Point Blue Report

Sierra Nevada National Forests Avian Management Indicator Species

2013 Annual Report

JULY 2014

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Conservation science for a healthy planet

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Sierra Nevada National Forests

Avian Management Indicator Species Project

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Cover photos: *Clockwise from top left: Mountain Quail, Hairy Woodpecker, Yellow Warbler, Fox Sparrow. Photos by Gary Woods.*

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SUMMARY

2013 marked the fifth year of monitoring four avian Management Indicator Species (MIS) across 10 National Forest units in the Sierra Nevada planning area. In 2013, we used multi-species point counts to sample 473 transects in upland habitat for Fox Sparrow, Hairy Woodpecker, and Mountain Quail. We surveyed an additional 96 transects in riparian habitats for Yellow Warbler.

We investigated multiple-year occupancy of MIS, as well as five additional habitat guild species for each MIS to assess whether patterns across multiple years are shared by other species using the same habitats. Occupancy trends indicate that the snags in green forest MIS and habitat guild species declined from 2010 to 2013, while the chaparral, conifer, and riparian MIS and habitat guild species appear to be stable or only declining slightly. Hairy Woodpecker occupancy at the scale of the entire region has declined at a significant rate of 2.6% per year while Fox Sparrow has also declined at a significant rate of 1.4% per year. Mountain Quail showed a non-significant decline of 1.2% per year while Yellow Warbler appeared the most stable of the four species with a 0.32% decline per year with a confidence interval that largely overlapped zero.

As part of our ongoing efforts to utilize this extensive dataset to answer management relevant questions for the Sierra Nevada we update information on Black-backed Woodpecker occupancy in green forest (see Appendix).

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 (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 Sparrows 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. In this report we describe the field efforts and data generated from our 2013 field season. We update information on the prevalence and occupancy of the four MIS and associated habitat guild members.

Large scale avian monitoring programs that sample multiple species may be a useful tool for answering important ecological and management related questions beyond their original scope (Hutto and Young 2002). With its geographic and elevational breadth, sample design and size, and multi-species point count methodology, our MIS monitoring project is a powerful dataset capable of answering numerous management relevant research questions. Here we provide an example of utility of this dataset to inform forest management by providing a summary of a manuscript in revision on Black-backed Woodpecker status and distribution in green forest in the Sierra Nevada (Appendix A).

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 proportional 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 Implementation Package (USDA Forest Service 2008). 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). These sites were chosen using Generalized Random-Tesselation Stratified (GRTS) algorithm to generate separate geographically balanced upland and riparian samples across the region and represent the maximum number of field sites that we can visit each year given current funding levels. 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, removal of the 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, and removed 11 sites where we had previously conducted surveys. The GRTS selection added 16 new sites, which resulted in a final sample of 237 upland sites. 2013 is the first field season where these 16 sites have been 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. Transect sample size was determined based on achieving not only a robust enough sample to detect relatively small changes (<10%) in the MIS species at the entire study area scale but also provide necessary information on forest level trends that could help inform management actions.

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.

We weighed the cost of conducting playback surveys against the value of the increased precision in our data. Since the primary cost of conducting surveys is accessing the sites the only real cost of the playback surveys is the initial purchase of playback devices. As such we decided the small additional cost of conducting playback surveys was worth the added precision we achieved (Point Blue unpublished data). For a more detailed account of sample design and survey methods see Roberts et al. (2011).

Analyses

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 2013 using the 'colext' occupancy function from the package 'unmarked' (Fiske and Chandler 2011) 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 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 species detections varied by species to create estimates at a similar scale to their 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 fire perimeters from the last 20 years to avoid including detections of birds within burned forest. We did not exclude transects wholly outside of recent fires but adjacent to them 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. This sample includes 1934 points on 392 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. This sample includes 2290 points on 464 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.

To demonstrate the effect of correcting for probability of detection we also show the proportion of points and transects (prevalence) at which we detected each of the four MIS. This uncorrected measure, or naïve occupancy, provides a base from which to evaluate our occupancy calculations and illustrate the variability in detections among years.

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 distance of all of the species analyzed in this report.

We identified a set of five additional species associated with each habitat for which the MIS were chosen to indicate that we refer to here as 'habitat guilds'. We relied heavily on our expert opinion, published literature, and existing focal species adopted by California Partners in Flight for Riparian and Coniferous habitat in California to populate our lists (CalPIF 2002, Riparian Habitat Joint Venture 2004). We assume that comparing trend estimates for MIS with those of habitat guild species will aid interpretation of any observed population changes in the MIS (Chase and Geupel 2005). For example, if a negative trend in Fox Sparrow was observed and a number of other shrub dependent species were also declining, it would increase confidence that the observed trend was related to effects on shrub habitat versus something specific to the species such as disease or loss of wintering habitat outside the Sierra Nevada. In selecting these habitat guild species, we recognized that it was important to include more common species for which we could acquire meaningful estimates of changes in occupancy over a relative short time frame (e.g. 4 – 10 years). Though fairly common, these species are not generalists and are all associated with native habitat in the Sierra Nevada. For each of the habitat guild species we calculated occupancy using the same procedure identified above for the MIS, including sampling unit scale based on territory size, and bootstrap standard error estimates. To assess trends in occupancy we calculated a simple linear regression on the estimates across years, and assessed significance of the linear trend using a two tailed t-test to evaluate whether the slope of the regression line was different than zero. By comparing trends among habitat guild species and MIS we can better evaluate whether breeding ground effects in the Sierra Nevada are likely to be driving observed patterns, therefore providing a more complete evaluation of the individual habitat components with which each species uniquely associates.

RESULTS

Survey Effort

In 2013, we surveyed 2742 point count stations on 569 transects (upland and riparian combined; Table 1). We conducted repeat surveys at 62% of transects for a total of 924 transect visits (compared to 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 2012 and selected remaining upland sites to revisit from a random draw to achieve 62% re-visit rate. We conducted two visits at a higher proportion of upland transects (62%) than riparian transects (54%) because riparian species detection probabilities tend to be high compared to many upland species, thus the repeat visits are less necessary for establishing presence (Roberts et al. 2013).

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.

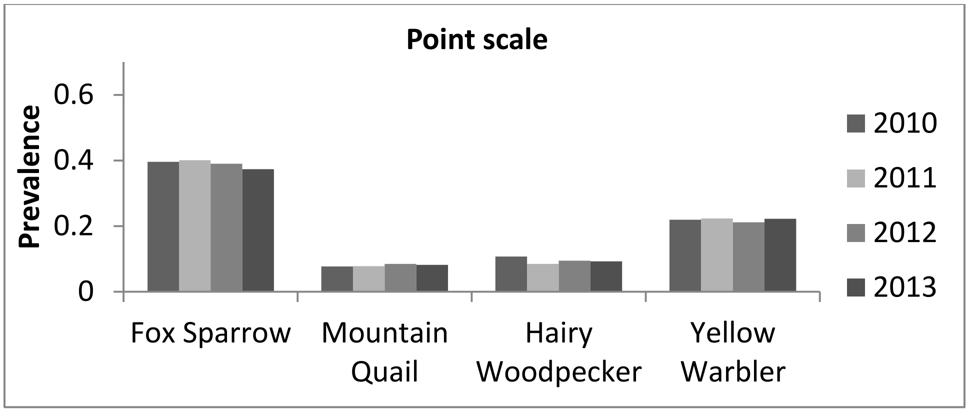
		2009	**2010**	**2011**	**2012**	**2013**
Transects Visited	*upland*	415	464	472	462	473
	riparian	43	94	96	100	96
Second visits	*upland*	250	267	220	369	303
	riparian	16	65	88	56	52
Second visit rate	*upland*	60%	58%	47%	80%	64%
	riparian	37%	69%	92%	56%	54%

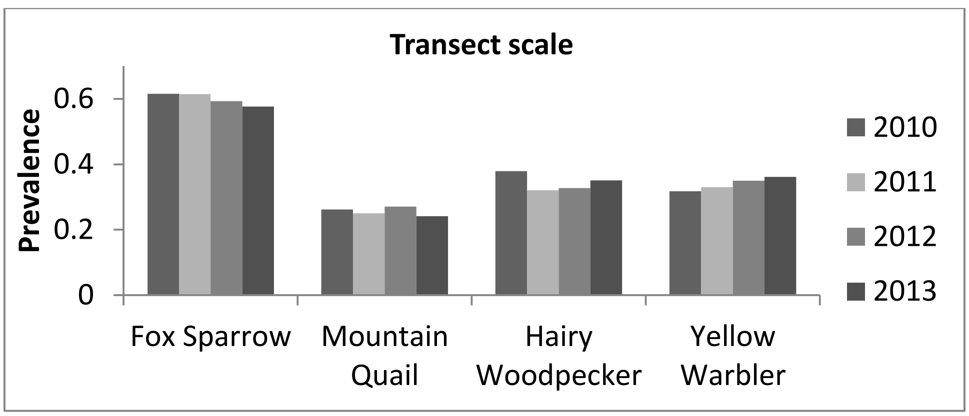
MIS Occupancy Trends

Fox Sparrows were detected at 38% of upland point count stations (prevalence, Figure 1) in 2013, and point scale occupancy corrected for detection probability was 0.44 (95% CI: 0.42 – 0.46); from 2010 – 2013 occupancy ranged from 0.44 – 0.48 (Figure 2), highest in 2010 and lowest in 2013. Probability of detection in 2013 was 0.72 (95% CI: 0.58 – 0.72) and ranged from 0.72 – 0.77 across years. Fox Sparrow occupancy has declined at a rate of -1.37% per year from 2010 – 2013 (P = 0.04).

Hairy Woodpeckers were detected at 35% of upland transects in 2013 (Figure 1), and transect scale occupancy was 0.85 (95% CI: 0.71 – 1.00) and has declined steadily each year from a high of 0.93 in 2010. Probability of detection in 2013 was 0.28 (95% CI: 0.24 – 0.32) and ranged from 0.23 – 0.28 among years. Occupancy has steadily declined at a rate of -2.64% per year (P < 0.01).

Figure 1. Proportion of point count stations and transects with detections (prevalence, or naïve occupancy) of MIS in 2010 – 2013 (< 100 m and excluding playback surveys). These numbers share the same scale as occupancy data but are not corrected for imperfect detectability.

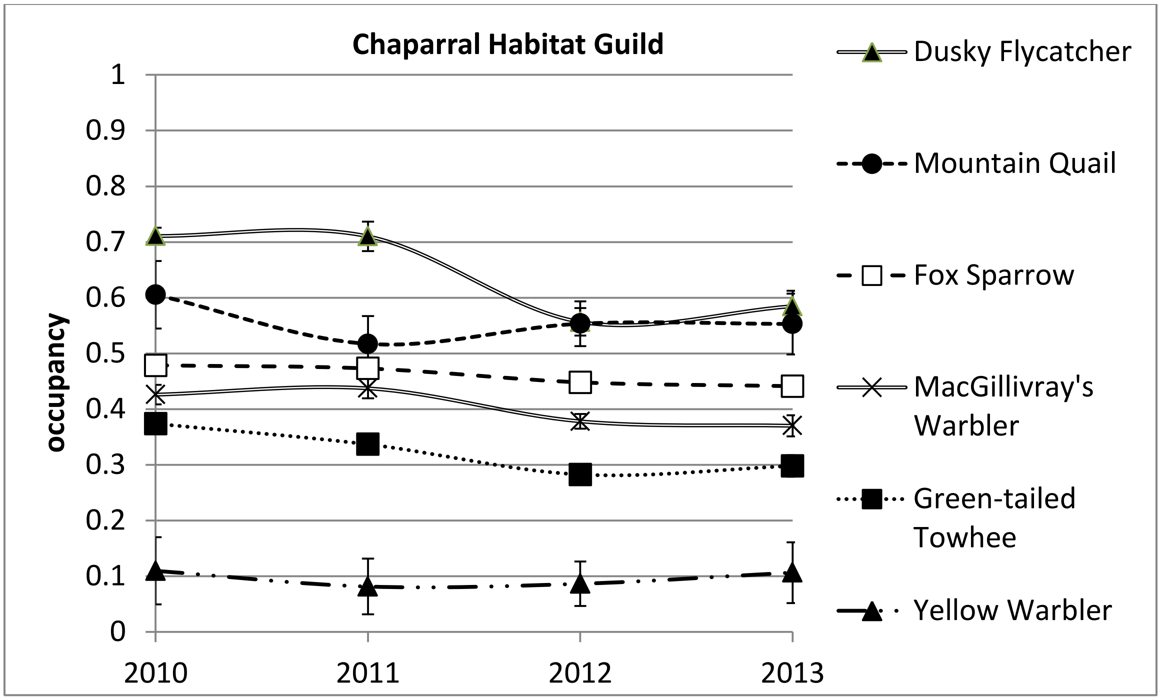


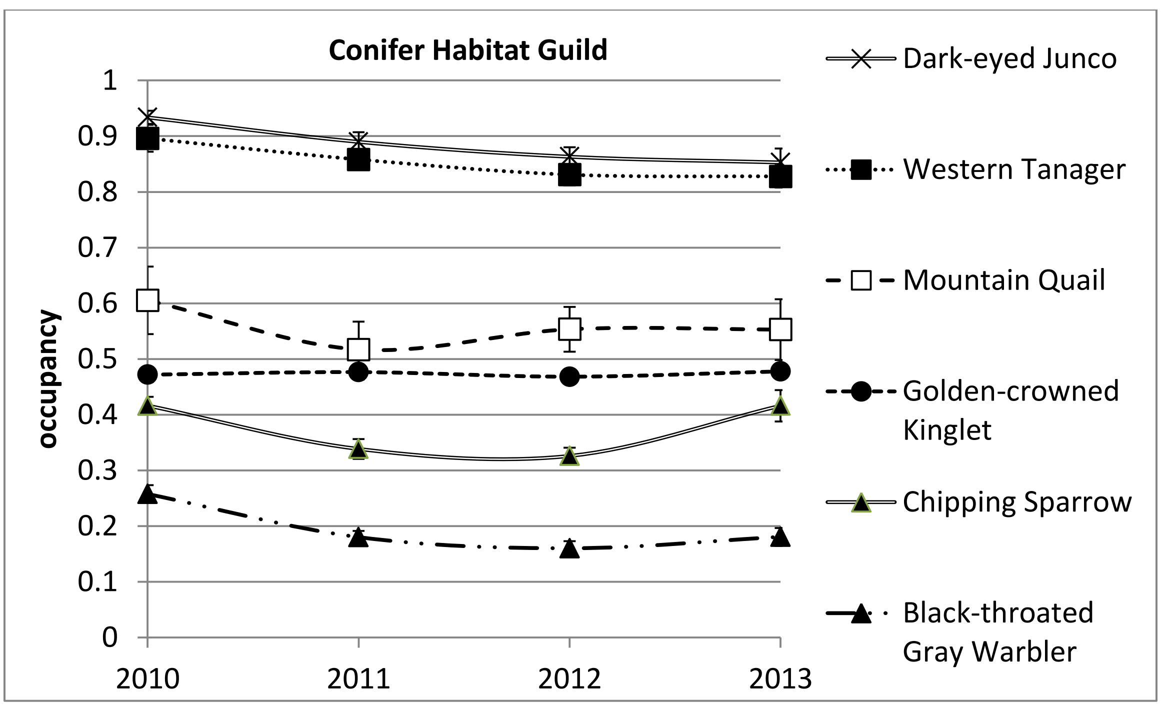


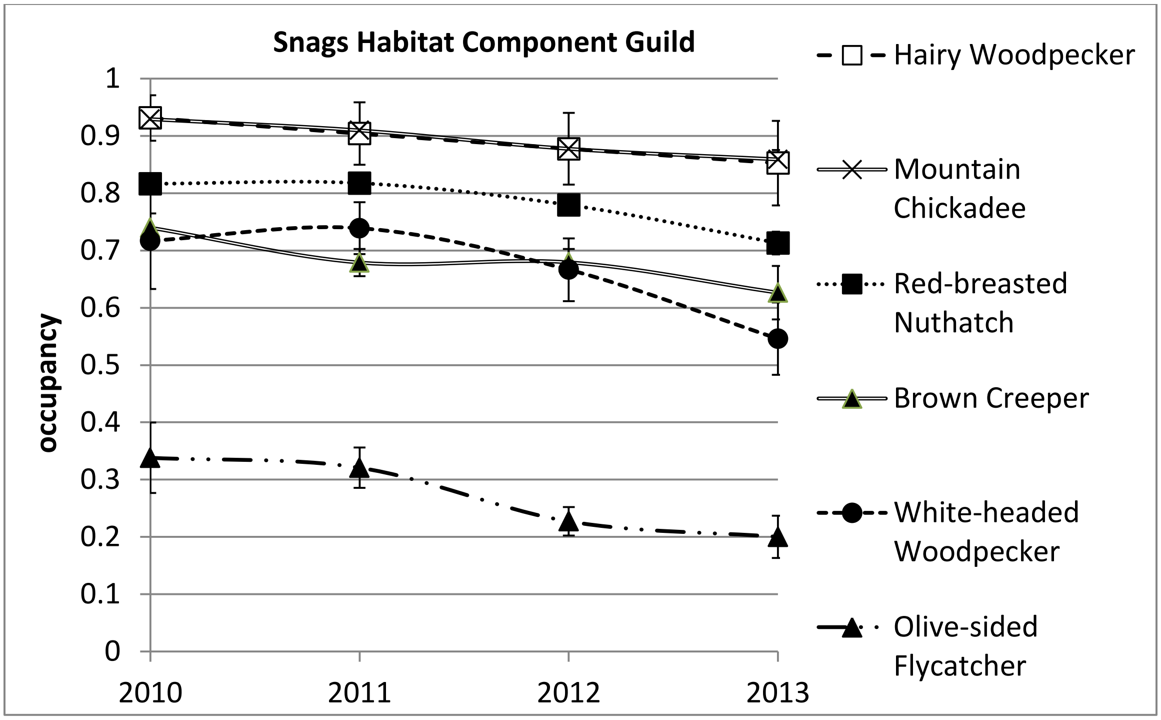
Mountain Quail was detected at 24% of upland transect locations in 2013, and transect scale occupancy was 0.55 (95% CI: 0.45 – 0.66) and ranged from 0.52 – 0.61 across years. Probability of detection in 2013 was 0.31 (95% CI: 0.26– 0.36) and ranged from 0.30 – 0.38 among years. Mountain Quail occupancy has declined at a rate of -1.21% per year, but the trend was not significant (*P* = 0.57).

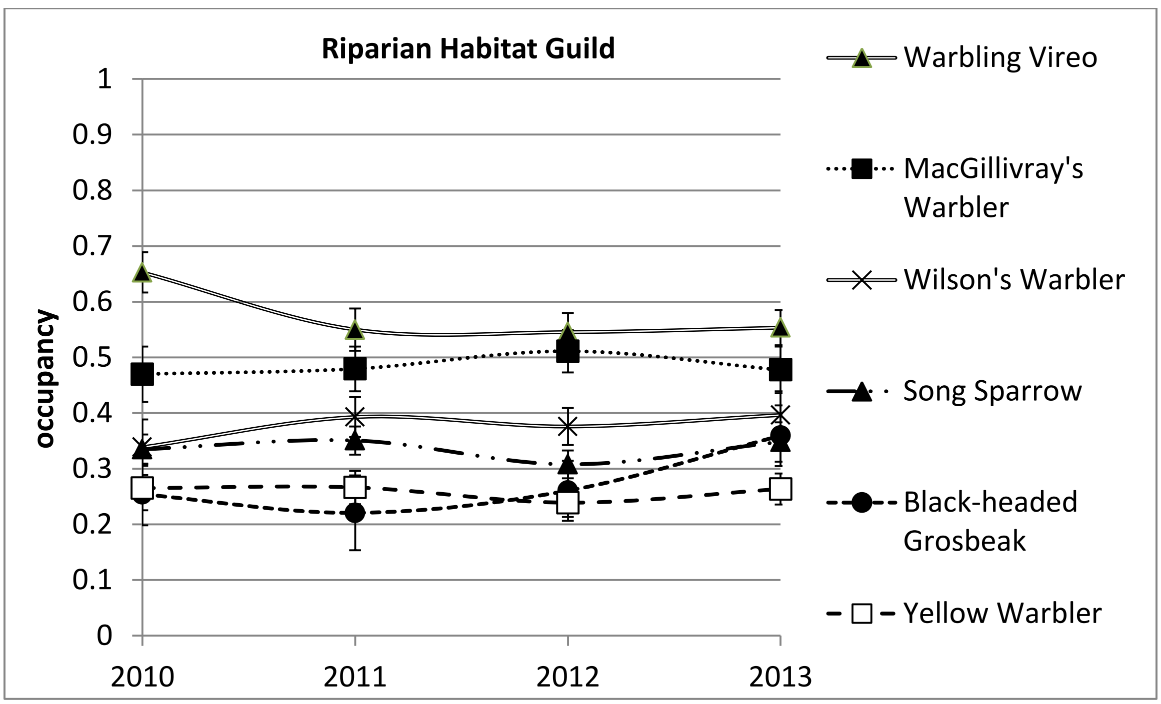
Yellow Warblers were detected at 22% of riparian point locations in 2013, and point scale occupancy was 0.26 (95% CI: 0.21 – 0.32) and ranged from 0.24 – 0.27 across years. Probability of detection in 2013 was 0.76 (95% CI: 0.63 – 0.85) with a range from 0.60 – 0.76 across years. Yellow Warbler occupancy appears to be stable across years with a non-significant decline of -0.32% per year (*P* = 0.68).

Figure 2. Multi-year occupancy estimates in 2010 – 2013 for the MIS and five associated habitat guild species for each habitat component. Error bars show +/-1 SE derived from multi-season occupancy model. MIS are show in each subfigure with hollow boxes.









Comparison of MIS and Associated Habitat Guild Species

Patterns in habitat guild species occupancy from 2010 to 2013 generally appeared to follow the patterns of MIS (Figure 2). The most prevalent chaparral habitat guild species were Dusky Flycatcher and Mountain Quail, both of which had higher occupancy than Fox Sparrow.

However, it is important to note that Mountain Quail occupancy was calculated at the transect scale while all other species in the guild were calculated at the individual point scale (see Methods above for an explanation of this variation in scale). Yellow Warbler occupancy was lowest of the chaparral guild species. Fox Sparrow occupancy was highest in 2010 and 2011, but declined each of the last two years. Other chaparral habitat guild species mirrored this pattern, including Dusky Flycatcher, MacGillivray's Warbler, and Green-tailed Towhee. The Dusky Flycatcher decline across the four years was rather sharp at -5.31% per year, though the pattern was not significant ($P = 0.15$).

Dark-eyed Junco and Western Tanager had the highest occupancy of the conifer habitat guild species, while Black-throated Gray Warbler had the lowest. For some of the conifer habitat guild species, there was a pattern of occupancy highest in 2010 and then a decline over the next three years. Species with declines greater than 2% per year include Dark-eyed Junco (-2.7%, $P = 0.04$) and Western Tanager (-2.3%, $P = 0.05$). Black-throated Gray Warbler also had a trend over 2% but, likely due to relatively small sample size for this species this trend was not significant (-2.5%, $P = 0.25$). Chipping Sparrow declined in 2011 and 2012 and then increased back to 2011 levels in 2013 resulting in a near zero trend across the four years (-0.03%, $P = 0.97$). Golden-crowned Kinglet occupancy appeared very stable across the four years.

The majority of the green forest snag habitat guild species had high occupancy. Highest among them were Mountain Chickadee and Hairy Woodpecker, while Olive-sided Flycatcher had the lowest occupancy. All of the species in this guild declined across the four years of monitoring with each of the six species reaching the lowest occupancy in 2013. Declines ranged from -2.4% to -5.8% per year and were all significant or marginally significant ($P < 0.13$).

Riparian habitat guild species generally had lower occupancy than species in the other habitat guilds. Only Warbling Vireo consistently occupied more than half of the riparian points and the remainder of the guild occurred at 20 – 40% of the points. Riparian guild occupancy was largely stable across years; the only potential trend was for Black-headed Grosbeak which increased at a rate of 3.55% per year, but the trend was not significant ($P = 0.23$).

SNAMIN

Further results for MIS, habitat guild species, and all species detected during MIS surveys can be found on the Sierra Nevada Avian Monitoring Information Network (SNAMIN) website (http://data.prbo.org/apps/snamin/). Across the five years of this project, we have amassed over 310,000 individual bird records of 195 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 (http://data.prbo.org/apps/snamin/index.php?page=bioreg-home-page).

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 40 or more 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. And while single species of management interest will likely always be a part of National Forest monitoring priorities, a broader suite of surrogate species - that represent not only habitat types but different elements within those types - should be considered an important tool for informing an ecologically-based and balanced approach to forest management (Burnett 2011). If continued long-term, this monitoring program can provide a wealth of information to help inform forest management in the face of accelerating threats and demands on the Sierra Nevada's resources. We suggest that a multi-species guild approach be adopted to help evaluate revised National Forest plans being drafted now as part of a robust region-wide adaptive forest management program.

MIS Summaries

While there are some interesting patterns in the data we present below, it is important to note that these trends only span four years, and during these four years we had disparate weather conditions from above average snowfall in 2010 and 2011 to drought in 2013. These conditions should be considered carefully when evaluating and interpreting these patterns.

Hairy Woodpeckers are 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 as their relatively large home ranges limit high densities. Detection probability for this species is relatively low, even with playback surveys, such that naïve prevalence estimates considerably underestimate the species true occupancy. They are strong primary excavators and as such they likely 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 have high transect scale occupancy in the study area but have shown a significant decline in occupancy since 2010. According to the Breeding Bird Survey (BBS; Sauer et al. 2014), from 2002 – 2012 Hairy Woodpecker abundance was stable. It is important to note that our sample excludes areas that have recently burned, as the species is designated as the indicator for snags in green forest, and the BBS does not exclude burned areas. Factors that could reduce green forest snag habitat elements include fuel reduction treatments, which can significantly reduce snag densities (Bigelow et al. 2012, Burnett et al. 2013). While snags are an important resource for this species, other factors could be driving the short-term declines we have observed. As with all of the MIS, further years of data are necessary to properly evaluate the species trend.

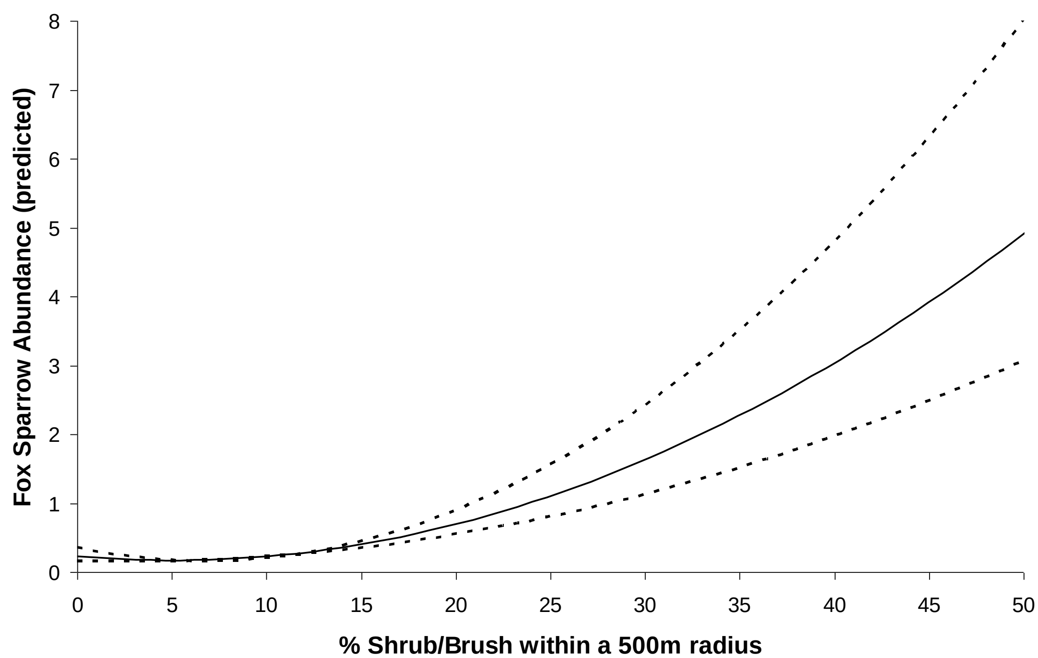
Hairy Woodpecker require snags for acquiring food, not just as a as a source of nest sites. Managing for snags as a food resource may require different considerations than measures intended to provide nest cavity resources. There is a need for a greater understanding of how both the spatial and temporal 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.

Fox Sparrow has a relatively high probability of detection and our naïve prevalence was similar to our occupancy estimate corrected by detection probability. Thus, naïve prevalence may provide a reasonable index of occupancy. With Fox Sparrow occurring at over 40% of all point count stations in the study area, it suggests that montane chaparral is fairly common. 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 did detect a significant decline in Fox Sparrow occupancy from 2010 to 2013. According to BBS data from 2002 – 2012 the species showed a non-significant decline in abundance of 0.65% per year.

Fox Sparrow is associated with dense shrub habitat in the Sierra Nevada. In a study in the Lassen National Forest they selected nest sites with higher shrub cover than the surrounding chaparral habitat, with shrub cover surrounding nest sites averaging 68% (Burnett et al. 2004). Using data from this study, Roberts et al. (2013) found shrub cover was the strongest predictor of Fox Sparrow occupancy in the Sierra Nevada. Fox Sparrow 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 (Stine et al. 2005), they also appear to be edge sensitive. We found Fox Sparrow abundance in that study area increased significantly when more of the surrounding landscape was dominated by montane chaparral (Figure 3). Thus, small patches of shrubs 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 10 acres, should benefit this species (Burnett et al. 2012). With over 20% of the Sierra Nevada avifauna nesting in shrubs and an even greater proportion utilizing chaparral resources (e.g. nectar, seeds, fruit) during some portion of the year, montane chaparral is an important component of Sierra Nevada forests.

Figure 3. Predicted Fox Sparrow abundance (within a 50 m radius circle) in relation to the amount of the surrounding landscape that was classified as shrub dominated habitat in the Plumas-Lassen Administrative Study area.



Mountain Quail naïve prevalence was much lower than occupancy estimates corrected for detectability. The use of uncorrected detections to estimate occupancy clearly underestimates the occupancy of this species. It is important to note that we calculated occupancy for this species at the transect scale due to their large territory size. Occupancy is relatively high, as the species occurred in over half of the 1 km square grid cells we sampled across the region. We found that occupancy was likely stable from 2010 – 2013 but according to the BBS between 2002 and 2012 Mountain Quail experienced a steep negative trend in abundance of 4.28% per year, but due to a small sample size the error around this estimate was large and thus the trend was only marginally significant. However, a potentially steep decline such as this warrants closer attention to factors that may be negatively impacting the species. With their large territory sizes, 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 the 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). Occupancy also increased with elevation, latitude, shrub height, and the portion of the ground covered by leaf litter. In the Northern Sierra, their abundance was higher 5 – 10 years following high severity wildfire than the surrounding unburned forest (Burnett et al. 2012). Increases in food (e.g. seeds, insects) and cover afforded by shrubs and herbaceous plants on the forest floor are likely to increase habitat quality for this species. Creating canopy gaps through the use of mechanical fuel reduction treatments, prescribed fire, and expansion of moderate severity fire should benefit this species. The management recommendations we listed above for Fox Sparrow should also benefit Mountain Quail. A better understanding is needed of this species' population limitations and habitat associations in the Sierra Nevada, which represents a substantial portion of the species range.

Yellow Warbler occurred at between 20 and 25% of our riparian point count stations from 2010 - 2013 and their occupancy appears stable in that timeframe. It is a California Bird Species of

Special Concern; primary threats 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. According to BBS data from 2002 – 2012, the species declined in the Sierra Nevada at a rate of 1.12% per year and this trend was significant.

Restoration of montane riparian and meadow riparian habitat in the Sierra Nevada will likely benefit this species of conservation interest. Based on Point Blue's extensive montane riparian/meadow dataset (n = 140 meadows) in high quality riparian meadow habitat within its primary elevational range (~4000 – 6000 feet) in the northern Sierra Nevada, this species can be abundant in functioning riparian and meadow habitats. The fact that they do not occur at 75% 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 (Point Blue unpublished data). 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 (Campos and Burnett 2012). 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).

Comparing MIS with other avian habitat indicators

Consideration of the trends in the broader suite of species associated with the same habitats as the MIS provides greater context for evaluating observed trends in the MIS. Of interest are the declines in every species in the snags in green forest habitat component guild. All of the snag species are permanent residents, which makes it reasonable to assume that any factors affecting their populations are occurring in the Sierra Nevada. We will be keen to add another year of data in 2014 to determine if these precipitous declines over especially the last two years continue. Additional years of data and further investigation targeted at each individual species are needed to determine if these patterns are real and to build evidence towards causes. In the interim, implementing the management recommendations listed above for Hairy Woodpecker would be prudent.

If the USDA Forest Service Region 5 were to select new monitoring target species, our data indicate that Fox Sparrow, with their close ties to montane chaparral habitat, ubiquity across most of the region, and high occupancy is indeed a good choice. In fact prevalence from naïve detection rates appears a good index of the species occupancy which could allow for more simple analyses of trends over time.

Similar to Fox Sparrow, Hairy Woodpecker is widely distributed across the study area and has relatively high occupancy compared to other woodpecker species in the Sierra Nevada. However, detectability is fairly low and thus detectability-corrected measures of occupancy are required and playbacks are advised. However, as one of the most abundant primary cavity excavators in the Sierra Nevada, they likely represent a good choice as an indicator of snag resources.

Montane Riparian habitat as defined by the California Wildlife Habitat Relationships (Mayer and Laudenslayer 1988) represents but a very small fraction of the riparian habitat in the Sierra Nevada and much of it is not appropriate habitat for Yellow Warbler. Our data from this project and ongoing analyses of our large riparian meadow dataset in the region suggest that this species reaches their greatest abundance in riparian meadow habitat with a substantial willow component. While these habitats are technically riparian they do not meet the definition of Montane Riparian in the CWHR database. Accurate maps of riparian habitats in the Sierra Nevada do not currently exist. We relied on the best available information in 2009 and 2010 to select riparian sites with GIS. In the end, we had to replace nearly 50% of these sites after conducting field reconnaissance as they were not potential Yellow Warbler habitat. Similarly, tracking changes in montane riparian habitat using remotely sensed data is unlikely to provide an indication of the change in the extent or quality of this important habitat type in the Sierra Nevada.

We suggest that Yellow Warbler is an excellent indicator of riparian meadow habitat. We have documented them responding quickly and vigorously to meadow restoration (Campos and Burnett 2012). With the diversity of types and structures within riparian habitat, its uniqueness compared to uplands, and importance to a diversity of wildlife, we suggest that a well established multiple-species guild would be the best approach to monitor the health of these habitats (e.g. Riparian Habitat Joint Venture 2004). We are now working with the National Fish and Wildlife Foundation to develop quantitative metrics such as meadow guild richness to evaluate riparian meadow restoration in the Sierra Nevada. We suggest that the USDA Forest Service Region 5 consider adopting this list of riparian birds as focal species under new National Forest Plans.

Mountain Quail would not be our first choice as an indicator of open canopy conifer forest. The species has large home ranges, has relatively low abundance, and are as common in open conifer habitat as they are in pure chaparral. They also present monitoring challenges, including reduced vocalization earlier in the year than most other species monitored with point counts (especially in years with low snowpack) which may confound detection probability estimates. As with riparian habitat, open conifer is a broad category and can be quite diverse in structure and plant species composition. Thus, it is difficult to identify a single species that would best indicate for this very broad category. As such, we would again recommend that a guild approach is best, ideally with species selected for multiple conifer forest types. However, if a single species needs to be selected, we would suggest Western Tanager may be more appropriate – at least within ponderosa pine and Sierra mixed conifer forest types.

While we understand the USDA Forest Service hesitance in selecting a large number of species to monitor and analyze as indicators or focal species, we recommend that a multi-species monitoring approach be adopted to indicate habitat conditions at a regional scale, to evaluate forest plan implementation, and for use in effectiveness monitoring at the project level (e.g., Burnett 2011). Multi-species monitoring of a select suite of bird species that are adequately sampled using a single standardized point count survey method has long been used to guide land management in California and could easily be incorporated into a robust adaptive management based monitoring program across National Forests in the Sierra Nevada. Analyses of the guilds presented here is an example of the framework of such an approach.

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). The species also inhabits green forest but little is known about occurrence and habitat use patterns outside of burned areas, especially in the Sierra Nevada of California. We used the MIS sampling approach described within the body of this report to evaluate occupancy patterns of Black-backed Woodpecker in green forest on National Forest land in the Sierra Nevada.

Methods

To evaluate Black-backed Woodpecker occupancy in green forest, we used survey data from the upland sample of the Avian Management Indicator Species sampling locations described in the body of this report (or see Roberts et al. 2011). We used data from 2011 – 2013 on the 460 upland transects located on 10 national forest units (Table A1; Figure A1). We defined green forest as areas that had not burned at moderate or high severity since 1991 and were more than 2 km from areas burned at moderate or high severity within the previous eight years (n = 386 transects).

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. There were three transects where the only Black-backed Woodpecker detections were from the Hairy Woodpecker/Mountain Quail playback survey. Due to our relatively small sample of Black-backed Woodpecker detections, we included those surveys in our analysis to include this information to better inform our models.

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). In each year, at least 96% of green forest transects were surveyed, and 93% were visited in all three years. The remaining 7% were visited in two out of the three years. Of the transects visited in all three years, 48% received two visits in 2011, 80% in 2012, and 62% in 2013, with the remainder receiving a single visit. Variable survey effort was accounted for in our occupancy modeling framework described below.

All analysis was conducted at the transect scale. 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 = 386 green forest transects there were a maximum of K = 12 survey occasions (up to two visits on two separate dates, plus two survey types, per year). We included occupancy covariates identified from a separate analysis that we found to strongly influence Black-backed Woodpecker occupancy.

Models were analyzed using R version 3.0 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 defined by logit-linear models. Probability of detection in both models was evaluated as a function of an intercept term, and a covariate for survey type, passive [0] or playback [1]. We defined the model for occupancy probability as the logit-transformed probability of occupancy in relation to the covariates listed above. Colonization logit(γ_i) and extinction logit(ε_i) were assumed to be constants since we did not have enough observation data to accommodate more covariates.

We derived annual occupancy estimates using the 'smoothed' estimator in the R package 'unmarked' and generated standard errors for occupancy estimates using 1000 non-parametric bootstraps. Turnover probability was calculated from the dynamic occupancy model colonization and extinction parameters and the derived occupancy estimates as described in Weir et al. (2009). We followed the approach of Kery and Chandler (2012), where the probability of a transect changing from occupied to unoccupied or vice-versa between years (τ_t) is a function of the colonization probability in the previous year (γ_{t-1}) the extinction probability in the previous year (ε_{t-1}), and the proportion of unoccupied sites in the previous year ($1- \psi_{t-1}$).

Results

Black-backed Woodpeckers were detected at green forest transects on all forests except for Sequoia National Forest and were most common on Inyo and Lassen National Forests (Table A1). Occupancy was stable across the three years of our study (Figure A2). Estimated occupancy ranged from 0.21 in 2011 to 0.19 in 2013 with confidence intervals overlapping each year.

Relatively low colonization and extinction probability (0.05 and 0.19, respectively) suggest that 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. Dynamic occupancy modeled turnover rates from 2012 to 2013, defined as a transect changing from occupied to unoccupied or vice versa, was 14%.

Though we detected the species across a fairly broad range of green forest habitat types and conditions there were a number of factors that significantly increased the probability of occupancy. Their occupancy was highest in lodgepole pine forest and increased with elevation, latitude, northerly aspects, number of snags, and stands with larger average tree diameter. There occupancy decreased as slope increased.

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
Modoc	8 (51)	8 (51)	4 (51)
Lassen	8 (65)	13 (65)	10 (65)
Plumas	0 (41)	2 (41)	1 (41)
Tahoe	2 (43)	3 (43)	4 (43)
LTBMU	0 (2)	0 (2)	0 (2)
Eldorado	0 (39)	2 (39)	3 (39)
Stanislaus	0 (33)	4 (33)	3 (43)
Inyo	5 (18)	2 (18)	5 (18)
Sierra	4 (62)	4 (62)	5 (62)
Sequoia	0 (32)	0 (32)	0 (32)
Total	27 (386)	38 (386)	35 (386)

Figure A1. Study area and green forest transect locations where Black-backed Woodpecker surveys were conducted between 2011 and 2013. Names of National Forests and units within the Sierra Nevada forest planning area are shown.

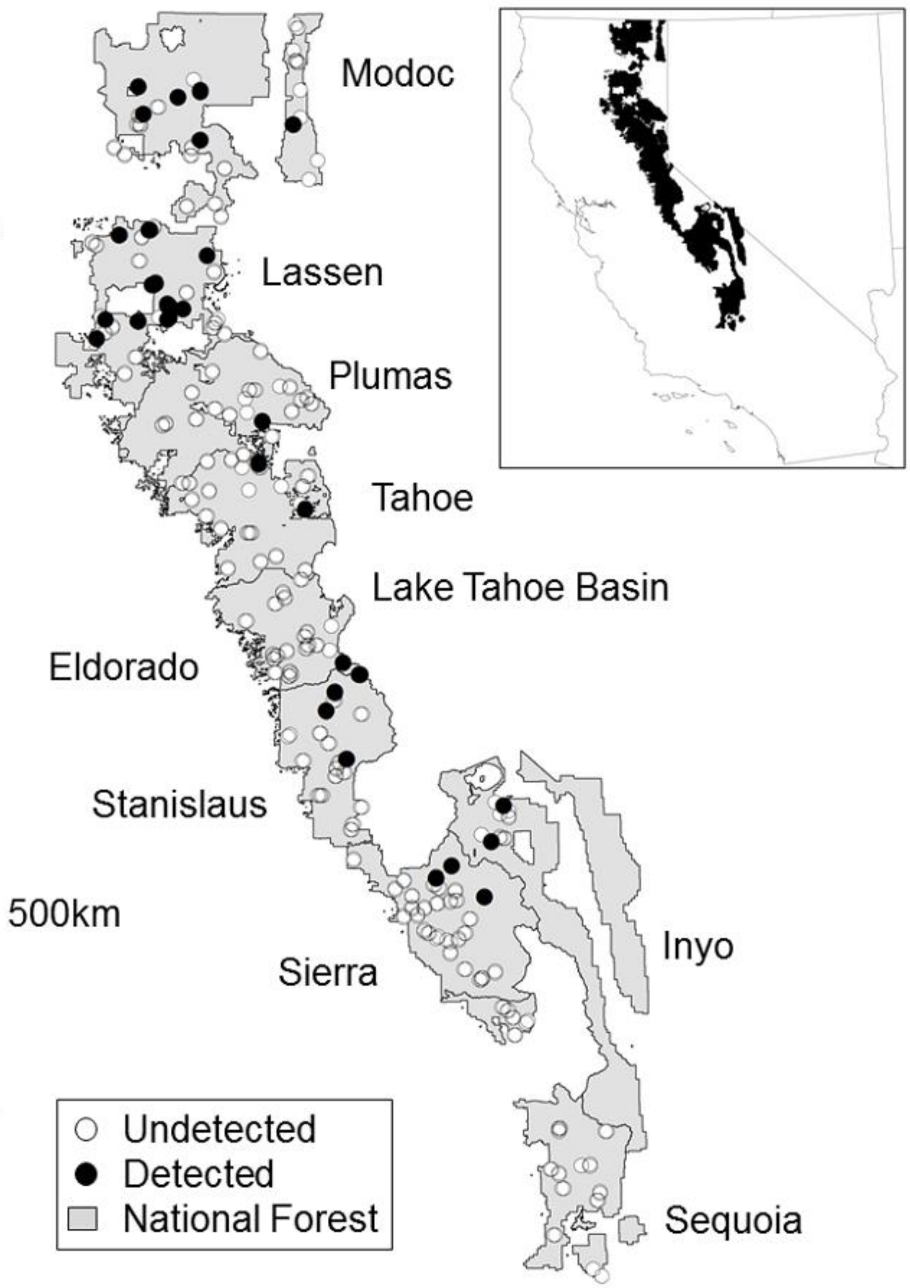
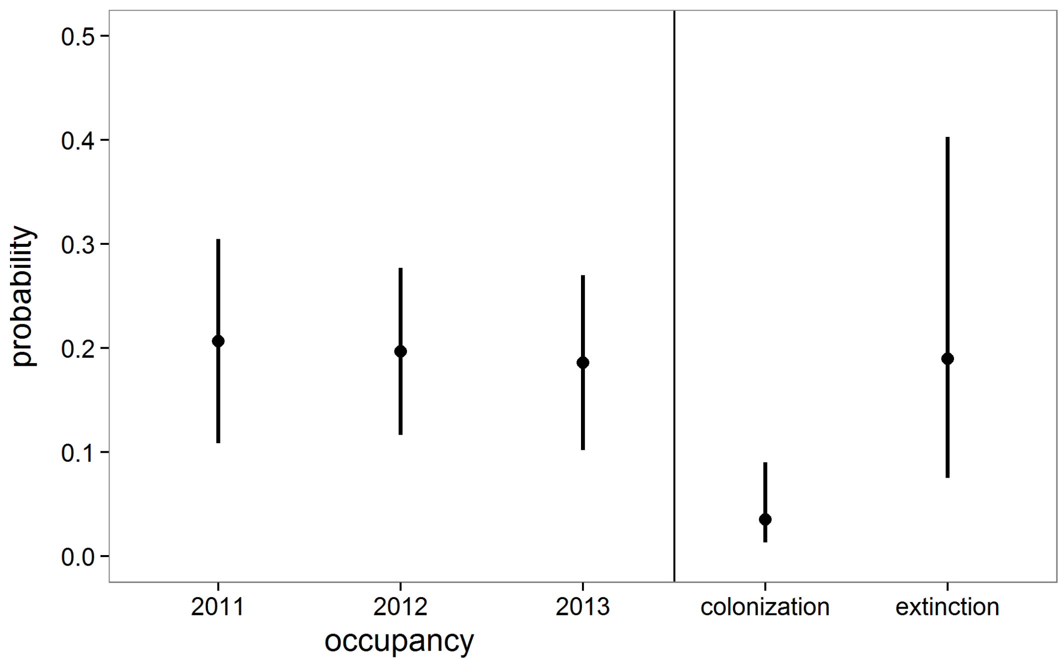


Figure A2: Annual occupancy estimates and colonization and extinction probabilities for Black-backed Woodpeckers in green forest. Vertical lines bounding each point indicate 95% confidence intervals.



LITERATURE CITED

Ammon, E.M., and P.B. Stacey. 1997. Avian nest success in relation to past grazing regimes in a montane riparian system. The Condor 99:7-13.

Bigelow, S., C. Dillingham, and L. Payne. 2012. Fuels reduction and group selection in

Sierran Mixed-Conifer Forest: short-term effects on environmental attributes. December 3, 2012. 51 pp. “Treated Stand Structure – 2012 Short term effects”. http://www.fs.fed.us/r5/hfqlg/monitoring/resource_reports/vegetation_and_botany/

Bock, C. E, VA. Saab, T. D. Rich, and D. S. Dobkin. 1993. Effects of livestock grazing on Neotropical migratory landbirds in western North America, p. 296-309. In D. M. Finch and P. W.

Stangel [eds.], Status and management of Neo-tropical migratory landbirds. Gen. Tech. Rep. RM-229. U.S. Dept. Agriculture, For. Serv., Rocky Mtn. For. Range Exp. Sta.

Burnett, R.D. D.L. Humple, T. Gardali, and M. Rogner. 2004. Avian Monitoring in Lassen National Forest: 2004 Annual Report. PRBO Conservation Science Technical Report # 1242.

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

Burnett, R.D., M. Preston, and N. Seavy. 2012. Plumas-Lassen Administrative Study 2011 Post-fire Avian Monitoring Report. PRBO Conservation Science Technical Report # 1869.

Burnett, R.D., N.E. Seavy, L. Salas, and D.L. Humple. 2013. Avian community response to mechanical fuel treatment in the Sierra Nevada, USA. PRBO Conservation Science, Petaluma, CA Contribution Number 1912. http://data.prbo.org/apps/snamin/uploads/images/fuels/PRBO%20QLG%20Fuel%20Treatment%20Final%20Report.pdf

CalPIF (California Partners in Flight). 2002. Version 1.1. The coniferous forest bird conservation plan: a strategy for protecting and managing coniferous forest habitats and associated birds in California (J. Robinson and J. Alexander, lead authors). PRBO Conservation Science, Petaluma, CA. http://www.prbo.org/calpif/plans.html

Campos, B.R., and R.D. Burnett. 2012. Avian monitoring in aspen and meadow habitats in the northern Sierra Nevada. 2011 annual report. PRBO Conservation Science, Petaluma, CA. Contribution Number 1881.

http://data.prbo.org/apps/snamin/uploads/images/aspen/PRBO%202011%20Aspen%20and%20Meadows%20report.pdf

Carlson, M., and F. Schmiegelow. 2002. Cost-effective sampling design applied to large-scale monitoring of boreal birds. Conservation Ecology 6:11.

Chase, M.K., and G.R. Geupel. 2005. The Use of Avian Focal Species for Conservation Planning in California. In: Ralph, C. John; Rich, Terrell D., editors. Bird Conservation Implementation and Integration in the Americas: Proceedings of the Third International Partners in Flight Conference. 2002 March 20-24; Asilomar, California, Volume 1. Gen. Tech. Rep. PSW-GTR-191. Albany, CA: U.S. Dept. of Agriculture, Forest Service, Pacific Southwest Research Station: p. 130-142

ESRI. 2011. ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute.

Fiske, I., and R. Chandler. 2011. Unmarked: An R package for fitting hierarchical models of wildlife occurrence and abundance. Journal of Statistical Software, 43: 1-23.

Hutto, R. L. 2008. The ecological importance of severe wildfires: some like it hot. Ecological Applications 18:1827-1834.

Hutto, R.L., and J.S. Young. 2002. Regional landbird monitoring: perspectives from the Northern Rocky Mountains. Wildlife Society Bulletin 30:738-750.

Hutto, R. L. 2005. Northern region landbird monitoring program: a program designed to monitor more than long-term population trends. *In* C. J. Ralph, and T. D. Rich, editors. *Bird Conservation Implementation and Integration in the Americas: Proceedings of the Third International Partners in Flight Conference*. 2002 March 20-24; Asilomar, California, USA. General Technical Report PSW-GTR-191. USDA Forest Service, Pacific Southwest Research Station, Albany, California, USA.

Keating, K.A., P.J.P. Gogan, J.M. Vore, and L.R. Irby. 2007. A simple solar radiation index for wildlife habitat studies. Journal of Wildlife Management 71:1344-1348.

Kery, M., and R. Chandler. 2012. Dynamic occupancy models in unmarked (unmarked R package vignette). Swiss Ornithological Institute, Sempach, Switzerland and USGS Patuxent Wildlife Research Center, Laurel, Maryland, USA. http://cran.r-project.org/web/packages/unmarked/vignettes/colext.pdf

MacKenzie, D.I. and J.D. Nichols. 2004. Occupancy as a surrogate for abundance estimation. Animal Biodiversity and Conservation 27:461-47.

MacKenzie, D.I., Nichols, J.D., Royle, J.A., K.H. Pollock, L.L. Bailey, and J.E. Hines. 2006. Occupancy Estimation and Modeling: Inferring Patterns and Dynamics of Species Occurrences Elsevier Academic Press, San Francisco.

Martin, K., and J. M. Eadie. 1999. Nest webs: A community-wide approach to the management and conservation of cavity-nesting forest birds. Forest Ecology and Management 115:243-257.

Mayer, K. E., and W. F. Laudenslayer. 1988. A guide to wildlife habitats of California. Department of Fish and Game, Sacramento, California, USA.

PRISM Climate Group. 2004. 30-year average annual precipitation estimates, 800 m resolution. URL: http://prism.oregonstate.edu, created 4 Feb 2004. Access date: 15 Jan 2014.

R Development Core Team. 2011. R: A language and environment for statistical computing. R

Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0. http://www.R-project.org/.

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

Riparian Habitat Joint Venture. 2004. The riparian bird conservation plan: a strategy for reversing the decline of riparian associated birds in California. California Partners in Flight. http://www.prbo.org/calpif/pdfs/riparian_v-2.pdf

Roberts, L.J., R.D. Burnett, A.M. Fogg, and G.R. Geupel. 2011. PRBO MIS Final Study Plan and Sampling Protocols for Mountain Quail, Hairy Woodpecker, Fox Sparrow, and Yellow Warbler. January, 2011. PRBO Contribution # 1714.

Roberts, L.J., A.M. Fogg, and R.D. Burnett. 2013. Sierra Nevada National Forests Management Indicator Species Project 2012 Annual Report. April, 2013. PRBO Contribution # 1934.

Saracco, J. F., R. B. Siegel, and R. L. Wilkerson. 2011. Occupancy modeling of Black-backed Woodpeckers on burned Sierra Nevada forests. Ecosphere 2(3): 31.

Sauer, J.R, J.E. Hines, J.E. Fallon, K.L. Pardieck, D.J. Ziolkowski, Jr., and W.A. Link. 2014. The North American Breeding Bird Survey, Results and Analysis 1966 - 2012. Version 02.19.2014. USGS Patuxent Wildlife Research Center, Laurel, Maryland. http://www.mbr-pwrc.usgs.gov/bbs/trend/tf12.html

Shuford, W.D., and T. Gardali (Eds.). 2008. California Bird Species of Special Concern. Studies of Western Birds No. 1. Western Field Ornithologists, Camarillo, CA and California Department of Fish and Game, Sacramento.

Stevens, D.L., and A.R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association, 99:262-278.

Stine, P., R.D. Burnett, N. Nur, C. Howell, and G. Geupel. 2005. Landbird Module of the Plumas Lassen Area Study. Fire and Fuels Management, Landscape Dynamics, and Fish and Wildlife Resources: Study Design for Integrated Research in the Plumas and Lassen National Forests. http://data.prbo.org/apps/snamin/uploads/images/fuels/PLAS_STUDY_PLAN_AVIAN_FINAL_Jan05.pdf

Tarbill, G. 2010. Nest site selection and influence of woodpeckers on recovery in a burned forest of the Sierra Nevada. M.S. Thesis. California State University, Sacramento, CA, USA.

Taylor, D. M., and C. D. Littlefield. 1986. Willow flycatcher and yellow warbler response to cattle grazing. American Birds 40:1169-1173.

Theobald, D. M., D. L. Stevens, D. White, N. S. Urquhart, A. R. Olsen, and J. B. Norman. 2007. Using GIS to generate spatially balanced random survey designs for natural resource applications. Environmental Management 40:134-146.

USDA Forest Service. 2004a. Sierra Nevada Forest Plan Amendment Final Supplemental Environmental Impact Statement January 2004. URL: www.fs.fed.us/r5/snfpa/final-seis/vol1/pdfs/snfpa-vol1.pdf.

USDA Forest Service. 2004b. Existing Vegetation – CALVEG. USDA Forest Service, Pacific Southwest Region, Remote Sensing Lab, McClellan, California, USA.

USDA Forest Service. 2007. Sierra Nevada Forests Management Indicator Species Amendment Record of Decision. Pacific Southwest Region. www.fs.fed.us/r5/snfmisa/rod/dat/rod-entire.pdf.

USDA Forest Service. 2008. SNFMISA Monitoring Implementation Package. April 2008. URL: www.fs.fed.us/r5/snfmisa/pdfs/2008_SNFMISA_Monitoring_Implementation_Package.pdf

Weir, L., I. J. Fiske, and J. A. Royle. 2009. Trends in anuran occupancy from northeastern states of the North American Amphibian Monitoring Program. Herpetological Conservation Biology 4:389-402.