Point Blue Report

Avian Monitoring of the Storrie and Chips Fire Areas

2014 Report

MAY 2015

Brent R. Campos and Ryan D. Burnett

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Cover photo: *A landscape burned in the Storrie Fire is home to high densities of shrub- and snag-nesting birds within two years after re-burning in the Chips Fire. Photo by Brent Campos.*

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EXECUTIVE SUMMARY

In this report we present our 2014 activities and results of avian monitoring in post-fire habitats of the Storrie and Chips Fires. By comparing data collected before (2010–2012) and after (2013–2014) the Chips Fire at sample units that have not experienced post-fire management and were green forest before the fire, we continue to detect substantial changes in the avifauna driven by burn severity. In 2014 we collected the first year of post-treatment data for a study on the effects of salvage logging in the Chips Fire. By comparing abundance from before and after salvage logging in a before-after control-impact framework for the 24 most prevalent bird species in our sample, we detected an effect of salvage logging on only a few species. Despite post-fire management activities, the post-fire snag guild in the Chips Fire has doubled in abundance from before to after the fire, a significant increase relative to changes at reference locations. Areas of the Storrie Fire that re-burned in the Chips Fire support twice the abundance of birds in the early seral and post-fire snag guilds, equivalent densities of the open forest guild, but fewer of the dense forest guild, than areas of the Chips Fire outside of the Storrie footprint.

2014 Activities

- We resurveyed existing post-fire study plots established in 2009 in the Storrie Fire footprint which re-burned in the Chips Fire (50 point count stations on 10 nest searching transects and 14 other point count stations).
- We surveyed 6 post-fire study plots established in 2013 in the Chips Fire area outside of the Storrie footprint (30 point count stations on 6 nest searching transects).
- We surveyed most Plumas-Lassen Administrative Study (PLAS) green forest point count stations that burned in the Chips fire (195 point count stations).
- We surveyed point count stations established in 2013 inside and outside salvage units in the Chips Fire area (110 point count stations).
- We collected vegetation/habitat data at 58 nests and 75 random locations in the Storrie and Chips Fires.

Post-fire Habitat Management Recommendations

Recommendations are a culmination 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–March).
- 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 that was forested and 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 landscape context (watershed, forest, ecosystem) and availability of different habitat types when planning post-fire management actions.
- Approach post-fire management through a climate-smart lens. Using the past to inform while planning 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.
- Be patient, strategic, and constrained in aiding the recovery of a post-fire landscape. Monitor, evaluate, and improve management activities.

Snags

- Manage a substantial portion of post-fire areas for large patches (20–300 acres) burned with high severity as wildlife habitat.
- 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.
- Retain snags in salvaged areas far greater than green forest standards and retain some 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 longer lasting source of snags for nesting birds.
- When reducing snags in areas more than five years post fire (e.g. Storrie 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 2 to 8 years they are used by Black-backed Woodpeckers.
- 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.
- Retain smaller snags in heavily salvaged areas to increase snag densities because a large range of snag sizes, from as little as 6 inches DBH, are used by a number of species for foraging and nesting. Though, most cavity nests are 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 a conifer-dominated ecosystem.
- Most shrub patches should be at least 10 acres and shrub cover should average over 50% across the area in order to support area-sensitive species such as Fox Sparrow.

- Retain natural oak regeneration with multiple stems; these dense clumps create valuable understory bird habitat in post-fire areas 5–15 years after the fire.
- When treating shrub habitats ensure some dense patches are retained.
- In highly decadent shrub habitat, consider burning or masticating half the area (in patches) in one year and burning the rest in the following years once fuel loads have been reduced.
- Maximize the use of prescribed fire to create and maintain montane chaparral habitat and consider a natural fire regime interval of 20 years as the targeted re-entry rotation for creating disturbance in this habitat.

Shaping Future Forest

- In areas with significant oak regeneration, limit replanting of dense stands of conifers. 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 burn severity 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 and natural recruitment of shade intolerant tree species.
- 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 to promote habitat mosaics.
- Avoid planting conifer species in or adjacent to riparian areas to avoid future shading of riparian deciduous vegetation and desiccation.
- Consider replanting riparian tree species (cottonwood, willow, alder, aspen) in riparian conservation areas affected by stand-replacing fire where natural regeneration is lacking.

INTRODUCTION

With the growing recognition of fire as a primary driver of ecosystem form and function in the Sierra Nevada (North et al. 2009; North 2012), and the increasing severity and extent of wildfires in the last few decades despite suppression efforts (Westerling et al. 2006; Miller & Safford 2012; Steel et al. 2015), there is substantial and urgent need to understand the value of habitats created by wildfire and how post-fire habitats are used by the unique wildlife community that occupy them (eg. Fontaine et al. 2009). Birds are excellent indicators of ecological processes that can provide important feedback regarding the health of managed fire-prone ecosystems (Alexander et al. 2007). There is increasing evidence that the response of birds to fire in montane habitats of the Western United States is not black and white, but rather a complex interaction between pre-fire habitat conditions, burn severity, patch size, and time since fire (Smucker et al. 2005; Kotliar et al. 2007; Fontaine et al. 2009; Fontaine & Kennedy 2012; Seavy & Alexander 2014). Effective management of post-fire areas depends on our understanding of these patterns.

In the Sierra Nevada, considerable debate surrounds the management of post-fire habitat. Management actions in post-fire habitat can affect the forest composition that will exist there for decades (Lindenmayer & Noss 2006; Swanson et al. 2010). Thus, it is necessary to carefully consider the species using post-fire habitat under different management prescriptions soon after fire and well into the post-fire time horizon. With an increasing emphasis on ecological restoration to improve ecosystem resilience and the delivery of ecosystem services, there is also a need to use ecological monitoring to minimize tradeoffs, seek complementarities among values, and optimize benefits among objectives (Hutto & Belote 2013).

Although post-fire forests provide habitat for unique assemblages of species, there are often other management objectives in burned forests. Post-fire timber harvest (i.e. salvage logging) is often proposed and implemented to meet economic, reforestation, or fuel-load objectives. Salvage logging directly or indirectly affects many aspects of post-fire habitat that wildlife respond to including snag density, retained snag longevity, and vegetation regeneration (Donato et al. 2006; Russell et al. 2006; Shatford et al. 2007), and as a result can influence presence and abundance of many wildlife species from the near term and to decades following harvest (Lindenmayer et al. 1997). While many studies have evaluated the effects of post-fire salvage logging on birds (e.g. LeCoure et al. 2000;

Morissette et al. 2002; Saab et al. 2007; Cahall & Hayes 2009), because variation in salvage prescriptions, treatment implementation, fire severity, and time since fire likely all influence the response of species to salvage logging, as well as regional and habitat differences for species of interest, results are not always consistent among studies. Further, some species may require specific habitat components, such as open habitat or shrubs for foraging, which vary independently of salvage treatments across regions, so results are not necessarily transferable across regions. There are no published studies on the effects of salvage logging on birds in the Sierra Nevada that local land managers can use to help guide their post-fire management decisions. Furthermore, we are only aware of one published study of post-fire salvage logging on birds, from the Boreal forest of eastern Canada, using a replicated before-after control-impact design (Schwab et al. 2006).

The Chips Fire in 2012 afforded several opportunities to greatly expand our knowledge of the effects of fire and post-fire management on Sierra Nevada avian communities. The Chips Fire burned through 75% of our Storrie Fire avian and vegetation monitoring sampling locations. By resurveying these locations we seized on a unique opportunity to assess the effects of re-burning on the avian community and vegetation with before and after data. In addition, the Chips Fire burned through a large portion of the Plumas-Lassen Administrative Study (PLAS) area where Point Blue had over 200 avian and vegetation sampling locations, just outside the boundaries of the Storrie Fire, with 4–10 years of pre-burn avian and vegetation data for these sampling locations. By resurveying these locations, we capitalized on a very rare opportunity to use data from before and after a fire across a fairly large landscape to understand avian response to this ecosystem driver. Lastly, we combined these datasets and additional sampling locations targeting post-fire timber harvest to conduct the first before-after control-impact study on the effects of salvage logging on birds in the Sierra Nevada. In this report we present data and results from our work to answer some of the management questions addressed by our avian monitoring projects in the Storrie and Chips Fires in an effort to help inform management of the post-fire landscapes across the Sierra Nevada.

METHODS

Study Location

The study area for projects presented in this report includes the Chips Fire and Storrie Fire footprints on the Almanor Ranger District of Lassen National Forest and the Mount Hough Ranger District of Plumas National Forest in the Sierra Nevada Mountains of Northeastern California (Figure 1). The Storrie Fire occurred in the summer of 2000, burning 56,677 acres. The Chips Fire occurred in the summer of 2012 and burned 76,890 acres; many of those acres are within the Storrie Fire footprint. The elevations of sites surveyed ranges from 1287–1941 m ($\bar{x}$ = 1533 m).

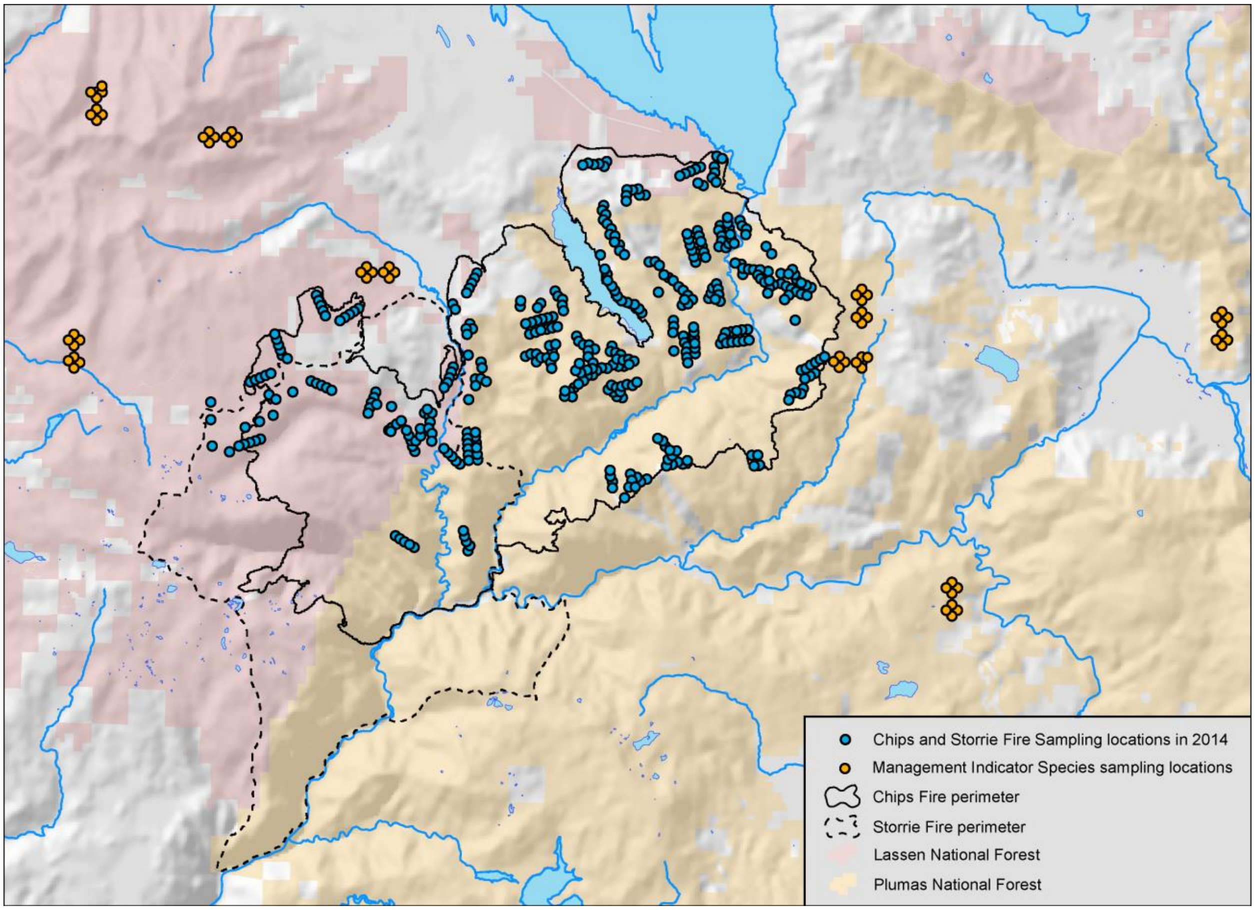
Sampling Design

We gathered data across four historic and current projects on the Almanor and Mount Hough Ranger Districts of the Lassen and Plumas National Forests to investigate the effects of timber salvage and wildland fire on landbirds. Survey locations were selected using four separate sampling design protocols.

One hundred and ninety-five of 399 avian survey sampling locations in the Chips Fire footprint surveyed in 2014 were originally established between 2002 and 2005 for the PLAS avian community response to fuel treatments study. Site selection for PLAS green forest survey locations followed a random stratified selection protocol. The PLAS site selection protocol for the unburned green forest sample is described in detail in the original PLAS study plan and previous annual reports (Stine et al. 2002; Burnett & Roberts 2015). For the purposes of this study, these sampling locations were used as: (1) impact samples for a BACI analysis of wildland fire, and (2) impact and control samples for a BACI analysis of timber salvage, depending on whether the points fell inside or outside of salvaged units.

We used data from sampling locations of the USFS Avian Management Indicator Species (MIS) project in conifer or montane chaparral that have not burned within 30 years, and within 20 km of the Chips Fire perimeter, as the control sample in our BACI analyses of changes in the avian community as a result of the Chips Fire (Figure 1). Details on the sampling design for the MIS project are described in Roberts et al. (2011).

Figure 1. Survey locations for data presented in this report.



In 2013, we added 110 sampling locations in the Chips Fire to monitor the effects of timber salvage operations. We used a site selection protocol where GIS layers of proposed salvage unit boundaries were used to place points in a way that would maximize the points a person could sample in one morning while covering the majority of treatment units in the fire. We used a subset of the PLAS green forest points as controls and supplemented them with newly selected points that resulted in a control sample with similar forest type, size class, density class, and burn severity as the pre-treatment impact sample.

Also in 2013, we added 30 sampling locations on six transects on the Chips Fire in Almanor Ranger District to monitor the habitat selection of cavity nesting birds. Our protocol for selecting these locations mirrored that used to select sampling locations for post-fire monitoring in the Storrie Fire. These sampling locations were also used as part of our control sample in our BACI analysis of timber salvage, as nearly all the points were placed outside of proposed timber salvage units.

Salvage Treatments

Salvage logging is the felling and removal of trees damaged by a natural disturbance, such as fire or insect outbreak. Salvage logging on Forest Service land in the Chips Fire started in 2013, before and during our field season. Tree harvest was primarily conducted by tractor-based logging systems or helicopter removal. Salvage treatments spanned the Lassen and Plumas National Forests. Tractor-based salvaged logging and helicopter-removal salvage logging was used on both forests. Salvage logging via helicopter removal on both National Forests and tractor based logging on the Lassen National Forest followed a prescription of retaining an average of 4 of the largest snags per acre as well as a number of non-merchantable trees (<12 in DBH) were also retained. Tractor-based salvage logging on the Plumas National Forest followed a prescription that retained 13% of each unit in untreated leave islands where all snags were left standing; in the remaining matrix very few merchantable trees were left standing.

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 three weeks of training to identify birds and estimate distances and passed a double-observer field test. All transects were visited twice during the peak of the breeding season from mid-May through the first week of July.

Nest Cavity Surveys

A 20-ha area (200 x 1000 m rectangle) surrounding the nest cavity point count transects was surveyed for nests of cavity-nesting birds following the protocol outlined in “A field protocol to monitor cavity-nesting birds” (Dudley & Saab 2003). In order to focus our attention on species of greatest management interest we ignored some of the more common cavity-nesters (e.g. chickadees, wrens). Our focal species included both species of bluebird, all woodpeckers, and all cavity-nesting raptors.

After the point count surveys were completed on all five point count locations, the nest survey was conducted for between two and four hours depending on the habitat, terrain, and time spent waiting to confirm a cavity's status. All nest surveys were completed by noon. The primary search method for finding nests was bird behavior, though, once an individual of the focal species was 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 up to 20 minutes to confirm the cavity was an active nest.

Black-backed Woodpecker Detections

We recorded the locations of all black-backed woodpecker detections in the Chips Fire footprint in 2014. This data is summarized in Appendix A. The detections presented in Appendix A are not independent because detections from multiple visits and multiple observers are included, such that each detection should not be considered a separate Black-backed Woodpecker.

Vegetation/Habitat Surveys

Vegetation data was collected at all point count locations in 2013. We measured vegetation characteristics within a 50-m radius plot centered at each point count station following a modified version of the relevé protocol outlined in Ralph et al. (1993). On these plots we measured shrub cover, live tree cover, herbaceous cover, as well as the relative cover of each species in the shrub and tree layers. We also measured basal area of live trees and snags using a 10-factor basal area key at five fixed locations in each plot.

In 2013 and 2014, at all nests confirmed as active, a variety of characteristics of both the nest tree and the cavity were recorded: diameter at breast height (DBH), tree height, tree species, tree decay class, scorch height on tree, cavity height, orientation of the cavity opening, aspect, and slope. For tree decay, we used a qualitative scale of decay ranging from one to eight, with one being a live, intact tree and eight being a severely decayed stump.

To estimate the density of snags on nest searching plots in 2013 and 2014, we counted every snag on 11.3-m plots ("snag plots") centered on point count locations, also recording each snag's DBH, species, height, and decay class. We collected these same snag plot data at all active nests and at five random locations distributed throughout the 20 ha nest plot. Once in the field, the observer navigated to within 10 m of a random location and chose the closest tree or snag >12 cm DBH as the snag plot center. The center trees of these random snag plots were used as a sample of random trees to compare to the trees with confirmed active nests. All data collected for trees and snags with active nests were also collected for these random trees.

Analysis: Unburned to Burned Forest

We used data collected inside and outside of the Chips Fire footprint in 2010–2012 and 2013–2014 in a before-after control-impact analysis to evaluate the change in abundance of 33 bird species in the two years following the Chips Fire where it burned through green forest. We identified 33 bird species to evaluate the ecological effects of the Chips Fire. We began with 81 species that are adequately sampled using our standardized point count method. Based on our local knowledge and published information about the habitat associations of these species, we selected the species mostly closely aligned with four broad forest conditions in the Sierra Nevada: post-fire snags, early seral understory, mid- to late-seral open canopy forest, and mid- to late-seral dense forest. The guilds represent four structural forest conditions that are created by fire or lack of fire: snags created by a very recent fire, early successional conditions created by regenerating vegetation following stand-replacing or frequent fire, open and mature conditions created by frequent low to moderate severity fire, and dense and mature conditions created by primarily long-term fire absence. We selected a total of 7 species in the post-fire snags guild, 9 species in the early seral understory guild, 9 species in the open forest guild, and 9 species in the dense forest guild. The species selected included year-round residents, short-distance migrants, and Neotropical migrants.

The mature dense forest (MDF) guild was comprised of: Pileated Woodpecker (*Dryocopus pileatus*), Cassin's Vireo (*Vireo cassinii*), Golden-crowned Kinglet (*Regulus satrapa*), Pacific Wren (*Troglodytes hiemalis*), Hermit Thrush (Catharus guttatus), Hermit Warbler (*Setophaga occidentalis*), Red-breasted Nuthatch (*Sitta canadensis*), Western Flycatcher (*Empidonax difficilis & occidentalis*), and Hammond's Flycatcher (*Empidonax hammondii*). The open mature forest (OMF) species are those that occur along forest edges and openings and/or utilize shade intolerant resources from the sub-canopy to the forest floor and included: Western Wood-Pewee (*Contopus occidentalis*), Olive-sided Flycatcher (*Contopus cooperi*), Warbling Vireo (*Vireo gilvus*), American Robin (*Turdus* *migratorius*), Nashville Warbler (*Oreothlypis ruficapilla*), Yellow-rumped Warbler (*Setophaga coronata*), Chipping Sparrow (*Spizella passerina*), Black-headed Grosbeak (*Pheucticus melanocephalus*), and Western Tanager (*Piranga ludoviciana*). The early seral forest (ESF) guild was comprised of species that use herbaceous and shrub habitats and included: Mountain Quail (*Oreortyx pictus*), Dusky Flycatcher (*Empidonax oberholseri*), Spotted Towhee (*Pipilo maculatus*), Green-tailed Towhee (*Pipilo chlorurus*), Fox Sparrow (*Passerella iliaca*), Chipping Sparrow (*Spizella passerina*),Yellow Warbler (*Setophaga petechia*), MacGillivray's Warbler (*Geothlypis tolmiei*), and Lazuli Bunting (*Passerina amoena*). Finally, the post-fire snag (PFS) guild was comprised of species that use fire-killed trees: Lewis' Woodpecker, Hairy Woodpecker (*Picoides villosus*), Black-backed Woodpecker (*Picoides arcticus*), White-headed Woodpecker (*Picoides albolarvatus*), Northern Flicker (*Colaptes auratus*), House Wren (*Troglodytes aedon*), and Mountain Bluebird (*Sialia currucoides*).

We tested whether the change in abundance from before to after the Chips Fire for these guilds was correlated with fire severity. We used the remotely sensed geospatial data layers created by the USGS and the USFS for the Monitoring Trends in Burn Severity project for the Chip Fire to classify burn severity at our sampling locations (USGS & USFS 2014). Fire severity was calculated as the mean Relativized differenced Normalized Burn Ratio (RdNBR) for the 30-m pixels within a 100-m radius of each sampling location in the Chips Fire. We then removed from analysis all points with a mean RdNBR below the threshold for low severity fire (RdNBR = 80) for the Chips Fire (USGS & USFS 2014). Using the USFS Region 5 Forest Activities geospatial dataset, we further restricted the impact sample to only points with less than 10% of the area within 100-m of the sampling location experiencing post-fire management activity. The unburned forest sample was comprised of point count data from our Management Indicator Species project collected outside of the Chips Fire perimeter that did not burn in the previous 30 years. For the purpose of this analysis, the RdNBR for these points was set to 0.

To evaluate the change in bird abundance before fire compared to the first and second breeding seasons following fire, relative to an unburned control sample, we built generalized linear mixed models with Poisson error and logarithmic link function using the package lme4 version 1.0-4 (Bates et al. 2013) in program R x64 version 3.0.2 (R Core Team 2013). Only point count locations with data from at least one of the three pre-fire breeding seasons (2010, 2011, and 2012) and both post-fire breeding seasons (2013 and 2014) were used. Our sample unit was a single point count visit and the dependent variable was the count of all individuals of each species in a guild. Random effects on the intercept parameter included transect, point, and a factor unique to each point-transect-year combination to account for repeated measures on each point within a year. There were three fixed effects: RdNBR (continuous), time (categorical: before, first, and second years after), and a RdNBR-by-time interaction. We interpreted a significant RdNBR-by-time interaction as a response to fire.

Analysis: Abundance in the Chips and Storrie Overlap Area

We used data collected inside and outside the Storrie and Chips Fire footprints between 2010 and 2014, before and after the Chips Fire, to evaluate two questions: (1) what differences in guild abundance exist in the Chips Fire inside and outside the Storrie Fire footprint, and (2) after two years of post-fire management activities following the Chips Fire (salvage logging and replanting), how abundant are the guilds in these two areas relative to nearby areas that did not burn? To investigate these questions, we built generalized linear mixed models with Poisson error and logarithmic link function using the package lme4 version 1.0-4 (Bates et al. 2013) in program R x64 version 3.0.2 (R Core Team 2013). Our sample unit was a single point count visit and the dependent variable was the count of each species. There were three fixed effects in the model: fire, time, and a fire-by-time interaction term. Fire was a categorical variable with three categories: unburned control (control), Storrie Fire area re-burned in Chips (twice-burned), and Chips Fire not burned in Storrie (once-burned). We did not control for the severity of either fire. Time was a categorical variable with three categories: before (2010–2012 breeding seasons), 2013, and 2014. Using the glht function in the package multcomp version 1.4-0 (Hothorn et al. 2008), we ran Tukey multiple comparisons to test for differences in the mean estimates of bird abundance for all combinations of the two factors, fire and time.

Analysis: Impacts of Salvage Logging

We used a BACI analysis to test for differences in the abundance of the 24 most prevalent species in our Chips Fire dataset in the breeding seasons before (year 2013) and after (year 2014) salvage logging, relative to untreated control stands. Unlike the other analyses in this report, we wanted to analyze species separately for this question;

we focused on the most prevalent species because of sample size constraints. This analysis is limited to the areas of the Chips Fire that were classified as conifer habitat before the fire according to the existing vegetation polygon feature classes in USFS Calveg geospatial datasets. We used the USFS Region 5 Forest Activities geospatial dataset to calculate the percent of the area within 100 m of our sampling units in seven different treatment categories/polygons: tractor logged, helicopter logged, roadside salvage, hazard tree removal, powerline threat tree removal, mechanical site prep, and manual site prep. We then compared these percentages to percentages our observers estimated during each visit to each sampling location and further evaluated treatment by reviewing post-salvage Google Earth imagery. Points where we recorded treatment but none was recorded in the GIS layers were removed from the analysis. We classified as impacted those sampling locations with at least 25% of the area treated by salvage helicopter or tractor methods, with the area treated by these methods greater than or equal to any mechanical or manual site preparation. We further restricted the impact sample by removing all points with 5% or more area affected by hazard tree removal, powerline tree removal, and roadside salvage. This resulted in 19 impact points on the Lassen NF (6 helicopter, 9 tractor, 4 helicopter and tractor) and 51 impact points (8 helicopter, 42 tractor, 1 helicopter and tractor) on the Plumas NF. The control sample was comprised of all sampling locations with 0% treated area within 100 m and RdNBR greater than the lowest mean burn severity at treated locations. This resulted in 13 and 66 control points on the Lassen and Plumas, respectively. The range and means of RdNBR values in the control and impact samples were similar (control: min=395, mean=741, max=1079; impact: min=380, mean=820, max=1114). The number of points in high burn severities was equivalent between the control (N=58) and impact (N=62) samples, though we had more points at moderate burn severities in the control sample (N=21) compared to the impact sample (N=8).

To estimate the interaction effect between the treatment and time variables on the discrete counts of each species, we built generalized linear mixed models with Poisson error and logarithmic link function using the package lme4 version 1.0-4 (Bates et al. 2013) in program R x64 version 3.0.2 (R Core Team 2013). Our sample unit was a single point count visit and the dependent variable was the count of each species within 100 m of the observer. There were three fixed effects included to assess treatment: treatment (continuous), time (binary: before/after), and a treatment-by-time interaction. The continuous treatment variable used the estimated area treated, as outlined above. Our use of a linear, continuous treatment variable accounts for the partial overlap of sampling units with treatment units. However, retained timber in salvage units is unaccounted for in the treatment variable, such that 100% treatment does not necessarily equate to all timber removed in the sampling unit. We also included fixed effects for fire severity, fire severity heterogeneity, elevation, aspect, pre-fire basal area, and pre-fire tree size. Fire severity (RdNBR) was calculated as described in the unburned to burned forest analysis above. As a measure of the heterogeneity of fire severity within 100 m, we also included the standard deviation (SD) of the pixels used to calculate the mean RdNBR. An interaction term between mean RdNBR and the SD RdNBR was included to test whether the effect of SD RdNBR depends on the mean RdNBR. Elevation and aspect were derived from a 30-m digital elevation model. Elevation was a continuous variable in meter units. Aspect was categorized as north, south, east, and west, with east used as the reference variable in the analysis. Pre-fire basal area was calculated as the cumulative 10-factor basal area of live and dead trees the year following the fire, as measured at each sampling point in the Chips Fire (see vegetation survey methods). Pre-fire tree size was derived from USFS Calveg geospatial data and categorized as pole (6–11″ DBH), small (11–24″ DBH), or large (>24″ DBH) trees, according to California Wildlife Habitat Relationships (CWHR) classification standards. Two points with missing data for basal area were removed from the analysis. Random effects on the intercept parameter included transect and point, which, together with year as a fixed effect in the model, accounted for repeated measures on each point within a year. We ran one model for each species. We interpreted a significant ($P < 0.05$) treatment-by-time interaction as a response to treatment.

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. Study site locations can be downloaded in various formats for use in GPS, GIS, or online mapping applications as well. Non-avian data (e.g., site narratives, vegetation) are stored on Point Blue's server.

RESULTS

Unburned to Burned Forest

The impact of the Chips Fire on birds in previously unburned forest varied with burn severity and guild. We did not detect a change in the abundance of the early seral forest guild, relative to unburned control points, in the first ($P = 0.783$) or second ($P = 0.926$) nesting seasons following the fire (Figure 2, Table 1). The open mature forest guild declined in the Chips Fire with increasing fire severity relative to controls in the first year following the fire ($P < 0.001$). However, by the second year following the fire, the difference in abundance of the open mature forest guild inside and outside the fire was the same as before the fire; but this was because of declines in the control sample rather than increasing abundance in the Chips Fire. The dense mature forest guild declined in areas with higher fire severity from before to after the fire in both post-fire years. Conversely, the post-fire snag guild increased in areas with higher fire severity and there was an increase in the guild from before to after the fire that correlated with fire severity.

Figure 2. The change in the index of abundance of bird species in four habitat guilds (y-axis), from before (2010–2012) to one (2013) and two(2014)years after the Chips Fire, in relation to the Relativized differenced Normalized Burn Ratio (RdNBR) at point count sampling locations (x-axis) in the Chips Fire and nearby unburned control points. Control points are represented as the value at zero RdNBR for each time step. Solid lines represent mean estimates. Dashed lines represent 95% confidence intervals.

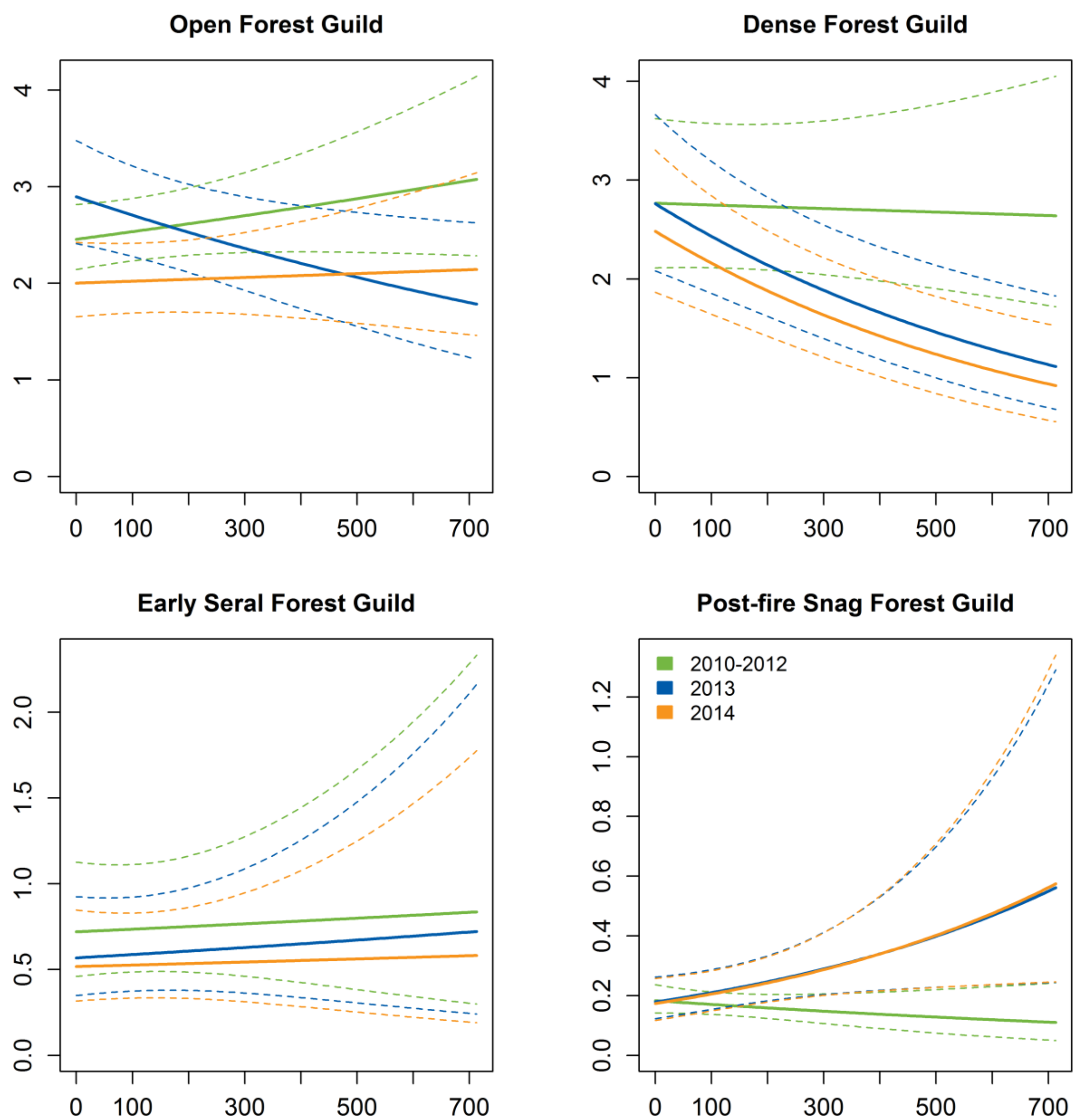


Table 1. Results from generalized linear mixed models for before-after control-impact changes in abundance of bird species in four habitat guilds before the Chips Fire and the two years after.

		β Estimate				
Guild	Variable	Mean	Lower 95% CI	Upper 95% CI	*Z*	*P*
Open Forest	Intercept	0.937	0.810	1.064	14.436	< 0.001
	RdNBR	0.057	-0.023	0.137	1.388	0.165
	Yr 2013	0.044	-0.125	0.213	0.507	0.612
	Yr 2014	-0.231	-0.404	-0.058	-2.612	0.009
	RdNBR × Yr 2013	-0.179	-0.272	-0.086	-3.765	< 0.001
	RdNBR × Yr 2014	-0.040	-0.135	0.056	-0.816	0.414
Dense Forest	Intercept	1.009	0.747	1.272	7.534	< 0.001
	RdNBR	-0.012	-0.113	0.090	-0.229	0.819
	Yr 2013	-0.148	-0.250	-0.047	-2.860	0.004
	Yr 2014	-0.269	-0.376	-0.162	-4.910	< 0.001
	RdNBR × Yr 2013	-0.217	-0.312	-0.123	-4.512	< 0.001
	RdNBR × Yr 2014	-0.239	-0.339	-0.138	-4.668	< 0.001
Early Seral	Intercept	-0.303	-0.717	0.111	-1.435	0.151
	RdNBR	0.038	-0.243	0.318	0.264	0.792
	Yr 2013	-0.221	-0.476	0.034	-1.701	0.089
	Yr 2014	-0.336	-0.598	-0.073	-2.510	0.012
	RdNBR × Yr 2013	0.023	-0.140	0.185	0.275	0.784
	RdNBR × Yr 2014	-0.008	-0.181	0.164	-0.093	0.926
Post-fire Snags	Intercept	-1.783	-2.004	-1.563	-15.852	< 0.001
	RdNBR	-0.129	-0.353	0.096	-1.121	0.262
	Yr 2013	0.258	-0.088	0.604	1.462	0.144
	Yr 2014	0.236	-0.118	0.591	1.305	0.192
	RdNBR × Yr 2013	0.417	0.104	0.730	2.614	0.009
	RdNBR × Yr 2014	0.431	0.113	0.749	2.656	0.008

Once- and Twice-Burned Managed Forest

The response of the post-fire snag (PFS) guild varied between once- and twice-burned areas. In the once-burned area, the change in abundance of PFS species was higher from before to the first ($P = 0.001$) and second ($P = 0.006$) years following the Chips Fire, relative to nearby unburned locations (Figure 3, Table 2). Whereas, in the twice-burned area, there was no change in the abundance of PFS species from before to the first ($P = 0.123$) and second ($P = 0.931$) years following the Chips Fire, relative to nearby unburned locations. Though PFS species increased in once-burned habitat because of the fire, abundance of PFS species in the once-burned and the unburned controls were not significantly different in any time period before or after the Chips Fire. Even though the PFS species did not increase in the twice burned area, in the second year after the Chips Fire, PFS species in the twice-burned area were two times as abundant as in unburned controls ($P < 0.01$).

We did not find an effect of the Chips Fire on the early seral forest (ESF) guild in either the once- or twice-burned habitats. ESF species declined in the once-burned ($P = 0.048$) and the twice-burned ($P < 0.001$) areas the first year after the Chips Fire. Though ESF species did significantly decline in once- and twice-burned habitat in the first year after fire, there was a concomitant decline at control stations, so the declines at burned location could not be attributed to the Chips Fire. In the second year after the fire, the abundance of ESF species in the twice-burned area increased slightly from the previous year, but was still significantly lower than pre-Chips levels ($P = 0.015$), while in the once-burned area, ESF abundance was not different from the first year post-Chips Fire. Notably, the ESF guild in the twice-burned area was 2–3 times more abundant compared to the once-burned area in all periods ($P < 0.05$).

The response of open mature forest (OMF) species to the Chips Fire was consistent among once- and twice-burned areas, but varied by time since fire. There was a significant decline of OMF species in the once-burned ($P < 0.001$) and twice-burned ($P < 0.001$) areas in the first year following the Chips Fire, relative to controls. However, there was not an effect of the Chips Fire in the second year in either area (once-burned: $P = 0.092$; twice-burned: $P = 0.102$), because there were declines in the OMF guild in the unburned control sample between the first and second years after the Chips Fire ($P =$

0.004). In the first and second years after the Chips Fire, OMF species remained 30–35% less abundant than before the Chips Fire in both once- and twice- burned areas.

We detected a significant decline in the abundance of the dense mature forest (DMF) guild in both the once- ($P < 0.001$) and twice-burned ($P = 0.010$) areas in the first two years after the Chips Fire, relative to controls. Despite the declines in DMF species in the once-burned area from before to after the Chips Fire, abundance in the once-burned and the control samples were not significantly different in the first ($P = 0.887$) or second ($P = 0.891$) post-fire years.

Figure 3. The change in the total summed abundance of bird species in each of four habitat guilds (y-axis), before and after the 2012 Chips Fire (x-axis) in areas that were previously burned in the Storrie Fire in 2000 (twice-burned) and those first burned in Chips (once-burned) compared to unburned controls in the adjacent landscape. Vertical lines represent 95% confidence intervals around mean estimates.

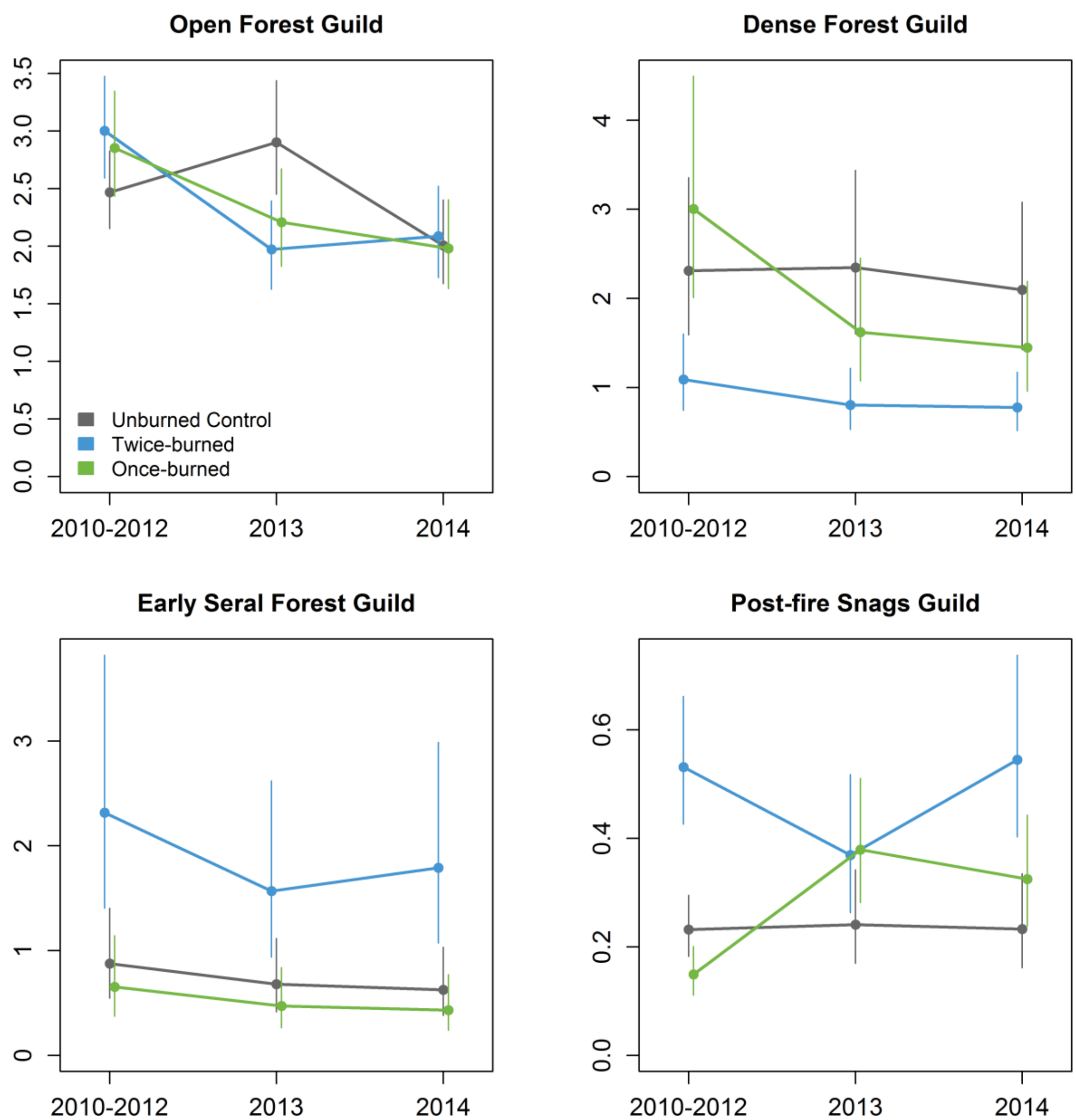


Table 2. Results from generalized linear mixed models for before-after control-impact changes in avian abundance in each of four habitat guilds as a result of the 2012 Chips Fire, in unburned, once-burned, and twice-burned forest.

		β Estimate				
Guild	Variable	Mean	Lower 95% CI	Upper 95% CI	*Z*	*P*
Open Mature Forest	Intercept	0.903	0.767	1.040	12.997	< 0.001
	Twice-burned	0.196	0.007	0.384	2.037	0.042
	Once-burned	0.146	-0.053	0.344	1.434	0.152
	Yr 2013	0.162	0.012	0.313	2.119	0.034
	Yr 2014	-0.207	-0.369	-0.046	-2.512	0.012
	Twice-burned × Yr 2013	-0.582	-0.764	-0.400	-6.269	< 0.001
	Once-burned × Yr 2013	-0.419	-0.589	-0.248	-4.810	< 0.001
	Twice-burned × Yr 2014	-0.156	-0.343	0.031	-1.637	0.102
	Once-burned × Yr 2014	-0.158	-0.342	0.026	-1.685	0.092
Dense Mature Forest	Intercept	0.838	0.465	1.211	4.401	< 0.001
	Twice-burned	-0.751	-1.287	-0.215	-2.748	0.006
	Once-burned	0.262	-0.287	0.811	0.936	0.350
	Yr 2013	0.015	-0.105	0.136	0.247	0.805
	Yr 2014	-0.098	-0.229	0.034	-1.458	0.145
	Twice-burned × Yr 2013	-0.321	-0.566	-0.076	-2.566	0.010
	Once-burned × Yr 2013	-0.632	-0.804	-0.459	-7.162	< 0.001
	Twice-burned × Yr 2014	-0.242	-0.486	0.001	-1.953	0.051
	Once-burned × Yr 2014	-0.632	-0.815	-0.448	-6.750	< 0.001
Early Seral Forest	Intercept	-0.133	-0.606	0.339	-0.553	0.580
	Twice-burned	0.974	0.287	1.660	2.781	0.005
	Once-burned	-0.292	-1.022	0.438	-0.785	0.433
	Yr 2013	-0.251	-0.450	-0.053	-2.482	0.013
	Yr 2014	-0.335	-0.547	-0.123	-3.096	0.002
	Twice-burned × Yr 2013	-0.139	-0.365	0.087	-1.207	0.227
	Once-burned × Yr 2013	-0.077	-0.349	0.195	-0.554	0.579
	Twice-burned × Yr 2014	0.077	-0.158	0.312	0.644	0.520
	Once-burned × Yr 2014	-0.081	-0.369	0.208	-0.549	0.583
Post-fire Snags	Intercept	-1.461	-1.703	-1.220	-11.870	< 0.001
	Twice-burned	0.829	0.502	1.156	4.975	< 0.001
	Once-burned	-0.440	-0.822	-0.058	-2.257	0.024
	Yr 2013	0.039	-0.339	0.417	0.202	0.840
	Yr 2014	0.004	-0.386	0.394	0.019	0.985
	Twice-burned × Yr 2013	-0.403	-0.915	0.109	-1.543	0.123
	Once-burned × Yr 2013	0.893	0.362	1.425	3.295	0.001
	Twice-burned × Yr 2014	0.022	-0.477	0.521	0.087	0.931
	Once-burned × Yr 2014	0.773	0.226	1.321	2.771	0.006

Salvage Logging

In the first breeding season following the completion of salvage logging activity on USFS lands in the Chips Fire, we detected a significant effect of salvage logging for 5 of the 24 species evaluated. Hermit Warbler, American Robin, Black-backed Woodpecker, and Hammond's Flycatcher, decreased with increasing area salvaged within 100 m of a point count circle (Figure 4); whereas Pine Siskin increased. We did not detect a change for any other species ($P > 0.05$). There was some evidence ($0.05 < P < 0.1$) of a treatment effect for two other species: Brown Creeper and Nashville Warbler.

The mean abundance of Hermit Warbler, Cassin's Finch, American Robin, Western Wood-pewee and Western Bluebird was significantly or very near significantly higher in the salvaged sample than the unsalvaged sample, even after controlling for the 13 environmental parameters included in our models. For these five species, some attribute of the composition of salvage units was correlated with their abundance, but not explained by the other variables in the model. Seven species declined in abundance from 2013 to 2014 across all sampling locations, regardless of whether or not they were salvaged. However, the effect of time was strongest for Lazuli Bunting, roughly quadrupling in abundance from 2013 to 2014.

Many of the variables used to control other environmental factors that influence bird abundance in the salvage logging model provided greater insight into bird use of post-fire habitats. Burn severity, as measured by mean RdNBR, explained a significant amount of the variation in abundance for 11 of the 24 species investigated. Four species were positively associated with higher burn severity and seven were negatively associated (Figure 5, Appendix B2). Two species were positively correlated with heterogeneity in burn severity, as measured by the standard deviation of RdNBR, and none were negatively correlated. Eight species had a significant interaction between the mean and heterogeneity of RdNBR, meaning that the effect of burn severity was stronger or weaker as the heterogeneity of burn severity increased, or vice versa. For example, for Yellow-rumped and Hermit Warblers, the negative effect of increasing mean burn severity is dampened as burn severity patchiness increases.

Species' abundances were correlated with the covariates of topography to varying degrees. In the elevation range of our sampling frame, seven of the 24 species were positively correlated with elevation, while two were negatively correlated. One species was less abundant on steeper slopes, and two were more abundant. We did not detect a correlation with aspect for most species. Black-backed Woodpecker showed some of the strongest relationships with aspect, with evidence that, compared to east aspects, they were moderately less abundant on south aspects and much less abundant on west aspects. Hammond's Flycatcher was positively correlated with north aspects. Hermit Warblers were negatively correlated with south aspects. Western Wood-pewee showed higher abundance on south aspects, and American Robin on west aspects.

For most species, abundance was more strongly affected by pre-fire tree size class than pre-fire basal area (Appendix B3). However, because of high variation around mean coefficient estimates of tree size class, only two of the relationships with tree size were significant, whereas five species were significantly correlated with basal area. Relative to stands with small trees (11–24″ DBH) pre-fire, stands with pole trees (6–11″ DBH) had fewer Cassin's Finch; whereas stands with of large trees (>24″ DBH), had more Mountain Chickadees. Hammond's Flycatcher, Hermit Warbler, Brown Creeper and Red-breasted Nuthatch were more abundant at sampling locations with higher pre-fire basal area, whereas Mountain Chickadee was less abundant.

Figure 4A. Partial dependency plots showing indices of avian abundance (y-axis) in relation to the percent of area treated within 100 m of point count locations in the Chips Fire (x-axis) before and one year after salvage logging. All other parameters in the model are held at their mean values or reference factor levels (aspect = east). Species with a *P*-value <0.05 for a treatment-by-time interaction term (trt:time) show a significant response to salvage logging treatments. Solid lines represent mean estimates. Dashed lines represent 95% confidence intervals. Species are ordered from most to least prevalent in the dataset.

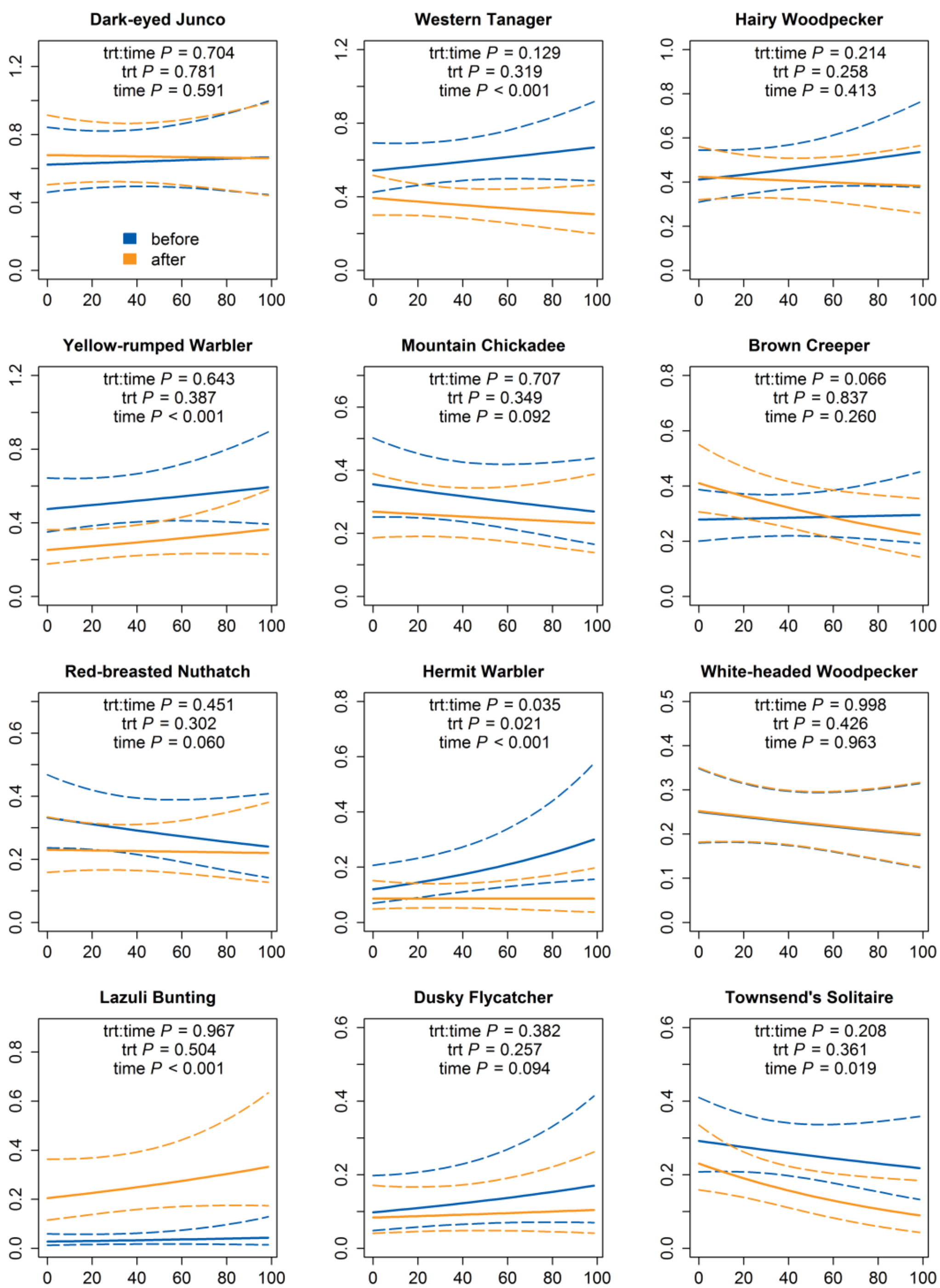


Figure 4B. Partial dependency plots showing indices of avian abundance (y-axis) in relation to the percent of area treated within 100 m of point count locations in the Chips Fire (x-axis) before and one year after salvage logging. All other parameters in the model are held at their mean values or reference factor levels (aspect = east). Species with a *P*-value <0.05 for a treatment-by-time interaction term (trt:time) show a significant response to salvage logging treatments. Solid lines represent mean estimates. Dashed lines represent 95% confidence intervals. Species are ordered from most to least prevalent in the dataset.

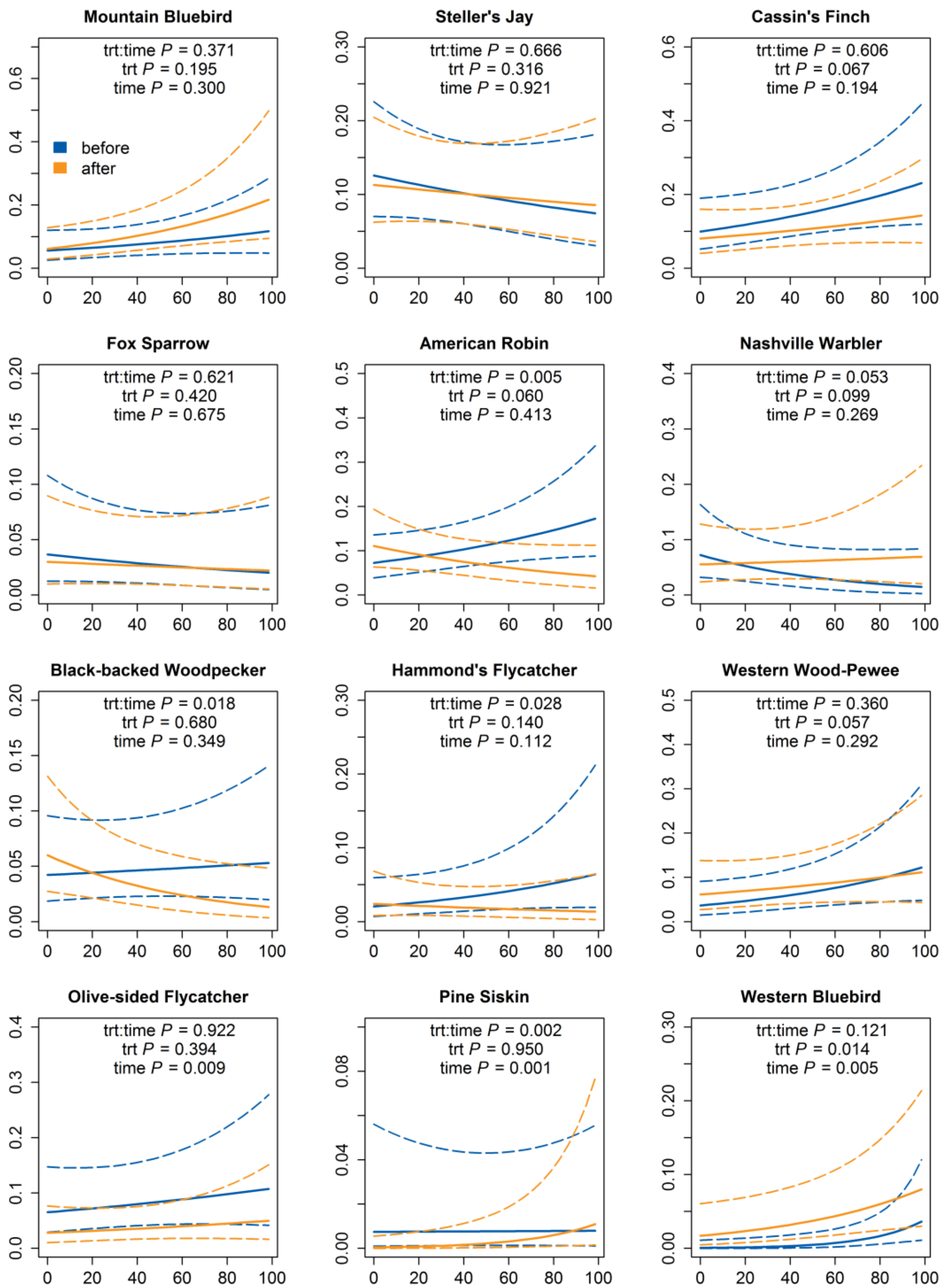


Figure 5A. Partial dependency plots showing indices of avian abundance (y-axis) in relation to the mean and heterogeneity (SD) of burn severity (RdNBR) within 100 m of point count locations in the Chips Fire (x-axis). All other parameters in the model are held at their mean values or reference factor levels (treatment = control, time=before, aspect = east). A *P*-value <0.05 for a mean-by-heterogeneity interaction term (mean:SD) indicates an effect of mean burn severity that depends on heterogeneity. Dots represent mean estimates over a gradient of burn heterogeneity (color gradient). Confidence intervals are not presented. Species are ordered from most to least prevalent in the dataset.

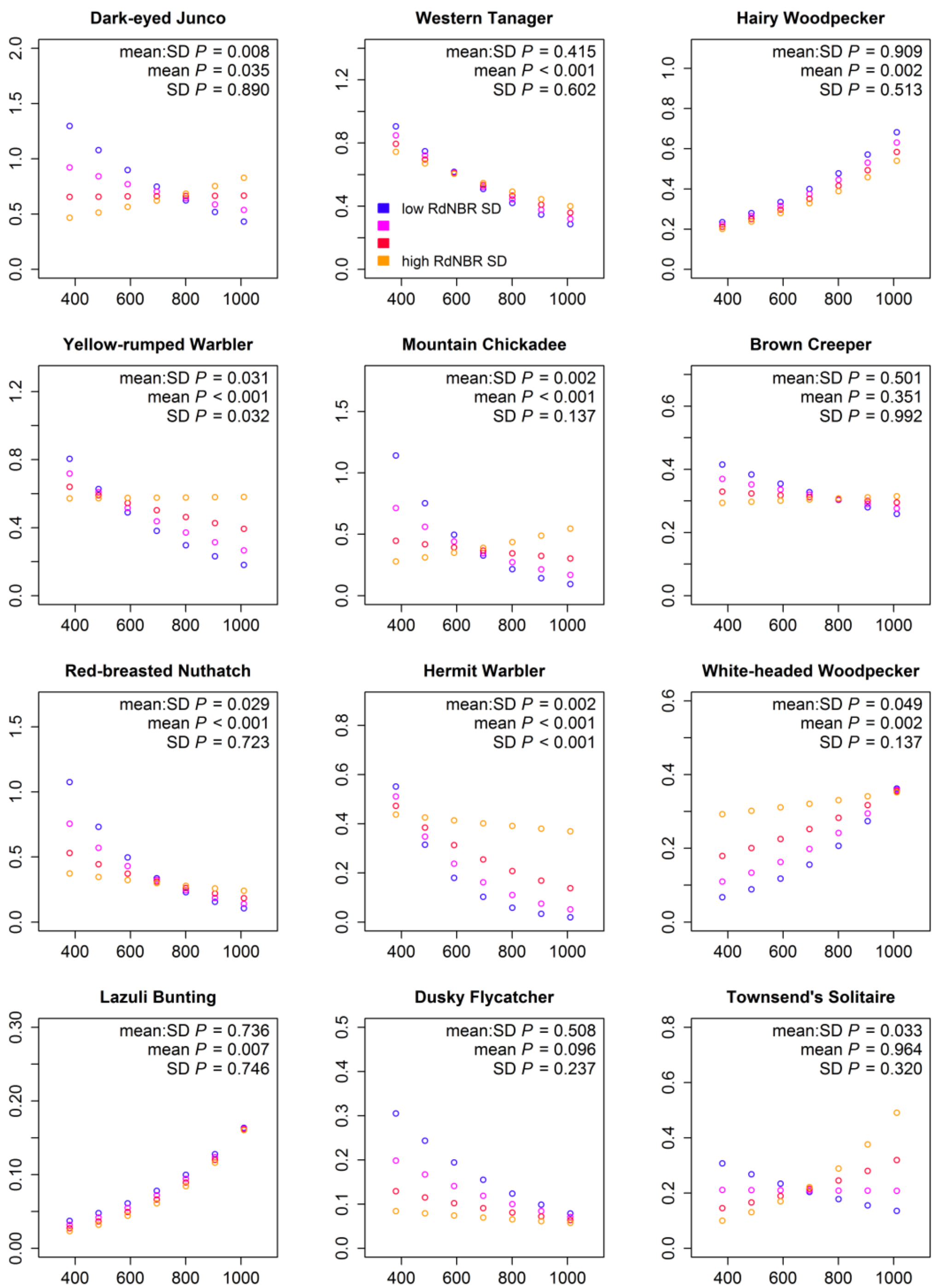
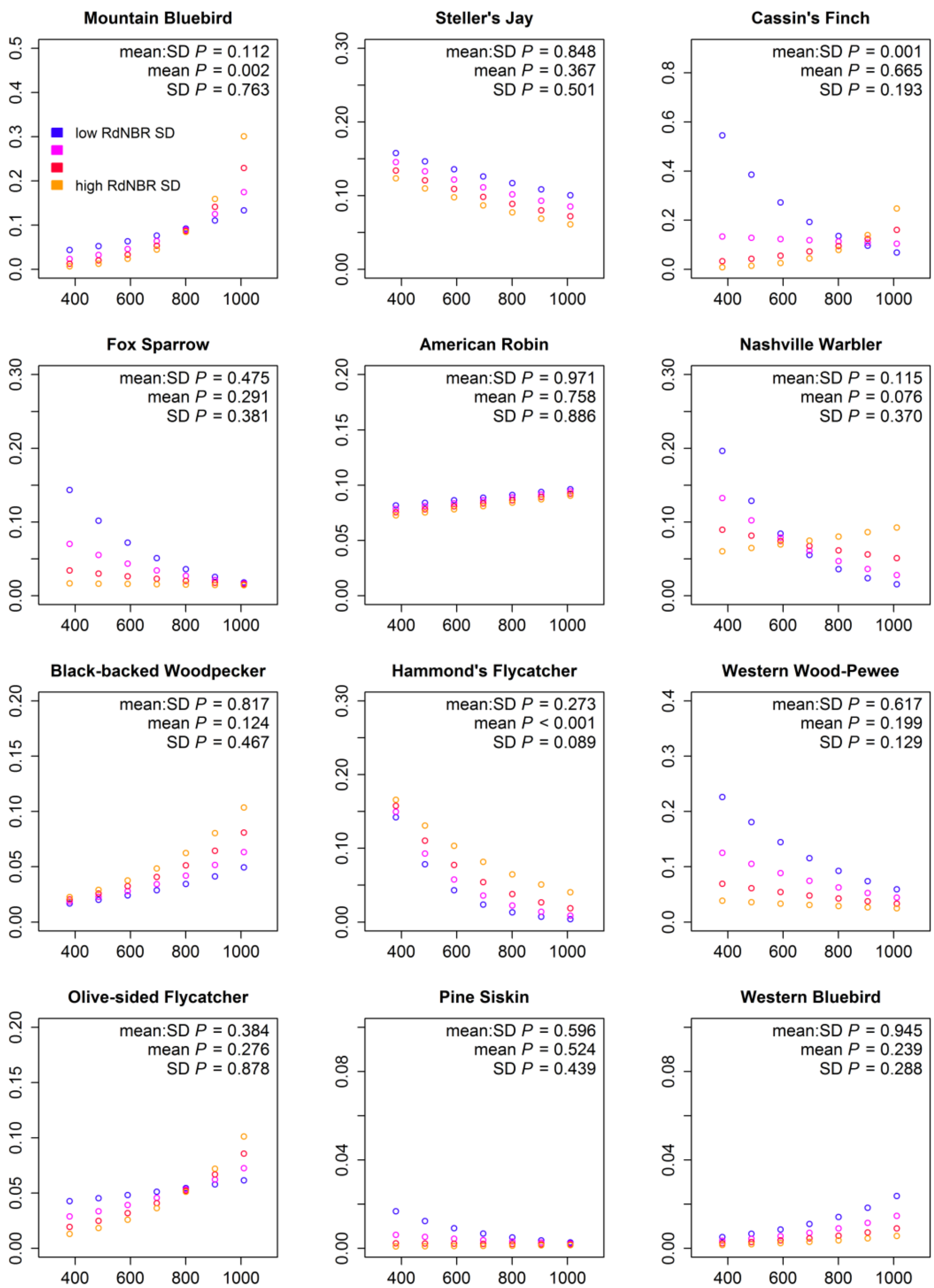


Figure 5B. Partial dependency plots showing indices of avian abundance (y-axis) in relation to the mean and heterogeneity (SD) of burn severity (RdNBR) within 100 m of point count locations in the Chips Fire (x-axis). All other parameters in the model are held at their mean values or reference factor levels (treatment = control, time=before, aspect = east). A *P*-value <0.05 for a mean-by-heterogeneity interaction term (mean:SD) indicates an effect of mean burn severity that depends on heterogeneity. Dots represent mean estimates over a gradient of burn heterogeneity (color gradient). Confidence intervals are not presented. Species are ordered from most to least prevalent in the dataset.



DISCUSSION

As average fire severity, fire size, and overall annual burned area increases in the Sierra Nevada (Westerling et al. 2006; Miller & Safford 2012), post-fire habitat management activities will also likely affect an increasing amount of land in the region, subsequently impacting plant and wildlife communities. In this report we assessed the effects of fire, degree of burn severity, repeat burning, and post-fire salvage logging on birds in two major fire areas in the northern Sierra mixed-conifer zone. Birds are excellent indicators of ecological processes that can provide important feedback regarding the health of managed fire-prone ecosystems (Alexander et al. 2007). After biological interpretation of these data, the information can be applied to future management actions in an adaptive management framework (Burnett 2011). As exemplified by our results, there is a differential response to ecosystem drivers (e.g. fire) and management (e.g. salvage logging) among bird species that yields information about the ecological condition of these burned landscapes. The findings presented here compliment a growing body of research into the effects of fire and post-fire management on western montane bird communities. Their value for management will increase as we continue data collection and analysis in subsequent years.

Where it burned through green forest, the Chips Fire resulted in substantial and immediate changes to the avian community, primarily attributable to vegetation burn severity. Before the Chips Fire, the landscape was dominated by mature dense and open forest associated species. In the two years following the fire, three of the four species guilds we analyzed were much more equally represented on the landscape, suggesting that, at the landscape scale, the fire increased avian diversity. As expected, the two species guilds with the strongest response to fire severity in the first two years after fire were the mature dense forest (MDF) and post-fire snag (PFS) guilds. The MDF species guild, which is mostly composed of species that glean insects from live tree foliage and bark, decreased with increasing tree mortality. The PFS guild, which is mostly composed of primary and secondary cavity nesters that nest in and forage on or from dead trees and dead sections of live trees, increased with increasing tree mortality. Both of these patterns are consistent with other studies (Raphael et al. 1987; Smucker et al. 2005). The early seral forest (ESF) guild was the least abundant guild before the fire and did not change following the fire. This is likely because the habitat attributes that these species are most closely associated with – herbaceous and shrub cover – were scarce before the fire and have not had sufficient time to develop in the recently burned landscape. As time since fire increases and vegetation conditions change, the early successional guild should dramatically increase as seen in other post-fire areas (Raphael et al. 1987; Fontaine et al. 2009; Burnett et al. 2012).

Comparing the abundance of different avian habitat guilds in once- and twice-burned areas to nearby unburned areas before and after the Chips Fire provides a unique opportunity to evaluate cumulative effects of large wildfires on wildlife communities. Abundances of each of the guilds in the twice-burned area appeared as expected, or higher than expected, relative to the unburned and once-burned areas. While there was an initial decline in open mature forest (OMF) species in the first year after the repeat fire, declines in the unburned area coupled with maintained densities in the burned areas over the two-year post-fire period, indicate that the twice-burned area is likely providing habitat of quality equivalent to nearby unburned forest for OMF species. The current levels of DMF species in the twice-burned area may seem low compared to pre-fire abundance, however, the DMF species decline was offset by the high abundance of ESF and PFS species in the twice-burned landscape. Prior to the reburn, the abundance of the ESF guild was high, and though it was initially reduced in the twice-burned area, it quickly rebounded in the second year post-fire in contrast to the once burned areas. ESF species abundance in the twice-burned area remained two times higher than the once-burned area in all time periods. The ability of this habitat to support ESF species is likely attributable to the vigorous stump sprouting exhibited by montane chaparral shrubs after fire. In 2014, stump sprouting shrubs were up to 2-m tall in some areas that burned at high severity in both the Chips and Storrie fires, providing ample nesting substrate for ESF species. This finding supports previous work illustrating that twice burned forest is not equivalent habitat to once burned to the avian community in western forests (Fontaine et al. 2009). Because of the rapid recovery of early seral forest conditions in re-burned areas, post-fire activities in re-burned areas in the first two years following the fire could result in greater impacts to nesting birds than in once-burned forest. PFS species in the twice-burned area were more than twice as abundant as controls before the Chips Fire, and remained so two years after the fire, demonstrating the value of burned (both once and twice) areas for snag-associated birds. Our results support earlier work showing that in western montane conifer forest, landscapes containing recently burned, recently re-burned, and not recently burned forests increases the diversity of the avian community at the landscape scale (Fontaine et al. 2009; Fontaine & Kennedy 2012).

Abundances of each of the guilds in the once-burned area also appeared mostly as expected relative to the twice-burned and unimpacted areas, with a couple exceptions. Though DMF species abundance in the once-burned area declined relative to pre-fire levels, counter to our predictions abundances are currently not significantly lower than nearby unburned areas. The other exception is the similarity in PFS species abundance in the once-burned and unburned areas; we would expect higher abundance of PFS species in the once-burned by the second year after the fire and an increase from the first to second years following the fire. These patterns may be a result of the relatively low portion of the once-burned area of the Chips Fire that burned at high severity and the burn severity heterogeneity, compared to initial assessments of other recent fires (e.g. Rim and King). Alternatively, the lower than expected abundance of the PFS guild in the second year post-fire may indicate post-fire management activities, such as salvage logging, are suppressing abundance.

In this report we present the results from, to our knowledge, the first before-after control-impact study of the effects of salvage logging on the bird community in the Sierra Nevada. In the first year after salvage logging activities, we detected four negative effects and one positive effect for the species we analyzed. A number of studies show effects of salvage logging on a larger portion of the avian community (e.g. Hutto & Gallo 2006; Saab et al. 2007; Cahall & Hayes 2009), including some of the species in this analysis for which we found no effect. We provide a few reasons why our initial results may conflict with these earlier studies. First, the snag retention guidelines used for tractor-based salvage logging operations on the Plumas, which retained at least 13% of all salvage units in 1–5 acre retention islands where all snags were left standing, could have mediated the negative effects of more aggressive harvest prescriptions. We also included 19 points that were at least partially salvaged via helicopter removal where a number of the smaller snags were left standing. Additionally, harvest units were often fairly small and the distance from our sampling stations to unsalavaged edge was often not far, with many of our sampling stations intersecting these edges. A few previous studies have found benefits of increased retention in harvested units, but results among regions and species are mixed and sometimes conflicting (Haggard & Gaines 2001; Schwab et al. 2006; Saab et al. 2009; Cahall & Hayes 2009). Second, many of the species we studied show high site tenacity and may return to an area and attempt to breed where they have been successful in the past despite changes in habitat quality (Bollinger & Gavin 1989; Haas 1998). Because of potential site fidelity in the first year following habitat changes, we would expect to detect effects of treatment for more species in subsequent years. Also, if salvage logging changes the trajectory of post-fire succession (Donato et al. 2012), we would expect greater changes to manifest as ecological processes that result in divergent habitat conditions play out. Third, we did not account for detection probability in these analyses. If detection probability is lower in unharvested stands than harvested stands, accounting for detection probability may translate into higher predicted abundances of birds in unharvested stands, and hence a larger treatment effect. However, in a study on the effects of mechanical aspen restoration treatments on birds on the Lassen Nation Forest that removed a similar amount of standing timber as the salvage logging prescriptions in this study, detection probability was not consistently higher or lower in unharvested compared to harvested stands for the 16 species analyzed (Campos & Burnett 2014).

The findings for the species for which we did detect a response to salvage logging are generally supported by previous studies on the topic. Many other studies have found negative effects of salvage logging on Black-backed Woodpeckers (Hutto & Gallo 2006; Koivula & Schmiegelow 2007; Saab et al. 2009), even in partially salvaged stands (Saab & Dudley 1998; Haggard & Gaines 2001; Cahall & Hayes 2009). The Black-backed Woodpecker is closely aligned with burned forests, and abundances typically dramatically increase after fire (Hutto 1995, 2008; Hoyt & Hannon 2002; Fogg et al. 2014). Because their preferred habitat is targeted for salvage logging (e.g. high densities of snags in areas burned by high severity fire), Black-backed Woodpeckers are of particular management interest in recent post-fire landscapes (Bond et al. 2012). Our finding of a decline in American Robin abundance after salvage logging is consistent with two other studies demonstrating a negative effect for this species (LeCoure et al. 2000; Schwab et al. 2006). However, a third study found no effect of salvage logging on American Robin (Cahall & Hayes 2009). The only study on salvage logging that we are aware of to include Brown Creeper found a negative effect of treatment (Cahall & Hayes 2009), which we also found some evidence for. Our finding of a negative effect of salvage logging on Hermit Warbler and Hammond's Flycatcher, and positive effect on

Pine Siskin, is the first time to our knowledge this has been documented for these species – we found no other studies on salvage logging that included these species.

This study represents only the second assessment of salvage logging on birds using both pre-and post-treatment data. The positive correlation of Western Bluebird and Hermit Warbler with the treatment covariate illustrates why before-after control-impact studies are important for testing hypotheses related to management actions. Without pretreatment data, we could have come to a different conclusion about the effects of salvage logging on these species. More species in this analysis would likely be correlated with treatment if the other non-treatment-related variables were removed.

The many environmental variables in our salvage logging models are not variables that explain the effects of logging treatments over time, so they should not bias our findings on the effects of salvage logging. Rather, by including these variables we absorbed variation in our samples that would not otherwise be accounted for in the model. Of the environmental variables we included, those related to burn severity resulted in the most informative and novel results. Species displayed a wide range of relationships with the mean and heterogeneity of burn severity at the 100-m scale. Our findings support the conclusions of other studies illustrating how diverse post-fire density patterns may be exhibited when burn severity is quantified and included in the analysis (Smucker et al. 2005; Kotliar et al. 2007). In future iterations of analyses including burn severity, we plan to use a model selection process to determine the scale at which individual species are most influenced by burn severity, as well as investigate the effects of burn patch size.

Looking Forward

The data we have collected and are continuing to collect in the Storrie and Chips Fires will be applied to many upcoming products. The analyses in this report will be expanded upon and finalized with an additional year of data collection in 2015. Three major products are planned. Firstly, a more detailed evaluation of the changes in the avian community following a large fire. This will be accomplished with a BACI analysis of individual species responses to fire that considers finer categories of fire severity in a longer time series. Secondly, by combining another year of data with those from several other concurrent studies in recent fires in the Sierra Nevada, we will be able to provide the first quantitative evaluation of the effects of salvage logging on the avian community of this region. For this analysis we will experiment with using a different measure of area treated: percent of basal area removed. This will enable us to simultaneously analyze the effects of other types of snag removal with tractor and helicopter salvage logging, including hazard tree removal and roadside salvage. Lastly, using the data collected at nest searching transects in the Chips, Storrie, Cub and Moonlight Fires, we will evaluate the local- and landscape-scale habitat associations for primary and secondary cavity nesting birds in burned areas of the northern Sierra Nevada.

LITERATURE CITED

Alexander, J. D., N. E. Seavy, and P. E. Hosten. 2007. Using conservation plans and bird monitoring to evaluate ecological effects of management: an example with fuels reduction activities in southwest Oregon. Forest Ecology and Management **238**:375–383.

Bates, D., M. Maechler, B. Bolker, and S. Walker. 2013. lme4: Linear mixed-effects models using Eigen and S4. Available from http://CRAN.R-project.org/package=lme4.

Bollinger, E. K., and T. A. Gavin. 1989. The Effects of Site Quality on Breeding-Site Fidelity in Bobolinks. The Auk **106**:584–594.

Bond, M. L., R. B. Siegel, and D. L. Craig, editors. 2012. A conservation strategy for the Black-backed Woodpecker (*Picoides arcticus*) in California. Version 1.0. The Institute for Bird Populations and California Partners in Flight, Point Reyes Station, California.

Burnett, R. D. 2011. Integrating avian monitoring into forest management: pine-hardwood and aspen enhancement on the Lassen National Forest. Pages 33–37 in J. L. Stephens, K. Kreitinger, C. J. Ralph, and M. T. Green, editors. Informing ecosystem management: science and process for landbird conservation in the western United States. U.S. Department of Interior, Fish and Wildlife Service, Biological Technical Publication, FWS/ BTP-R1014-2011, Washington, D.C.

Burnett, R. D., M. Preston, and N. E. Seavy. 2012. Plumas-Lassen Administrative Study 2011 Post-fire avian monitoring report. PRBO Conservation Science, Petaluma, CA.

Burnett, R.D. and L.J. Roberts. 2015. A Quantitative Evaluation of the Spotted Owl Conservation Umbrella in the Sierra Nevada. PLoS ONE 10(4): e0123778.

Cahall, R. E., and J. P. Hayes. 2009. Influences of postfire salvage logging on forest birds in the Eastern Cascades, Oregon, USA. Forest Ecology and Management **257**:1119–1128.

Campos, B. R., and R. D. Burnett. 2014. Avian Response to Mechanical Aspen Restoration in Sierra Nevada Coniferous Forest. Restoration Ecology **22**:616–624.

Donato, D. C., J. L. Campbell, and J. F. Franklin. 2012. Multiple successional pathways and precocity in forest development: can some forests be born complex? Journal of Vegetation Science **23**:576–584.

Donato, D. C., J. B. Fontaine, J. L. Campbell, W. D. Robinson, J. B. Kauffman, and B. E. Law. 2006. Post-Wildfire Logging Hinders Regeneration and Increases Fire Risk. Science **311**:352–352.

Dudley, J., and V. A. Saab. 2003. A field protocol to monitor cavity-nesting birds. RMRS-RP-44. US Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Fogg, A. M., L. J. Roberts, and R. D. Burnett. 2014. Occurrence patterns of Black-backed Woodpeckers in green forest of the Sierra Nevada Mountains, California, USA. Avian Conservation and Ecology **9**. Available from http://www.ace-eco.org/vol9/iss2/art3/.

Fontaine, J. B., D. C. Donato, W. D. Robinson, B. E. Law, and J. B. Kauffman. 2009. 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.

Fontaine, J. B., and P. L. Kennedy. 2012. Meta-analysis of avian and small-mammal response to fire severity and fire surrogate treatments in U.S. fire-prone forests. Ecological Applications **22**:1547–1561.

Haas, C. A. 1998. Effects of Prior Nesting Success on Site Fidelity and Breeding Dispersal: An Experimental Approach. The Auk **115**:929–936.

Haggard, M., and W. L. Gaines. 2001. Effects of stand-replacement fire and salvage logging on a cavity-nesting bird community in Eastern Cascades, Washington **75**:387–396.

Hothorn, T., F. Bretz, and P. Westfall. 2008. Simultaneous inference in general parametric models. Biometrical Journal **50**:346–363.

Hoyt, J. S., and S. J. Hannon. 2002. Habitat associations of black-backed and three-toed woodpeckers in the boreal forest of Alberta. Canadian Journal of Forest Research **32**:1881–1888.

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. 2008. The ecological importance of severe wildfires: some like it hot. Ecological Applications **18**:1827–1834.

Hutto, R. L., and R. T. Belote. 2013. Distinguishing four types of monitoring based on the questions they address. Forest Ecology and Management **289**:183–189.

Hutto, R. L., and S. M. Gallo. 2006. The effects of postfire salvage logging on cavity-nesting birds. The Condor **108**:817–831.

Koivula, M. J., and F. K. A. Schmiegelow. 2007. Boreal woodpecker assemblages in recently burned forested landscapes in Alberta, Canada: Effects of post-fire harvesting and burn severity. Forest Ecology and Management **242**:606–618.

Kotliar, N. B., P. L. Kennedy, and K. Ferree. 2007. Avifaunal responses to fire in southwestern montane forests along a burn severity gradient. Ecological Applications **17**:491–507.

LeCoure, M., F. Schwab, N. Simon, and A. Diamond. 2000. Effects of post-fire salvage logging on breeding birds in western Labrador. Northeast Wildlife **55**:39–46.

Lindenmayer, D. B., R. B. Cunningham, and C. F. Donnelly. 1997. Decay and collapse of trees with hollows in eastern australian forests: impacts on arboreal marsupials. Ecological Applications **7**:625–641.

Lindenmayer, D. B., and R. F. Noss. 2006. Salvage logging, ecosystem processes, and biodiversity conservation. Conservation Biology **20**:949–958.

Miller, J. D., and H. Safford. 2012. Trends in wildfire severity: 1984 to 2010 in the Sierra Nevada, Modoc Plateau, and southern Cascades, California, USA. Fire Ecology **8**:41–57.

Morissette, J. L., T. P. Cobb, R. M. Brigham, and P. C. James. 2002. The response of boreal forest songbird communities to fire and post-fire harvesting. Canadian Journal of Forest Research **32**:2169–2183.

North, M. 2012. Managing Sierra Nevada forests. PSW-GTR-237. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA.

North, M., P. Stine, K. O'Hara, W. J. Zielinski, and S. Stephens. 2009. An ecosystem management strategy for Sierran mixed-conifer forests. PSW-GTR-220. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA.

Ralph, C. J., S. Droege, and J. R. Sauer. 1995. Managing and monitoring birds using point counts: standards and applications. Pages 161–169 in C. J. Ralph, J. R. Sauer, and S. Droege, editors. Monitoring bird populations by point counts. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, California.

Ralph, C. J., G. R. Geupel, P. Pyle, T. E. Martin, and D. F. DeSante. 1993. Handbook of field methods for monitoring landbirds. PSW-GTR-144. Pacific Southwest Research Station, Forest Service, US Department of Agriculture, Albany, CA.

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

R Core Team. 2013. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. Available from http://www.R-project.org/.

Roberts, L. J., R. D. Burnett, and A. M. Fogg. 2011. Sierra Nevada National Forests Management Indicator Species Project 2010 Annual Report. PRBO Conservation Science, Petaluma, CA.

Russell, R. E., V. A. Saab, J. G. Dudley, and J. J. Rotella. 2006. Snag longevity in relation to wildfire and postfire salvage logging. Forest Ecology and Management **232**:179–187.

Saab, V. A., and J. G. ; Dudley. 1998. Responses of cavity-nesting birds to stand-replacement fire and salvage logging in ponderosa pine/Douglas-fir forests of southwestern Idaho. RMRS-RP-11. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Ogden, UT. Available from http://www.treesearch.fs.fed.us/pubs/23853.

Saab, V. A., R. E. Russell, and J. G. Dudley. 2007. Nest densities of cavity-nesting birds in relation to postfire salvage logging and time since wildfire. The Condor **109**:97–108.

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

Schwab, F. E., N. P. P. Simon, S. W. Stryde, and G. J. Forbes. 2006. Effects of postfire snag removal on breeding birds of western Labrador. Journal of Wildlife Management **70**:1464–1469.

Seavy, N. E., and J. D. Alexander. 2014. Songbird response to wildfire in mixed-conifer forest in south-western Oregon. International Journal of Wildland Fire **23**:246–258.

Shatford, J. P. A., D. E. Hibbs, and K. J. Puettmann. 2007. Conifer regeneration after forest fire in the Klamath-Siskiyous: how much, how soon? Journal of Forestry **105**:139–146.

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.

Steel, Z. L., H. D. Safford, and J. H. Viers. 2015. The fire frequency-severity relationship and the legacy of fire suppression in California forests. Ecosphere **6**:art8.

Stine, P., M. Landram, J. Keane, D. Lee, B. Laudenslayer, P. Weatherspoon, and J. Baldwin. 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.

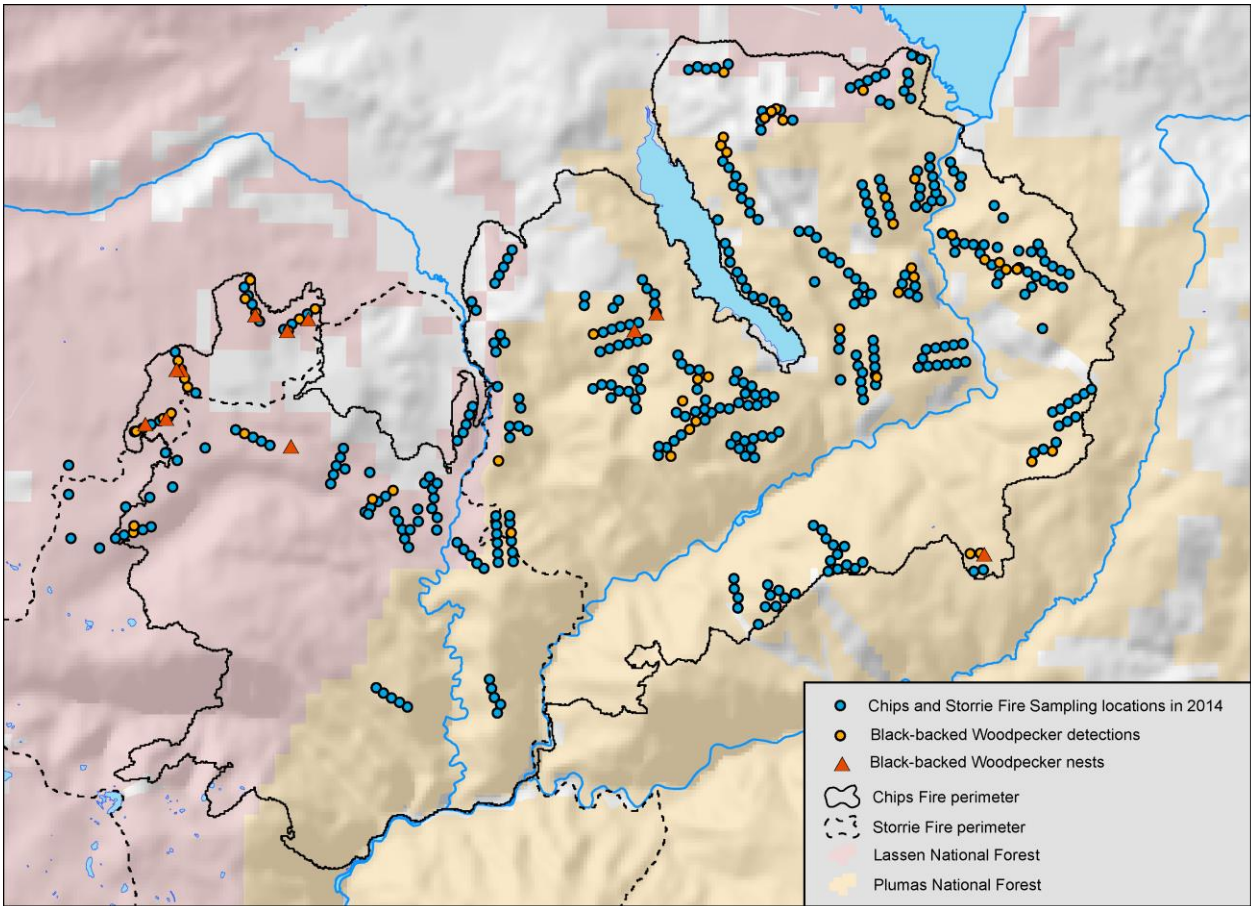
Swanson, M. E., J. F. Franklin, R. L. Beschta, C. M. Crisafulli, D. A. DellaSala, R. L. Hutto, D. B. Lindenmayer, and F. J. Swanson. 2010. The forgotten stage of forest succession: early-successional ecosystems on forest sites. Frontiers in Ecology and the Environment **9**:117–125.

U.S. Geological Survey, and U.S. Forest Service. 2014. Monitoring Trends in Burn Severity assessment of Fire Information: ca4001012127720120729. Sioux Falls, SD.

Westerling, A. L., H. G. Hidalgo, D. R. Cayan, and T. W. Swetnam. 2006. Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity. Science **313**:940–943.

APPENDICES

Appendix A1. Black-backed woodpecker detections in the Chips Fire perimeter during the 2014 field season.



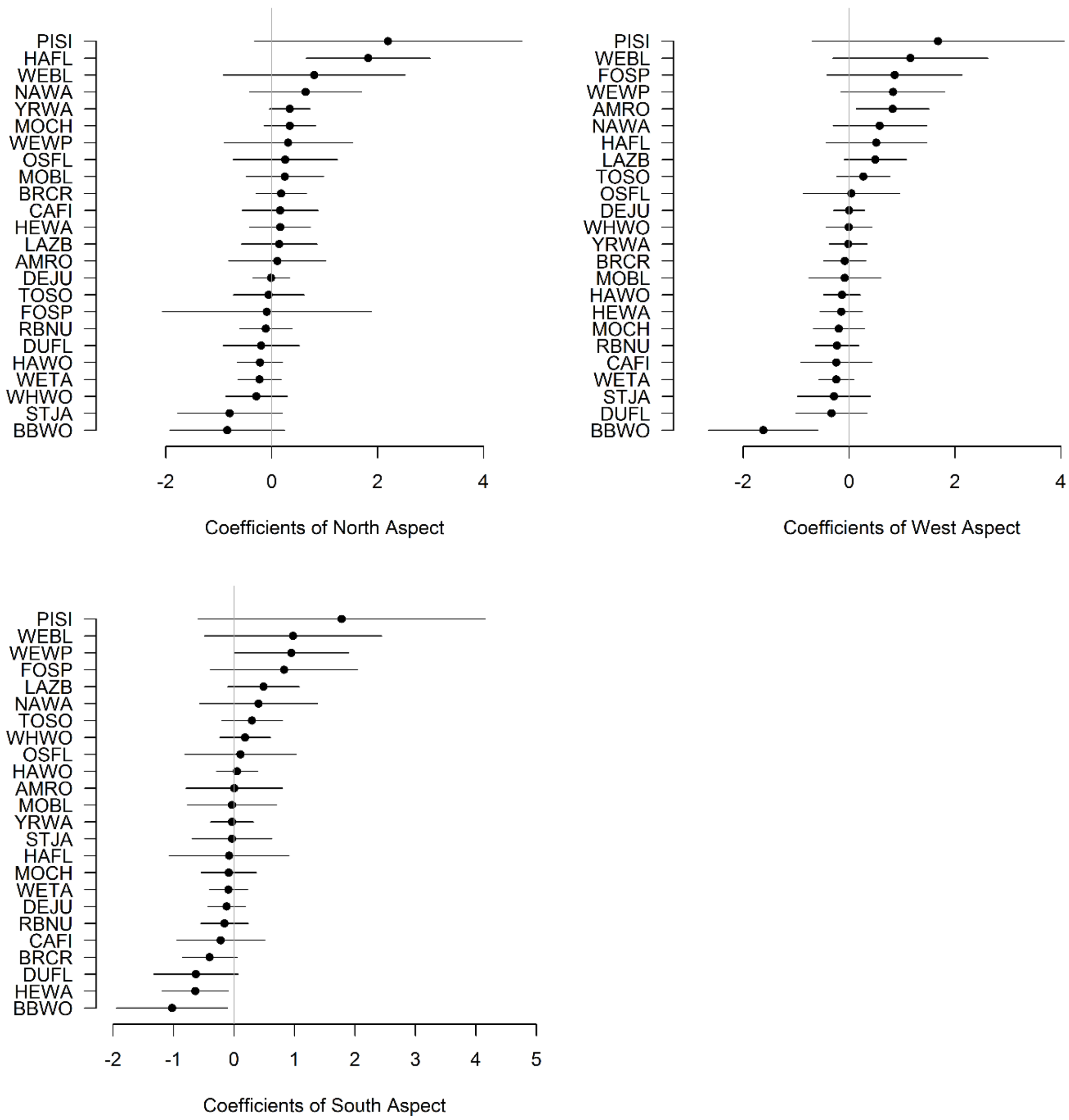
Appendix A2. Black-backed woodpecker detections in the Chips Fire perimeter during the 2014 field season.

Date	Number Detected	Nest	Easting (UTM WGS84)	Northing (UTM WGS84)	Transect	Nearest Point
5/7/2014	2		657442	4448822	CS01	12
5/7/2014	1		657541	4448883	CS01	1
5/7/2014	2		657391	4448774	CS01	2
5/7/2014	1		657245	4448630	CS01	4
5/16/2014	1		643854	4442998	CH03	4
5/16/2014	2	X	645249	4442882	CH04	2
5/16/2014	1	X	644692	4442551	CH04	5
5/16/2014	1		645431	4443156	CH04	1
5/18/2014	1		657415	4448809	CS01	12
5/18/2014	1		657734	4448585	CS01	10
5/18/2014	1		656115	4449809	CS02	2
5/19/2014	1		660460	4441829	224	7
5/19/2014	1		652871	4442727	MSQ2	6
5/20/2014	1		661299	4447141	223	2
5/20/2014	1		647665	4438390	ST13	5
5/20/2014	1		647125	4438141	ST13	3
5/22/2014	1		650848	4437371	214	1
5/25/2014	1		641475	4440104	CH01	4
5/25/2014	2		640726	4439738	CH01	1
5/25/2014	1		642099	4440962	CH02	1
5/25/2014	1		641829	4441656	CH02	4
5/25/2014	1	X	641920	4441421	CH02	3
5/25/2014	1		642012	4441190	CH02	2
5/25/2014	1		642099	4440962	CH02	1
5/25/2014	1	X	644900	4439485	LA08B	S
5/28/2014	1		663100	4437218	314	8
5/28/2014	1	X	663463	4437218	314	5
5/30/2014	1		660961	4444103	CS04	1
5/30/2014	1		661362	4444527	CS04	5
5/30/2014	1		660526	4446621	OHC1	9
5/31/2014	1		650449	4439274	CS09	14
5/31/2014	3	X	654520	4443352	CS10	9
6/1/2014	1		664102	4444825	213	1
6/1/2014	1		663229	4445055	OHC2	7
6/1/2014	1		663812	4444810	OHC2	10
6/1/2014	1		662344	4445678	OHC2	1
6/1/2014	1		663627	4444986	OHC2	9
6/2/2014	1		655042	4439549	CAR1	12
6/2/2014	1		655305	4441030	CS08	13

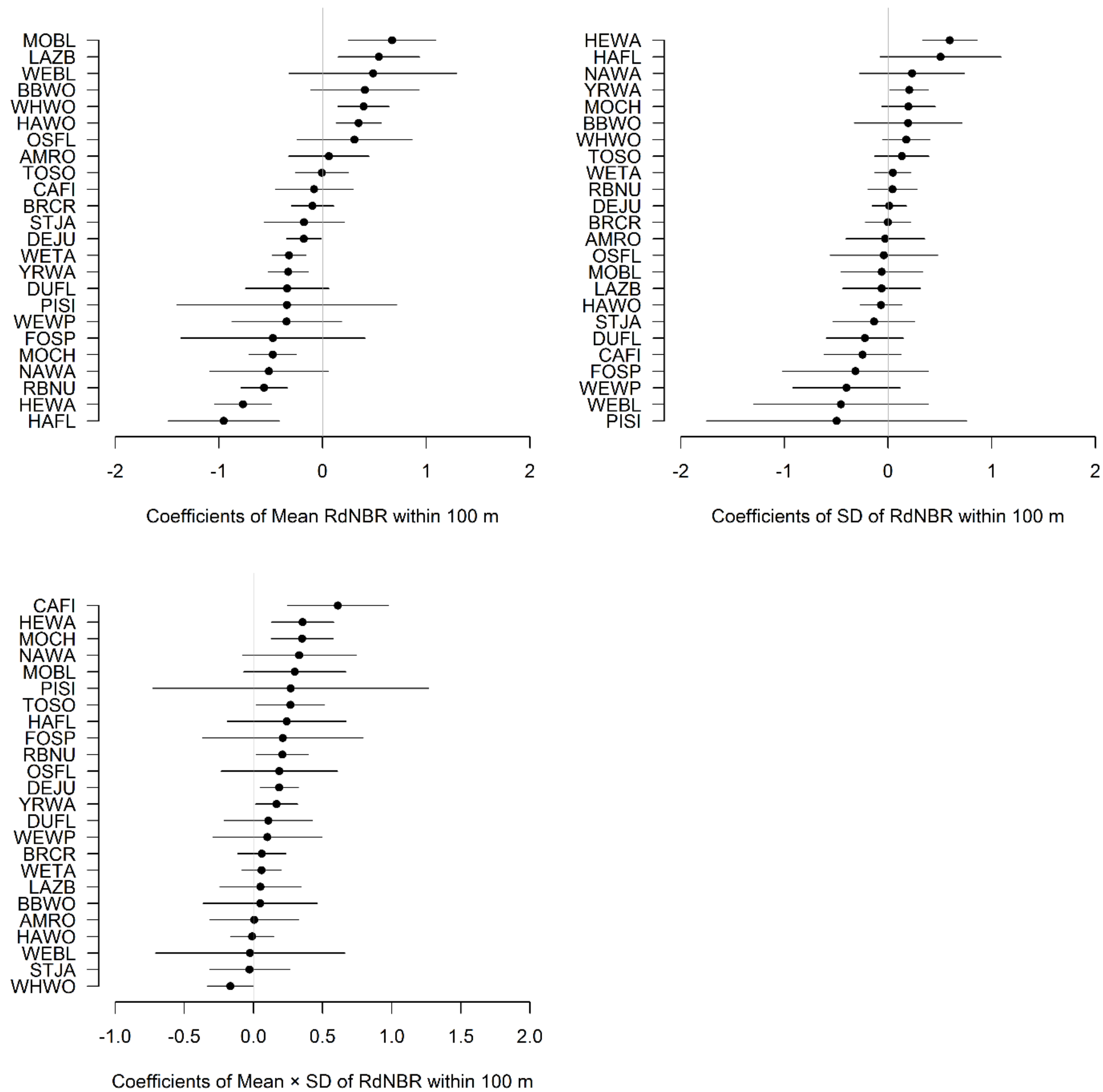
Appendix A2 (continued). Black-backed woodpecker detections in the Chips Fire perimeter during the 2014 field season.

Date	Number Detected	Nest	Easting (UTM WGS84)	Northing (UTM WGS84)	Transect	Nearest Point
6/4/2014	1		640779	4437048	ST15	3
6/5/2014	1		665205	4440016	CS12	2
6/5/2014	1		664666	4439720	CS12	5
6/5/2014	2	X	653947	4442873	MSQ2	2
6/8/2014	1		659844	4449453	CH05	4
6/9/2014	1		643676	4443869	CH03	1
6/9/2014	1		643555	4443366	CH03	2
6/9/2014	2		641617	4440149	CH03	5
6/9/2014	2	X	643828	4442934	CH03	4
6/9/2014	1		645431	4443156	CH04	1
6/9/2014	1		645025	4442872	CH04	3
6/9/2014	1		644740	4442556	CH04	5
6/14/2014	2		659423	4443078	CS06	7
6/15/2014	2		640767	4439745	CH01	2
6/15/2014	1		641617	4440149	CH01	5
6/15/2014	2	X	641550	4440117	CH01	5
6/15/2014	1	X	640999	4439950	CH01	3
6/15/2014	2		641688	4440252	CH01	5
6/15/2014	1		641920	4441421	CH02	3
6/15/2014	1		641829	4441656	CH02	4
6/15/2014	1	X	641787	4441420	CH02	3
6/15/2014	1		643655	4439774	ST06	2
6/16/2014	2		640793	4437227	ST15	3
6/18/2014	1		664666	4439720	CS12	5
6/18/2014	1		660760	4445924	OHC1	12
6/19/2014	3		661283	4444767	CS04	4
6/19/2014	2		661362	4444527	CS04	5
6/21/2014	1		656158	4448081	BVR3	1
6/21/2014	1		656100	4447859	BVR3	2
6/21/2014	2		656264	4447684	BVR3	3
6/23/2014	1		663101	4437218	314	5
6/23/2014	1		663372	4437238	314	6
6/23/2014	1		655678	4440496	CAR1	7
6/23/2014	2		655517	4440276	CAR1	8
6/23/2014	1		655969	4441691	CS08	5
6/23/2014	1		655686	4441617	CS08	6
6/23/2014	1		655305	4441030	CS08	13

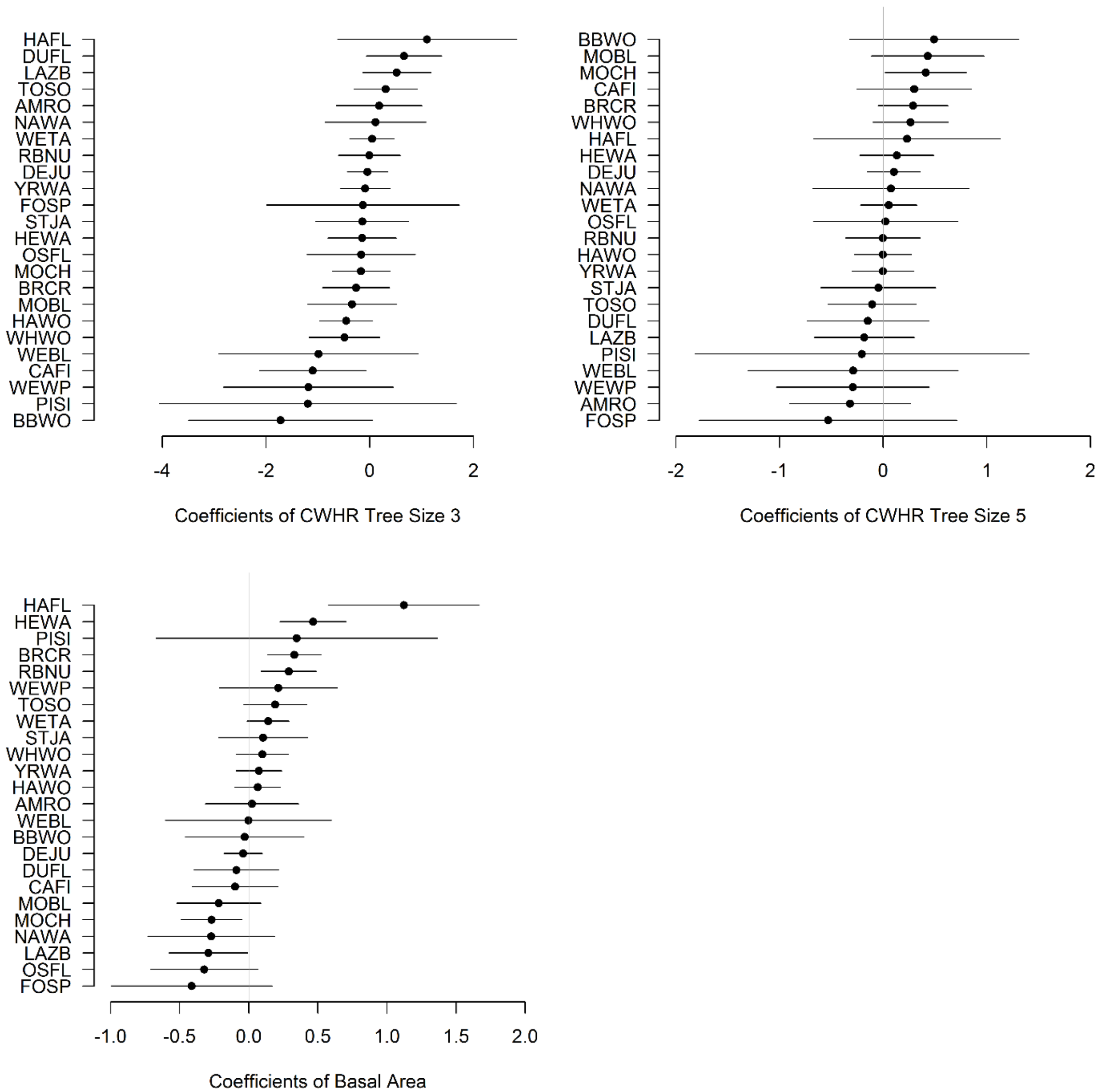
Appendix B1. Coefficient estimates for covariates of aspect from generalized linear mixed models analyzing the effects of salvage logging on 24 species in the Chips Fire. All estimates are in reference to abundance on east aspects.



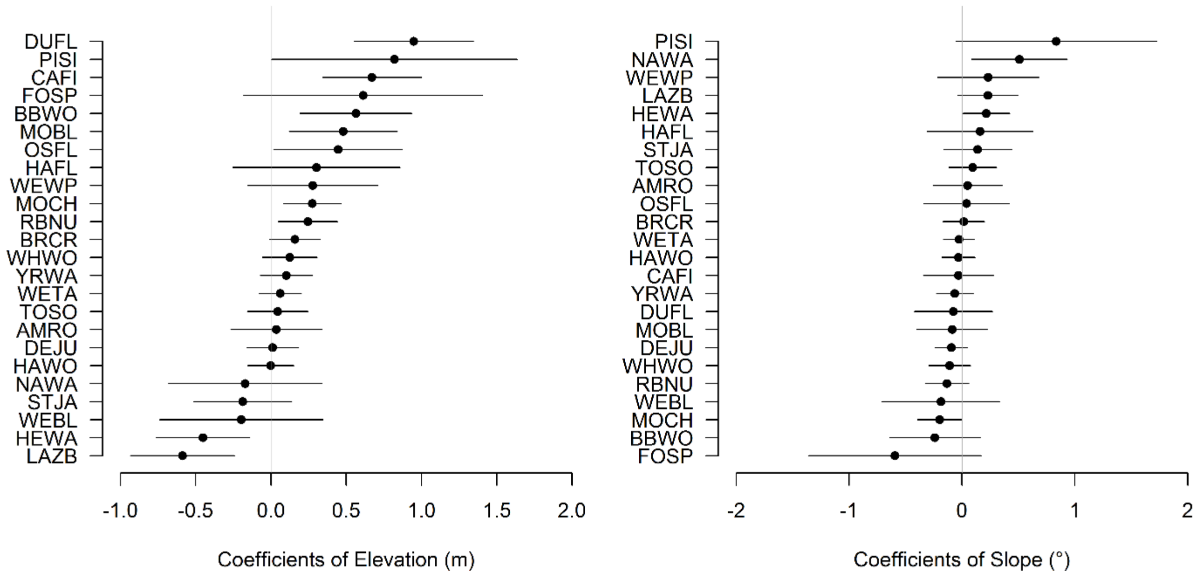
Appendix B2. Coefficient estimates for covariates of burn severity (Relativized differenced Normalized Burn Ratio [RdNBR]) from generalized linear mixed models analyzing the effects of salvage logging on 24 species in the Chips Fire.



Appendix B3. Coefficient estimates for covariates of pre-fire tree size and pre-fire basal area from generalized linear mixed models analyzing the effects of salvage logging on 24 species in the Chips Fire. Tree sizes are categorized according the California Wildlife Habitat Relationship (CWHR) classification system, with size 3 being pole trees (6–11” DBH) and tree size 5 being large trees (>24” DBH). Coefficients for tree size class are statistical estimates of the difference in abundance in each tree size class relative to the reference category, CWHR tree size 4, small trees (12–24” DBH).



Appendix B4. Coefficient estimates for covariates of elevation and slope from generalized linear mixed models analyzing the effects of salvage logging on 24 species in the Chips Fire.



Appendix B5. Coefficient estimates for covariates of time period, level of salvage treatment, and the interaction between time and treatment from generalized linear mixed models analyzing the effects of salvage logging on 24 species in the Chips Fire.