Fuel Management in the Lake Tahoe Basin:
Effects of fuels treatments on small mammals, birds, and forest structure

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MANAGEMENT SUMMARY

BACKGROUND

- The National Fire Plan and the Healthy Forest Restoration Act mandate federal land managers to restore forest habitats and reduce the risk of wildfire, particularly in the wildland-urban interface. The Healthy Forest Initiative implementation plan includes monitoring and tracking performance to confirm that these objectives are being met.
- This report summarizes the results of a comprehensive nine year experiment investigating the effects of fuels reduction treatments on wildlife populations in the Lake Tahoe Basin.
- Data were collected for 14 paired treatment and control units (28 units total) on the west, south, and east shores of the Basin.
- We collected detailed data on birds, small mammals, and vegetation structure and composition before and after treatments were implemented.

KEY RESULTS

- Fuels treatments resulted in more open forest with fewer small diameter trees. Post-treatment tree species composition was less fir-dominated and included a greater proportion of pines. In the understory, treatments reduced shrub cover, but did not significantly impact either coarse woody debris volume or herbaceous cover.
- Small mammal community richness and evenness shifted negligibly following treatment. Overall abundance of mammals increased significantly following treatment.
- Measures of bird community richness and evenness were largely unchanged following treatment. Pooled abundance of all bird species did not change significantly after treatment.
- We observed significant responses to treatment in 12 species of birds and 2 species of small mammals, with a majority of these species responding positively to treatment. Likewise, the majority of these species had not been adequately investigated in prior fuels treatment studies, highlighting a distinct lack of prior research in the Sierra Nevada.

IMPLICATIONS FOR MANAGEMENT

Our results indicate that implementation of conventional fuels reduction treatments is consistent with maintenance of bird and small mammal community diversity over short time frames, and may result in overall increases in community abundance, particularly for small mammals. This observed increase in abundance may provide enhanced foraging opportunities for predator species within the Basin, though this will vary based on the prey specificity of local predators. Individual species showed a variety of responses to fuels treatments, but the majority of species which responded significantly to treatment were more abundant following treatment implementation. Further research is needed to investigate longer-term impacts of fuels treatments on wildlife communities, and to identify differences in wildlife response to non-conventional fuels treatments, such as those focused on enhancing forest structural heterogeneity.

1.0 INTRODUCTION AND BACKGROUND

Prior to Euro-American settlement, low- to moderate-intensity fires occurred regularly in the mixed-conifer forests of the Sierra Nevada. These frequent fires strongly influenced both the species composition and vegetation structure of these forests. However, intensive fire management beginning in the early 20th century, in concert with logging, grazing, and expansion of the wildland-urban interface (WUI), has resulted in forests that differ substantially from pre-settlement forests (Agee and Skinner 2005, Collins et al. 2007). Fire-intolerant species are more common, tree stem densities have increased, and ground and ladder fuels are found at greater densities. Fire behavior has changed accordingly, as fires have grown in both scale and intensity, a change highlighted by the appearance of recent mega-fires such as the Rim and King fires (Lydersen et al. 2014). The risk of large-scale, high-intensity wildfire is now one of the most vexing concerns facing forest managers in the Sierra Nevada.

In addition to these range-wide concerns, forest management in the Lake Tahoe Basin is constrained by a unique suite of challenges. Long renowned for its natural beauty and year-round recreational opportunities, the Tahoe Basin has higher levels of development and visitation pressures than virtually any other area in the Sierra Nevada. Furthermore, there are additional limitations associated with air and water quality concerns in the Tahoe Basin, specifically regarding release of either sediment or smoke that could arise from forest management activities. The presence of widespread, high-value infrastructure in the midst of fire-prone forests presents clear management challenges, ones that are only compounded by the competing management needs of air and water resources.

Despite these challenges, fuels management has been a top priority in the Basin in recent years. The 2007 Angora fire, which burned more than 1200 ha and damaged or destroyed over 250 homes, focused attention on the risks posed by fire-suppressed forests, particularly within the wildland-urban interface (WUI). The National Fire Plan, the Healthy Forests Restoration Act, and the Sierra Nevada Public Lands Management Act (SNPLMA) have made more funds available for management of fuel loads in fire-prone forests. In accordance with these management directives and funding opportunities, over 12,000 ha of forest were thinned within the Lake Tahoe Basin between 2000 and 2010. More recently, the Lake Tahoe Basin Management Unit (LTBMU) has pursued fuels treatments on more than 4000 ha as part of the South Shore Fuels Reduction and Healthy Forest Project, which was approved in 2012 and contains many of the treatment units considered in this report. The proximity of these forests to populated areas and the importance of tourism have limited the use of prescribed burning as a management option, and fuels treatments have largely taken the form of mechanical fuel removal. Smoke and liability issues, along with a small number of allotted burn days in many years, have limited the number of acres that have been treated with fire.

2.0 GOALS AND OBJECTIVES

2.1 CURRENT STATE OF KNOWLEDGE

A large body of scientific literature addresses many issues associated with wildland fire and fuel treatments applied in frequent-fire forests. The application of these treatments is understandably aimed primarily at modifying fire behavior and reducing risk of high-intensity fires, and corresponding research has focused on understanding how treatments modify behaviors of future fires. With respect to wildlife habitat, treatments that are primarily designed to reduce fire risk may simplify and homogenize the landscape (North et al. 2009). The removal of overstory and understory trees, more uniform spacing of residual trees, and mastication or removal of ground fuels and vegetation will likely result in significant changes in wildlife populations, particularly species that are closely associated with specific habitat features (e.g., canopy cover, snag density, coarse woody debris; Manley 2009).

Much of the prior research examining wildlife response to fuels management has been limited by the challenge of applying fuels treatments across a sufficiently large number of treatment locations. Due to sample size limitations, it was often difficult to draw conclusions except in the most abundant of species. To overcome the limits imposed by small sample sizes, Fontaine and Kennedy (2012) used a meta-analysis to examine wildlife (primarily bird and small mammal) response to fuels management from locations throughout North America. This research presented results for many species found within the Lake Tahoe Basin, although the data used were primarily from different forest types located outside of the Sierra Nevada. Furthermore, the majority of data for these species came from monitoring following prescribed fires, as opposed to fuels treatments in the absence of fire. We hope to build upon the work presented by Fontaine and Kennedy to 1) present information for species not considered previously, 2) examine whether responses to fuels treatments are consistent with reported responses to prescribed fire, and 3) determine whether fuels treatment responses within the Tahoe Basin are consistent with those found in different regions and forest types.

In our prior work within the Basin as part of the Upland Fuels project, we examined response of both the bird and small mammal communities to fuels treatments (Manley et al. 2012). At the community level, we observed no significant change in diversity or evenness of either birds or mammals, although we did observe consistent but non-significant changes in abundance following treatment. When considering individual species, we found significant treatment responses in a handful of species. However, most observed responses were non-significant, perhaps a result of sample size limitations. The Forest Health project provides an opportunity to build upon this knowledge base and draw conclusions from a more robust sample size.

2.2 PROJECT OBJECTIVES

With this study, we aimed to understand the changes to plant and animal communities in response to conventional fuels treatments in the LTBMU. Specifically, our objectives were to:

- Understand how fuels treatments may change community composition and abundance of small mammals and birds, including examination of novel variables focused on treatment intensity
- Describe changes in forest structure following fuels treatments

Understanding how these elements respond to fuels treatments is essential for addressing key management questions identified in the Sierra Nevada Forest Plan Amendment (SNFPA). The data for this project has been collected across a range of treatment types and intensities, encompassing mixed-conifer and Jeffrey pine/red fir forests throughout the Lake Tahoe Basin. The resulting dataset represents a synthesis of 9 years of research aimed at understanding wildlife response to fuels management as currently implemented by the LTBMU and other landowners in the Basin.

3.0 METHODS

3.1 STUDY SITES

We collected data for this report throughout the Lake Tahoe Basin, at 28 sites along the west, south, and east shores of the lake (Figure 1). Climate in the Basin is Mediterranean with a summer drought period. The majority of precipitation falls as snow in the winter from December to March, with less than 3% falling as rain between May and October. The western portion of the Basin receives greater precipitation and water balance declines eastward in the Basin, resulting in higher plant and animal species richness on the west shore. Mean annual precipitation on the west shore at Tahoe City, CA is 32 in (80 cm) and mean annual snowfall is 190 in (483 cm). Mean annual precipitation on the east shore at Glenbrook, NV is 18 in (46 cm) and mean annual snowfall is 93 in (236 cm). At lake level near Tahoe City, average January high temperature is 42 °F (6 °C). Summers are mild with an average high temperature of 79 °F (26 °C) in August (Western Regional Climate Center 2012).

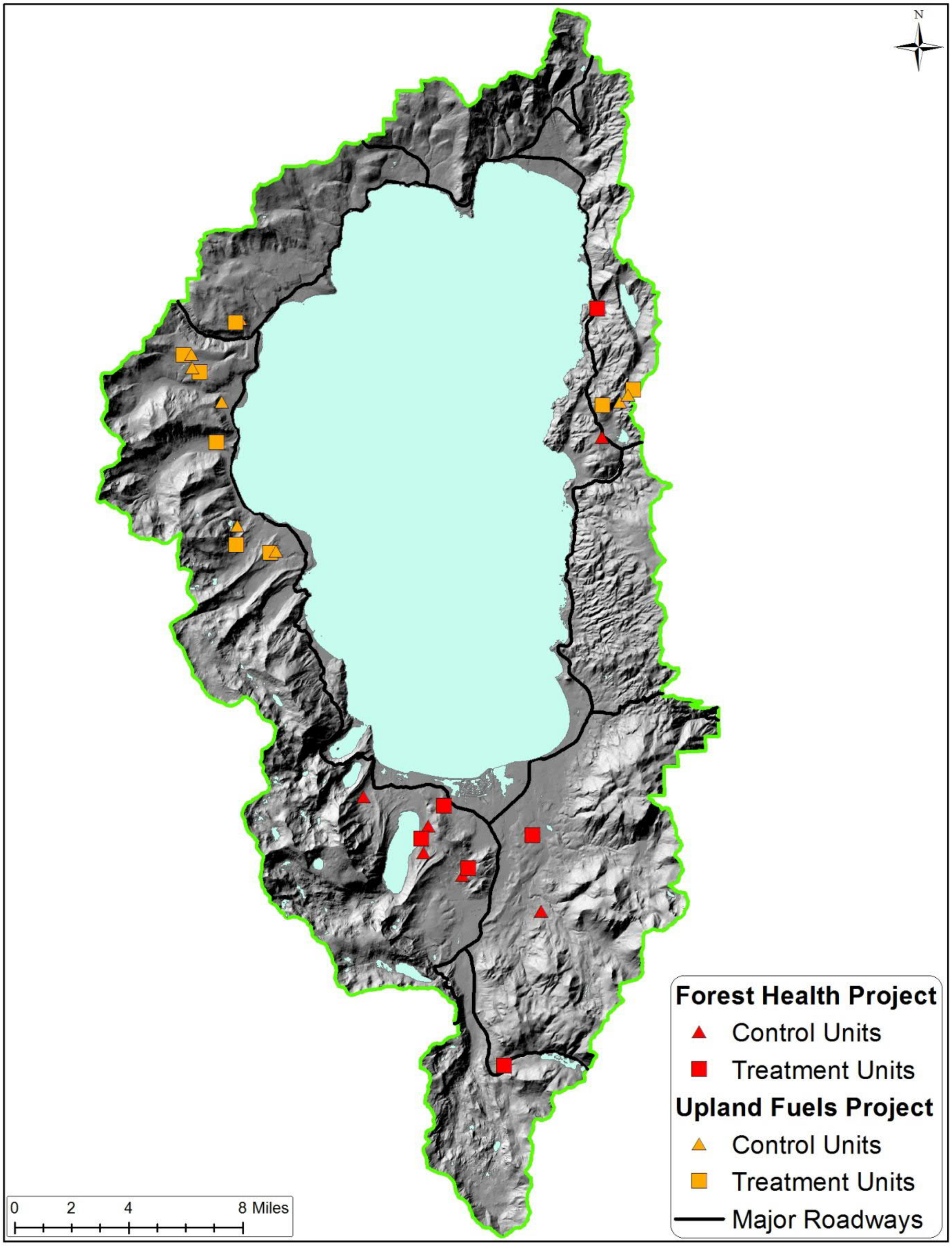

Figure 1. Overview of research unit locations for the Forest Health and Upland Fuels projects in the Lake Tahoe Basin.

3.2 FUELS REDUCTION TREATMENTS

Fuels treatments for the Forest Health project were covered under two separate NEPA review processes. East shore treatment units were considered under the Spooner Fuel Reduction and Forest Health Restoration Project (approved in 2010), while south shore treatments were reviewed under the South Shore Fuel Reduction and Healthy Forest Restoration Project (approved in 2012). Treatment units associated with the Upland Fuels project were covered under three different NEPA review processes: the North Shore Project (1996), the Ward Management Area Fuel Hazard Reduction Project Environmental Assessment (2002), and the Quail Vegetation and Fuel Treatment Project (2005). Given that the treatment units surveyed here were spread across five separate environmental review processes, there is understandable variation among the desired post-treatment conditions and exact fuels prescriptions. For instance, the maximum allowable harvestable tree size increased from 24 to 30 in in 2004 in the SNFPA.

Throughout the Basin, fuels reduction treatment prescriptions are applied to retain highest priority conifer species as follows: (1) sugar pine (2) Jeffrey pine (3) white/red fir, incense cedar (4) lodgepole pine. In addition to live tree retention guidelines, all treatment prescriptions specified retention of at least 3 snags and 3 down logs per acre (7.5/ha), both in the largest diameter size class.

Three of the treatment units were located in protected activity centers (PACs) for California Spotted Owl and Northern Goshawk. Treatment prescriptions for PACs within the west shore units were prepared in consultation with wildlife biologists in order to maintain or enhance habitat conditions while meeting the objectives of the proposed fuel reduction. The general prescription for mechanical treatment within a unit containing a PAC allows for the retention of larger trees, twice as many snags, two canopy layers and a higher minimum percentage of residual canopy closure.

3.3 SAMPLING DESIGN AND TIMELINE

An integrated sampling design was used to collect data on vegetation structure and fuel loads, birds, and small mammals. For the Forest Health Project, a macroplot of 150 x 240 m (3.6 ha), marked at 30m intervals along both axes, was established in a relatively homogeneous and representative portion of each unit. The macroplot provided the grid for 54 small mammal trapping stations, 3 bird survey points, and 6-10 randomly selected vegetation plots (Figure 2). The macroplot for units in the Upland Fuels project was 150 x 330 m (5.1 ha), allowing for 18 additional small mammal trapping stations, 1 additional bird survey point, and up to 2 additional vegetation plots. The similarity in macroplot design allowed us to pool survey results across projects to enhance our statistical power. We used abundance metrics that allowed us to correct for differences in plot sizing between projects. For both projects, we sampled vegetation in 1 year pre-treatment and 1 year post-treatment, and small mammals and birds 1-2 years pre-treatment and 1-2 years post-treatment to examine the impact of fuels treatments on wildlife at these sites (Figure 3).

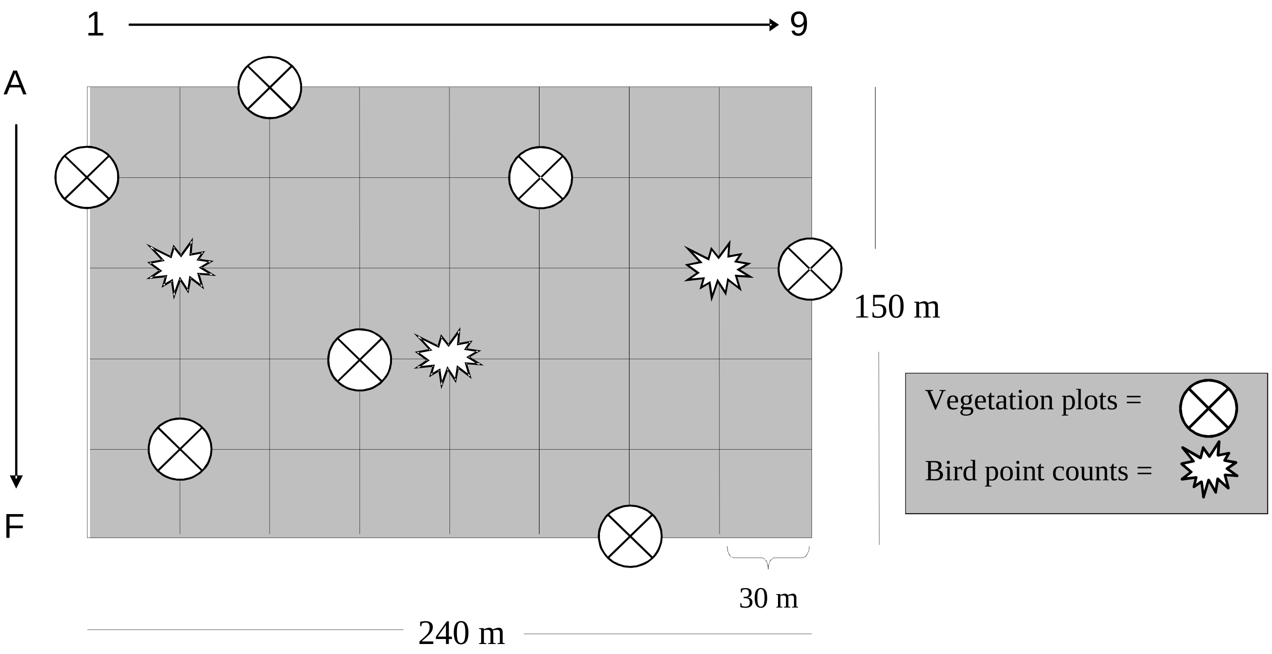

Figure 2. Sampling macroplot layout for the Forest Health project. Each macroplot occupied 3.6 ha and consisted of 54 small mammal trapping points (every intersection on the grid), 3 bird survey points, and 6-8 vegetation plots (location of vegetation plots varied by unit). Macroplots for the Upland Fuels project were 90 m longer (150 x 330 m), and included an additional 18 trapping points, one additional bird survey point, and 1-2 additional vegetation plots.

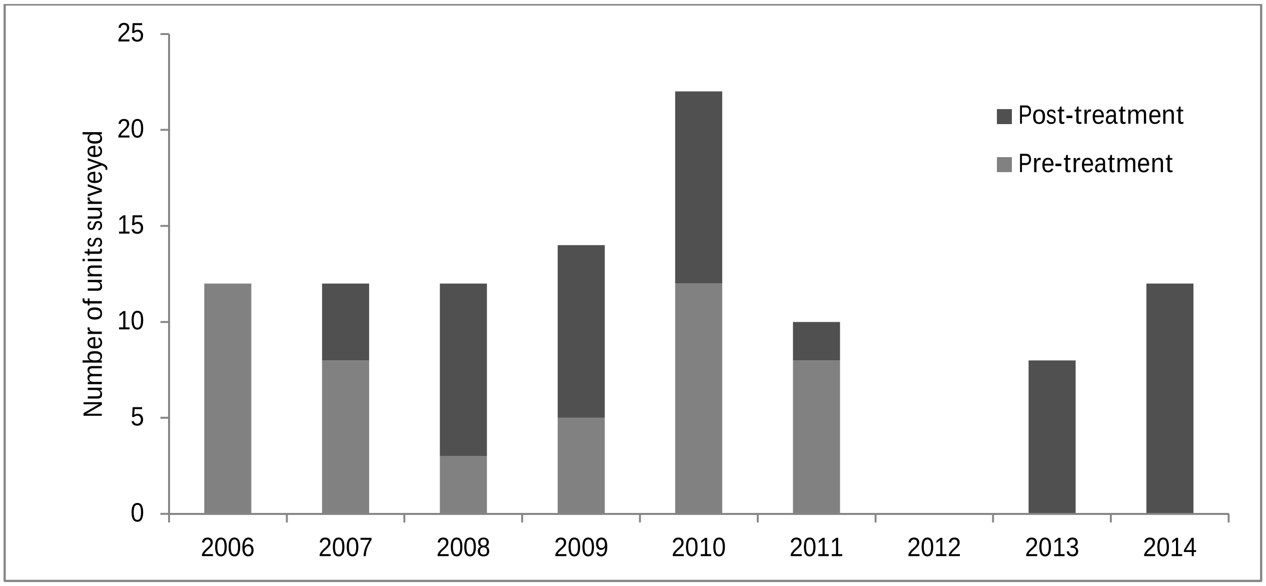

Figure 3. Fuels treatment and wildlife sampling timeline for 28 research units in the Lake Tahoe Basin. Pre-treatment sampling for the Forest Health project took place from 2009-2011, while post-treatment sampling occurred in 2013 and 2014. Upland Fuels pre-treatment surveys were conducted in 2006-2008, and post-treatment surveys ranged from 2007-2011.

3.4 VEGETATION AND FUELS

Vegetation sampling focused on forest structure, understory composition, and fuel loads. Vegetation plot lay-out and sampling protocols were developed in collaboration with the USFS Adaptive Management Services Enterprise Team (AMSET, located on the Tahoe National Forest) and the LTBMU. Vegetation sampling plots had fixed-radii of 17.84 m (0.1 ha), originating at 6-10 random grid points within each unit (Figure 2). Every tree and snag ≥ 15 cm (6 in) diameter at breast height (DBH) was tagged with a unique number, identified to species, and measured for DBH values. Canopy cover was measured using a GRS site-tube densitometer within at 25-point (5 x 5) grid, with 5 m spacing between points. Coarse woody debris was sampled on four 17.84 m transects in each plot using the line-intercept method (Brown and Johnston 1976). Herb and shrub percent cover were measured via visual cover estimates in five 0.25-m^2 quadrats along each transect.

3.5 WILDLIFE

The Lake Tahoe Basin supports diverse bird and small mammal communities, which were the focus of our wildlife sampling. We chose to focus our surveys on these taxa for several reasons. Given their general abundance, we were likely to get adequate sample sizes to draw reliable inferences regarding the impact of fuels treatments on birds and small mammals. Furthermore, birds and small mammals can significantly influence forest health and structure, through dispersal and consumption of seeds and fungal spores (Terwilliger and Pastor 1999, Tomback and Linhart 1990, Willson 1993) and by limiting forest insect abundance (Johnson et al. 2008, Schwenk et al. 2010). Finally, these taxa serve as the primary prey for several species of special status in the Basin, namely the California spotted owl, northern goshawk, and American marten (*Martes americana*).

We trapped small mammals to determine species occupancy and abundance. We sampled small mammals by placing one Tomahawk™ live trap (12.5 x 12.5 x 40 cm) and one extra-large Sherman live trap (10 x 11.5 x 38 cm) at each of 72 trap stations (6 x 12 stations, 30 m apart = 150 x 330 m grid = 5 ha area) (Figure 5). We attached Tomahawk™ traps to the trunk of trees > 20 in (50 cm) DBH, 1.5-2.0 m above ground. We selected trees that were as close to the trap station as possible, ideally within 5 m. We covered the traps with a tarp around the outside and placed a nest box (10 x 10 x 6 cm cardboard) at the back of the trap with polystyrene for warmth. We placed Sherman traps on the ground at the base of trees or along larger logs or under shrubs. Traps were securely placed such that they did not rock or move when an animal entered. We covered each Sherman trap with natural materials to insulate traps from the sun and rain, and placed polystyrene in the back of the trap for warmth. We used a bait mixture of oats, bird seed and raisins. We attempted to include peanut butter and molasses, following the general formula used by Carey et al. (1991), but excessive bear damage required that these ingredients were eliminated or reduced. Traps were set, baited, and locked open for a minimum of three nights before trapping began to allow for acclimation, then opened for five days, starting with traps being set in the late afternoon/early evening prior to the first trap evening (just before dusk). We checked traps twice per day, generally before 10 a.m. for morning checks and after 4 p.m. for afternoon checks. All traps were removed the morning after the fourth night. We calculated trapping effort by correcting for traps rendered unavailable for some (0.5; disturbed, robbed, or sprung) or all (1.0; missing or destroyed) of a trapping occasion. Correcting for trapping effort allowed more accurate comparisons between grids which differed in amount of trap disturbance. We identified all individuals captured to species, marked each animal using uniquely numbered ear tags, and recorded data on sex, age (juvenile or adult), and weight. Ear, leg, or tail measurements were taken on individuals whose identification was in question.

Bird point count stations were located at three points along the center line of the sample plot (Figure 2). We conducted three visits to each count station between late May and early July. We used a 10 minute survey period and recorded the distance to all birds using 20 m increments, out to 60 m maximum to avoid repeated counting of individuals at separate points. Multiple observers were rotated among visits across sites in order to minimize observer bias. Surveys began at least 15 minutes after sunrise and were completed before 9:30 a.m. We avoided conducting surveys during conditions which limited bird activity or detectability (e.g., strong wind or rain).

3.6 DATA ANALYSIS

3.6.1 Vegetation and Fuels

We characterized forest conditions before and after treatment by calculating values for canopy cover, tree density, tree basal area, snag density, the amount of coarse woody debris (hereafter CWD), and shrub and herbaceous cover. We calculated tree density by species and diameter class to assess composition and vegetation structure. For the herbaceous and shrub layers, we did not examine changes in species composition, only changes to the extent of shrub or herb cover.

We analyzed changes in these vegetation variables using PROC MIXED in SAS 9.4 (SAS Institute 2012). As we were not interested in main effects (treatment or timing) in isolation, but rather the interaction of main effects, we included the interaction of treatment and timing as our only fixed effect. Unit was included as a random effect. To examine differences between treatment types, we included an ESTIMATE statement. This statement provides estimated differences in response variables between specified treatment types and time periods.

3.6.2 Wildlife

To examine small mammal response to fuel treatment, we examined community-level changes in species richness and composition. In addition, we looked at changes in abundance of individual species following treatment implementation. Abundance was calculated using the number of unique individuals captured per 100 trap-nights, which allowed us to better compare sites with different levels of trap disturbance. We analyzed species-specific responses to treatment using PROC MIXED in SAS 9.4 (SAS Institute 2012). In our model, we included abundance as the response variable, and the interaction of treatment (treatment or control) and timing (pre- or post-treatment) as our fixed effect. Treatment unit and year were included as random effects.

Because we surveyed units that spanned five EIS projects, and thus our treatments varied in design and objectives, we also attempted to examine the importance of variance in treatment intensity. Previous authors have considered wildlife response to varying fire intensities (Fontaine and Kennedy 2012, Smucker et al. 2005), but existing research has not considered variation in treatment intensity (Fontaine and Kennedy 2012). We defined treatment intensity as change in basal area between pre- and post-treatment time periods (indicative of the density of trees removed by treatment). Treatments with higher amounts of basal area removal thus had greater treatment intensity scores. We used change in abundance between pre- and post-treatment time periods as our response variable. For this model, treatment intensity was our sole fixed effect, while treatment unit and year were included as random effects. We excluded any species that were captured less than 25 times over the course of our study.

Bird species richness and abundance metrics were calculated for each site. Bird species richness was based on all species encountered over the course of all three visits to a site during a year. We calculated bird abundance as the mean number of individuals detected across all three visits for each site and year. We analyzed species-specific responses to treatment and treatment intensity as outlined above for small mammals. We did not analyze response for any species that were detected fewer than 30 times.

We examined changes in wildlife community diversity and evenness in response to treatment. We used Shannon's diversity index (Shannon 1949) to examine changes in both species richness and dominance at the treatment sites before and after treatment. We also separately examined community evenness before and after treatment using Shannon's Evenness index (Pielou 1966). These metrics were calculated for birds and small mammals at each site and each year sampled. We calculated species richness by tallying all unique species detected at a site over the course of the survey period.

We then assessed changes to Shannon's diversity and evenness indices using PROC MIXED, as outlined above for abundance of small mammals and birds, with the relevant community index as the response variable. Finally, we combined abundance of all species (i.e. all small mammals or all birds) to examine community-wide changes in abundance following treatment, using the mixed model analyses outlined above.

4.0 RESULTS

4.1 VEGETATION

Pre-treatment forests at our west shore units were largely dominated by white and red fir (*Abies concolor* and *A. magnifica*), east shore sites were dominated primarily by pine (*Pinus* spp.), and south shore sites ranged between these two extremes, depending primarily on elevation and aspect. Incense cedar (*Calocedrus decurrens*) was a minor but regular component of forests particularly within the west and south shore units. Pre-treatment forests were composed of a roughly even mix of small (15-30 cm DBH) and medium (30-61 cm) trees (Figure 4). While treatment prescription and intensity varied by site, treatments generally targeted smaller-diameter trees, and preferentially removed firs due to their fire susceptibility and ability to serve as ladder fuels. Although still fir-dominated, post-treatment forests showed a greater composition of pines (Figure 5), and were generally dominated by 30-61 cm trees (Figure 4). While the quantity of large (>61 cm) trees was unchanged, they became a more prominent component of post-treatment forests, given the removal of trees in smaller size classes.

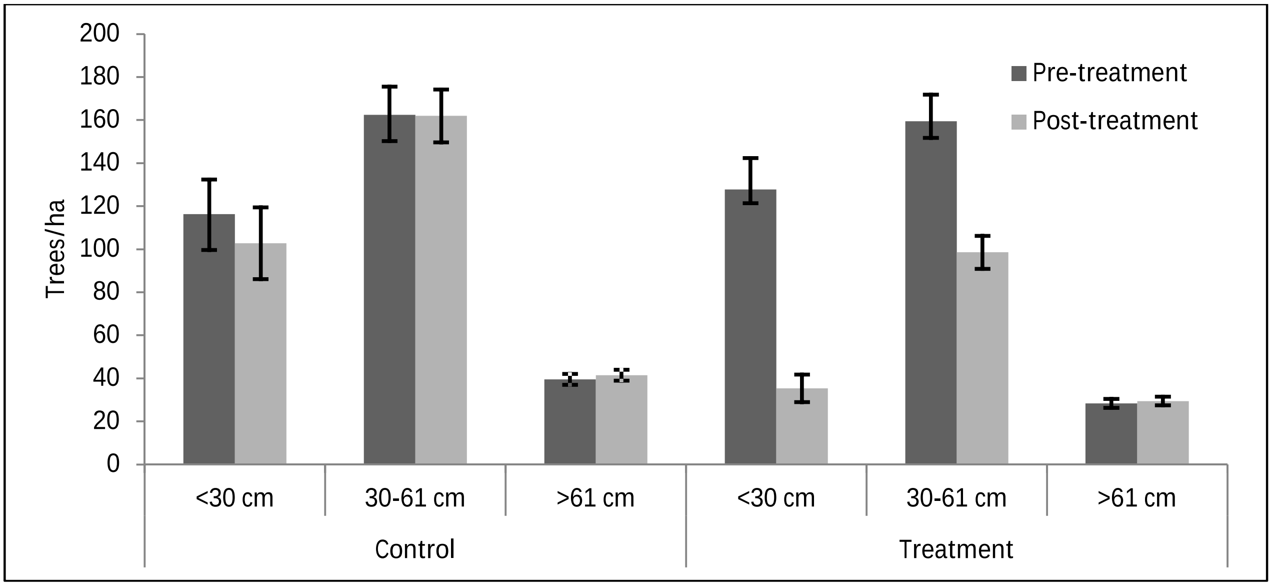

Figure 4. Pre- and post-treatment mean tree density by diameter class at 28 research units (14 treatments, 14 controls) in the Lake Tahoe Basin.

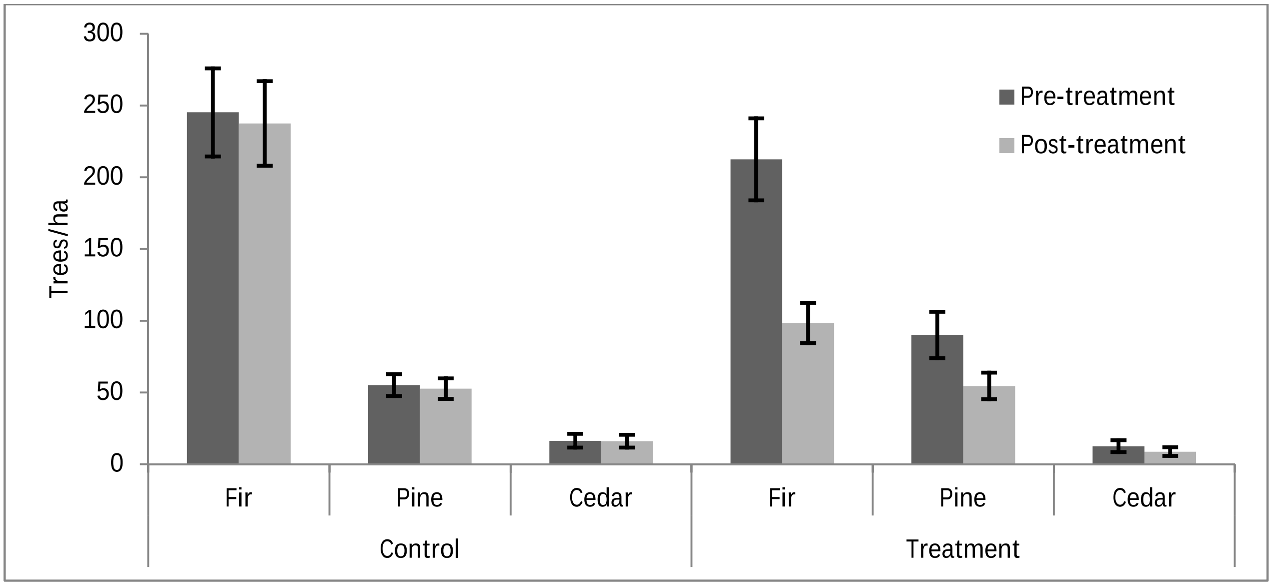

Figure 5. Pre- and post-treatment tree species composition at 28 research units (14 treatments, 14 controls)in the Lake Tahoe Basin.

Fuels treatments led to significant reductions in basal area (-15.5 ± 3.7 m^2/ha, $p < 0.001$; Figure 6), although there was wide variation between units. Post-treatment changes in basal area ranged from -1.2 to -41.7 m^2/ha, while the basal area of retained trees varied almost three-fold, ranging from 22.4 to 60.3 m^2/ha (average of 40.9 m^2/ha).

Basal area of snags was also reduced following treatment (-5.6 ± 1.9 m^2/ha, $p = 0.006$; Figure 6). As with live trees, the basal area of snags removed showed substantial variation among treatment units, ranging from 0 (no measured snag removal) to 25.9 m^2/ha. Post-treatment snag basal area ranged from 0 (no observed snags) to 21.2 m^2/ha.

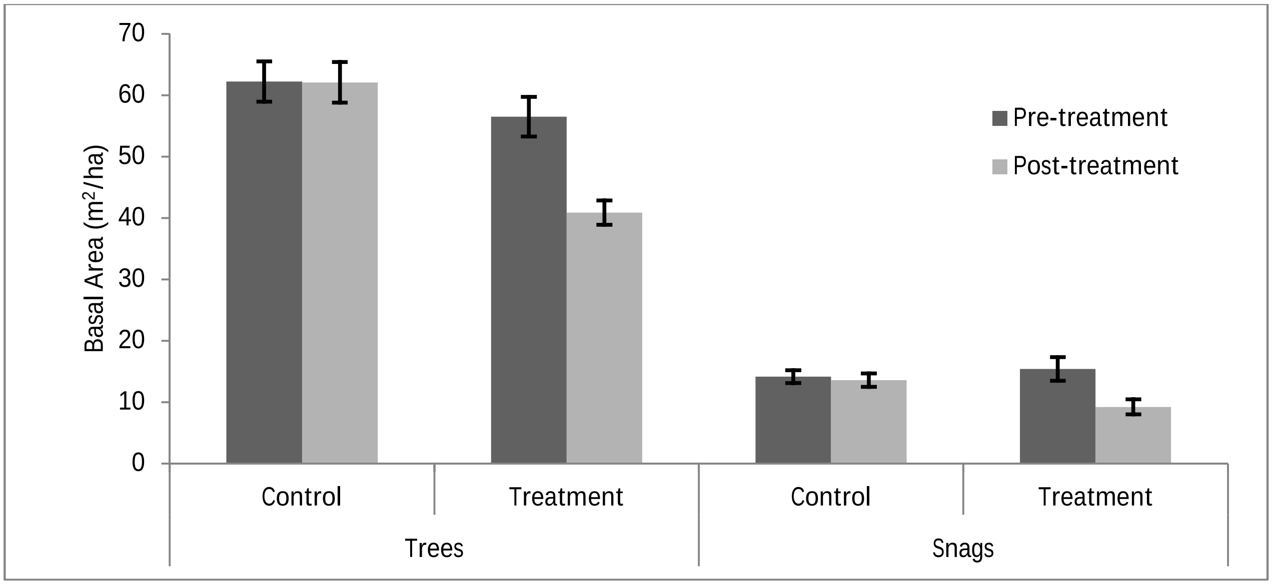

Figure 6. Pre- and post-treatment basal area (m^2/ha) for trees and snags on 28 research units in the Lake Tahoe Basin.

Given the removal of both live trees and snags, there was a predictable decrease in canopy cover at all treatment sites, with an average reduction of -16.7% (±3.6; Figure 7; $p < 0.001$). However, there was considerable variation in this measure, with treatments resulting in between 0.7 and 25.2% reduction in canopy cover, depending on the treatment unit. Post-treatment canopy cover ranged from 27.3 to 52%, with a mean of 37%.

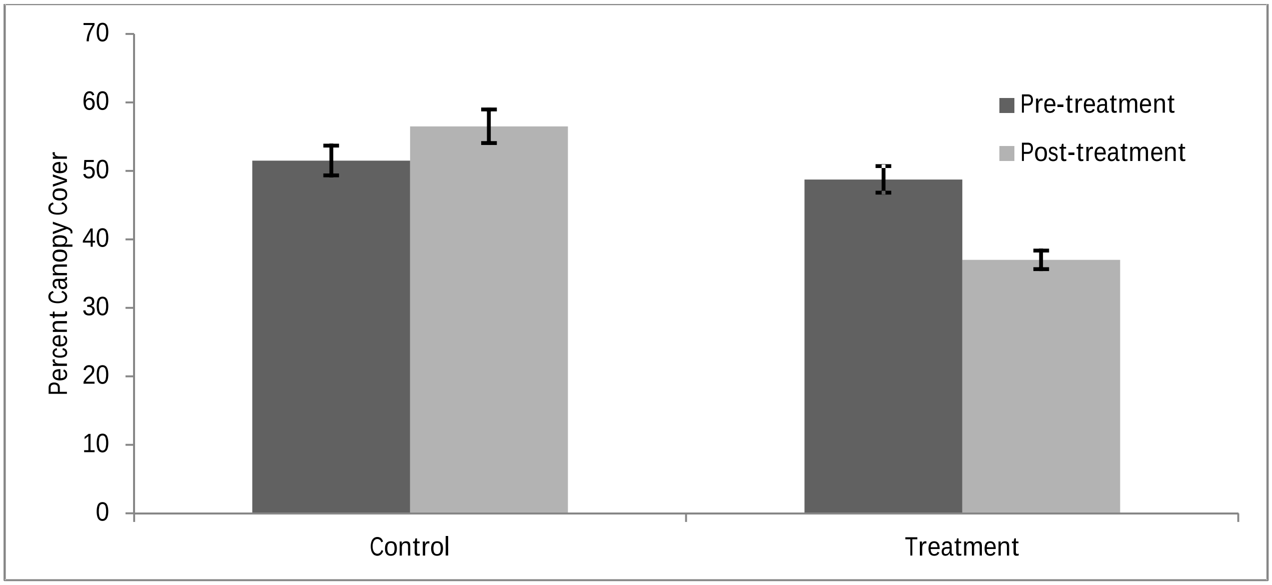

Figure 7. Pre- and post-treatment average canopy cover on 28 research units in the Lake Tahoe Basin.

Understory vegetation showed greater variation following treatment. Shrub cover was reduced on all treatment plots, averaging -6.3% (±2.6) less shrub cover (range -0.9 to -18.7%, $p = 0.02$; Figure 8). Post-treatment shrub cover ranged from 1.5 to 29.2%. We observed much greater variation in the extent of herbaceous cover following treatment, with change on treatment units ranging from a 7.4% decline to an 8.1% increase in cover. Herbaceous cover was not significantly impacted by treatment ($p = 0.14$) – although there was a very slight decline in herbaceous cover when averaged across all treatment units, there was an even greater decline on control units. This may reflect the greater role of climatic variability in influencing herbaceous cover, as all post-treatment surveys for our Forest Health units were completed in 2014, the third successive drought year in the Sierra Nevada.

Another important component of forest understory structure, CWD, was on average reduced in treatment units but, as with herbaceous cover, this change was non-significant ($p = 0.23$) and there was considerable variation among units (Figure 9). Mean change in CWD was -44.4 (±35.7) m^3/ha, and ranged from -106.5 m^3/ha decrease to 43.1 m^3/ha increase in CWD volume. The increase in CWD observed on two treatment units was the result of hand-piling of residual fuels, which occurred at sites with slopes which precluded mechanical access. While these piles are planned to be burned on-site, burning had not been completed on any of our treatment units during our survey period.

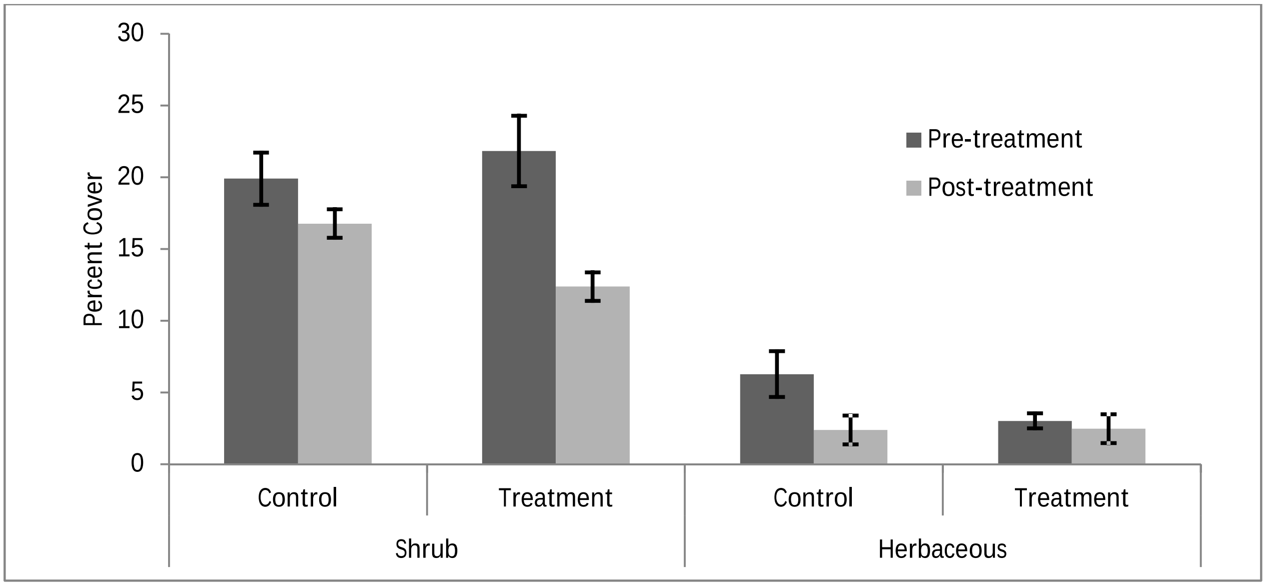

Figure 8. Average shrub and herbaceous cover on 28 research units before and after treatments in the Lake Tahoe Basin.

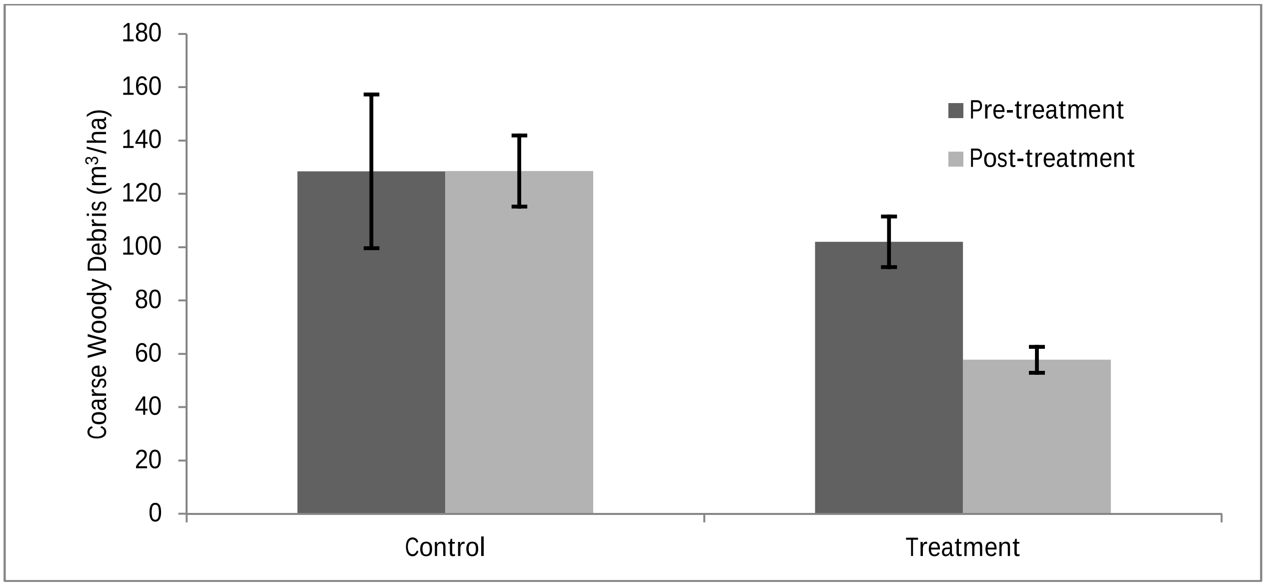

Figure 9. Average coarse woody debris density on 28 research units before and after treatment in the Lake Tahoe Basin.

Table 1. Changes in vegetation variables on treatment units, relative to control units, as a result of fuels reduction treatments. Treatment change is per each variable's measurement unit, listed alongside the variable name. Significant changes ($p < 0.05$) are in bold.

Variable	**Treatment Change**	***t***	***p***
Small (< 30 cm) trees/ha	**-78.89**	**-4.09**	**<0.001**
Medium (30-61 cm) trees/ha	**-60.31**	**-4.33**	**<0.001**
Large (> 61 cm) trees/ha	-0.74	-0.38	0.71
Canopy Cover (%)	**-16.74**	**-4.59**	**<0.001**
Basal Area (m^2/ha)	**-15.53**	**-4.22**	**<0.001**
Shrub Cover (%)	**-6.31**	**-2.47**	**0.02**
Coarse Woody Debris (m^3/ha)	-44.39	-1.24	0.23

4.2 SMALL MAMMALS

We captured 8026 small mammals from 17 species over the course of our project (Appendix A). At the community level, there was minimal change in response to treatment. Treatment units had 16 species detected during both pre- and post-treatment surveys. Shannon's Diversity index remained virtually unchanged in the post-treatment time period, with no significant difference between treatment and control units ($t = -0.76$, $p = 0.45$). Likewise, there was minor, non-significant change in community evenness following treatment, as indicated by Shannon's Evenness Index ($t = -0.04$, $p = 0.97$), suggesting that the proportion of the community represented by different species remained similar.

When considered as a whole, the small mammal community showed a significant increase in abundance following treatments. Abundance increased 26% (9.7 (±4.6) individuals/100 trap-nights; $t = 2.12$, $p = 0.04$; Figure 10) on treatment units relative to controls, and appeared to be driven primarily by increases in chipmunks (*Tamias* spp.) following treatment.

At the species level, we had sufficient data from 12 species to analyze their response to treatment and treatment intensity (Table 2). Although several species exhibited substantial changes in abundance following treatment, these changes were statistically significant for only 2 species. Northern flying squirrels (*Glaucomys sabrinus*) declined on treatment units (-0.56 individuals/100 trap-nights; $p = 0.05$), and yellow-pine chipmunks (*Tamias amoenus*) increased following treatments (+5.92 individuals/100 trap-nights; $p = 0.004$). With respect to treatment intensity (change in basal area), we did not observe any significant changes in populations of small mammals.

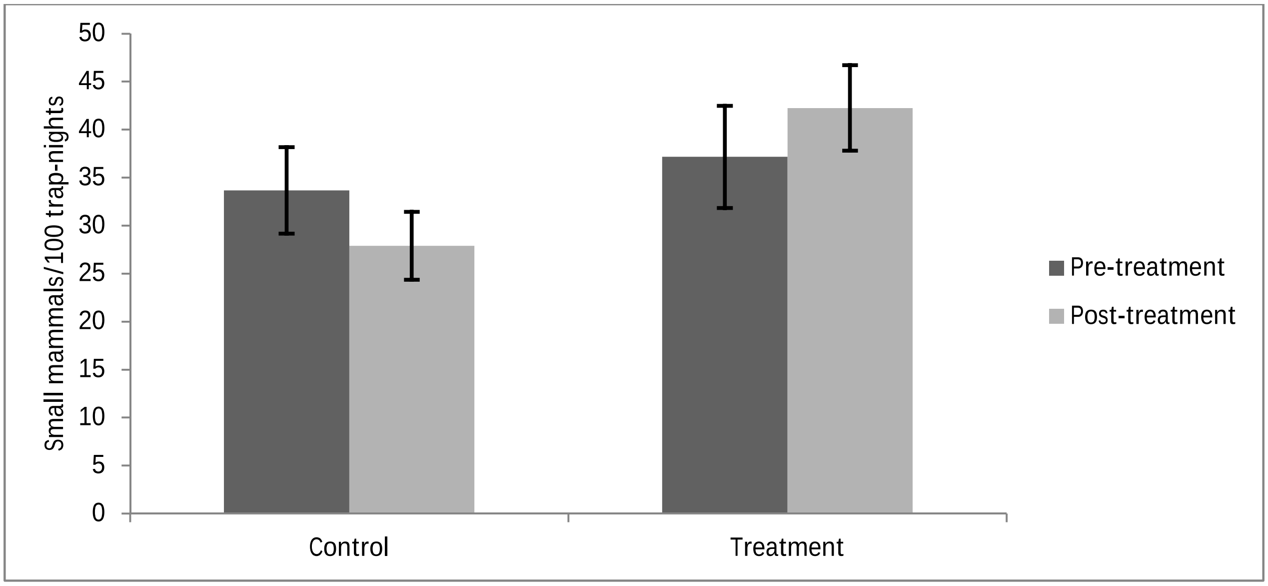

Figure 10. Mean small mammal abundance on 28 treatment and control units, across pre- and post-treatment time periods, in the Lake Tahoe Basin. Means are corrected for differences in trapping effort and reported as # captures/100 trap-nights.

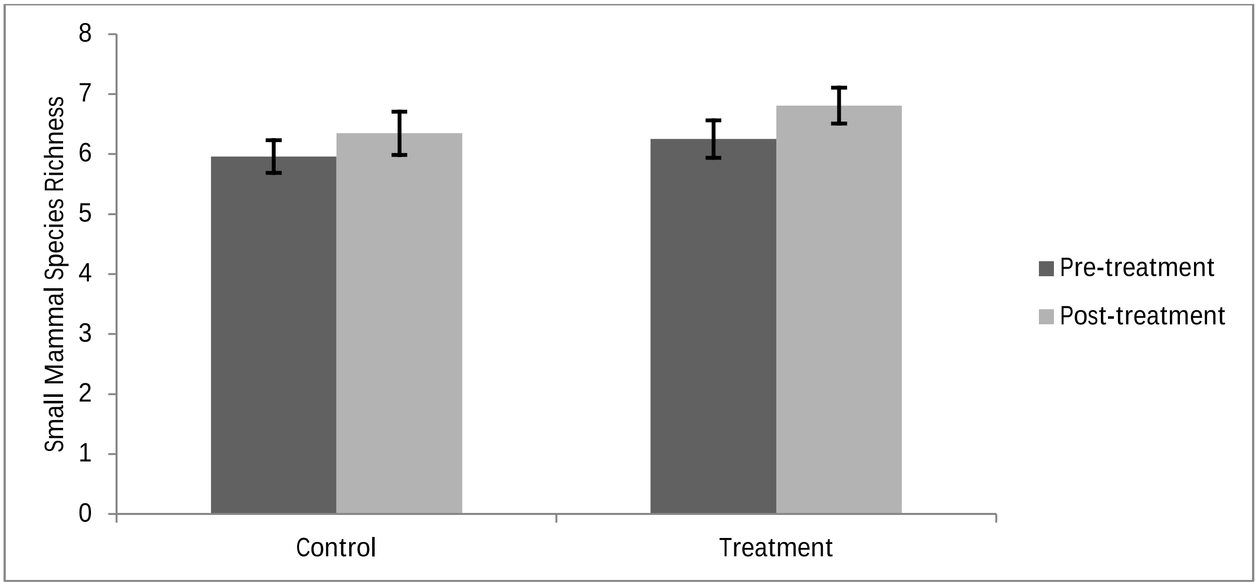

Figure 11. Small mammal species richness, across pre- and post-treatment time periods, at 28 research units in the Lake Tahoe Basin.

Table 2. Change in abundance, relative to control sites, following fuels reduction treatments among small mammal species detected in the Lake Tahoe Basin, 2006-2014. Changes are expressed relative to number of individuals per 100 trap-nights, which corrects for differences in trapping effort across sites.

	Treatment			**Treatment Intensity**	
Species	**Treatment Change (#Ind/100 TN)**	***t***	***p***	***t***	***p***
Allen's chipmunk	1.79	1.11	0.27	0.73	0.47
California ground squirrel	-0.08	-0.37	0.71	0.58	0.56
Deer mouse	-0.52	-0.59	0.56	-1.00	0.33
Douglas' squirrel	-0.32	-0.7	0.49	0.07	0.94
Golden-mantled ground squirrel	0.19	0.37	0.71	0.17	0.86
Least chipmunk	0.09	0.31	0.76	-0.44	0.67
Lodgepole chipmunk	0.8	0.63	0.53	0.32	0.75
Long-eared chipmunk	0.77	0.49	0.62	-0.37	0.72
Long-tailed vole	0.02	0.32	0.75	0.16	0.87
Northern flying squirrel	**-0.56**	**-1.99**	**0.05**	-1.72	0.10
Trowbridge's shrew	0.04	0.64	0.53	0.65	0.52
Yellow-pine chipmunk	**5.92**	**3.02**	**0.004**	1.58	0.13

4.4 BIRDS

Across the nine years of our study, we observed 17,288 individuals from 83 species of birds (Appendix B). There were small and non-significant changes in both Shannon's Diversity index (3.19 pre-treatment, 3.09 post-treatment; $t = 0.96$, $p = 0.34$) and Shannon's Evenness index (0.90 before treatment, 0.89 following treatment; $t = 0.33$, $p = 0.74$), indicating that there were minimal changes in community diversity and relative abundance following treatment. When all species were grouped for analysis, abundance of the entire bird community showed a non-significant increase ($t = 1.27$, $p = 0.21$; Figure 12) on treatment units.

We analyzed changes in abundance of 35 bird species for which we had greater than 30 observations (Table 3). With respect to changes in response to treatment, we observed significant ($p < 0.05$) changes in abundance for nine species. We found positive responses to treatment in the hairy woodpecker (*Picoides villosus*), olive-sided flycatcher (*Contopus cooperi*), pygmy nuthatch (*Sitta pygmaea*), warbling vireo (*Vireo gilvus*), and western wood-peewee (*Contopus sordidulus*). Negative responses were observed in the golden-crowned kinglet (*Regulus satrapa*), hermit thrush (*Catharus guttatus*), Nashville warbler (*Oreothlypis ruficapilla*), and red-breasted nuthatch (*Sitta canadensis*). When examining response to treatment intensity, we observed significant changes in abundance in four species – American robin (*Turdus migratorius*), evening grosbeak (*Coccothraustes vespertinus*), and western wood-peewee were positively associated with treatment intensity, while the fox sparrow (*Passerella iliaca*) was negatively associated with treatment intensity.

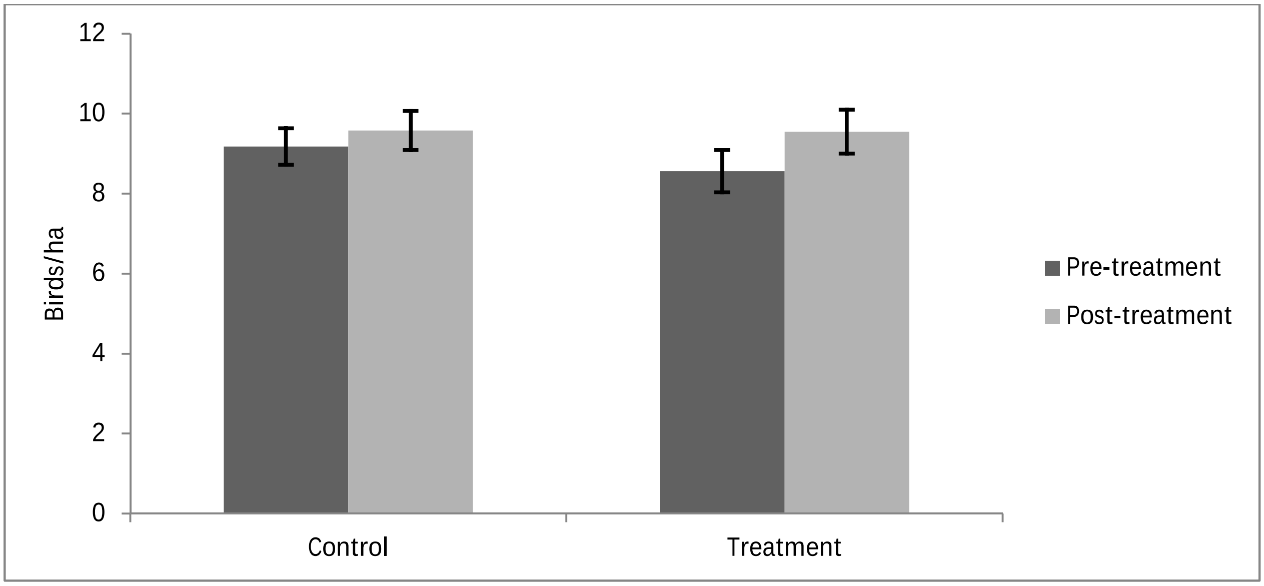

Figure 12. Change in mean bird abundance in between pre- and post-treatment periods, on 28 research units in the Lake Tahoe Basin.

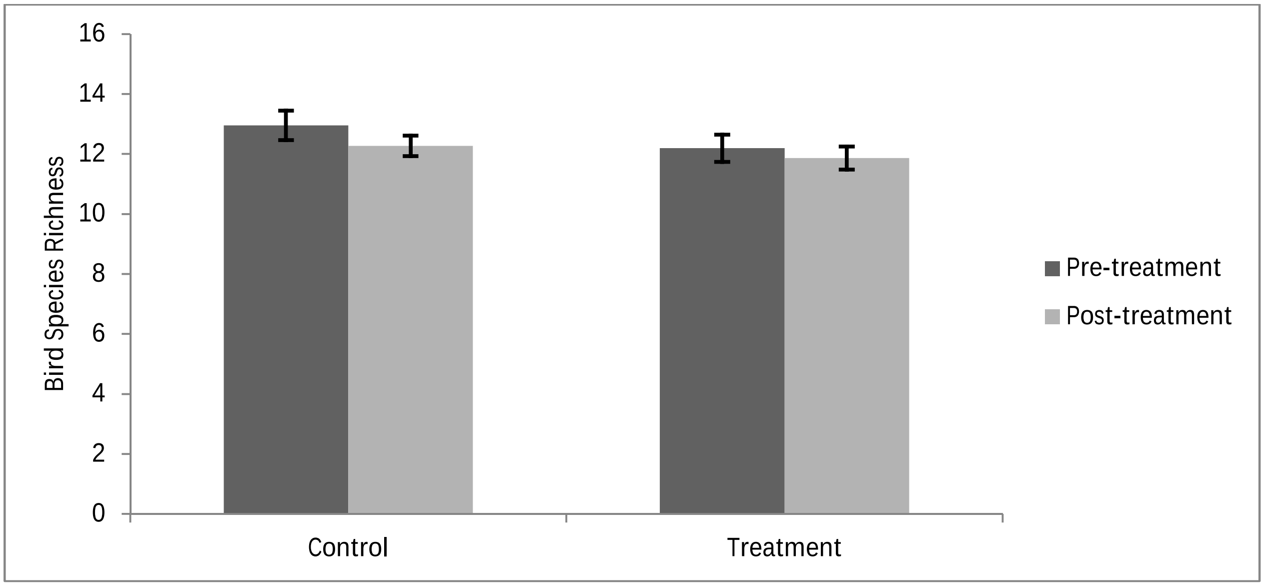

Figure 13. Change in bird species richness across pre- and post-treatment time periods at 28 research units in the Lake Tahoe Basin.

Table 3. Change in abundance of bird species following fuels treatments, relative to control sites, in the Lake Tahoe Basin. Results are presented for species with > 30 detections. Significant changes are in bold.

Species	**Treatment**			**Treatment Intensity**	
	Density Change (#/10 ha)	***t***	***p***	***t***	***p***
American robin	1.36	1.8	0.07	**2.22**	**0.04**
Band-tailed pigeon	-0.06	-0.3	0.73	-0.70	0.49
Black-backed woodpecker	-0.05	-0.3	0.77	-0.41	0.68
Brown creeper	0.09	0.14	0.89	-0.03	0.97
Brown-headed cowbird	0.28	0.49	0.63	0.96	0.35
Cassin's finch	0.03	0.08	0.94	0.90	0.38
Cassin's vireo	0.14	0.5	0.62	0.50	0.62
Chipping sparrow	0.25	1.37	0.17	0.63	0.53
Clark's nutcracker	-0.01	-0.1	0.95	-0.35	0.73
Dark-eyed junco	1.73	1.53	0.13	0.81	0.43
Dusky flycatcher	0.36	0.56	0.58	-0.82	0.42
Evening grosbeak	1.56	1.72	0.09	**2.61**	**0.02**
Fox sparrow	-0.61	-0.9	0.36	**-2.14**	**0.04**
Golden-crowned kinglet	**-2.8**	**-3**	**0.003**	-1.54	0.13
Green-tailed towhee	-1.16	-1.4	0.1	-0.96	0.35
Hairy woodpecker	**1.21**	**2.74**	**0.007**	1.88	0.07
Hermit thrush	**-0.87**	**-2.8**	**0.005**	-1.84	0.08
Hermit warbler	0.4	1.31	0.19	0.30	0.76
MacGillivray's warbler	-0.25	-0.9	0.36	-0.30	0.77
Mountain chickadee	2.47	1.59	0.11	-0.06	0.95
Nashville warbler	**-1.61**	**-2.9**	**0.004**	-0.42	0.68
Northern flicker	-0.21	-1	0.31	-0.78	0.45
Olive-sided flycatcher	**0.57**	**2.03**	**0.04**	-0.55	0.59
Pine siskin	0.08	0.11	0.91	0.48	0.63
Pygmy nuthatch	**2.94**	**2.66**	**0.003**	1.11	0.28
Red crossbill	0.58	1.26	0.21	-0.37	0.72
Red-breasted nuthatch	**-2.25**	**-2**	**0.04**	-0.20	0.84
Steller's jay	-0.89	-1	0.32	-0.29	0.77
Townsend's solitaire	0.35	0.91	0.36	0.43	0.67
Warbling vireo	**1.04**	**2.88**	**0.004**	1.22	0.24
Western tanager	1.29	1.61	0.11	1.27	0.22
Western wood-pewee	**2.34**	**3.93**	**<0.001**	**2.05**	**0.05**
White-breasted nuthatch	0.13	0.27	0.79	0.02	0.98
White-headed woodpecker	0.4	0.9	0.37	0.70	0.49
Yellow-rumped warbler	0.11	0.11	0.91	-0.95	0.35

5.0 DISCUSSION

5.1 VEGETATION AND FUELS

Fuels treatments throughout the LTBMU produced a variety of structural changes associated with mitigating risks of high-intensity fires. Treatment implementation, while varied across our study units, resulted in more open forests with fewer smaller-diameter trees. In particular, we saw significant reductions in density of small (15-30 cm) and medium-sized (30-61 cm) trees, canopy cover, and basal area of both trees and snags following treatments. Density of large trees was unaffected, one of the few overstory variables that did not change as a result of fuels management. Tree composition also shifted following fuels treatments, as density of both firs and pines was significantly reduced. However, there was proportionately greater removal of firs, resulting in post-treatment forests with a greater proportion of pine.

In addition to the structural and compositional changes in the canopy, forest understory structure changed significantly after fuels treatments. In our measures of understory vegetation, we observed a significant decrease in shrub cover, but no significant change in herbaceous cover. However, given the opening of forest canopies following treatment, additional light penetration would presumably result in increases in both shrub and herbaceous cover over longer time periods. At this time, we have no data to allow us to predict the pace of this regeneration, or how it may vary based on treatment type or location. Our other measure of understory structure, coarse woody debris, was typically reduced on treatment units but increased on several units where residual fuels were placed into burn piles.

Although we observed consistent patterns across treatment units, the magnitude of these changes varied considerably. In particular, changes in overstory and canopy structure differed dramatically between treatment units. These differences were driven primarily by two factors which limited the intensity of fuels management. First, in locations with steep slopes, mechanical access is precluded and fuels management is achieved through hand-thinning and manual relocation of fuels, which often results in less overall fuel removal. Additionally, several treatment units overlapped with habitat for special status species, such as California spotted owl or northern goshawk, which are associated with denser forests and high levels of canopy cover. Treatment prescriptions on these units were drafted with these habitat considerations in mind and thus resulted in lower levels of fuel removal by design.

5.2 WILDLIFE

Our synthesis of research throughout the Tahoe Basin makes a significant contribution to the literature regarding wildlife response to fuels management. Across two separate SNPLMA grants, we conducted wildlife surveys across multiple forest types throughout the Basin, thus providing robust sample sizes and allowing us to adequately assess treatment response from a wide range of species. In our final report for our Upland Fuels project (Manley et al. 2012), we emphasized that our results were likely influenced by our moderate sample sizes, and noted that we were only able to find significant responses for the most abundant species. Here, we found significant treatment responses in both abundant and less common species, thus providing a greater range of management-relevant information. Furthermore, we complement Fontaine and Kennedy's (2012) work by providing responses to treatment for several species not considered in their work, as well as providing supporting or contradictory evidence for many other species included in their analysis.

Within the small mammal community, we observed minimal change in species composition and relative abundance, as determined by the Shannon's diversity and evenness indices. However, we did observe a significant increase in overall small mammal abundance following treatments, driven primarily by an increase in chipmunks. This is consistent with the pattern we observed in our Upland Fuels report (Manley et al. 2012), where we documented a moderate increase in overall mammal abundance. However, our results from that work were non-significant, thus emphasizing the importance of the increased sample size afforded by our Forest Health research. This change in abundance was significant only when considered relative to treatment, but not treatment intensity. Thus, the amount of basal area removed was not a significant predictor for the patterns of overall mammal abundance. It remains unclear what portions of the fuels treatment process were responsible for the observed increase in abundance, although our results are consistent with changes in community abundance observed elsewhere in the mountain West (Bagne and Finch 2010, Converse et al. 2006). Many of the components of forest structure that were reduced following treatment (e.g., shrub cover, coarse woody debris) are recognized as essential habitat features for many small mammals (Carey and Harrington 2001, Wilson and Carey 2000). We hope that future research will elucidate the drivers of the observed increase following treatments.

At the species level, we observed significant responses to treatment in two mammal species. Yellow-pine chipmunks, the most abundant species in our study, increased significantly in response to treatment. On average, the number of individuals on treated units was more than double that found on control units, representing a substantial increase in available biomass for higher trophic levels. These results are consistent with those found by Fontaine and Kennedy (2012), who found substantial (though non-significant) increases for this species following treatment. Northern flying squirrels declined significantly, a pattern consistent with their response to other types of forest thinning (Manning et al. 2012, Meyer et al. 2007), suggesting that they may respond negatively to a range of thinning intensities.

Like the small mammal community, the bird community at our study locations exhibited minor changes in species diversity or evenness following treatment. We detected 83 species total, 9 of which were detected only in pre-treatment samples, and 11 of which were found exclusively in post-treatment surveys. Total abundance of birds showed a non-significant increase following treatment, in contrast to our Upland Fuels results (Manley et al. 2012). Following treatments for that project, we reported a consistent non-significant decline in total bird abundance, indicating that bird populations responded more positively to treatments on Forest Health units.

When examined at the species level, we observed significant responses to treatment or treatment intensity in 12 of the 35 species we analyzed. Golden-crowned kinglet, hermit thrush, red-breasted nuthatch, and Nashville warbler all responded negatively to fuels treatments, largely supporting patterns observed earlier during the Upland Fuels component of our work. During the Upland Fuels project, we found declines in all four of these species following treatment, and those declines were significant for all but the hermit thrush, likely a result of a small sample size for that species. These species also showed negative responses to treatment intensity, though none of these responses were significant. When examining influence of treatment intensity, we observed a significant decline in only one species, the fox sparrow, a species associated with mature forests with high levels of shrub cover. Of these five species which responded negatively to either treatment or treatment intensity, Fontaine and Kennedy (2012) were only able to analyze response to thinning-based fuels treatments for the hermit thrush, which they also found to decline significantly following thinning treatments.

We observed significant positive responses to treatment in five species, the hairy woodpecker, olive-sided flycatcher, pygmy nuthatch, warbling vireo, and western wood-pewee. While we observed small increases for all of these species following our Upland Fuels research, none of those increases were significant, which reinforces the importance of our expanded sample sizes afforded by the Forest Health project. Again, when examining treatment intensity our results differed considerably from our analysis of response to treatment. Three species showed significant positive responses to treatment intensity, the American robin, evening grosbeak, and western wood-pewee, the latter being the only species which showed significant responses to both treatment and treatment intensity. Fontaine and Kennedy (2012) similarly found a significant increase in hairy woodpeckers following thinning. However, they were unable to report on the other 6 species regarding response to thinning, emphasizing the lack of prior research concerning Sierran wildlife response to fuels treatments.

The discrepancy in response to treatment and treatment intensity indicates that our measurement of intensity represents a different suite of habitat changes than does classifying a site as treatment or control. This may indicate that many of the species which responded significantly to treatment were influenced primarily by factors outside of basal area, such as canopy cover, tree density, or ground cover, all factors which were incompletely captured in our measurement of treatment intensity. Nonetheless, we feel that variation in treatment intensity is an important driver of changes in abundance, and that understanding this variation is important in better predicting species response to fuels management. We hope that future research will further refine our attempt at understanding the significance of variability between fuels treatments.

Our research makes significant contributions to our understanding of how fuels management affects wildlife both within the Sierra Nevada and throughout the western U.S. In our Upland Fuels project, we observed significant results primarily in abundant species, indicating that we likely lacked power to detect responses to treatment in all but the most common species (Manley et al. 2012). Here, we were able to observe significant treatment responses in species spanning a range of relative abundance. Because of our increased sample size, we are able to present results for a broader range of species and draw conclusions regarding management impacts with a greater degree of certainty.

Likewise, we have expanded substantially upon the meta-analysis presented by Fontaine and Kennedy (2012) with respect to species found in the Lake Tahoe Basin. In particular, we were able to present information on 4 species of birds and 9 species of mammals not considered in their analysis. In addition, much of their information on avian response to fuels management came from studies of prescribed fire. For reasons mentioned above, opportunities to manage via prescribed fire are limited within much of the Sierra Nevada, and information regarding response to thinning-based fuels management is likely to have greater relevance to regional land managers. In our current work, we present results for 24 additional bird species which lacked data on their response to thinning-based fuels treatments, thus providing decision-makers with information more applicable to regional management options.

Finally, our results indicate a divergence in habitat suitability between thinning-based fuels treatments and prescribed fire. While these thinning operations are often referred to as “fire surrogates” (Converse et al. 2006, Knapp et al. 2004, Stephens et al. 2012), their ability to mimic many of the ecological effects of low-intensity fire has been poorly explored. In comparing our observed responses to thinning with responses to low-intensity fire reported by Fontaine and Kennedy (2012), we found little consistency in the effect of these two fuels management approaches. Of 34 species of birds and small mammals examined in both projects, the reported response to low-intensity fire matched our observed response to thinning in only 21 species, with 13 species having inconsistent responses. This indicates that managing fuels exclusively through thinning fails to mimic the effects of fire for a large proportion of species in the Sierra Nevada. While fuels treatments may effectively reduce the risk of future high-intensity fires, these treatments may not be effective surrogates for the range of ecological effects produced by an active fire regime.

6.0 CONCLUSION

Over the course of nine years and two SNPLMA grants, we were able to provide a thorough examination of wildlife response to fuels management as currently applied in the Lake Tahoe Basin. This project expands significantly upon the existing literature by filling information voids for many species within the Tahoe Basin and by highlighting the limitations of using fuels treatments as a true fire surrogate. Our research findings allow managers to make more fully informed decisions regarding the location and intensity of fuels management projects based on local wildlife objectives.

We observed significant responses to treatment at both the community and species levels. At the community level, diversity of small mammals was not influenced by treatment, but overall small mammal abundance increased significantly, a trend that was driven primarily by increases in chipmunk abundance. This represents a significant increase in available prey biomass for higher trophic orders and may enhance fitness of predators which specialize on small mammals. The bird community was not significantly impacted by treatment implementation, indicating that current fuels management strategies are consistent with maintenance of bird diversity and abundance in the Lake Tahoe Basin.

Within the bird community, we found significant responses to treatment or treatment intensity for 12 of the 35 bird species analyzed, a substantial increase over our Upland Fuels research and an indication of the benefits provided by our enhanced sample sizes. Only two of these 12 species had been previously examined for their response to fuels treatments (Fontaine and Kennedy 2012), indicating the prior lack of research available to guide land managers in the Sierra Nevada. With small mammals, we were able to detect significant treatment responses in only two species, the yellow-pine chipmunk, which increased significantly, and the northern flying squirrel, which decreased following treatments. The yellow-pine chipmunk had been found to increase following treatments elsewhere in its range (Fontaine and Kennedy 2012). Northern flying squirrels had not been well-researched with respect to fuels treatments, but it appears sensitive to forest thinning across a range of intensities (Manning et al. 2012, Meyer et al. 2007). Given its importance in the diet of spotted owls (Forsman et al. 2004), changes in northern flying squirrel abundance and distribution may be an important consideration for many managers.

In general, our results indicate that fuels treatments as currently applied within the Lake Tahoe Basin are likely to maintain or enhance diversity and abundance of small mammals and birds. Drawing on an expanded sample size spanning a large range of forest types, we were able to present robust conclusions regarding treatment response for a wide diversity of species. We hope that future research will build upon our conclusions and further refine our understanding of fuels management outcomes in this diverse region.

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APPENDICES

Appendix A. Total number of individuals and site frequency of small mammal species caught and marked during live-trapping surveys conducted late May through late August across 28 units in the Lake Tahoe Basin, 2006-2014.

Common Name	**Scientific Name**	**Total Individuals**	**Site Count**
Allen’s chipmunk	*Tamias senex*	958	27
Brush mouse	*Peromyscus boylii*	4	3
Bushy-tailed woodrat	*Neotoma cinerea*	3	3
California ground squirrel	*Spermophilus beecheyi*	260	19
Deer mouse	*Peromyscus maniculatus*	1365	28
Douglas’ squirrel	*Tamiasciurus douglasii*	200	24
Golden-mantled ground squirrel	*Spermophilus lateralis*	578	17
Least chipmunk	*Tamias minimus*	27	11
Lodgepole chipmunk	*Tamias speciosus*	814	19
Long-eared chipmunk	*Tamias quadrimaculatus*	1660	27
Long-tailed vole	*Microtus longicaudus*	40	13
Northern flying squirrel	*Glaucomys sabrinus*	245	27
Pinyon mouse	*Peromyscus truei*	13	7
Trowbridge’s shrew	*Sorex trowbridgii*	37	15
Vagrant shrew	*Sorex vagrans*	11	5
Western gray squirrel	*Sciurus griseus*	1	1
Yellow-pine chipmunk	*Tamias amoenus*	1810	24

Appendix B. Total number of detections and site frequency of all bird species detected during point count surveys conducted late May through early July across 28 units in the Lake Tahoe Basin, 2006-2014.

Common Name	Scientific Name	Total Detections	Site Count
American kestrel	*Falco sparverius*	2	1
American robin	*Turdus migratorius*	680	28
Bald eagle	*Haliaeetus leucocephalus*	1	1
Band-tailed pigeon	*Columba fasciata*	32	11
Bewick's wren	*Thryomanes bewickii*	1	1
Black-backed woodpecker	*Picoides arcticus*	33	14
Black-headed grosbeak	*Pheucticus melanocephalus*	32	14
Black-throated gray warbler	*Setophaga nigrescens*	3	2
Brewer's blackbird	*Euphagus cyanocephalus*	26	9
Brown creeper	*Certhia americana*	494	28
Brown-headed cowbird	*Molothrus ater*	375	24
Calliope hummingbird	*Stellula calliope*	6	3
Cassin's finch	*Carpodacus cassinii*	205	25
Cassin's vireo	*Vireo cassinii*	130	17
Chipping sparrow	*Spizella passerina*	43	12
Clark's nutcracker	*Nucifraga columbiana*	51	9
Common raven	*Corvus corax*	38	12
Cooper's hawk	*Accipiter cooperii*	4	2
Dark-eyed junco	*Junco hyemalis*	1180	28
Downy woodpecker	*Picoides pubescens*	8	4
Dusky flycatcher	*Empidonax oberholseri*	689	28
European starling	*Sturnus vulgaris*	4	3
Evening grosbeak	*Coccothraustes vespertinus*	638	27
Fox sparrow	*Passerella iliaca*	784	27
Golden-crowned kinglet	*Regulus satrapa*	836	27
Golden-crowned sparrow	*Zonotrichia atricapilla*	3	2
Great horned owl	*Bubo virginianus*	1	1
Green-tailed towhee	*Pipilo chlorurus*	68	7
Hairy woodpecker	*Picoides villosus*	222	27
Hammond's flycatcher	*Empidonax hammondii*	6	4
Hermit thrush	*Catharus guttatus*	245	23
Hermit warbler	*Setophaga occidentalis*	120	14
House wren	*Troglodytes aedon*	32	7
Lesser goldfinch	*Carduelis psaltria*	4	2
Lewis's woodpecker	*Melanerpes lewis*	2	1
Lincoln's sparrow	*Melospiza lincolnii*	2	2

Common Name	**Scientific Name**	**Total Detections**	**Site Count**
MacGillivray's warbler	*Oporornis tolmiei*	114	21
Mountain bluebird	*Sialia currucoides*	3	1
Mountain chickadee	*Poecile gambeli*	2393	28
Mountain quail	*Oreortyx pictus*	12	11
Mourning dove	*Zenaida macroura*	27	9
Nashville warbler	*Oreothlypis ruficapilla*	338	22
Northern flicker	*Colaptes auratus*	127	24
Northern goshawk	*Accipiter gentilis*	4	2
Northern pygmy-owl	*Glaucidium gnoma*	6	2
Olive-sided flycatcher	*Contopus cooperi*	93	17
Orange-crowned warbler	*Oreothlypis celata*	5	4
Osprey	*Pandion haliaetus*	10	5
Pacific wren	*Troglodytes pacificus*	2	1
Pacific-slope flycatcher	*Empidonax difficilis*	1	1
Pileated woodpecker	*Dryocopus pileatus*	27	10
Pine grosbeak	*Pinicola enucleator*	5	4
Pine siskin	*Carduelis pinus*	248	27
Purple finch	*Carpodacus purpureus*	14	2
Pygmy nuthatch	*Sitta pygmaea*	96	16
Red crossbill	*Loxia curvirostra*	73	10
Red-breasted nuthatch	*Sitta canadensis*	1455	28
Red-breasted sapsucker	*Sphyrapicus ruber*	47	21
Red-shouldered hawk	*Buteo lineatus*	4	3
Red-tailed hawk	*Buteo jamaicensis*	16	3
Red-winged blackbird	*Agelaius phoeniceus*	28	3
Ruby-crowned kinglet	*Regulus calendula*	21	2
Rufous hummingbird	*Selasphorus rufus*	4	4
Sharp-shinned hawk	*Accipiter striatus*	2	2
Song sparrow	*Melospiza melodia*	9	3
Sooty grouse	*Dendragapus fuliginosus*	7	4
Sora	*Porzana carolina*	1	1
Spotted sandpiper	*Actitis macularia*	4	2
Spotted towhee	*Pipilo maculatus*	3	1
Steller's jay	*Cyanocitta stelleri*	1078	28
Townsend's solitaire	*Myadestes townsendi*	213	27
Townsend's warbler	*Setophaga townsendi*	1	1
Tree swallow	*Tachycineta bicolor*	1	1
Warbling vireo	*Vireo gilvus*	268	22
Western bluebird	*Sialia mexicana*	3	2

Common Name	Scientific Name	Total Detections	Site Count
Western tanager	*Piranga ludoviciana*	1030	28
Western wood-pewee	*Contopus sordidulus*	555	28
White-breasted nuthatch	*Sitta carolinensis*	222	25
White-headed woodpecker	*Picoides albolarvatus*	288	27
Williamson's sapsucker	*Sphyrapicus thyroideus*	48	15
Wilson's warbler	*Wilsonia pusilla*	49	13
Yellow warbler	*Setophaga petechia*	1	1
Yellow-rumped warbler	*Setophaga coronata*	1331	28