2 – 2.7) at unburned forest points to 6.5 individuals (CI: 5.4 – 7.5) at high severity points. Early successional species richness increased from 1.9 species per point (CI: 1.7 – 2.0) in unburned forest to 3.7 species (CI: 3.2 – 4.1) at high severity points.

The open and edge guild reached its highest abundance in unburned forest with a predicted mean of 4.4 individuals per point (CI: 4.1 – 4.7) and then decreased with burn severity to 2.0 individuals per point (CI: 1.8 – 2.4) in high severity. Low and moderate severity abundance were similar (3.5 and 3.4 individuals per point, respectively) but they were significantly lower than unburned forest. Species richness was also highest in unburned forest (mean = 3.1; CI: 2.9 – 3.3) with no difference between unburned forest, low and moderate severities but high severity was significantly lower (mean = 1.6; CI: 1.3 – 1.9) compared to unburned forest.

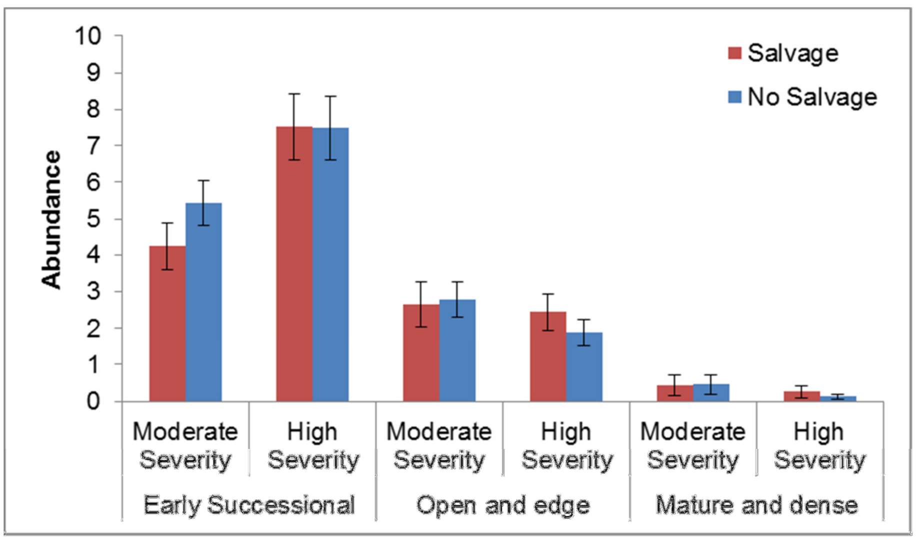
The mature and dense guild exhibited more variation in abundance and species richness compared to the other two guilds, as shown in larger 95% confidence intervals, and likely also due to lower sample sizes. Abundance was highest in unburned forest (mean = 2.3; CI: 1.2 – 3.4), declined slightly among low and moderate severity points then more dramatically to 0.32 (CI: 0.2 – 0.5) individuals at high severity points. Species richness showed a similar pattern with a high of 1.7 species (CI: 0.9 – 2.5) among unburned points to a low of 0.3 species (CI: 0.1 – 0.5) among high severity points.

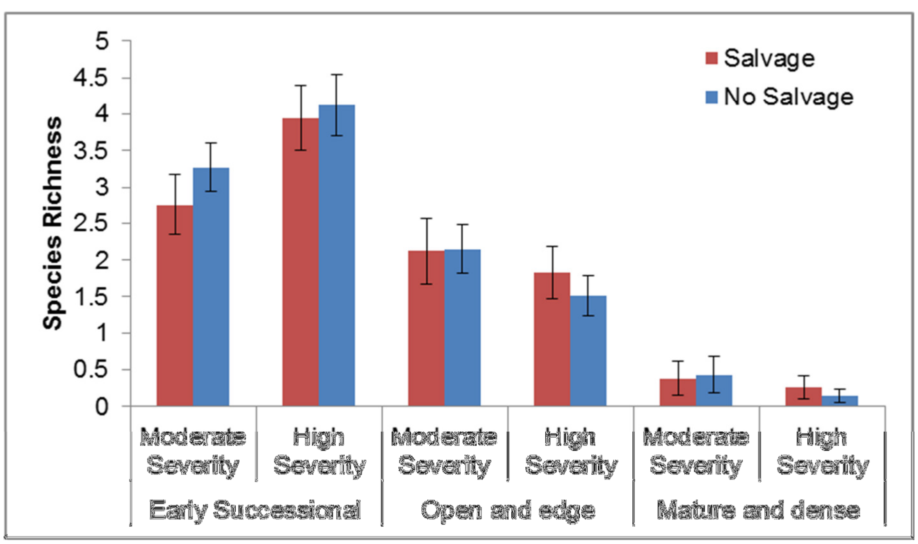
**Figure 4.** Predicted abundance and species richness of early successional, open and edge and mature, dense forest species guilds at point count locations in low, moderate and high fire severities relative to nearby unburned points. Bars indicate 95% confidence intervals.



The impact of salvage logging also varied among burn severities and species guilds (Figure 5). Salvage logging had a negative effect ($P = 0.009$) on early successional birds but this was dependent on fire severity. At moderate severity points that had been salvage logged, early successional birds had significantly lower abundance (mean = 4.2; CI: 3.6 – 4.8) compared to points that had not been logged (mean = 5.4; CI: 6.1 – 7.5). Differences were not significant for high severity points. However, reforestation had a positive effect ($P < 0.001$), indicating that even when taking salvage logging into account, planting trees may have resulted in increased abundance of some early successional birds. Patterns were similar for species richness. The open and edge guild and the mature and dense guild showed no difference in relation to salvage logging or reforestation.

**Figure 5**. Predicted abundance and species richness in relation to salvage logging in moderate and high severity burned areas across three species guilds in the Freds and Power fires. Bars indicate 95% confidence intervals.



## DISCUSSION

As average fire severity, fire size and overall annual burned area increases in the Sierra Nevada (Westerling et al. 2006, Miller and Safford 2012), increasing amounts of forest habitat is affected by this dynamic disturbance. Post-fire habitat management activities will also likely affect an increasing amount of land in the region, subsequently impacting plant and wildlife communities. Birds are excellent indicators of ecological processes that can provide important feedback regarding the health of managed fire-prone ecosystems (Alexander et al. 2007).

**Avian Community Composition: Burned vs. Unburned Forest**

Our findings suggest for all the species adequately assessed through point count surveys, avian abundance and richness is higher within unburned forests than those areas burned within the 2004 Freds and Power fire perimeters. However, we did include all points that were affected by salvage logging, site preparation and reforestation, and thus our results should be pertinent to landscapes that burned at predominantly moderate and high severity and were heavily managed post-fire. However, when relatively common species were modeled individually, nearly double the number of species showed higher abundance in burned forests compared to the number of species that showed higher abundance in unburned forests. This may be due to higher densities of birds that occur in unburned forests (e.g., Yellow-rumped Warbler and Hermit Warbler). In the fires, we also detected species considered rare or uncommon across the Sierra landscape, including Golden Eagle, Lewis's Woodpecker, Mountain Bluebird and Black-chinned Sparrow. Our results support earlier work showing that many species are reliant on periodic fire as an ecological process and that landscapes containing both burned and unburned forests are necessary to maintain a healthy avian community in fire prone western forests (Fontaine and Kennedy 2012).

Our data show a clear preference for burned areas among several cavity nesters, as well as shrub, ground, and edge-associated species. Canopy-foraging species that generally glean insects from live tree foliage were far less abundant in the fires, which is consistent with other studies from the Sierra Nevada (Raphael et al. 1987, Burnett et al. 2011, 2012). Many of the shrub-nesters (Yellow Warbler, MacGillivray's Warbler, Green-tailed Towhee and Lazuli Bunting) reached their highest abundance in Freds Fire, potentially due to a difference in pre-fire structure compared to the Power Fire, including higher conifer forest cover or tree densities, differences in site productivity or a response to higher levels of salvage logging in the Freds Fire. Remote sensing data and vegetation plot data, from Point Blue or the USFS Region 5 Ecology program, will help parse out the drivers behind these differences between the Freds and Power fire and help guide post-fire management for shrub-nesting species.

**Effects of Fire Severity and Post-Fire Management**

Understanding differential species responses to disturbance and forest succession allows us to group species into guilds and assess the effects of fire severity and post-fire management with greater statistical power. For example, both Power and Freds fires burned at similar severity, under similar weather conditions and are located in similar topographic positions. However, Power Fire experienced substantially less salvage logging than Freds Fire, and thus retained more snags and potentially more green trees if these were damaged and/or logged in the Freds Fire.

Among the individual species that reached their highest abundance in unburned forest, many had far higher abundance in the Power Fire compared to the Freds Fire. The majority of these species are associated with closed canopy, dense forest and forage in the canopy layer. Several other species that showed no preference between burned and unburned areas, also showed a higher abundance in Power Fire compared to Freds Fire (White-headed Woodpecker, Warbling Vireo and Brown Creeper). Lower salvage logging intensity in the Power Fire may have left more green trees (which can be knocked over or injured during salvage operations), including conifers and oaks, and forest structural components intact for these canopy-associated species. In the future, with more data collection we plan to build species-specific abundance models in relation to post-fire management variables coupled with habitat data.

Consistent with our predictions, the early successional species guild showed greater abundance and richness as fire severity increased within the two fires. Conversely, the two guilds associated with conditions characterized by later successional stages (open/edge and mature/dense species) showed greater abundance and richness in unburned forests versus areas burned at high severity. The open and edge guild showed a significant decrease in abundance from unburned to low severity but values were similar between low and moderate severity points. This decrease between unburned forest and low and moderate severity points is surprising considering many of these individual species showed either no change in abundance between burned and unburned areas (6 of 12 species) or an increase in abundance in the fires (3 of 12 species). However, the same pattern was found in the Chips Fire in the northern Sierra for open and edge species (Campos and Burnett 2014). In contrast, the mature and dense guild showed a stable pattern between unchanged and low severity points, which is not surprising considering the dominant canopy layer is generally intact in forests burned at low severity. However, compared to other guilds, there were large confidence intervals around mean abundance estimates in unburned and low severity, indicating unaccounted for variation in abundance likely attributable to unmeasured factors (e.g. patch size, basal area, etc). Indeed not all of the points outside the fire were mature dense forest.

In the tenth year after the two fires, our only detected effect of salvage logging was in areas that burned at moderate severity: early successional species were predicted to be less abundant in salvaged areas compared to unsalvaged areas. Removing snags would directly affect cavity nesters, including House Wren which was the fourth most abundant species in the Power Fire, but effects on shrub-nesting birds is less clear. There was no effect of salvage logging at high severity points, where abundance of early successional species was highest. Reforestation appeared to have a positive effect on early successional species, although our sample sizes limited testing for an interaction with salvage logging. Planting trees where natural regeneration was poor may offer more habitat structure for nesting and foraging or reforestation may be correlated with other variables we did not take into account, such as topographical conditions, site productivity, pre-fire forest structure and site preparation activities.

Given a number of studies showing negative effects of salvage logging on the avian community (Hutto and Gallo 2006, Saab et al. 2007, Cahall and Hayes 2009) the general lack of effects is somewhat unexpected. Much of the previous work on salvage logging effects on wildlife species has been limited to the first few years following a fire and subsequent harvest. The Black-backed Woodpecker (*Picoides arcticus*) in particular has received substantial attention in such studies. However, this species tends to use areas of high severity fire primarily 1-7 years following fire (Saracco et al. 2011) and was not observed in any of our 2014 Freds or Power fire surveys. This might lead one to infer that while salvage logging is likely detrimental to some species of conservation concern during the initial successional stages following a fire, the effects of logging and reforestation after a decade may be less severe. However, in our guild analysis, the abundance of the shrub nesters likely swamped the cavity nesters, which are most sensitive to salvage logging. Suitable post-fire habitat for cavity nesters decreases with fire age, as snags fall down and insect infestations decline (Saab et al. 2007), and thus at ten years post-fire, we would be less likely to detect an effect on the cavity-nesters. Looking at individual species and comparing Freds Fire to Power Fire, which received far less salvage logging, Hairy Woodpecker showed no difference but White-headed Woodpecker and Northern Flicker actually reached their highest abundance in Power Fire. In future analyses, we plan to analyze the early successional shrub-nesters and cavity-nesters separately to better parse out the effects of post-fire management, since these nesting guilds likely show differential responses (Campos and Burnett 2014).

Potential ecological reasons for the observed neutral associations with salvage logging for early successional birds, predominantly the shrub-nesting birds, in high severity burned areas include positive influences on nesting and foraging shrub and ground habitat. Shrub volume has been found to increase more post-fire in salvage-logged stands compared to unsalvaged areas with accordingly large increases in Fox Sparrow density (Cahall and Hayes 2009). Soil disturbance during salvage logging may stimulate shrub species by bringing viable seeds to the surface which can result in prolific shrub regeneration (Poff 1996), which is apparent in both the Freds and Power fires. Avian nest predators, including Stellar's Jay and Common Raven, may use snags as perches to observe shrubby areas and search for nests and salvage-logged areas would have fewer of these available perches. Mammalian nest predators, including chipmunks and tree squirrels (Family Sciuridae), tend to decrease in abundance following fire (Fisher and Wilkinson 2005), but could decrease even further if remnant green trees are unavailable to escape from their own set of predators, or if downed logs are unavailable as means to travel through dense shrub fields. In addition, in post-fire areas, small mammals will use woodpecker cavities in snags for nesting and as cover (Tarbill et al. 2015), and thus these would have been less available in salvaged stands. It is also possible that the areas that were salvage logged in these two fires were inherently different than areas that were not, such as what has been found in the Chips Fire (Brent Campos, *personal communication*).

## Conclusions and Management Recommendations

An understanding of the differences in avian community composition between unburned forest and post-fire habitats can help guide the management of these areas. As expected, we found high severity burned areas have low densities of late-seral associated species and high densities of early successional species, and thus these areas may best be prioritized for sustaining populations of early successional species.

Managing for dense and diverse shrub habitats interspersed with areas of green forest should maximize avian diversity in post-fire habitats. Protecting these green forest 'islands' from future high severity fire would also ensure a conifer seed base and provide a habitat mosaic for a diversity of species. Information about colonization rates and how long after a fire shrub-dependent species persist at maximum levels can be used to determine appropriate re-entry rotations for managing habitat following fire. Based on our results and results from studies from northern Sierra fires (Burnett et al. 2012), shrub habitat supports a diverse and robust breeding bird community by five years post-fire and well beyond a decade post-fire. A re-entry rotation of 20 – 30 years for managing shrub habitat may maximize abundance of shrub-nesting species such as Green-tailed Towhee, Fox Sparrow and MacGillivray's Warbler. This re-entry timeframe would mimic the historic fire return interval for montane chaparral habitat in the Sierra Nevada (Barbour and Major 1988).

As exemplified by our results, there is a differential response to fire and post-fire management (e.g. salvage logging) among bird species that yields information about the ecology of the sampled areas. After biological interpretation of these data, the information can be applied to future management actions in an adaptive management framework (Burnett 2011). For example, mastication efforts in post-fire landscapes have been shown to cause significant decreases in shrub-nesting bird abundance and species richness in the Storrie Fire (Campos and Burnett 2014). The Power Fire contains high-quality shrub habitat, although individual species abundances indicate that Freds Fire supports higher densities of shrub-nesting birds. The data we are collecting can be used to generate spatially-explicit models to identify those areas with the highest shrub-nesting bird abundance and species richness. These areas could be prioritized for exclusion from planned mastication efforts. If mastication is used, retaining leave islands of very dense shrubs will help provide nesting habitat and reduce negative impacts to shrub-dependent species. However, best management practices for these species would be to avoid disturbing this habitat for at least 20 years post-fire, to mimic the natural fire return interval in Sierra Nevada chaparral (Barbour and Major 1988).

**Future Directions**

These data and the data we are continuing to collect in the Freds and Power fires will be applied to many upcoming products. The analyses in this report will be expanded upon and finalized in coming years. Future directions with additional data include: 1) incorporating vegetation survey data to examine habitat associations, especially for early-successional species, 2) employing more sophisticated models that incorporate detection probability for assessing fire severity and management actions, 3) assessing landscape context as a potential driver of the bird community (e.g., distance of point from edge of high-severity patch/fire perimeter, size and shape of burned patches, etc.), 4) incorporating monitoring data into plans for mastication, reforestation and potential herbicide treatments in the Power Fire, and 5) pooling Freds and Power fire data with those from the Government, Rim and northern Sierra fires for a broader-scale (both geographically and temporally) analysis. We will also use these results to refine Point Blue's post-fire habitat management recommendations and provide assistance to post-fire planning for land managers in the Sierra Nevada.

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## APPENDICES

Appendix A. List of UTM locations (NAD83, zone 10) of point count stations in the Freds and Power fires.

Freds Fire UTM coordinates:

| Point | Easting | Northing | Point | Easting | Northing |
|---|---|---|---|---|---|
| FR01.1 | 737694 | 4297403 | FR05.4 | 732149 | 4296735 |
| FR01.2 | 737780 | 4297148 | FR05.5 | 731936 | 4296922 |
| FR01.3 | 737993 | 4296939 | FR05.6 | 732122 | 4297134 |
| FR01.4 | 738215 | 4296732 | FR05.7 | 732335 | 4296948 |
| FR01.5 | 738425 | 4296538 | FR05.8 | 732548 | 4296761 |
| FR01.6 | 738789 | 4296561 | FR05.9 | 732760 | 4296575 |
| FR01.7 | 738588 | 4296752 | FR05.10 | 732973 | 4296389 |
| FR01.8 | 738394 | 4296932 | FR06.1 | 735995 | 4296940 |
| FR01.9 | 738194 | 4297141 | FR06.2 | 735794 | 4297141 |
| FR01.10 | 737993 | 4297339 | FR06.3 | 735594 | 4297341 |
| FR02.1 | 729601 | 4296326 | FR06.5 | 735194 | 4297742 |
| FR02.2 | 729397 | 4296532 | FR06.6 | 735186 | 4298159 |
| FR02.3 | 729194 | 4296738 | FR06.7 | 735390 | 4297951 |
| FR02.4 | 728993 | 4296937 | FR06.8 | 735595 | 4297743 |
| FR02.5 | 728793 | 4297137 | FR06.9 | 735793 | 4297535 |
| FR02.6 | 728791 | 4297544 | FR06.10 | 735991 | 4297327 |
| FR02.7 | 728990 | 4297339 | FR07.1 | 731622 | 4295271 |
| FR02.8 | 729190 | 4297135 | FR07.2 | 731810 | 4295096 |
| FR02.9 | 729392 | 4296938 | FR07.3 | 732000 | 4294919 |
| FR02.10 | 729594 | 4296741 | FR07.4 | 732192 | 4294738 |
| FR03.1 | 730975 | 4296722 | FR07.5 | 732411 | 4294535 |
| FR03.2 | 731129 | 4296929 | FR07.6 | 732242 | 4294342 |
| FR03.3 | 731283 | 4297135 | FR07.7 | 732029 | 4294535 |
| FR03.4 | 731438 | 4297342 | FR07.8 | 731792 | 4294739 |
| FR03.5 | 731592 | 4297549 | FR07.9 | 731605 | 4294909 |
| FR03.6 | 731526 | 4297970 | FR07.10 | 731433 | 4295097 |
| FR03.7 | 731358 | 4297753 | FR08.1 | 736175 | 4296477 |
| FR03.8 | 731191 | 4297537 | FR08.2 | 736395 | 4296741 |
| FR03.9 | 730971 | 4297218 | FR08.3 | 736578 | 4296930 |
| FR03.10 | 730752 | 4296899 | FR08.4 | 736772 | 4297135 |
| FR04.1 | 733399 | 4295587 | FR08.5 | 736966 | 4297352 |
| FR04.2 | 733594 | 4295790 | FR08.6 | 737359 | 4297374 |
| FR04.3 | 733789 | 4295993 | FR08.7 | 737164 | 4297163 |
| FR04.4 | 733972 | 4296404 | FR08.8 | 736974 | 4296950 |
| FR04.5 | 734350 | 4296629 | FR08.9 | 736791 | 4296737 |
| FR04.6 | 734569 | 4296423 | FR08.10 | 736579 | 4296492 |
| FR04.7 | 734379 | 4296217 | FR08.11 | 736381 | 4296285 |
| FR04.8 | 734188 | 4296012 | FR08.12 | 736186 | 4296082 |
| FR04.9 | 733994 | 4295795 | FR08.13 | 736021 | 4295890 |
| FR04.10 | 733799 | 4295577 | FR08.14 | 735601 | 4295875 |
| FR05.1 | 732786 | 4296176 | FR08.15 | 735777 | 4296060 |
| FR05.2 | 732574 | 4296362 | FR08.16 | 735976 | 4296267 |
| FR05.3 | 732361 | 4296549 | | | |

| Point | Easting | Northing |
|---|---|---|
| FR09.1 | 729594 | 4295130 |
| FR09.2 | 729394 | 4295333 |
| FR09.3 | 729194 | 4295537 |
| FR09.4 | 729005 | 4295751 |
| FR09.5 | 728793 | 4295938 |
| FR09.6 | 728590 | 4296141 |
| FR09.7 | 728481 | 4296361 |
| FR09.8 | 728793 | 4296340 |
| FR09.9 | 728979 | 4296152 |
| FR09.10 | 729194 | 4295940 |

Power Fire UTM Coordinates:

| Point | Easting | Northing |
|---|---|---|
| PW01.1 | 736650 | 4265522 |
| PW01.2 | 736844 | 4265728 |
| PW01.3 | 737078 | 4265943 |
| PW01.4 | 737229 | 4266137 |
| PW01.5 | 737422 | 4266344 |
| PW01.6 | 737619 | 4266551 |
| PW01.7 | 737398 | 4266744 |
| PW01.8 | 737206 | 4266552 |
| PW01.9 | 737014 | 4266342 |
| PW01.10 | 736806 | 4266139 |
| PW03.1 | 730930 | 4262735 |
| PW03.2 | 731138 | 4262546 |
| PW03.3 | 731334 | 4262362 |
| PW03.4 | 731544 | 4262164 |
| PW03.5 | 731754 | 4261966 |
| PW03.6 | 732153 | 4261996 |
| PW03.7 | 731953 | 4262180 |
| PW03.8 | 731732 | 4262382 |
| PW03.9 | 731532 | 4262566 |
| PW03.10 | 731333 | 4262749 |
| PW04.1 | 747035 | 4266271 |
| PW04.2 | 746848 | 4266446 |
| PW04.3 | 746637 | 4266647 |
| PW04.4 | 746430 | 4266839 |
| PW04.5 | 746231 | 4267025 |
| PW04.6 | 746503 | 4267311 |
| PW04.7 | 746711 | 4267116 |
| PW04.8 | 746905 | 4266932 |
| PW04.9 | 747113 | 4266732 |
| PW04.10 | 747309 | 4266544 |
| PW05.1 | 741246 | 4266078 |
| PW05.2 | 741048 | 4265863 |
| PW05.3 | 740856 | 4265660 |
| PW05.4 | 740662 | 4265453 |

| Point | Easting | Northing |
|---|---|---|
| PW05.5 | 740470 | 4265246 |
| PW05.6 | 741070 | 4265267 |
| PW05.7 | 741151 | 4265527 |
| PW05.8 | 741455 | 4265681 |
| PW05.9 | 741645 | 4265890 |
| PW05.10 | 741826 | 4266089 |
| PW06.1 | 737910 | 4263546 |
| PW06.2 | 737711 | 4263755 |
| PW06.3 | 737520 | 4263949 |
| PW06.4 | 737292 | 4264179 |
| PW06.5 | 737109 | 4264350 |
| PW06.6 | 737498 | 4264400 |
| PW06.7 | 737696 | 4264188 |
| PW06.8 | 737904 | 4263964 |
| PW07.1 | 743245 | 4266135 |
| PW07.2 | 743033 | 4266339 |
| PW07.3 | 742824 | 4266539 |
| PW07.4 | 742430 | 4266918 |
| PW07.5 | 742032 | 4266892 |
| PW07.6 | 742230 | 4266704 |
| PW07.7 | 742425 | 4266521 |
| PW07.8 | 742639 | 4266319 |
| PW07.9 | 742846 | 4266123 |
| PW07.10 | 742629 | 4266725 |
| PW08.1 | 736283 | 4265116 |
| PW08.2 | 736057 | 4265304 |
| PW08.3 | 735867 | 4265482 |
| PW08.4 | 735644 | 4265691 |
| PW08.5 | 735472 | 4265871 |
| PW08.6 | 735449 | 4265484 |
| PW08.7 | 735665 | 4265293 |
| PW08.8 | 735867 | 4265099 |
| PW08.9 | 736071 | 4264902 |
| PW08.10 | 736280 | 4264710 |

| Point | Easting | Northing |
|---|---|---|
| PW09.1 | 735076 | 4264675 |
| PW09.2 | 734864 | 4264851 |
| PW09.3 | 734660 | 4265053 |
| PW09.4 | 734451 | 4265250 |
| PW09.5 | 734664 | 4265432 |
| PW09.6 | 734863 | 4265238 |
| PW09.7 | 735069 | 4265050 |
| PW09.8 | 735268 | 4264878 |
| PW09.9 | 735509 | 4264673 |
| PW09.10 | 735686 | 4264490 |
| PW10.1 | 740065 | 4268510 |
| PW10.2 | 739865 | 4268310 |
| PW10.3 | 739665 | 4268110 |
| PW10.4 | 739465 | 4267910 |
| PW10.5 | 739265 | 4267710 |
| PW10.6 | 739665 | 4267710 |
| PW10.7 | 739865 | 4267910 |
| PW10.8 | 740065 | 4268110 |
| PW10.9 | 740265 | 4268310 |
| PW10.10 | 740460 | 4268510 |
| PW12.1 | 733146 | 4263934 |
| PW12.2 | 733346 | 4263734 |
| PW12.3 | 733546 | 4263534 |
| PW12.4 | 733746 | 4263334 |
| PW12.5 | 733946 | 4263134 |
| PW12.6 | 733746 | 4262934 |
| PW12.7 | 733546 | 4263134 |
| PW12.8 | 733346 | 4263334 |
| PW12.9 | 733146 | 4263534 |
| PW12.10 | 732946 | 4263734 |
| PW13.1 | 744247 | 4266175 |
| PW13.2 | 744042 | 4266365 |
| PW13.3 | 743842 | 4266566 |
| PW13.4 | 743642 | 4266766 |
| PW13.5 | 743451 | 4266964 |
| PW13.6 | 743851 | 4266964 |
| PW13.7 | 744042 | 4266766 |
| PW13.8 | 744242 | 4266566 |
| PW13.9 | 744442 | 4266366 |
| PW13.10 | 743272 | 4267111 |

| Point | Easting | Northing |
|---|---|---|
| PW14.1 | 736333 | 4262732 |
| PW14.2 | 736533 | 4262932 |
| PW14.3 | 736758 | 4263130 |
| PW14.4 | 736933 | 4263332 |
| PW14.5 | 737133 | 4263532 |
| PW14.6 | 736933 | 4263732 |
| PW14.7 | 736733 | 4263532 |
| PW14.8 | 736533 | 4263332 |
| PW14.9 | 736333 | 4263132 |
| PW14.10 | 736133 | 4262932 |
| PW15.1 | 741133 | 4267132 |
| PW15.2 | 741333 | 4267332 |
| PW15.3 | 741533 | 4267532 |
| PW15.4 | 741733 | 4267732 |
| PW15.5 | 741933 | 4267932 |
| PW15.6 | 742133 | 4267732 |
| PW15.7 | 741933 | 4267532 |
| PW15.8 | 741733 | 4267332 |
| PW15.9 | 741533 | 4267132 |
| PW15.10 | 741333 | 4266932 |
| PW16.1 | 731133 | 4264332 |
| PW16.2 | 730933 | 4264132 |
| PW16.3 | 730733 | 4263932 |
| PW16.4 | 730533 | 4263732 |
| PW16.5 | 730333 | 4263532 |
| PW16.6 | 730533 | 4263332 |
| PW16.7 | 730733 | 4263532 |
| PW16.8 | 730933 | 4263732 |
| PW16.9 | 731133 | 4263932 |
| PW16.10 | 731333 | 4264132 |
| PW17.1 | 731733 | 4265332 |
| PW17.2 | 731533 | 4265532 |
| PW17.3 | 731333 | 4265733 |
| PW17.4 | 731166 | 4265957 |
| PW17.5 | 730933 | 4266132 |
| PW17.6 | 731133 | 4266332 |
| PW17.7 | 731333 | 4266133 |
| PW17.8 | 731533 | 4265932 |
| PW17.9 | 731733 | 4265732 |
| PW17.10 | 731902 | 4265579 |

**Appendix B**. List of all species detected in Freds or Power fires during 2014 point surveys (unlimited by distance). Detections are listed as mean individuals observed per point count survey. Asterisks (*) following the common name indicate the species was not included in the total abundance and total species richness analysis. Species are sorted taxonomically.

| Common Name | Scientific Name | Freds Fire | Power Fire | Unburned Forest |
|---|---|---|---|---|
| Canada Goose* | *Branta canadensis* | --- | 0.02 | 0.01 |
| Mountain Quail | *Oreortyx pictus* | 1.02 | 0.85 | 0.33 |
| California Quail | *Callipepla californica* | 0.01 | 0.02 | 0.01 |
| Sooty Grouse | *Dendragapus fuliginosus* | 0.02 | 0.01 | 0.01 |
| Wild Turkey* | *Meleagris gallopavo* | 0.01 | --- | 0.01 |
| Turkey Vulture* | *Cathartes aura* | 0.01 | --- | --- |
| Osprey* | *Pandion haliaetus* | --- | 0.01 | --- |
| Red-tailed Hawk* | *Buteo jamaicensis* | 0.02 | 0.02 | 0.01 |
| Golden Eagle* | *Aquila chrysaetos* | 0.01 | --- | --- |
| American Kestrel* | *Falco sparverius* | 0.04 | 0.03 | --- |
| Band-tailed Pigeon | *Patagioenas fasciata* | 0.05 | 0.02 | 0.06 |
| Mourning Dove | *Zenaida macroura* | 0.07 | 0.01 | 0.01 |
| Anna's Hummingbird | *Calypte anna* | 0.02 | 0.01 | 0.01 |
| Belted Kingfisher | *Megaceryle alcyon* | --- | 0.01 | --- |
| Lewis's Woodpecker | *Melanerpes lewis* | 0.02 | 0.03 | --- |
| Acorn Woodpecker | *Melanerpes formicivorus* | 0.22 | 0.14 | 0.04 |
| Red-breasted Sapsucker | *Sphyrapicus ruber* | 0.03 | 0.04 | 0.08 |
| Hairy Woodpecker | *Picoides villosus* | 0.12 | 0.15 | 0.11 |
| White-headed Woodpecker | *Picoides albolarvatus* | 0.13 | 0.20 | 0.13 |
| Northern Flicker | *Colaptes auratus* | 0.52 | 0.76 | 0.19 |
| Pileated Woodpecker | *Dryocopus pileatus* | 0.01 | 0.04 | 0.05 |
| Olive-sided Flycatcher | *Contopus cooperi* | 0.25 | 0.26 | 0.13 |
| Western Wood-Pewee | *Contopus sordidulus* | 0.31 | 0.58 | 0.18 |
| Hammond's Flycatcher | *Empidonax hammondii* | --- | 0.05 | 0.25 |
| Gray Flycatcher* | *Empidonax wrightii* | --- | 0.02 | --- |
| Dusky Flycatcher | *Empidonax oberholseri* | 0.18 | 0.23 | 0.59 |
| Cassin's Vireo | *Vireo cassinii* | 0.06 | 0.21 | 0.39 |
| Hutton's Vireo | *Vireo huttoni* | 0.01 | 0.02 | 0.07 |
| Warbling Vireo | *Vireo gilvus* | 0.08 | 0.21 | 0.25 |
| Steller's Jay | *Cyanocitta stelleri* | 0.90 | 0.89 | 0.53 |
| Western Scrub-Jay | *Aphelocoma californica* | 0.02 | 0.00 | 0.01 |
| Common Raven* | *Corvus corax* | 0.02 | 0.02 | 0.04 |
| Mountain Chickadee | *Poecile gambeli* | 0.40 | 0.52 | 0.58 |
| Chestnut-backed Chickadee | *Poecile rufescens* | --- | 0.01 | 0.02 |
| Bushtit | *Psaltriparus minimus* | 0.07 | 0.06 | 0.02 |
| Red-breasted Nuthatch | *Sitta canadensis* | 0.12 | 0.46 | 0.97 |

| Common Name | Scientific Name | Freds Fire | Power Fire | Unburned Forest |
|---|---|---|---|---|
| White-breasted Nuthatch | *Sitta carolinensis* | --- | 0.06 | 0.01 |
| Pygmy Nuthatch | *Sitta pygmaea* | 0.02 | 0.01 | 0.01 |
| Brown Creeper | *Certhia americana* | 0.12 | 0.34 | 0.17 |
| Rock Wren | *Salpinctes obsoletus* | 0.15 | 0.02 | --- |
| Canyon Wren | *Catherpes mexicanus* | 0.04 | 0.01 | --- |
| Bewick's Wren | *Thryomanes bewickii* | 0.04 | 0.29 | 0.03 |
| House Wren | *Troglodytes aedon* | 0.65 | 0.89 | 0.01 |
| Pacific Wren | *Troglodytes pacificus* | --- | 0.01 | 0.05 |
| Golden-crowned Kinglet | *Regulus satrapa* | 0.07 | 0.15 | 0.54 |
| Blue-gray Gnatcatcher | *Polioptila caerulea* | 0.01 | 0.01 | 0.01 |
| Western Bluebird | *Sialia mexicana* | 0.08 | 0.08 | --- |
| Mountain Bluebird | *Sialia currucoides* | 0.01 | 0.02 | --- |
| Townsend's Solitaire | *Myadestes townsendi* | 0.05 | 0.07 | 0.09 |
| Hermit Thrush | *Catharus guttatus* | 0.01 | --- | 0.11 |
| American Robin | *Turdus migratorius* | 0.26 | 0.30 | 0.19 |
| Wrentit | *Chamaea fasciata* | 0.11 | 0.03 | 0.04 |
| Orange-crowned Warbler | *Oreothlypis celata* | 0.16 | 0.27 | 0.04 |
| Nashville Warbler | *Oreothlypis ruficapilla* | 0.30 | 0.45 | 0.67 |
| Yellow Warbler | *Setophaga petechia* | 0.28 | 0.14 | 0.08 |
| Yellow-rumped Warbler | *Setophaga coronata* | 0.15 | 0.28 | 0.72 |
| Black-throated Gray Warbler | *Setophaga nigrescens* | 0.04 | 0.07 | 0.14 |
| Hermit Warbler | *Setophaga occidentalis* | 0.04 | 0.16 | 1.02 |
| MacGillivray's Warbler | *Geothlypis tolmiei* | 0.53 | 0.40 | 0.33 |
| Wilson's Warbler | *Cardellina pusilla* | 0.02 | 0.04 | 0.06 |
| Green-tailed Towhee | *Pipilo chlorurus* | 1.15 | 0.66 | 0.10 |
| Spotted Towhee | *Pipilo maculatus* | 0.81 | 0.97 | 0.36 |
| California Towhee | *Melozone crissalis* | --- | 0.01 | --- |
| Chipping Sparrow | *Spizella passerina* | 0.21 | 0.22 | 0.06 |
| Brewer's Sparrow | *Spizella breweri* | 0.03 | 0.00 | --- |
| Black-chinned Sparrow | *Spizella atrogularis* | 0.08 | 0.01 | --- |
| Fox Sparrow | *Passerella iliaca* | 1.10 | 1.18 | 0.70 |
| Song Sparrow | *Melospiza melodia* | 0.04 | 0.03 | --- |
| Dark-eyed Junco | *Junco hyemalis* | 0.18 | 0.25 | 0.57 |
| Western Tanager | *Piranga ludoviciana* | 0.41 | 0.56 | 0.78 |
| Black-headed Grosbeak | *Pheucticus melanocephalus* | 0.39 | 0.49 | 0.71 |
| Lazuli Bunting | *Passerina amoena* | 0.81 | 0.82 | 0.10 |
| Red-winged Blackbird | *Agelaius phoeniceus* | 0.03 | --- | --- |
| Western Meadowlark | *Sturnella neglecta* | 0.02 | --- | --- |
| Brown-headed Cowbird | *Molothrus ater* | 0.02 | --- | 0.04 |
| Bullock's Oriole | *Icterus bullockii* | 0.03 | 0.01 | --- |
| Purple Finch | *Carpodacus purpureus* | 0.02 | 0.04 | 0.12 |

| Common Name | Scientific Name | Freds Fire | Power Fire | Unburned Forest |
|---|---|---|---|---|
| Cassin's Finch | *Carpodacus cassinii* | 0.02 | 0.05 | 0.08 |
| Red Crossbill | *Loxia curvirostra* | --- | 0.01 | 0.01 |
| Lesser Goldfinch | *Spinus psaltria* | 0.15 | 0.05 | 0.01 |
| Lawrence's Goldfinch | *Spinus lawrencei* | 0.01 | --- | --- |
| Evening Grosbeak | *Coccothraustes vespertinus* | 0.04 | 0.02 | 0.10 |

**Appendix C.** Estimated detection probability (± SE) for 36 species in the Freds and Power fires and adjacent unburned forest. Astericks following species name indicate different detection probability between fires and unburned forest (**P* <0.05, ***P* <0.01).

| | ***Freds & Power fires*** | ***Unburned forest*** |
|---|---|---|
| Mountain Quail | 0.15 ± 0.03 | 0.11 ± 0.05 |
| Acorn Woodpecker | 0.15 ± 0.05 | 0.36 ± 0.15 |
| Hairy Woodpecker | 0.08 ± 0.04 | 0.10 ± 0.04 |
| White-headed Woodpecker | 0.15 ± 0.06 | 0.11 ± 0.04 |
| Northern Flicker | 0.16 ± 0.03 | 0.08 ± 0.04 |
| Olive-sided Flycatcher | 0.14 ± 0.06 | 0.10 ± 0.07 |
| Western Wood-Pewee | 0.16 ± 0.05 | 0.19 ± 0.09 |
| Hammond's Flycatcher | 0.08 ± 0.14 | 0.23 ± 0.08 |
| Dusky Flycatcher* | 0.19 ± 0.05 | 0.41 ± 0.04 |
| Warbling Vireo | 0.24 ± 0.09 | 0.33 ± 0.09 |
| Cassin's Vireo | 0.27 ± 0.09 | 0.29 ± 0.05 |
| Stellar's Jay | 0.27 ± 0.03 | 0.21 ± 0.03 |
| Mountain Chickadee | 0.19 ± 0.04 | 0.23 ± 0.03 |
| Red-breasted Nuthatch | 0.21 ± 0.08 | 0.28 ± 0.03 |
| Brown Creeper | 0.27 ± 0.07 | 0.33 ± 0.10 |
| Golden-crowned Kinglet | 0.40 ± 0.09 | 0.30 ± 0.05 |
| House Wren* | 0.40 ± 0.01 | 0.01 ± 0.01 |
| Bewick's Wren | 0.16 ± 0.05 | 0.09 ± 0.11 |
| Rock Wren | 0.30 ± 0.14 | 0.00 ± 0.00 |
| American Robin | 0.17 ± 0.05 | 0.16 ± 0.06 |
| Yellow-rumped Warbler | 0.20 ± 0.07 | 0.35 ± 0.06 |
| Hermit Warbler | 0.40 ± 0.09 | 0.35 ± 0.04 |
| Black-throated Gray Warbler | 0.36 ± 0.13 | 0.19 ± 0.05 |
| Nashville Warbler | 0.21 ± 0.06 | 0.35 ± 0.04 |
| Yellow Warbler | 0.42 ± 0.08 | 0.30 ± 0.14 |
| MacGillivray's Warbler | 0.25 ± 0.06 | 0.27 ± 0.09 |
| Green-tailed Towhee | 0.34 ± 0.03 | 0.25 ± 0.12 |
| Spotted Towhee | 0.29 ± 0.03 | 0.26 ± 0.06 |
| Chipping Sparrow | 0.22 ± 0.08 | 0.31 ± 0.17 |
| Fox Sparrow | 0.39 ± 0.03 | 0.41 ± 0.06 |
| Dark-eyed Junco** | 0.17 ± 0.04 | 0.39 ± 0.04 |
| Lazuli Bunting** | 0.26 ± 0.04 | 0.65 ± 0.12 |
| Western Tanager* | 0.21 ± 0.04 | 0.35 ± 0.04 |
| Black-headed Grosbeak** | 0.26 ± 0.03 | 0.51 ± 0.04 |
| Lesser Goldfinch | 0.15 ± 0.05 | 0.05 ± 0.08 |
| Purple Finch* | 0.52 ± 0.19 | 0.19 ± 0.08 |