



Point Blue Report

Sierra Nevada National Forests Avian Management Indicator Species



2014 Annual Report

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Sierra Nevada National Forests

Avian Management Indicator Species Project

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SUMMARY

2014 marked the sixth year of monitoring four avian Management Indicator Species (MIS) across 10 National Forest units in the Sierra Nevada planning area. In 2014, we used multi-species point counts to sample 474 transects in upland habitat for Fox Sparrow, Hairy Woodpecker, and Mountain Quail. We surveyed an additional 97 transects in riparian habitats for Yellow Warbler.

We investigated multiple-year occupancy of MIS to assess whether population distributions are changing from year to year. Occupancy trends indicate that three of the four MIS populations are relatively stable across 2010-2014, the exception being Fox Sparrow which has shown a significant 1% per-year decline. Changes in the other MIS were similar in magnitude to Fox Sparrow, 1% per-year declines for Hairy Woodpecker and Mountain Quail, and 1% per-year increase for Yellow Warbler, but none of these trends were significant.

We also examined the relationship between abundance of the upland MIS (Fox Sparrow, Hairy Woodpecker, and Mountain Quail) and time since fire and management, and compared their abundances at managed and burned locations with abundance on reference unmanaged and unburned locations. Moderate-high severity fire stands out as being strongly positive for all three species, though the association through time is different. Hairy Woodpecker abundance is significantly higher in the 2-8 years following moderate-high severity fire, and then declines to levels similar to unmanaged locations. Fox Sparrow abundance is significantly higher for a short period 6-9 years after fire and then declines to lower than unmanaged locations by 15 years post-fire. Mountain Quail abundance is not significantly different in the few years following moderate-high severity fires, but is significantly higher by 10 years and then increases strongly though 20 years post-fire. Prescribed and low severity fire appears to

be beneficial for up to 10 years for Hairy Woodpecker and Fox Sparrow, though only marginally significant difference due potentially to small sample size. Only Hairy Woodpecker responds positively to management, but the response is significant only up to 5 years, while both Fox Sparrow and Mountain Quail show no response or in the case of overstory mechanical treatments a short term (2-3 years) marginally significant negative effect.

Over the past 20 years, from 1994-2014, approximately 24% of our target study area received some form of management (including all forms of vegetation removals except fire). Just over 10% of the study area burned in that time frame. It seems clear that the Sierra Nevada landscape is experiencing less fire than was typical of pre-European settlement, and this reduced frequency fire regime may have negative consequences for MIS and biodiversity.

The value of bioregional monitoring programs such as this ongoing Sierra Nevada project goes far beyond analyzing trends for the four MIS that are the targets of this study. In recent publications we have demonstrated the importance of green forest to Black-backed Woodpecker, assessed habitat associations for meadow birds, and identified baseline reference locations for post-fire analyses. We plan to continue using the Sierra Nevada bioregional monitoring dataset to help inform forest management across this ecologically important mountain range.

INTRODUCTION

In 1982, planning regulations for National Forests in the Sierra Nevada region guided the establishment of Management Indicator Species (MIS) that were chosen to reflect the diversity of plant and animal communities and their response to forest plan implementation [1982: 36 CFR 219.19(a)]. In 2007 the land management plans for each of the nine forests in the Sierra Nevada and the Lake Tahoe Basin Management Unit were amended to adopt a common suite of MIS (USDA Forest Service 2007). We developed a monitoring program to track trends in the distribution of four of these species at the bioregional scale on managed National Forest lands (Roberts et al. 2011). The four MIS targeted for monitoring with this project are Mountain Quail (*Oreortyx pictus*), Hairy Woodpecker (*Picoides villosus*), Yellow Warbler (*Setophaga petechia*), and Fox Sparrow (*Passerella iliaca*). Mountain Quail was chosen as the indicator for early and mid-seral conifer forest, Hairy Woodpecker as the indicator for snags in green forest, Yellow Warbler as the indicator for riparian habitat, and Fox Sparrow for shrub and chaparral. The total area targeted for monitoring these species encompasses approximately half of the 12 million acres of Sierra Nevada National Forest land.

Silvicultural treatments and fire are the primary disturbances affecting forests in the Sierra Nevada, but few studies have shown quantitatively how wildlife react to these events over the long-term. New geographically referenced data sources exist that allow us to investigate the response of wildlife to management and fire over long time periods rather than just the immediate response to these events in more traditional before-after-control analyses. Fire and silvicultural treatments have the potential to strongly influence avian community composition in the short term (Campos and Burnett 2014). However, few if any studies have looked at long term effects of these disturbance events on the avian community in western forests.

Many species in the Sierra Nevada are disturbance-dependent, including the three upland MIS, and the role of disturbance as an integral part of Sierra Nevada biodiversity is generally underappreciated (Swanson et al. 2010, DellaSala et al. 2014). Recent work shows that the Sierra Nevada landscape is under-disturbed as a result of fire suppression compared to the pre-European settlement fire regime (Safford and Van de Water 2014). It is unclear what effect this long-term lack of disturbance is having on the native biodiversity in the Sierra Nevada, but many studies suggest that it is negative overall (e.g. Tingley and Beissinger 2013, DellaSala et al. 2014).

In this report we describe the field efforts and results updated through the 2014 field season including updated information the trends in occupancy for the four MIS. In order to help inform the use of these species as indicators we evaluate the three upland species' response to fire and mechanical treatments over a long time period (2 – 20 years).

METHODS

Sampling Design

We conducted surveys across nine National Forests and the Lake Tahoe Basin Management Unit in the Sierra Nevada Forest Planning area (USDA Forest Service 2004a). This area extends from Modoc National Forest near the Oregon border to Sequoia National Forest east of Bakersfield. Sample locations ranged in elevation from 800 – 2800 m, were limited to areas within 1 km of accessible roads, slopes less than 35 degrees, and were targeted towards green forest, shrub, and riparian habitats. These stratifications reduced potential sampling locations to approximately 50% of the area within Sierra Nevada National Forest jurisdictional boundaries (approximately 1.5 million hectares). All spatial data were processed in ArcGIS (ESRI 2011).

To ensure that our monitoring program is efficient and representative of the actively managed Forest Service land in the Sierra Nevada region - as well as within each individual forest - we used a spatially balanced sampling design (Stevens and Olsen 2004). Our goal was to ensure that our sampling design provides parameter estimates that are statistically sound (i.e. unbiased and precise) and applicable to populations across the entire region, while at the same time being flexible enough to adapt to logistical constraints as well as potential changes in effort across years due to varying levels of funding that are common to long-term monitoring projects. To achieve all this, we used a generalized random-tessellation stratified (GRTS) sampling scheme to distribute transects evenly across the region to avoid clustering in any given area (one particular forest for example) while remaining random at the local level to avoid bias due to natural spatial patterns of habitat and physiognomic conditions (Theobald et al. 2007). The spatial pattern of GRTS samples are therefore both balanced (at large scales, in this case the entire study area) and random (at small scales, in this case at approximately the National Forest Ranger District scale).

GRTS is an efficient design for monitoring programs aimed at identifying trends of species with widely differing population metrics (Carlson and Schmiegelow 2002). Another feature of GRTS is that survey locations are ordered such that any consecutive group of survey sites retains the overall spatial balance, allowing for easy adjustment to the number of sites surveyed each year (for example, due to different sizes of field crews between years) while maintaining the statistical rigor and minimizing the variance of the sample (Stevens and Olsen 2004).

The set of potential survey locations was built from a tessellation generated in ArcGIS (ESRI 2011) consisting of a grid of cells with a random origin covering the entire study area. We did not choose to stratify by geographical location (e.g. latitude bands) or by jurisdictional boundaries other than Forest Service ownership, nor did we define *a priori*

a target number of survey locations within different National Forests. Thus, we used the GRTS algorithm to select survey locations with equal weight across the entire study area, resulting in the placement of survey locations proportionally to the amount and spatial distribution of suitable area for sampling (based on the habitats and other stratifications listed below).

We used two sampling frames to identify survey locations based on the species of interest. The target habitats for each species (see below) were identified from the Sierra Nevada Forests MIS documentation (USDA Forest Service 2007). Habitats for Hairy Woodpecker ('green forest'), Fox Sparrow ('chaparral'), and Mountain Quail ('early to mid-seral conifer') are widely distributed and relatively abundant across the Sierra Nevada landscape and overlap or integrate with each other. In contrast, riparian habitats, for which Yellow Warbler is the chosen indicator, are sparsely distributed across the landscape, often in linear patches that are not sufficiently represented by existing GIS habitat layers, and are discretely different than habitat identified for the three other species. Thus, we built a common sampling frame for Fox Sparrow, Hairy Woodpecker, and Mountain Quail, and a separate one for Yellow Warbler.

The original sample consists of 250 upland sites covering the study area, and 50 riparian sites (Roberts et al. 2011). Prior to the 2013 field season we identified a set of upland sites that are logistically infeasible, many of which consisted of sites within Wilderness Areas, and thus we re-processed the GRTS site selection. Changes to the original sampling frame include removal of Wilderness and Roadless Areas, no maximum elevation limit, and increase of the lower elevation limit to 1000 m which slightly altered the distribution of the sampling frame. In the new GRTS site selection we included 232 of the original 250 upland sites after removing 18 sites that were not logistically feasible, and attempted to keep as many of these legacy sites as possible while maintaining a spatially balanced random GRTS sample. The new GRTS selection

of sites included 221 of the original sites. The GRTS selection added 16 new sites, which resulted in a final sample of 237 upland sites. 2013 was the first field season these 16 sites were visited. Our goal is to visit all 237 upland sites each year, but given potential fluctuations in funding, the sample size can be adjusted by using priority numbers assigned by the GRTS algorithm.

At each of the upland sites there are two transects, each with five point count locations arranged such that four points are spaced at 250 m in the cardinal directions from a fifth point at the center. The adjacent upland transects are separated by 1 km between center points. A small number of transects vary slightly on this spatial arrangement due to logistical constraints. At each riparian field location we established two transects composed of four points each, at 200 – 300 m intervals in roughly linear arrangements along stream corridors or in meadows near stream corridors. Field reconnaissance has led to the replacement of some points and transects over the first two years of data collection due to inadequacy of remotely sensed data in identifying riparian habitat. The total sample consists of 474 upland transects distributed as 237 spatially balanced pairs, and 100 riparian transects distributed as 50 spatially balanced pairs. This sample size was selected to achieve the most robust sample possible in order to detect relatively small changes in occupancy of the MIS species at the entire study area scale given current funding levels. In most cases, i.e. for the relatively abundant species, this sample size is also large enough to evaluate forest-scale occupancy trends that could help inform management actions. There are approximately 30-90 transects per forest (150-450 point count locations), and typical power analyses recommend at least 60 survey sites for reasonably precise and unbiased occupancy analyses given typical conditions (e.g. McKann et al. 2013).

Avian Surveys

At each point we conducted a standardized point count survey (Ralph et al. 1995), where a single observer estimated the distance to the location of each individual bird detected within a five minute time span from a fixed location. All observers underwent an intensive, three week training period focused on bird identification and distance estimation prior to conducting surveys. Counts began at local sunrise, were completed within four hours, and did not occur in inclement weather. Laser rangefinders were used to assist in distance estimation. Each season we return to 50-80% of the sites a second time to conduct repeat surveys.

At the center point on upland transects we performed a five-minute playback survey for Hairy Woodpeckers and Mountain Quail and a six-minute playback survey for Black-backed Woodpecker (*Picoides arcticus*). Playback surveys were always conducted after all passive point count surveys for a transect were completed. All three species have large home ranges, and woodpeckers may vocalize infrequently, thus the probability of detecting them on a point count can be low. The goal of the playback survey was to increase the probability of detecting individuals that were available for sampling. For a more detailed account of sample design and survey methods see Roberts et al. (2011).

Analysis: Distribution Population Monitoring

To assess temporal patterns in species distributions we calculated occupancy using methods that estimate the proportion of sites (points or transects) occupied by correcting raw counts for probability of detection (MacKenzie et al. 2006). Uncorrected counts can be misleading due to variation in detectability between species, for example because of different singing rates or volumes. These methods incorporate the detection history over multiple visits to estimate detection probability. We used multiple-season occupancy models to assess changes in MIS population distribution from 2010 to 2014

using the 'colect' occupancy function from the package 'unmarked' (Fiske and Chandler 2011, Kery and Chandler 2012) in program R (R Development Core team 2011). We excluded the 2009 pilot year of the study as a large number of transects from that year were dropped and replaced in following years.

Occupancy and detection covariates can improve model fit and give more accurate trend estimates (MacKenzie et al. 2006). We included a set of covariates on occupancy including CWHR habitat type (Mayer and Laudenslayer 1988, USDA Forest Service 2004b) simplified into six classes: Sierra mixed conifer [includes ponderosa pine, Douglas fir, and pine-hardwood types]; eastside pine [includes Jeffrey pine]; white fir; red fir; lodgepole pine; and all remaining non-forest types [includes barren, bitterbrush, grassland, and wet meadow] were combined into "other". Other remotely sensed covariates included latitude, elevation corrected for latitude, yearly precipitation (PRISM Climate Group 2004), and solar radiation index (SRI), which is a linear representation of aspect (Keating et al. 2007). Tree cover, shrub cover, counts of snags greater than 10cm in diameter, and total basal area covariates were estimated using habitat assessment surveys (see Roberts et al. 2013). Covariates on detection, colonization, and extinction included only year and was included in all models. We chose final occupancy models for each species by iteratively removing one occupancy covariate with the lowest significance until AIC did not improve. Model selection results are not shown; see Roberts et al. 2013 for an analysis of MIS habitat and topographic associations. Standard errors for each occupancy estimate were estimated using 100 non-parametric bootstraps.

We estimated occupancy at the transect scale for Hairy Woodpecker and Mountain Quail (where transect is considered an independent sampling unit) and the point scale for Fox Sparrow and Yellow Warbler (where point is considered an independent sampling unit). The scale at which we aggregated the detections varied by species in

order to create estimates at a similar scale to each species home range size (Mackenzie et al. 2006). This was done to ensure that occupancy estimates were closely related to other metrics of management value such as number of breeding pairs in territorial species (Mackenzie and Nichols 2004).

Since Hairy Woodpecker is the indicator for snags in *green* forest, we removed all transects with at least one point that was located within 50m of a patch of medium to high severity fire that occurred in 1994 or later to minimize including detections of birds within burned forest. We did not exclude transects outside but close to recent fires as our study is designed to monitor specific habitat types regardless of their landscape context. Thus, for a wide ranging species such as Hairy Woodpecker, a small portion of the birds detected in green forest may be at least in part using adjacent burned forest habitat. The green forest sample includes 2167 points on 429 transects. Because chaparral and conifer habitats represent a successional continuum in much of the Sierra Nevada region, we included all upland locations in occupancy models for Fox Sparrow and Mountain Quail. The upland sample includes 2394 points on 474 transects. The riparian sample includes 397 points on 100 transects. A small number of points in each data set were removed due to missing data.

Each species varies in the distance at which observers can detect typical vocalizations (e.g. songs, calls, drums) and therefore the effective area sampled varies when the distance of detections is not standardized. In the extreme case of Mountain Quail, individuals were regularly recorded at estimated distances of over 300 m, therefore a potentially sizable proportion of detections were from single individuals detected multiple times on adjacent points. We correct for these 'double counts' by limiting the detections included in all analyses to 100 m from the point count center. Using this distance cut-off makes it unlikely that we included double counts of the same individual on adjacent survey locations that were at least 250 m apart and is within the

effective maximum detection distance of all of the species analyzed in this report. Detections of Mountain Quail and Hairy Woodpecker from the playback surveys are included for transect-scale occupancy analyses, in previous annual reports we had used only passive point count detections.

Analysis: Long-term Effects of Fire and Management on MIS Abundance

Newly available GIS datasets provide an opportunity to evaluate the relationship between MIS abundance and time since fire and mechanical treatments. We separately evaluated changes in the abundance of these species in relation to the time since management activities that remove canopy trees, pre-commercial thinning activities that remove some trees to allow the remainder to grow faster to maturity, low severity fire including both management-prescribed and wild fires, and moderate-high severity fire (all wild), in comparison to areas where no management actions or fires have occurred since 1994.

We used the Region 5 VegBurnSeverity GIS layer (2014 Version1, USDA Forest Service 2014a) to establish the year and severity of the most recent fire at each of our survey points and then calculated the number of years to that event for each point visit in our dataset. Fires with a severity of moderate and high (as measured with the Composite Burn Index, Key and Benson 2005) were included in the moderate-high severity fire category, while low severity locations were included with prescribed fire events (as described management database below). If multiple fires have occurred at a single location we only use the severity and number of years since the most recent fire.

Similarly we calculated the number of years since an accomplished management event using the Southwest Region Accomplishments of the Past 20 Years GIS database (FACTS, USDA Forest Service 2014b). Again, only the most recent event of a qualifying type was included and if multiple events have occurred the previous ones were

ignored. Year of activity was assigned based on the end of spring migration prior to breeding season (April 1) so that any activities that occurred in January-March were assigned to the previous year rather than the current year.

Many criteria were implemented from this rich database to identify and properly categorize management events. All accomplished activities indicating large-equipment removals of mature trees including Commercial Thin, Group Selection, Overstory Removal, Sanitation Cut, Seed Tree Cut, and Stand Clearcut were classified as “Overstory Mechanical”. All Precommercial Thin activities were included in their own category. Prescribed fires were combined with low severity fire events from the VegBurnSeverity database. We created an additional category that includes all shrub and ground vegetation manipulation activities such as mastication, tree release and weed, moving and piling of fuels, site preparation for planting, and chipping of slash and called this category “Other Understory Treatments”. We report the percentage of all upland survey points that intersect each of the various fire and management classes between 1994 and 2014.

To relate abundance to time since fire or management we used linear and Poisson mixed-effects regression models (functions ‘lmer’ and ‘glmer’ in the R package ‘lme4’, Bates et al. 2014). We used the number of individuals detected during passive surveys within a 100m radius as our abundance metric and the dependent variable in the regression model. Each point/visit/year combination was treated as a separate sampling unit. With this data formulation we increased the effective sample size while also allowing for each year from the five years of this study to inform the time since fire regression rather than averaging time across multiple years of surveys at a single point. Site, or adjacent transect pair (10 points total), was included in the model as a random effect to account for spatial autocorrelation among points. Regression models were produced individually for the four treatment/fire types: overstory mechanical ($N = 1519$

point visits on 81 sites), precommercial thin ($N = 899$ point visits on 62 sites), prescribed and low severity fire ($N = 405$ point visits on 24 sites), and moderate-high severity fire ($N = 1063$ point visits on 33 sites). Fixed effects in the models included time since fire or management, elevation, elevation², latitude, latitude², visit day of year, visit time of day, and visit year. We do not report results for effects of time since Other Understory Treatments as this category is very heterogeneous and difficult to interpret or devise management recommendations. We will explore additional management activities in future efforts.

Average time since fire/management

A separate set of models was produced for untreated (unmanaged and unburned) points to arrive at baseline MIS abundance estimates for comparison with the managed and burned model results. Sample sizes for the untreated models were much larger because they potentially include the entire sample from our monitoring project ($N = 8586$ point visits on 191 sites). However, to ensure that the baseline abundance estimates are fair comparisons to the management and fire model estimates we needed to filter the untreated sample locations to be similar to their comparison treated samples. To accomplish this we calculated summary statistics on slope and elevation from the treated sample, and removed all points that occur outside approximately 95% of the range for each variable from the untreated sample. For all untreated samples we removed the highest (over 2700m) and lowest (less than 1100m) elevations, and for all samples except moderate-high severity fire we removed the highest slopes (greater than 37 degrees). The moderate-high severity fire comparison untreated sample included those high slopes, but we removed the lowest slopes less than 3 degrees to match the sample of points within fires ($N = 7854$ point visits). For the prescribed fire untreated sample we also removed elevations higher than 2200m ($N = 6262$ point visits). We removed all non-forest types from the precommercial thin untreated sample ($N = 7676$

point visits), and also all non-conifer types from the overstory mechanical untreated sample ($N = 6606$ point visits).

We plot the estimated abundance for each of the four treatment types from the final best AIC model against time since treatment using the function 'Effect' from the R package 'effects' (Fox 2003). Confidence intervals (95%) are estimated from within the same function using the 'confint' option. We also plot the treatment abundance estimates at three time since treatment periods; 2, 10 and 18 years, for each species on a single figure to compare abundances among the treatment types. To keep these figures simple, and since all the reference estimates were very similar, we use only the overstory mechanical untreated sample as the comparison reference value.

Data Management and Access: Sierra Nevada Avian Monitoring Information Network

Further results for MIS and all other species detected during MIS surveys can be found on the Sierra Nevada Avian Monitoring Information Network (SNAMIN) website (data.prbo.org/apps/snamin/). Across the six years of this project, we have amassed over 380,000 individual bird records of 202 species at approximately 3000 point count stations spread across 1.5 million hectares of National Forest land in the Sierra Nevada planning area. SNAMIN allows users to generate summary, abundance, and species richness analyses for MIS as all other species detected at the scale of individual transects, ranger districts, forests, or the entire bioregion. In addition to the analyses listed above, there are map tools for visualizing the spatial distribution of survey locations and presence/absence of species at those locations and a link to request raw data (data.prbo.org/apps/snamin/index.php?page=bioreg-home-page).

RESULTS

Survey Effort

In 2014, we surveyed 2752 point count stations on 571 transects (upland and riparian combined; Table 1). We conducted repeat surveys at 55% of transects for a total of 884 transect visits (compared to 924 in 2013, 987 in 2012, 876 in 2011, and 890 in 2010). We conducted two visits at all upland sites where only single visits had been performed in 2013 and randomly selected locations from the remaining upland sites to revisit.

Table 1. Survey effort by year. The target upland sample includes 474 transects. In 2009 we targeted 50 riparian transects and in 2010 and 2011 we increased the target number to 100.

		2009	2010	2011	2012	2013	2014
Transects Visited	<i>upland</i>	415	464	472	462	473	474
	<i>riparian</i>	43	94	96	100	96	97
Second visits	<i>upland</i>	250	267	220	369	303	261
	<i>riparian</i>	16	65	88	56	52	55
Second visit rate	<i>upland</i>	60%	58%	47%	80%	64%	55%
	<i>riparian</i>	37%	69%	92%	56%	54%	57%

MIS Occupancy Trends

Fox Sparrows were detected at 36% of upland point count stations in 2014, and point scale occupancy corrected for detection probability was 0.43 (95% CI: 0.40 – 0.46). From 2010 – 2014 occupancy ranged from 0.43 – 0.48, highest in 2010 and lowest in 2014 (Figure 1). Probability of detection in 2014 was 0.74 (95% CI: 0.62 – 0.80) and ranged

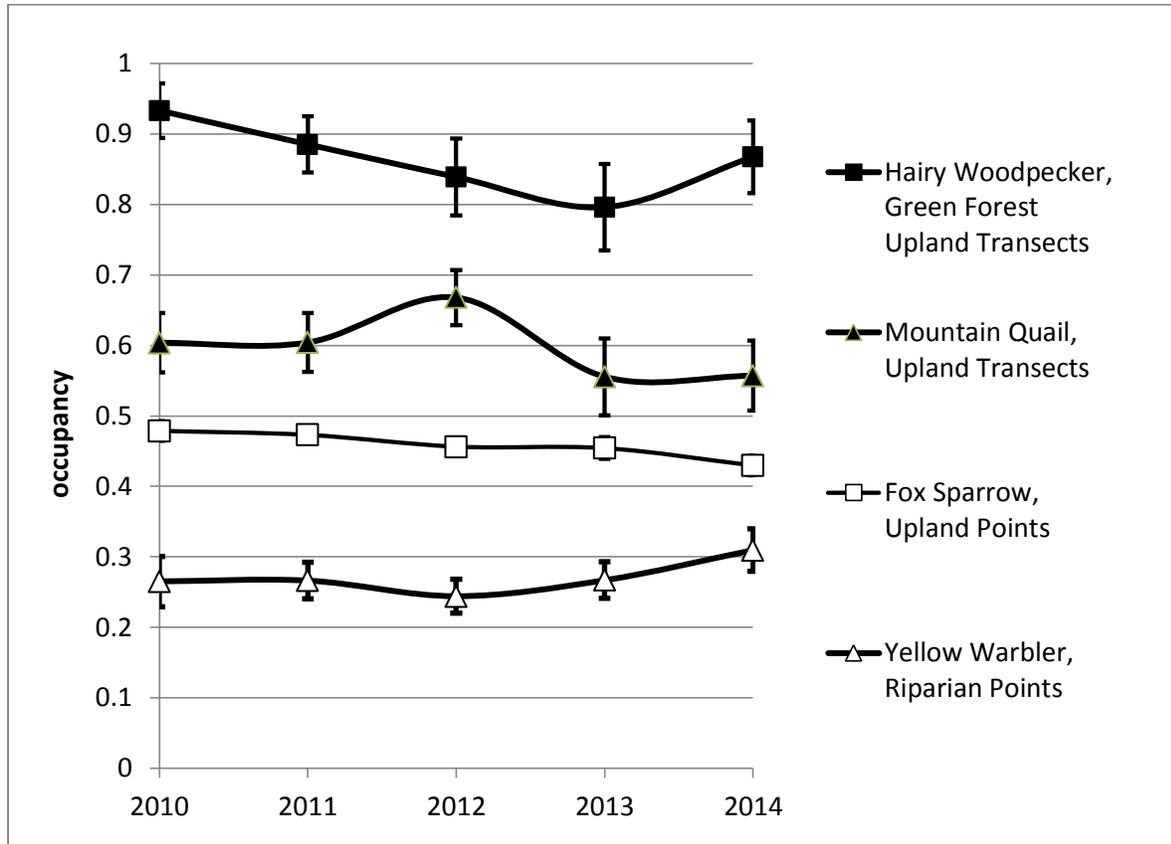
from 0.70 – 0.76 across years. Fox Sparrow occupancy has declined at a rate of -1.17% per year from 2010 – 2014 ($P = 0.01$).

Hairy Woodpeckers were detected at 53% of upland transects in 2014, and transect scale occupancy was 0.89 (95% CI: 0.79 – 0.98), rebounding after a steady 3% per year decline from 2010-2013 (Figure 1). Occupancy showed no significant trend due to the recovery in 2014, declining overall at a rate of -1.30% per year ($P = 0.31$). Probability of detection was higher at 0.46 (95% CI: 0.34 – 0.59) in 2014 than in previous years which ranged from 0.37 – 0.42.

Mountain Quail were detected at 28% of upland transect locations in 2014, and transect scale occupancy was 0.56 (95% CI: 0.49 – 0.63) and ranged from 0.53 – 0.66 across years (Figure 1). Occupancy showed a non-significant declining trend of -1.77% per year ($P = 0.30$). Probability of detection in 2014 was 0.37 (95% CI: 0.25– 0.50) and ranged from 0.36 – 0.43 among years.

Yellow Warblers were detected at 23% of riparian point locations in 2014, and point scale occupancy was 0.31 (95% CI: 0.25 – 0.37), the highest since start of this project (Figure 1). Occupancy in other years ranged from 0.24 – 0.27. Yellow Warbler occupancy appeared to be stable across years with a non-significant increase of 0.89% per year ($P = 0.29$). Probability of detection in 2014 was lowest since the start of the project at 0.56 (95% CI: 0.24 – 0.84) with a range from 0.60 – 0.75 across other years.

Figure 1. Multi-year occupancy estimates in 2010 – 2014 for the MIS. Error bars show ± 1 standard error derived from 100 non-parametric bootstraps of the multi-season occupancy model.



Effects of mechanical treatments and fire on MIS

Approximately 30% of our upland survey points have been subject to mechanical treatments or fire at least one time within the last twenty years (Table 2). Mechanical treatments were more common than fire within the study area, with 24% of our survey points receiving at least one mechanical treatment, while 11% burned. A higher frequency of overstory mechanical treatments occurred prior to 2003, while most of the understory treatments and prescribed fires occurred after 2003.

Table 2. Percentage and count of all upland point count locations that have received mechanical treatments or burned at least once between 1994-2014. These counts are not additive because multiple events may occur at a single location within the time frame.

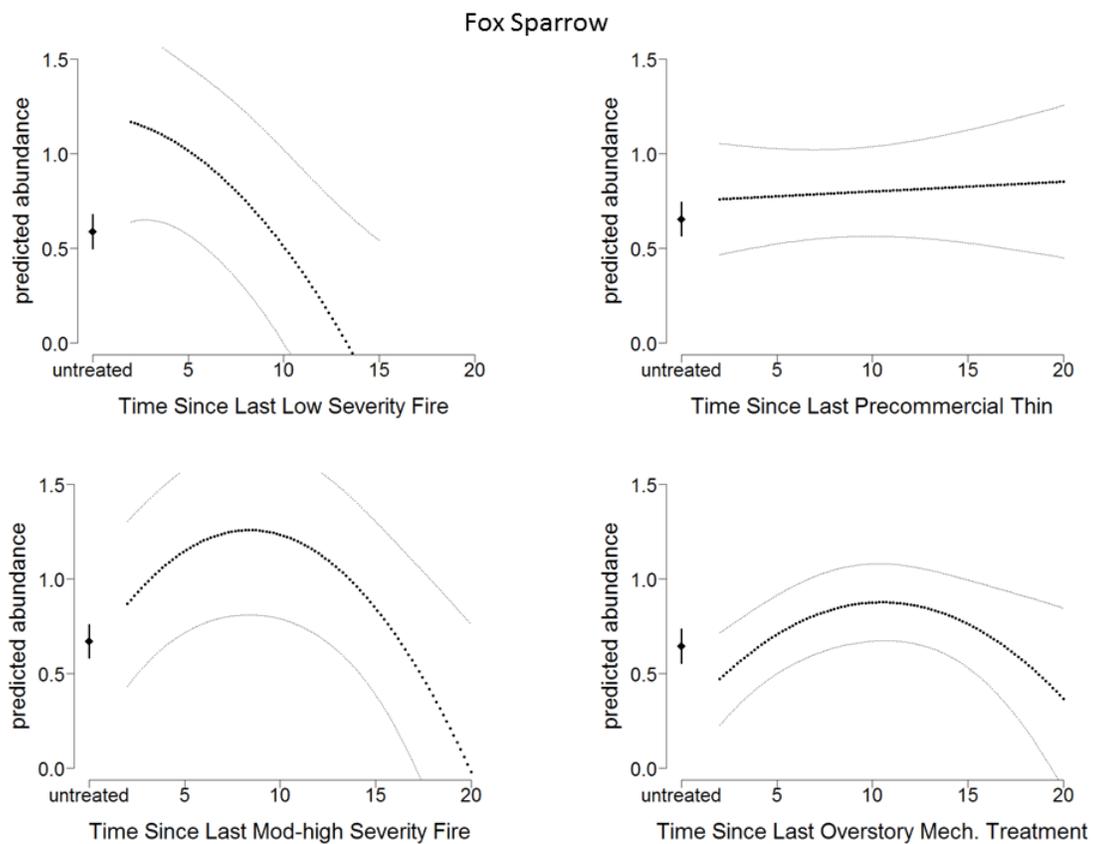
Disturbance type	% of all upland points	
	1994-2014	number of points
Mod-high severity Fire	6.1	130
Prescribed and low severity Fire	7.3	157
Overstory Mechanical	15.1	325
Precommercial Thin	11.2	240
Other Understory Treatments	13.1	281
Any Fire	10.7	230
Any mechanical treatment	24.0	516
Any treatment or fire	30.3	651

All three species showed a significant difference in abundance between one or more treatment types in comparison to untreated locations. Due to a small sample size for prescribed-low severity fire there were very few point-visit events at locations that were more than ten years since fire, so confidence in those estimates is poor and we removed those data points from some of the figures.

Fox Sparrow was perhaps the least responsive to fire and management among the three species evaluated. Abundance was significantly higher following prescribed and low severity fire, and then decreased to untreated levels after approximately 6 years (Figure 2). Abundance was marginally higher immediately after moderate-high severity fire, and continued to increase through the time period so that 8 years post-fire abundance was significantly higher at nearly double the level of untreated locations, but then declining to lower than untreated after 15 years. We did not find evidence of a response to pre-commercial thinning but there was some evidence they responded negatively to

overstory treatments in the short term, though their abundance quickly returned to untreated levels within five years.

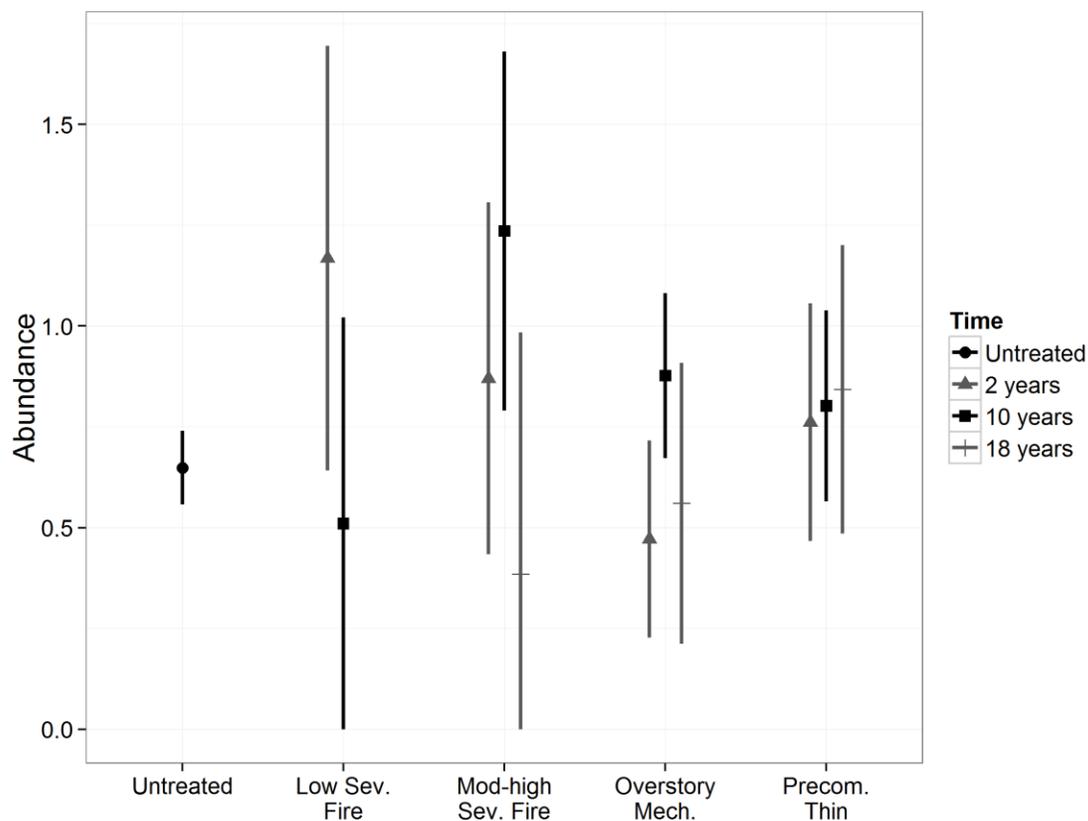
Figure 2. Predicted Fox Sparrow abundance from fitted regression model as a function of time since the last fire or mechanical treatment. The single dot on the left represents the species abundance at untreated reference locations. Error bars and lines represent 95% confidence intervals.



Comparing among the fire and mechanical treatment types (Figure 3), we found that Fox Sparrow had a greater increase in abundance following fire than mechanical treatments. Low severity fires resulted in a short-term increase in abundance while in moderate to high severity fires the increases in abundance were sustained for approximately 15 years. At the 2 year mark, low severity fire resulted in the greatest increase in Fox Sparrow abundance. At the 10 year mark, moderate to high severity fire

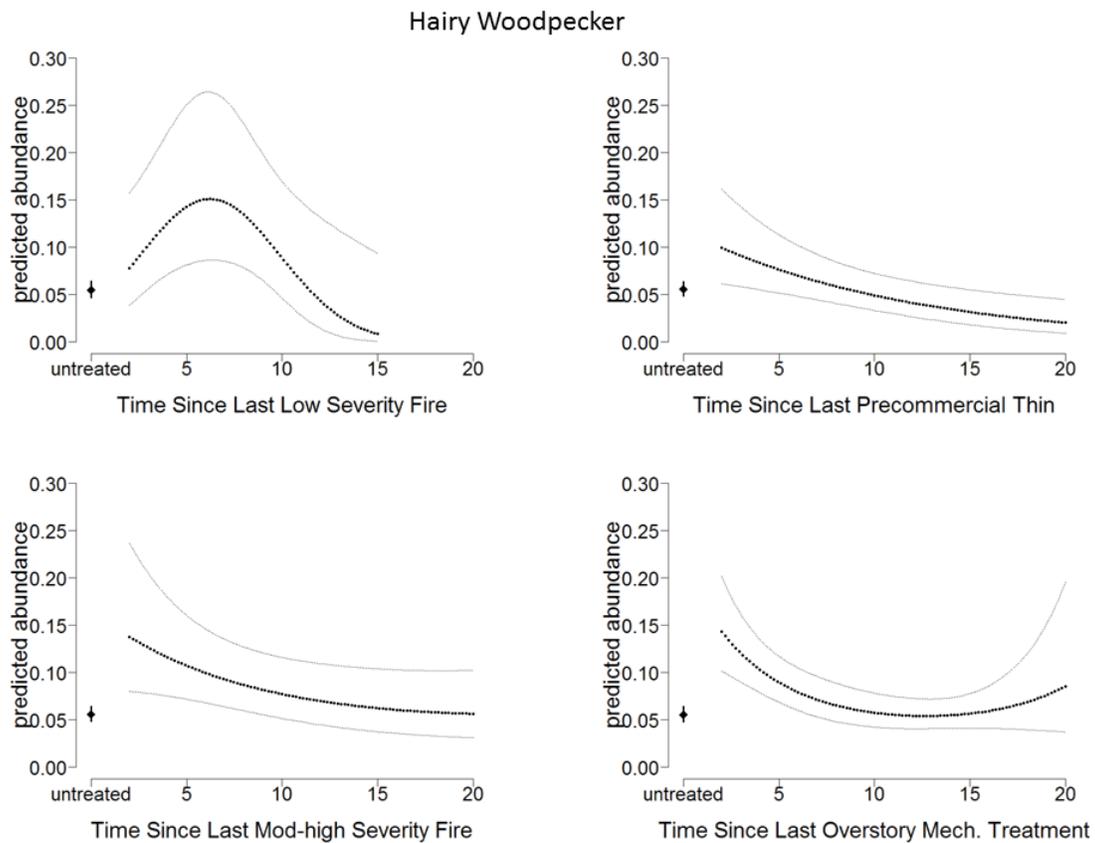
resulted in the highest abundance. Overstory mechanical treatments showed a spike at the 10 year post-treatment mark, but by year 18 their abundance was no different than untreated locations. Only the 10 period following moderate to high severity fires was significantly different than untreated locations, all other treatments across all time periods had overlapping confidence intervals.

Figure 3. Predicted Fox Sparrow abundance from fitted regression model at three separate times since last fire or mechanical treatment. The untreated reference value is calculated from the overstory mechanical sample (n=1519 point visits on 81 sites). Error bars represent 95% confidence intervals. The low severity fire 18 year prediction is not shown due to small sample size resulting in low confidence.



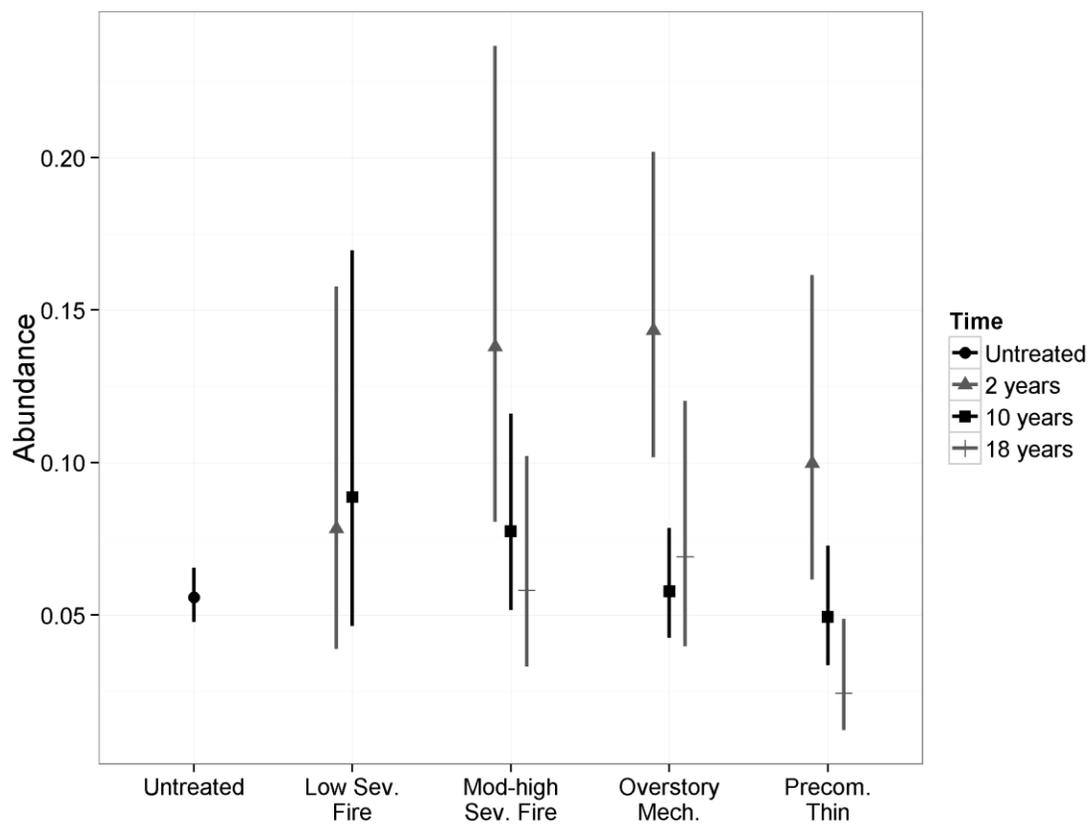
Hairy Woodpecker abundance was significantly higher following all four types of disturbance relative to the untreated sample, though the time period at which abundance was highest varied (Figure 4). There was no difference for the first 3 years following low severity and prescribed fire, but abundance was significantly higher from 4-8 years post fire. Hairy Woodpecker Abundance then falls rapidly, so that by 10 years post-fire they are at or below reference levels. Abundance increased immediately following moderate-high severity fire and persisted at a significantly higher level above reference for 5 years before declining to within the confidence intervals of the reference level. Hairy Woodpecker showed an immediate positive response to both overstory and understory mechanical treatments. The magnitude of the increase for overstory mechanical treatments was similar to that observed in burned areas, and the difference was also significant for 5 years post treatment. In precommercial thins the increase was less than in observed in burned areas, and the difference was only marginally significant. For all treatments the increase in Hairy Woodpecker abundance following treatment lasted no more than 10 years.

Figure 4. Predicted Hairy Woodpecker abundance from fitted regression model as a function of time since the last fire or mechanical treatment. The single dot on the left represents the species abundance at untreated reference locations. Error bars and lines represent 95% confidence intervals.



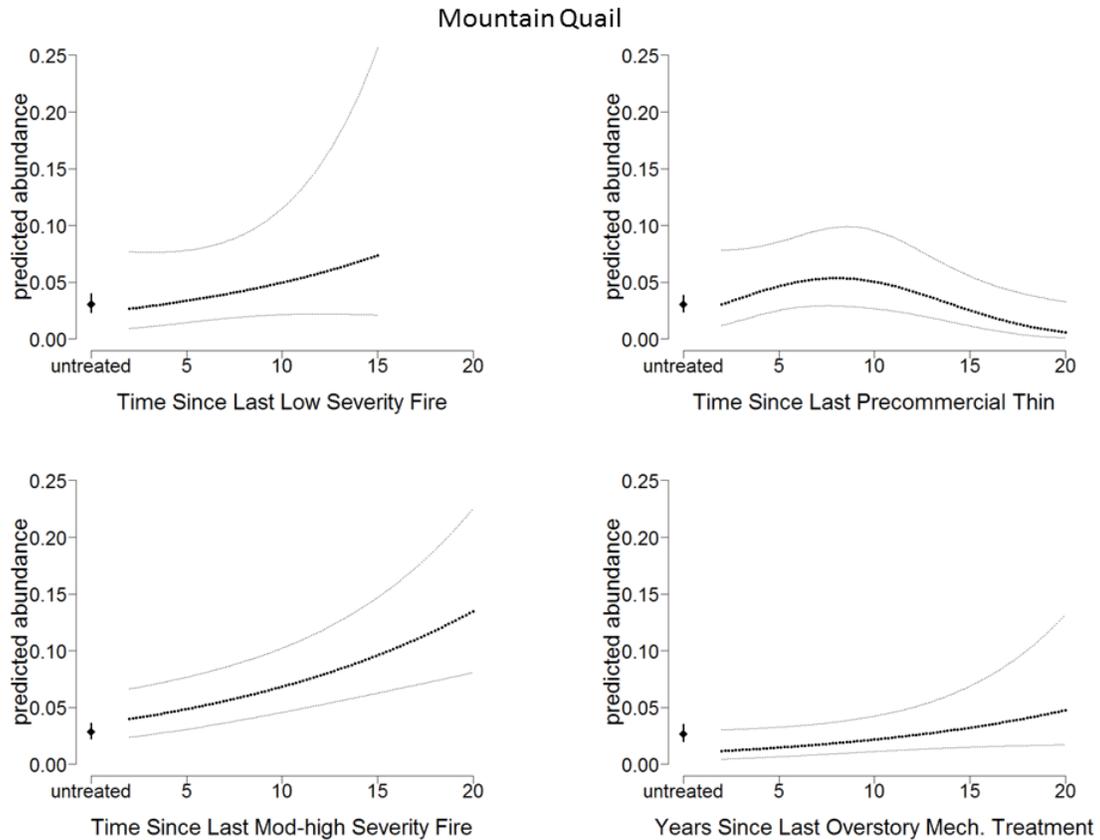
When comparing among the fire and treatment types (Figure 5), Hairy Woodpecker had significantly higher abundance immediately (2 years) following moderate-high severity fire and overstory mechanical treatments, and possibly also in precommercial thins but this difference was marginally significant. Harvest treatments returned to untreated levels by 8 years whereas abundance in both types of fire remained marginally significantly higher in the 10 year period. Precommercial thins had significantly lower abundance 18 years post-treatment in comparison to untreated locations, whereas abundance in moderate-high severity fire and overstory mechanical was similar to untreated locations.

Figure 5. Predicted Hairy Woodpecker abundance from fitted regression model at three separate times since fire or management. The untreated reference value is calculated from the overstory mechanical sample (n=1519 point visits on 81 sites). Error bars represent 95% confidence intervals. The low severity fire 18 year prediction is not shown due to small sample size resulting in low confidence.



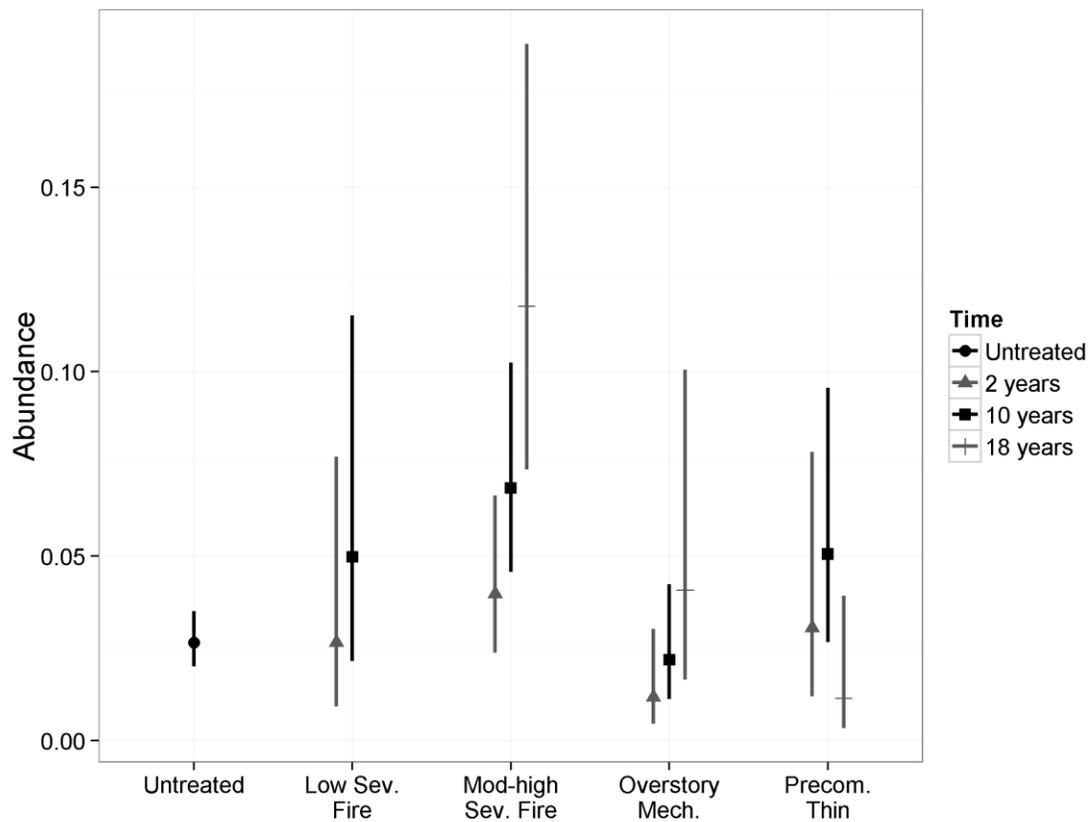
Unlike Hairy Woodpecker, Mountain Quail only responded significantly to one of the four treatment types (Figure 6). They showed a strongly significant positive response at 10-20 years following moderate-high severity fire, but little or no difference in abundance following low severity fire or mechanical treatments. Their abundance 20 years after moderate to high severity fire is four times higher than at reference locations.

Figure 6. Predicted Mountain Quail abundance from fitted regression model as a function of time since the last fire or mechanical treatment. The single dot on the left represents the species abundance at untreated reference locations. Error bars and lines represent 95% confidence intervals.



Comparing the treatment types further illustrates that moderate-high severity fire had a much stronger influence on Mountain Quail abundance than low severity fire or mechanical treatments (Figure 7). At the 18 year period following moderate-high severity fire there was significantly higher abundance compared to reference locations, and also significantly or marginally significantly higher than all periods following the mechanical treatments.

Figure 7. Predicted Mountain Quail abundance from fitted regression model at three separate times since fire or mechanical treatment. The untreated reference value is calculated from the overstory mechanical sample (n=1519 point visits on 81 sites). Error bars represent 95% confidence intervals. The low severity fire 18 year prediction is not shown due to small sample size resulting in low confidence.



DISCUSSION

The Point Blue Sierra Nevada bioregional monitoring program tracks trends in avian MIS but can also be used to track population and distribution changes over time for at least 40 other bird species, a valuable source of information to better understand the patterns of distribution for a substantial portion of the avian community of the Sierra Nevada. It can help to inform management decisions at multiple scales from the entire Sierra Nevada region down to individual forests, and help recognize large scale changes in habitat conditions related to overriding factors such as climate change.

This project is an example of a large scale ecological monitoring effort that provides information on a broad suite of species using a single standardized methodology. The large size of this sample makes it useful for assessing associations with fine-scale habitat features, management or other disturbances, opportunistic before-after-control studies (e.g. when wildfires occur on our field sites), space-for-time analyses, and evaluating occupancy or abundance shifts on elevational gradients and other smaller geographic areas. If continued long-term, this monitoring program can provide a wealth of information to help inform forest management and conserve biodiversity in the face of accelerating threats from climate change and increased demand on the Sierra Nevada's natural resources.

Sierra Nevada forests look different today than they did prior to European settlement. The primary drivers of this change are decades of timber harvest and fire suppression, which have resulted in a substantial range-wide reduction in late-seral old growth forest (McKelvey and Johnston 1992, Franklin and Fites-Kaufmann 1996, Beardsley et al. 1999), as well as an overall increase in tree densities (Parsons and DeBenedetti 1979, Minnich et al. 1995, Barbour et al. 2002). The dearth of fire has also been linked to a decrease in shade intolerant plant assemblages (Vankat and Major 1978, Nagel and

Taylor 2005, Rogers et al. 2007, Beaty and Taylor 2008). If these trends continue, the disturbance-dependent wildlife species that rely on early successional and open forest habitats are likely to decline on the landscape.

In our analysis of MIS abundance at locations with different times since disturbances, we are using a space-for-time substitution to infer long-term effects of the disturbance legacy. In particular we wanted to determine whether similar forest structural changes that occur by different mechanisms, fire vs. mechanical removal, would have different effects on MIS abundances. In this analysis we pared down the varied list of management activities to two general types which represent the removal of canopy trees (overstory mechanical) and younger understory trees and shrubs (precommercial thin), to compare to fires that removed canopy trees (moderate-high severity fire) and fires that removed only surface fuels and understory trees and shrubs (prescribed and low severity fire). Some may view a distinction here between the “natural” disturbance of fire, vs. anthropogenic disturbance of management. However, we feel that the entire forest is effectively “managed” since even wildfires ignited by lightning are vigorously suppressed, and many other wildfires are caused by humans, therefore the distinction between natural and anthropogenic disturbance is blurred. Due to the desire to analyze relatively pure samples of each of these disturbance types we chose to remove from the analysis many locations that received multiple disturbances, which reduced our sample sizes and increased confidence intervals. Because prescribed fires often occur in conjunction with other management activities, this category had the smallest sample size.

MIS Summaries

While we are beginning to see trends in these species’ distributions, these data only span five years during which time the Sierra Nevada endured disparate weather conditions from above average snowfall in 2010 and 2011 to severe drought in 2013 and

2014. These conditions should be considered carefully when evaluating and interpreting any trends. Understanding how each species responds to management actions is important to inform management decisions to reverse potential declines. In this report one of our goals was to increase the value of three upland avian MIS as indicators of management in the Sierra Nevada by quantifying their response over time to fire and mechanical treatments. Specifically we show how abundance of each of these species changes for up to twenty years following fire or mechanical treatments.

In regards to disturbance, these three upland MIS appear to indicate somewhat distinct stages of vegetation succession. Hairy Woodpecker is an early colonizer of disturbed areas, possibly taking advantage of open structural conditions and food associated with tree mortality (i.e. bark and wood boring beetles). Their abundance is higher following all four forms of disturbance we investigated, but this effect lasted less than ten years in fires and no more than eight years in the mechanical treated areas. Fox Sparrow may be an intermediate responder with higher abundance as shrubs develop following disturbance, though in our analyses it was not clear that they were positively associated with any treatments other than moderate-high severity fire. Mountain Quail abundance was higher 10-20 years following moderate-high severity fire, suggesting an association with a more mature post-fire understory plant community.

Our findings suggest a benefit to these early successional species from moderate-high severity fire relative to forest management activities. This result is consistent with findings for these species from western forests (Burnett et al. 2012, Fontaine and Kennedy 2012, DellaSala et al. 2014). All three species had significantly higher abundance in moderate-high severity fire locations, though the patterns were temporally distinct. Neither Mountain Quail nor Fox Sparrow showed any lasting significant change in abundance following mechanical treatment, while Hairy Woodpecker is unique among these three species with a statistically significant positive

response to mechanical treatments. In Aspen restoration treatments in the Sierra Nevada, where the majority of conifers were removed, Hairy Woodpecker shows a similarly strong positive response (Campos and Burnett 2014).

In the following species summaries we update information from previous reports to provide a summary of the patterns of the species distribution, habitat needs, and response to management actions that may prove useful in using these species to help guide management.

Fox Sparrow

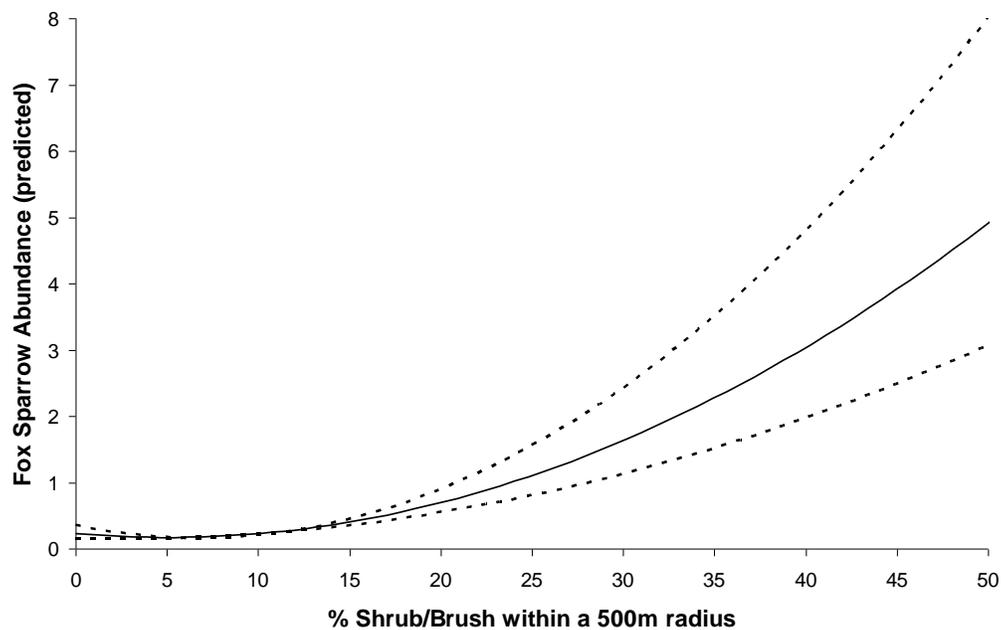
Fox Sparrow occurred at over 40% of all point count stations in the study area, suggesting that montane chaparral habitats are well represented in the region. However, this species is not evenly distributed across the region. Fox Sparrow occupancy is especially high in the central and southern Sierra, but low in the Modoc, Lassen, and Inyo National Forests (Roberts et al. 2013). We detected a significant, though small, decline in Fox Sparrow occupancy from 2010 to 2014. The potential causes of a decline in this species should be considered in future management planning efforts.

Fox Sparrow is associated with dense shrub habitat in the Sierra Nevada. In a study in the Lassen National Forest, Fox Sparrows selected nest sites within chaparral habitat with higher shrub cover relative to what was available in the surrounding landscape (Burnett et al. 2004). Similarly, in a previous report we found that shrub cover was the strongest predictor of Fox Sparrow occupancy across the Sierra Nevada (Roberts et al. 2013). Fox Sparrow occupancy also increased with elevation, and decreased with latitude and overstory tree cover.

Based on analysis of point count data from the Plumas-Lassen Administrative Study Area, Fox Sparrows also appear to be edge sensitive. Fox Sparrow abundance in that

study area increased significantly when more of the surrounding landscape was dominated by montane chaparral (Figure 8, reproduced with data and methods described in Burnett et al. 2004). Thus, small patches of isolated chaparral within forested habitat will likely have reduced density and occupancy of this species. Management actions that inhibit or remove large swaths of shrub habitat, such as fire suppression, mastication, and broad scale herbicide treatments, are likely to reduce Fox Sparrow occupancy over time in the Sierra Nevada. High severity fire patches and prescribed burning of overly decadent chaparral, especially those larger than ten acres, should benefit this species in the long-term (Burnett et al. 2012).

Figure 8. Predicted Fox Sparrow abundance in relation to the amount of the surrounding landscape that was classified as shrub dominated habitat in the Plumas-Lassen Administrative Study area. Figure produced from regression model fitted with detections within 50m radius over years 2002 to 2006 (Point Blue unpublished data). Model includes many landscape and local habitat measurements, % shrub within 500m was the strongest predictor. See Burnett and Roberts (2015) for description of study area and data collection methods.



Hairy Woodpecker

Hairy Woodpecker is the most widely distributed woodpecker species in the Sierra Nevada, occurring in all conifer dominated habitat types east and west of the crest. Though they are widespread, they are not among the most abundant birds in the Sierra Nevada. Their relatively large home ranges limit high densities. Detection probability for this species is relatively low, even with playback, such that field survey counts considerably underestimate the species' true occupancy. They are strong primary excavators and as such they play an important role as cavity creators in the Sierra

Nevada and throughout their range (Martin and Eadie 1999, Tarbill 2010). The species is closely tied to snags in both green and burned forest, not only for nest sites but for foraging resources. This species, like most of the woodpeckers in the Sierra Nevada, reaches its greatest density in recently burned forest (Burnett et al. 2012).

Hairy Woodpeckers require snags for acquiring food, not just as a source of nest sites. Managing for snags as a food resource may require different considerations than measures intended to provide nest cavities. There is a need for a greater understanding of how both the spatial and temporal patterns of snag resources influence the occupancy patterns of woodpeckers and other dead-wood dependent wildlife in the Sierra Nevada to better manage these important resources. Increasing snag retention rates in fuel treatment projects and creating new snags through low and mixed severity prescribed and wildland fire use would likely increase these resources in green forests. Snag retention of multiple tree species and decay classes, including beetle infested dying trees, should be retained for this and other bole foraging wildlife species.

In 2013 we reported a significant decline of nearly 3% per year for Hairy Woodpecker, but occupancy rebounded in 2014. As snag density and understory cover conditions on our field sites are not likely to have changed significantly over this time span, they are unlikely drivers of this pattern. With additional years of data we will be better able to identify patterns in the species population trend from natural annual variation.

Our finding of an immediate significant increase in Hairy Woodpecker abundance following moderate-high severity fires can be easily understood as by definition these are locations with high tree mortality. However, the increased abundance following management is likely not due to snag density increasing. Typically, mechanical treatments of the types we included in our analysis can significantly reduce snag densities (Bigelow et al. 2012, Burnett et al. 2013). While snags are an important resource

for this species, another set of factors must be driving the immediate increase in abundance at recently treated locations. One possibility would be that this species prefers open forest conditions. Other studies have found a positive response after commercial thinning treatments for Hairy Woodpecker (Hager et al. 1996, Fontaine and Kennedy 2012, Campos and Burnett 2014).

Mountain Quail

Mountain Quail occupancy was lower in 2013 and 2014 than in previous years. If not for 2012 when occupancy peaked, it would appear to have declined significantly across the five years. Because of their large territory size, this species' total population in the Sierra Nevada is likely far less than for species with smaller territory sizes whose occupancy has been estimated at the point scale (e.g. Fox Sparrow).

While they are the indicator for early and mid-seral conifer forest, we have found this species most closely tied to shrub habitat, but unlike Fox Sparrow they readily occur in the understory of both early-seral and mature open-canopy forest with a shrub component (Roberts et al. 2013). In the Northern Sierra, their abundance was significantly higher 5-10 years following moderate-high severity fire than the surrounding unburned forest (Burnett et al. 2012), a finding that is supported with our result showing a lasting and consistent increase in abundance at least up to twenty years after moderate-high severity fire. There is weaker evidence that prescribed fire may also lead to higher abundance. It is likely that certain features of prescribed fire may improve Mountain Quail habitat, especially when they promote canopy gaps and other vegetation patterns that mimic the conditions created by wildfire. Mountain Quail appear largely insensitive to mechanical treatments – with low abundance before and following treatments.

Yellow Warbler

Yellow Warbler occurred at between 25% and 30% of our riparian point count stations from 2010-2014 and their occupancy appears stable in that timeframe. It is a California Bird Species of Special Concern, and the primary threats to their population include habitat degradation/loss and cowbird parasitism that has occurred across much of California's riparian areas (Shuford and Gardali 2008). It appears that the majority of the remaining California population breeds in the Sierra Nevada.

Restoration of montane riparian and meadow riparian habitat in the Sierra Nevada will likely benefit this species of conservation interest. Based on an extensive montane riparian/meadow dataset of 140 meadows (Campos et al. 2014), in high quality riparian meadow habitat within its primary elevation range (~4000-6000 feet) in the northern Sierra Nevada this species can be abundant. The fact that they do not occur at 70% of our sampling stations suggests that their distribution may be limited by both elevation and habitat degradation. Ongoing analysis of factors affecting Yellow Warbler distributions show that riparian deciduous shrub cover, primarily willow species, is the strongest driver of Yellow Warbler abundance in the Sierra Nevada (Campos et al. 2014). Restoring floodplain function and increasing the cover of riparian deciduous shrubs has been shown to increase Yellow Warbler and other riparian associated avian species abundance in the Sierra Nevada (Burnett and Campos 2015). Elsewhere in their range, Yellow Warbler has been shown to increase in abundance following the removal of cattle grazing (Taylor and Littlefield 1986). Both habitat modification by grazing and an increase in nest predation may have deleterious effects on this species in riparian habitats in the western USA (Bock et al. 1993, Ammon and Stacey 1997).

Closing remarks

This five year data set represents a significant investment on the part of the USFS and Point Blue, and its value will only increase over time as a baseline to assess management actions well into the future. The utility of bioregional monitoring

programs, such as this ongoing Sierra Nevada project, goes far beyond analyzing trends for target species. In a recent publication, we demonstrated the importance of green forest to a burned forest specialist, the Black-backed Woodpecker (Fogg et al. 2014). Riparian meadow transects from this project were included along with locations from other studies to examine habitat associations for meadow birds (Campos et al. 2014). We have also used unburned locations as reference data for post-fire analyses on Lassen National Forest (Campos and Burnett 2014), and in an analysis of the effects of fire on the Eldorado National Forest (Fogg et al. 2015a). Over 60 locations burned in the 2013 Rim Fire on Stanislaus National Forest and along with adjacent unburned locations, we are currently using these for analyses looking at the avian community in post-fire habitat (Fogg et al. 2015b). We plan to continue using the Sierra Nevada bioregional monitoring dataset in future reports, publications, and presentations to help inform forest management and conservation of biodiversity across this ecologically important mountain range.

APPENDIX A: Black-backed Woodpeckers in Green Forest

The Black-backed Woodpecker (*Picoides arcticus*) is an uncommon to rare habitat specialist that reaches its greatest density in moderate and high severity burned forest (Saracco et al. 2011, Hutto 2008). This species also inhabits green forest but few have studied their life history outside of burned areas. Recently we published an analysis on their habitat associations and occupancy in unburned forest in the Sierra Nevada of California (Fogg et al. 2014). In this appendix we update results published in that manuscript and the previous Annual Report (Roberts et al. 2014) with one additional year of survey data.

Methods

To evaluate Black-backed Woodpecker occupancy in green forest, we used survey data from the upland sampling locations described in the body of this report (or see Roberts et al. 2011). We used point count data from 2011-2014 on the 474 upland transects located on 10 national forest units (Table A1). We defined green forest as areas that had not burned at moderate or high severity from 1993-2014 and were more than 2 km from areas burned at moderate or high severity from 2004-2014 ($n = 377$ transects). These criteria are slightly different from our prior reports and recent publication which removed locations within fires from 1991-2012, and locations within 2km from areas burned from 2002-2012 ($n=368$ transects). We relaxed the fire year constraints on the sample because fires in 2013, including the Rim Fire, occurred within 2km of 39 transects which would have reduced our sample size by more than 10%. We thus added 30 new transects based on updating the fire year cutoffs to balance the removal of recently burned forest sampling units.

At each of the five point count stations within a transect we conducted a standardized unlimited distance 5 min point count survey (Ralph et al. 1995), where a single observer estimated the distance to the location of each individual bird they detected (hereafter

“passive surveys”). Following the five passive surveys, at the center point of each transect only, we conducted a 5 min playback survey for Hairy Woodpecker (*Picoides villosus*) and Mountain Quail (*Oreortyx pictus*), and a 6 min playback survey for Black-backed Woodpecker. We conducted surveys for the two other species as part of the MIS protocol. Black-backed Woodpecker survey duration was 6 min, with three increments of 25 sec playbacks followed by 95 sec of listening and watching. Playbacks included the scream-rattle-snarl and pik calls and territorial drumming sounds (recording by G. A. Keller, Macaulay Library of Natural Sounds, Cornell Laboratory of Ornithology). Playbacks were broadcast at a standardized volume (90 db) using FOXPRO® ZR2 digital game callers (FOXPRO Inc., Lewistown, Pennsylvania, USA). Playback surveys have been shown to significantly increase detection probability for this species compared to individual passive point count surveys (Saracco et al. 2011). Playback surveys were only conducted once per transect visit after all passive point count surveys were completed to avoid influencing detection probability on passive surveys via individuals drawn towards the broadcast from large distances away. The approximate range at which human observers can hear the playback calls is 200 m, but variable depending on topography and vegetation. We also included any Black-backed Woodpecker detections from the Hairy Woodpecker/Mountain Quail playback survey.

All observers underwent an intensive, three week training period focused on bird identification prior to conducting surveys. Surveys were conducted between local sunrise and 1000 h from May 13 – July 15. Surveys did not occur in inclement weather that could reduce detectability (e.g. high wind, rain, dense fog). Variable survey effort was accounted for in our occupancy modeling framework described below.

We assembled detection histories for each transect by combining all detections from the five passive point counts during a single transect visit, and considered this as a separate survey event from the playback surveys at the center point. The total time of surveys

was different among the survey types, with five, 5 min passive point counts (25 min of passive survey time total per transect) compared to one 5 min Hairy Woodpecker/Mountain Quail playback survey plus one 6 min Black-backed Woodpecker playback survey (11 min of playback survey time per transect). We visited each transect up to twice per year, for a maximum of $K = 4$ survey events per year per transect. For all models we included survey type (passive or playback) as a covariate of detection probability.

In order to evaluate Black-backed Woodpecker patterns of occurrence we used occupancy models (MacKenzie et al. 2006). We used a multi-season dynamic model which includes probabilities of transect colonization and extinction between seasons (in our case, years). Therefore, for each of the $n = 377$ green forest transects there were a maximum of $K = 16$ survey occasions (up to two visits on two separate dates each year, and two survey types per visit). We included the occupancy covariates identified from a separate analysis that we found to most strongly influence Black-backed Woodpecker occupancy (Fogg et al. 2014). These include latitude, elevation, slope, and snag density.

Models were analyzed using R version 3.1 statistical software and the package 'unmarked' (R Development Core Team 2011; Fiske and Chandler 2011). All counts were converted to detection/non-detection (1 or 0). Both occupancy and probability of detection were fit with logit-linear models. We defined the model for occupancy probability as the logit-transformed probability of occupancy in relation to the covariates listed above. Probability of detection was a function consisting of an intercept term, the year of survey, and a covariate for survey type, passive [0] or playback [1]. Colonization $\text{logit}(\gamma_i)$ was assumed to be constant and extinction $\text{logit}(\epsilon_i)$ varied by year. The addition of year of survey as a covariate with detection probability and extinction is different from previous analyses with these data. We derived annual occupancy

estimates using the 'smoothed' estimator and generated standard errors for occupancy estimates using 100 non-parametric bootstraps.

Results and Discussion

Black-backed Woodpeckers were detected at green forest transects on all forests except for Sequoia National Forest and the Lake Tahoe Basin Management Unit (Table A1).

They are present on burned forest transects in Lake Tahoe Basin Management Unit, but no detections on burned or unburned transects have occurred on Sequoia National Forest during our surveys (data not shown).

Contrary to previous analyses, occupancy was not stable across the four years of our study as 2014 marked a sharp decrease from previous years (Figure A1). Estimated occupancy ranged from 0.33 in 2011 to 0.14 in 2014 with confidence intervals overlapping for 2011-2013, but largely distinct for 2014. Estimates of occupancy in this new analysis were higher than previous analyses (Roberts et al. 2014), due both to the changes in the set of transects included in the analysis, and because we allowed probability of detection to vary by year in this analysis but not in previous years. The 39 transects that were removed for this analysis but included in the previous report and recent Fogg et al. (2014) manuscript were primarily lower elevation locations that had a low average estimated occupancy of 0.11. The 30 transects we added for this current analyses were moderate elevation sites with higher average estimated occupancy of 0.19.

Probability of detection for combined passive and playback surveys increased substantially over time, from 0.19 in 2011 to 0.32, 0.33, and 0.42 in 2012-2014, respectively. The especially lower estimate for the first year that we conducted playback surveys for Black-backed Woodpecker is plausible given that our field observers became more experienced in identifying a rare species across multiple field seasons.

The model estimated low colonization (0.02, held constant across years in the model) and extinction rates for 2011-2012 and 2012-2013 (0.20 and 0.09 respectively), followed by a very high extinction rate for 2013-2014 (0.49). Error bars for extinction rate estimates are large, but we feel it is important to illustrate the potential for a strong change in green forest occupancy that may be occurring.

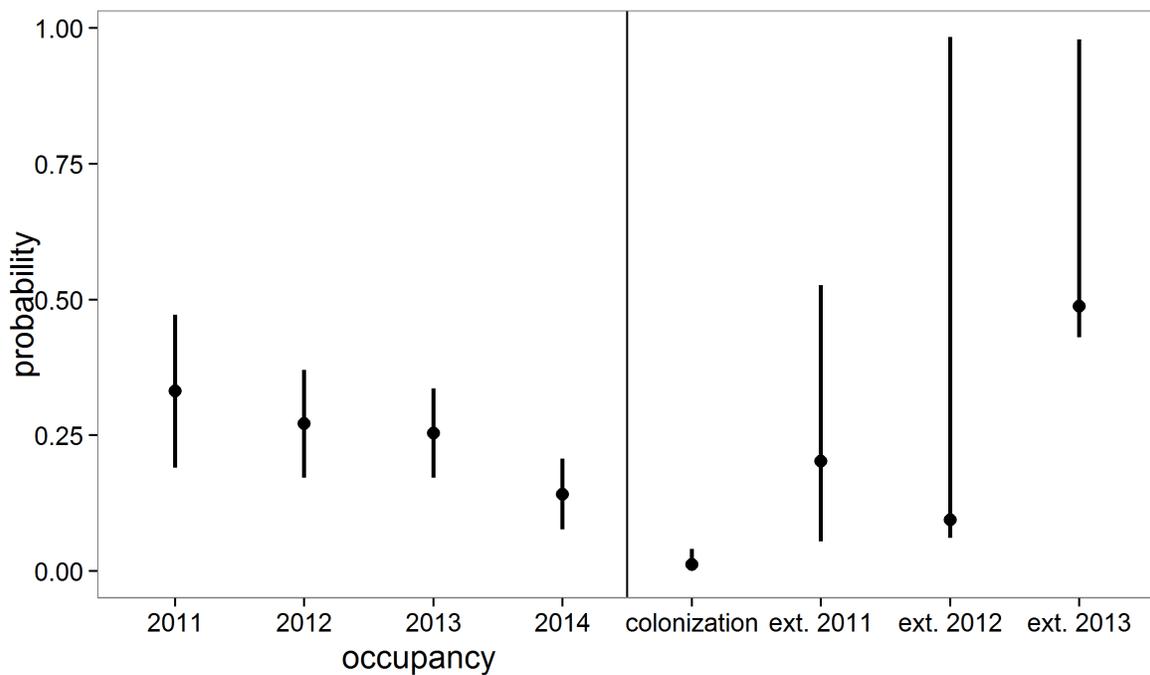
These results suggest that prior to 2014 many of the individuals detected in green forest were not just actively dispersing across the landscape in search of burned areas, but were occupying relatively stable home ranges. A large number of fires occurred in 2012 and especially 2013, and we feel this might account for the high extinction rate as it is possible that many individuals that had been occupying our field sites moved to the recent fire areas following the 2012 and 2013 field seasons. These results are preliminary and future work will be necessary to further elucidate this pattern.

Though we detected Black-backed Woodpecker across a fairly broad range of green forest habitat types, there are a number of habitat and landscape factors that are associated with high occupancy. To date, all our analyses have shown that occupancy is highest in lodgepole pine and red fir forest, and is positively associated with elevation (approximately 1500m in the northern Sierra and 1800 m in the south), northerly latitudes (more than 37 degrees), lower than 30% slopes, and patches of high snag density (> 10 snags per acre).

Table A1. Number of green forest transects with Black-backed Woodpecker detections for each National Forest Unit in the Sierra Nevada planning area. LTMBU = Lake Tahoe Basin Management Unit. The total number of transects surveyed for each unit is in parentheses.

Forest	2011	2012	2013	2014
Modoc	6 (44)	7 (44)	3 (46)	6 (46)
Lassen	8 (62)	12 (60)	10 (62)	7 (62)
Plumas	0 (39)	2 (39)	1 (39)	2 (39)
Tahoe	2 (38)	3 (42)	4 (42)	2 (42)
LTBMU	0 (2)	0 (2)	0 (2)	0 (2)
Eldorado	1 (40)	2 (40)	4 (45)	4 (46)
Stanislaus	0 (20)	4 (24)	4 (26)	0 (26)
Inyo	5 (18)	2 (18)	6 (20)	7 (20)
Sierra	5 (57)	4 (57)	6 (61)	5 (61)
Sequoia	0 (29)	0 (29)	0 (33)	0 (33)
Total	27 (349)	36 (355)	38 (376)	33 (377)

Figure A1: Annual occupancy estimates (left panel), with colonization and extinction probabilities (right panel), for Black-backed Woodpeckers in green forest. Vertical lines bounding each point indicate 95% confidence intervals. Colonization was held constant in this multi-season occupancy model, while extinction varied by year: “ext. 2011” refers to extinction rate between 2011 and 2012, and likewise “ext. 2012” for 2012-2013, and “ext. 2013” for 2013-2014.



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