Sierra Nevada National Forests Management Indicator Species Project 2012 Annual Report

L. Jay Roberts, Alissa M. Fogg, and Ryan D. Burnett

PRBO Conservation Science
3820 Cypress Drive #11, Petaluma, CA 94954
www.prbo.org

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Summary

2012 marked the fourth year of monitoring four USDA Forest Service Region 5 avian Management Indicator Species (MIS) across 10 National Forest units in the Sierra Nevada planning area. In 2012 a total of 2308 points on 462 transects in upland habitat were surveyed for Fox Sparrows, Hairy Woodpeckers, and Mountain Quail. An additional 400 points on 100 transects were surveyed in riparian habitats for Yellow Warblers. Despite no changes in staffing from 2011 to 2012, we increased overall second visit rate from 54% in 2011 to 76% in 2012, largely due to improved field conditions.

Occupancy values fluctuated somewhat across years, but no obvious directional trends are apparent. For all occupancy measures, 95% confidence intervals for each year largely overlapped, indicating that distribution of these populations is generally stable. Additional years of data are necessary to evaluate whether there are any important trends in the distribution of these species within the Sierra Nevada. Abundance of MIS across different forests show that Fox Sparrow and Mountain Quail reach their highest abundance in the central and to a lesser extent, southern Sierra Nevada. There was no discernible pattern in abundance across forests for Hairy Woodpecker, and Yellow Warbler was most abundant on the Lassen, Plumas and Tahoe National Forests, and absent from riparian habitats on Modoc and Eldorado.

Habitat associations of MIS imply that their distributions across forests are likely affected by broad geographic and vegetation associations. For example, Fox Sparrow was strongly associated with higher elevation and thus may not adequately indicate montane chaparral habitat at its lower elevation bounds. Neither Hairy Woodpecker nor Mountain Quail had strong associations with their habitat components (snags in green forest or early and mid-seral conifer cover, respectively), suggesting that indicators for these habitats warrant reevaluation. Yellow Warbler was associated with willow (*Salix* spp.) cover and lower elevations across the Sierra bioregion. Thus they may not be adequate indicators in riparian habitats devoid of willows or at higher elevations, such as in the Warner Mountains of Modoc National Forest.

We also identified five additional habitat guild species for each habitat component to augment analyses of MIS distribution and abundance. Collectively we refer to these six species as the habitat guild. We calculated average abundance for the MIS and habitat guild species and compared abundance over time among them. By examining these data we can evaluate whether management is likely to be driving the patterns, for example if all species appear to show the

same pattern, or we can identify unique patterns isolated within one or more species and potentially identify changes in individual habitat components that these species may be uniquely associated with. We found that patterns in abundance were mostly stable for habitat guild species from 2010 to 2012. For the chaparral guild, Fox Sparrow had their highest abundance in 2011, a high snowpack year when most other chaparral species (including Dusky Flycatcher, Green-tailed Towhee, MacGillivray's Warbler, Mountain Quail, and Yellow Warbler) were at slightly lower abundance. Conifer guild species were mostly stable across the study period (Mountain Quail, Chipping Sparrow, Golden-crowned Kinglet, Black-throated Gray Warbler, and Western Tanager), except for Dark-eyed Junco which increased each year. Snags in green forest guild species were also largely stable (Hairy Woodpecker, Brown Creeper, Olive-sided Flycatcher, Red-breasted Nuthatch, and White-headed Woodpecker) were also stable across years, except for Mountain Chickadee which declined from 2010 to 2011. Riparian habitat guild species (Yellow Warbler, MacGillivray's Warbler, Song Sparrow, Warbling Vireo, Wilson's Warbler, and Black-headed Grosbeak) also declined in 2011 but abundance of most riparian species rebounded in 2012.

To assist Region 5 in their assessment of indicator species, we examined correlations between the abundance of MIS and habitat guild species across all points within each habitat type or component. Fox Sparrow and Yellow Warbler abundances were highly correlated with other habitat guild species abundance and richness suggesting they are relatively strong indicators for chaparral and riparian habitat types. None of the early and mid-seral conifer species were strongly correlated with habitat guild species abundance or richness, although Mountain Quail was the most highly correlated within the group. Correlations were only slightly higher for snags in green forest habitat guild species. In the snags in green forest habitat guild, White-headed Woodpecker had the highest correlation with habitat guild species richness, followed by Hairy Woodpecker. Instead of selecting single species to indicate ecological integrity of entire habitats, we recommend designating a suite of species that as a group represent a broad set of habitat components and attributes, and individually can inform the management of specific components within each. Alternately we suggest that it would be preferable to identify and monitor ecosystem integrity of more distinct conifer forest habitat types, and to assess unique indicators for each.

This report is intended as a companion document to PRBO's Sierra Nevada Avian Monitoring Information Network website (http://data.prbo.org/apps/snamin) where data from this project are stored and can be accessed for analyses or download. By providing open-access, online data and analysis tools, our goal is to not only aid the USDA Forest Service in meeting their monitoring requirements but also inform staff and partners of these powerful tools that can help meet multiple objectives, including the effects of management across the entire Sierra bioregion. During our fifth year of monitoring, we plan to evaluate pressing management concerns such as fire and meadow habitat quality and examine how avian community responds to these ecological processes. We will present results to forest planning staff and continue participating in public meetings to clarify how monitoring programs such as this one are scientifically rigorous and provide multiple extended benefits other than trends in MIS target species, such as avian community response to fire history or restoration efforts in montane meadows.

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, 2008). 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 were chosen as the indicator for early and mid-seral conifer forest, Hairy Woodpeckers as the indicator for snags in unburned forest, Yellow Warblers 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.

Region 5 of the USDA Forest Service is currently implementing management plan revisions for each of its forests under new national Rules and Regulations [2012: 36 CFR 219] that entail modifications to existing monitoring programs. As per the Planning Rule (section § 219.12 Monitoring), each forest is responsible for developing a monitoring program in coordination with regional monitoring efforts. The targets of the monitoring program are to address: watershed, terrestrial, and aquatic conditions; status of focal species selected to indicate ecosystem integrity, ecosystem diversity, federally listed threatened or endangered species, and other species of conservation concern; measureable changes relating to climate change and other stressors; and progress toward meeting desired conditions and objectives. We feel the choice of focal species to indicate ecosystem integrity and diversity will be a particularly important measure to ensure that useful and scientifically sound data are available for assessing ecosystem responses to management and other stressors such as climate change. We now have baseline occurrence data from the past four years at the Sierra Nevada regional scale through the PRBO Bioregional MIS monitoring program that can be used to inform these responses to management and stressors. Birds are considered excellent indicators (Koskimies 1989) because they are highly conspicuous, have well known habitat associations, existing occurrence data is abundant, and fulfill many of the criteria typically used for selecting indicators (Pearson 1995).

The Land Management Planning Handbook (USDA Forest Service 2012) advises choosing focal species that are representative of broadly defined ecological health and integrity, to optimize the effort and cost involved in monitoring. One of the most proximate indicators of ecological health and integrity is biodiversity (Rapport et al. 1998). For many taxa it can be too difficult and expensive to monitor biodiversity, and thus it is necessary to find other indicators, ideally single species or small groups of species that are easy to monitor, and correlate their abundance and distribution with biodiversity through careful examination using a large baseline database.

However, in the final planning rule (USDA Forest Service 2012) focal species are defined as single species that when monitored provide "information regarding the effectiveness of the plan in providing the ecological conditions necessary to maintain the diversity of plant and animal communities and the persistence of native species in the plan area." The use of focal species as surrogates of ecosystem conditions has been criticized in conservation literature, but is generally supported as long as stringent conditions are met and it is well understood what aspect of biodiversity or ecosystem health is targeted (Duelli and Obrist 2003).

For example, Favreau et al. (2006) suggest that surrogate species should be thoroughly evaluated using data-rich systems and the monitoring metrics carefully selected and applied to long-term monitoring data. Still, there are few objective guidelines concerning the selection of indicators that will provide the greatest utility for monitoring biodiversity, though it seems clear that monitoring more taxa provides better representation (Grantham et al. 2010). Using single species as indicators risks associations with particular habitat components that may not be broad enough to describe the overall integrity of the habitat of interest, and also risks chance changes in population size or distribution due to factors extraneous to breeding-season habitat quality (e.g. wintering or migration habitat degradation). In some cases unique factors have a large influence on ecological integrity and thus the best indicators might be endemics (Trindade-Filho and Loyola 2011), however Chase and Geupel (2005) note that the best focal species may be common species whose populations are not in decline or found on conservation priority lists.

Ideal indicators are species for which occurrence is 1) easily measured, 2) sensitive to changes in their environments and 3) responsive to those changes in predictable ways (Dale and

Beyeler 2001). A list of potential indicators should be prioritized based both on conservation need and cost-effectiveness of management actions (Arponen 2012). Carignan and Villard (2002) conclude that indicators of ecological integrity can be useful if: many species are monitored; a sound quantitative database is employed to select indicators; and great care is applied to distinguish actual trends from variation that may be unrelated to ecological integrity.

Indicators of ecosystem integrity are difficult to establish with great certainty, and identifying relationships between species occurrence and ecosystem function can involve complex non-linear threshold effects across a multitude of ecosystem functions (Zavaleta et al. 2010). We feel that it is appropriate for monitoring programs to target as many focal species (or other indicators) as possible rather than just one or a few (e.g. Chase et al. 2000) in order to adequately represent the myriad ecosystem processes in forests (Anderson and Ferree 2010, Lindenmayer et al. 2000, Saetersdal and Gjerde 2011). The avian focal species identified by Partners in Flight should be considered in addition to other wildlife (fish, herpetofauna, mammals and invertebrates) as avian species are among the most cost-effective monitoring targets (Garson et al. 2002).

Our four years of field monitoring on this project has resulted in over 240,000 individual bird records of 192 species across approximately 3000 point count stations spread across 1.5 million hectares of National Forest land in the Sierra Nevada. This extensive regional database can be used as a baseline set of occurrence data for a large portion of the species we have identified, can be used to track population and distribution changes over time for these species, and provide an excellent source for evaluating potential focal species and other indicators of ecosystem integrity. The primary data access point is the Sierra Nevada Avian Monitoring Information Network (SNAMIN) website (http://data.prbo.org/apps/snamin/). SNAMIN allows users to quickly and easily generate summary, abundance, and species richness analyses for hundreds of point count transects across the Sierra Nevada bioregion for MIS species as well as all other species detected. Results can be generated at the scale of individual transects, ranger district, forest, 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.

In this report we describe the field efforts and data generated from our 2012 field season, the abundance, prevalence, and distribution of the four MIS that are targets of this monitoring project, and an initial evaluation of MIS and other habitat guild species associated with MIS target habitats as indicators of ecological integrity for those habitats.

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 2004). 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).

The sample consists of 230 upland and 50 riparian locations that were selected using a Generalized Random-Tesselation Stratified (GRTS) algorithm to generate a spatially balanced sample of species occurrences. We also selected 20 additional upland locations more than 1 km from roads to be representative of areas with minimal management, however these locations are not visited every year. At each of the upland locations we created 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 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.

Survey methods

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.

At the center point on upland transects we also performed a five-minute call-playback survey for Hairy Woodpeckers and Mountain Quail after conducting passive point count surveys at the outer points and directly following the fifth passive point count. Both 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 are available for sampling. Each season we return to 60-75% of the sites a second time to conduct repeat surveys. For a more detailed account of sample design and survey methods see Roberts et al. (2011).

Habitat assessments

At each point count location we conducted vegetation surveys within a 50 m radius of the plot center using a modified relevé protocol outlined in Stine et al. (2004). We measured shrub cover, live tree cover, and herbaceous cover as well as the relative cover of each species in the shrub and tree layers through ocular estimation. We also measured basal area of live trees using a 10-factor basal area tool and counted snags in three diameter at breast height (dbh) categories, using the two largest categories (30-60cm and >60cm) in models. We used the California Wildlife Habitat Relationships (CWHR) system to classify habitat to several forest, shrub, and riparian types (Mayer and Laudenslayer 1988).

Analyses

To assess patterns across the study area and between years, we calculated total number of MIS individual detections, abundance, prevalence (proportion of sites with at least one detection: “naïve occupancy”), and occupancy estimates. Detection counts can be misleading if used solely to assess abundance or prevalence. Each species varies in the distance at which observers can detect typical songs and other vocalizations 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, and therefore potentially a 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 various analyses to distances (typically 100 m) from the point count plot center. Using distance cut-offs makes it unlikely that we included double counts of the same individual on adjacent survey locations. We calculated an index of abundance for MIS and habitat guild species using the average number of individuals detected per point count station per visit per year using the “Explore Project Results” feature in SNAMIN. While this metric is not adjusted for imperfect detection (i.e., individuals present but not heard or seen) it can be a useful metric to compare species distribution.

We used occupancy models to assess changes in MIS population distribution over time and examine the factors influencing the patterns of occurrence for these species (Table 1). Occupancy models estimate the probability of occurrence while simultaneously accounting for errors in the detection process (MacKenzie et al. 2006). These models can account for unequal effort (e.g., transects with different numbers of visits) and variation in the detection process due to species behavior, singing volume and rates, and survey conditions (e.g. vegetation cover, weather, noise sources, and time of day). Occupancy methods incorporate the detection history over multiple visits to estimate detection probability. If detectability is not accounted for it is more likely that erroneous trends will be identified by monitoring programs which can have serious consequences including mis-management of habitats (Quinn et al. 2011).

Results were generated using standard single-season occupancy functions using the program R (R Development Core team 2011) with the package ‘unmarked’ (Fiske and Chandler 2011). Occupancy covariates included geographic variables such as elevation, latitude, and vegetation variables such as canopy cover, shrub cover, number of snags and basal area (Table 1). Detection covariates included weather variables such as wind and temperature in addition to day of year and time of survey. We used a stepwise covariate removal process to identify ‘best’ models by including all covariates listed above in the first model and ranked each model using Akaike’s Information Criterion (AIC; Burnham and Anderson 2002) selecting the model with the lowest AIC as the ‘best’ model. To generate a list of models we iteratively removed the parameter estimate with lowest significance ($P > |z|$) until the removal of a variable did not improve AIC and then ranked that set of models. We selected detection covariates first, without including any occupancy covariates, using the lowest AIC model and stepwise removal process, then included the set of detection variables from the lowest AIC model in a second process to select occupancy covariates

Table 1. Covariates included in MIS occupancy models. The global model set of covariates differed by MIS. Covariates with the same letter superscript were correlated (r > 0.4) and only the covariate with the lowest p-value was included in the global model.

Occupancy covariates		FOSP	MOUQ	HAWO	YEWA
Elev	Elevation in meters	X	X	X	X
Latitude	Latitude in decimal degrees	X	X	X	X
tree.cov[a]	% cover of canopy + subcanopy trees, all species	X		X	X
CA.conif	% cover of canopy conifer trees		X		
SUB.conif	% cover of subcanopy conifer trees		X		
tree.conif[a]	% cover of canopy + subcanopy conifers		X		
ba.avg[a]	Average basal area, 3 measurements of 10BAF tool, all trees within view	X	X	X	X
dbh.avg	Average dbh of dominant canopy trees		X		
snags	Total count of snags > 30 cm dbh and > 1.3 m in height			X	
shrub[b]	% cover of shrubs and trees < 3 m tall		X		X
real.shrub[b]	% cover of shrub species	X			
tree.shrub[b]	% cover of tree species < 3 m tall		X		
willow	% willow cover				X
alder	% alder cover				X
shrub.ht	Average height of shrub foliage	X	X		X
forb[c]	% cover of forb species		X		X
grass[c]	% cover of grass, sedge, or rush species		X		X
litter[c]	% cover of litter		X		X
Detection covariates					
noise	Scale 1-5 indicating ambient noise level	X	X	X	X
wind	Beaufort scale (0-5)	X	X	X	X
temp	Temperature in degrees C	X	X	X	X
cloud	Percent cloud cover	X	X	X	X
day	Day of year (julian day)	X	X	X	X
time	Time of survey (seconds)	X			X

The scale of occupancy analyses varied by species. We report occupancy estimates for Fox Sparrow and Yellow Warbler as point-scale values averaged over all transects (upland transects for Fox Sparrow; riparian transects for Yellow Warbler). We estimated occupancy at the transect scale for Hairy Woodpecker and Mountain Quail to incorporate the use of broadcast playback surveys and to create an occupancy estimate at a similar scale to their home range size (Mackenzie et al. 2006). Since Hairy Woodpecker is the indicator for snags in *green* forest, we excluded transects that were located within fire perimeters from the last 20 years (CAL FIRE 2010) to avoid including detections of birds within burned forest. Since 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. We included all detections within 100 m for Fox Sparrow and Yellow Warbler to avoid detecting the same individual on adjacent points which were separated by a minimum distance of 200 m. We included all detections within 160 m for Hairy Woodpecker and 260 m for Mountain Quail since multiple detections at adjacent points would not change the assessment of presence or absent at the transect scale. To assess trends in MIS population distributions we calculated a simple linear regression on occupancy estimates (without covariates) across the three years.

We identified a set of five additional habitat guild species associated with each habitat for which the MIS were chosen to indicate. We hypothesize that comparing trend estimates for MIS with those of other habitat guild species will aid interpretation of population changes that result from changes in important ecosystem components. In selecting these habitat guild species, we recognized that it was important to include common species whose populations are not already in decline to avoid potentially confusing variation (Chase and Geupel 2005). For example, many factors unrelated to forest management have the potential to affect occupancy or abundance for any species, and may be more likely to influence small populations or uncommon species. By examining trends in habitat guild species populations and comparing across the suite of species we can better evaluate whether management is likely to be driving the patterns, and provide a more complete evaluation of the individual habitat components that each species may be uniquely associated with. To compare the trends in populations of MIS with their associated habitat guild species we calculated density (average number of individuals recorded within 100 m, not including playback surveys) per point count visit and compared the results across species.

The habitat guild species we selected for early-mid seral conifer forest are Western Tanager (*Piranga ludoviciana*), Dark-eyed Junco (*Junco hyemalis*), Golden-crowned Kinglet (*Regulus satrapa*), Black-throated Gray Warbler (*Setophaga nigrescens*), and Chipping Sparrow (*Spizella passerine*). Chaparral habitat guild species are Dusky Flycatcher (*Empidonax oberholseri*), MacGillivray's Warbler (*Geothlypis tolmiei*), Mountain Quail, Yellow Warbler, and Green-tailed Towhee (*Pipilo chlorurus*). While Mountain Quail is a MIS for early-mid seral conifer, and Yellow Warbler for riparian habitat, they are both also known to use chaparral habitat. Snag habitat guild species are White-headed Woodpecker (*Picoides albolarvatus*), Mountain Chickadee (*Poecile gambeli*), Red-breasted Nuthatch (*Sitta Canadensis*), Olive-sided Flycatcher (*Contopus cooperi*), and Brown Creeper (*Certhia americana*). Riparian habitat guild species are Song Sparrow (*Melospiza melodia*), Wilson's Warbler (*Cardellina pusilla*), Warbling Vireo (*Vireo gilvus*), Black-headed Grosbeak (*Pheucticus melanocephalus*), and MacGillivray's Warbler.

To determine the efficacy of individual MIS and associated habitat guild species as indicators of ecological integrity of the four habitat components of interest, we compared their presence and abundance with that of all other habitat guild species. We hypothesize that the potential for MIS and associated habitat guild species to function as good indicators of habitat condition can be assessed based on the correlation between their point-scale abundance and the summed abundance and richness of the other species within the guild. To quantify these relationships, we calculated the Pearson correlation coefficient (R) between the average abundance for each habitat guild species across all visits to each point in 2010-2012 with: 1) average habitat guild species richness (excluding the habitat guild species that was the subject of the test), 2) average habitat guild species abundance (excluding the habitat guild species that was the subject of the test), 3) average richness of all species adequately detected with point count surveys (i.e. no raptors, ducks, or shorebirds), and 4) average abundance of all species. We did this only for points categorized as individual habitat types using our field vegetation survey data: all points classified as shrub types (N = 168 points) for chaparral MIS and habitat guild species; all points classified as conifer types with at least 50% tree (canopy + subcanopy) relative cover of conifer species and average diameter < 60cm (N = 886 points) for early-mid seral conifer MIS and habitat guild species; all riparian points regardless of vegetation (N = 414 points) for riparian MIS and habitat guild species; all unburned forest points (i.e. excluding shrub, nonforest, and riparian) regardless of vegetation composition (N = 1842) for snags in unburned forest MIS and habitat guild species. We then graphed the correlations and assumed that higher correlations indicate greater potential for use as an indicator of ecosystem function.

Results

Survey effort

In 2012 we surveyed 2708 point count stations on 562 transects (upland and riparian combined, Table 2). We only visited 2 of the 40 roadless transects and instead focused on increasing our repeat survey rate at the main body of upland transects. We conducted repeat surveys at 76% of transects for a total of 987 transect visits (compared to 876 in 2011 and 890 in 2010). The increase in total number of transect visits was achieved not because of increased crew size but because of better field conditions (e.g. good weather, reduced snowpack). We conducted two visits at all upland sites where only single visits had been performed in 2011 and randomly assigned visit status to the remaining upland sites to achieve the high revisit rate. We conducted two visits at a higher proportion of upland transects (80%) than riparian transects (56%) because detection probabilities of Yellow Warblers are high compared to the upland MIS species, thus the repeat visits are less necessary for establishing presence.

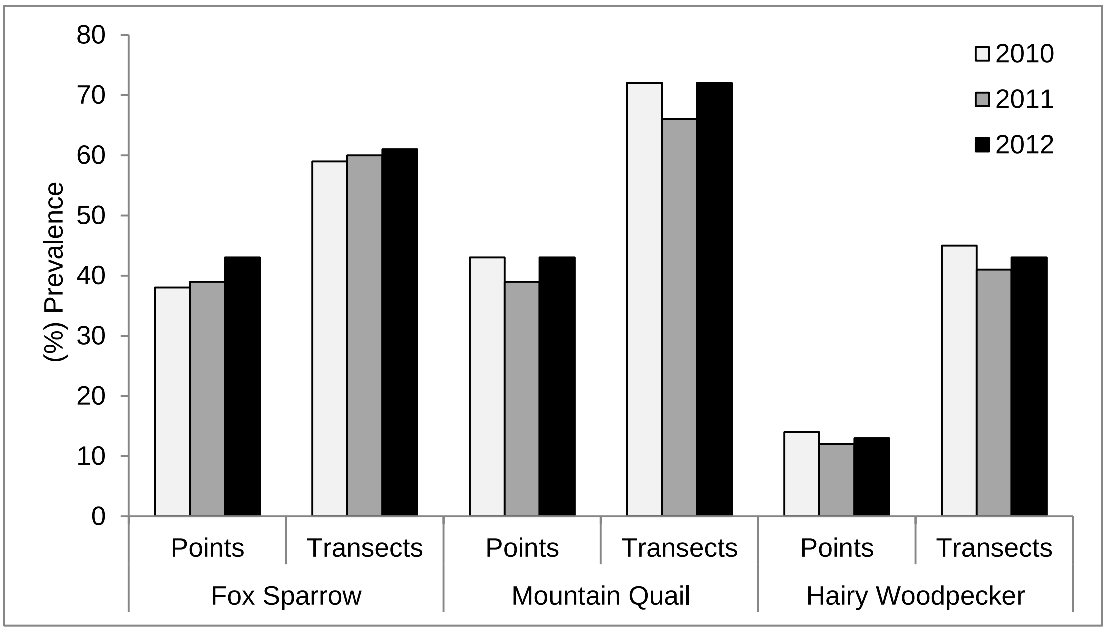
Table 2. Survey effort by year. The target upland sample includes 500 transects (40 of which are roadless transects, 2 roadless transects were visited in 2012). In 2009 we targeted 50 riparian transects and in 2010 and 2011 we increased the target number to 100.

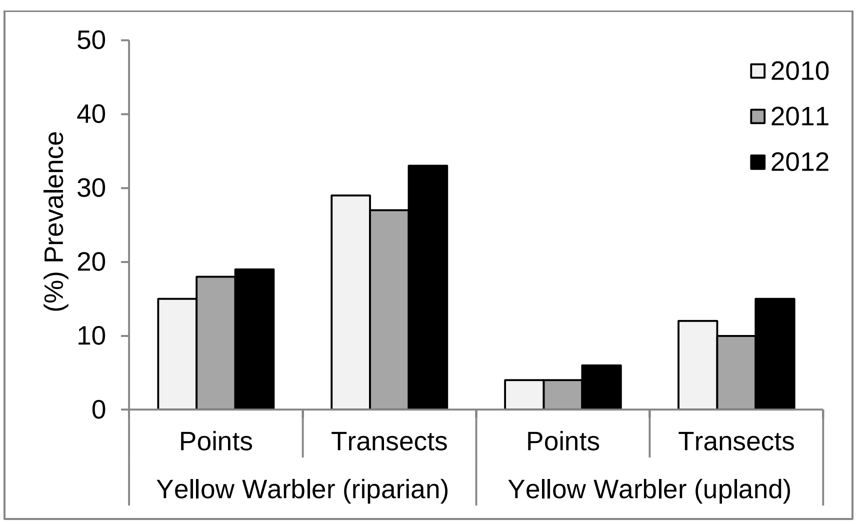
		2009	2010	2011	2012
Transects Visited	*upland*	415	464	472	462
	riparian	43	94	96	100
Second visits	*upland*	250	267	220	369
	riparian	16	65	88	56
Second visit rate	*upland*	60%	58%	47%	80%
	riparian	37%	69%	92%	56%

MIS prevalence and abundance

We compared prevalence (proportion of survey locations where each species was detected) of the four MIS between 2010 and 2012 for the entire study area (Figure 1) and only used detections from first visits to avoid bias between years from differing revisit rates. Mountain Quail and Hairy Woodpecker transect prevalence was lowest in 2011 indicating that both species may have responded negatively to the late snowpack and harsher weather conditions that year. Fox Sparrow prevalence at both the point and transect scale increased slightly each year. Yellow Warbler prevalence on riparian points was stable among years but prevalence on transects increased from 2010 to 2012. Fox Sparrow and Yellow Warbler detection probabilities are much higher than Hairy Woodpecker and Mountain Quail (see Results: *Occupancy Trends*), so it follows that the differences in prevalence among years would be less sensitive to the number of revisits.

Figure 1. Prevalence of MIS across targeted survey locations in 2010 - 2012. Prevalence is calculated as % of points and transects where each species was detected, not limited by distance, not corrected for detectability, and not including playback surveys. We included only first visit detections to control for varying second visit rates across years.





Abundance of MIS based on point count detections varied across forests (Figure 2). The three upland MIS have been detected on all forests. Yellow Warblers were detected on all forests when upland transects are included, but were not detected on riparian transects in Eldorado National Forest. Fox Sparrows and Mountain Quail were more abundant in the central and southern Sierra forests with the highest abundance on the Tahoe, Eldorado, Stanislaus and Sequoia. Hairy Woodpeckers and Mountain Quail had low abundance across all forests even though occupancy was high (see Results: *Occupancy Trends*). Yellow Warbler abundance was also variable, but highest on Lassen, Plumas, Tahoe and Inyo national forests.

Occupancy trends

Fox Sparrow point-scale occupancy ranged from a low of 0.43 in 2012 to a high of 0.48 in 2011 (Figure 3). Confidence intervals around occupancy estimates were small and probability of detection ranged from 0.60 – 0.75. Fox Sparrow declined slightly between 2010 and 2012, at a rate of 2% per year. Hairy Woodpecker and Mountain Quail, both resident species, show a similar pattern to each other in occupancy across the three years. The lowest estimate for both species was in 2011 and both rebounded to their highest occupancy in 2012. Trend estimates reveal a 5% per year increase for Hairy Woodpecker, and 3.5% per year increase for Mountain Quail. However, confidence intervals around occupancy estimates for both species largely overlap for all years. Transect level detection probability for Hairy Woodpecker ranged from 0.39 - 0.52 and for Mountain Quail 0.64 – 0.80. Yellow Warbler occupancy on riparian points shows a small but consistent increase across years. Estimates ranged from 0.24 in 2010 to 0.27 in 2012, indicating a 1.5% per-year increase. But confidence intervals also overlapped across all years. Detection probability for Yellow Warbler was high (range: 0.65 – 0.71). However, with only three years of data (excluding the 2009 pilot year because the number of survey sites was much smaller) we advise caution in interpreting any apparent long-term patterns.

Figure 2. Index of abundance of MIS by National Forest in the Sierra Nevada in 2012. Abundance was calculated as average number of detections <100 m per point count station. Playback surveys were not included. Only upland transects were used for Fox Sparrow, Mountain Quail, and Hairy Woodpecker. Only riparian transects were used for Yellow Warbler. Bars indicate 95% confidence intervals.

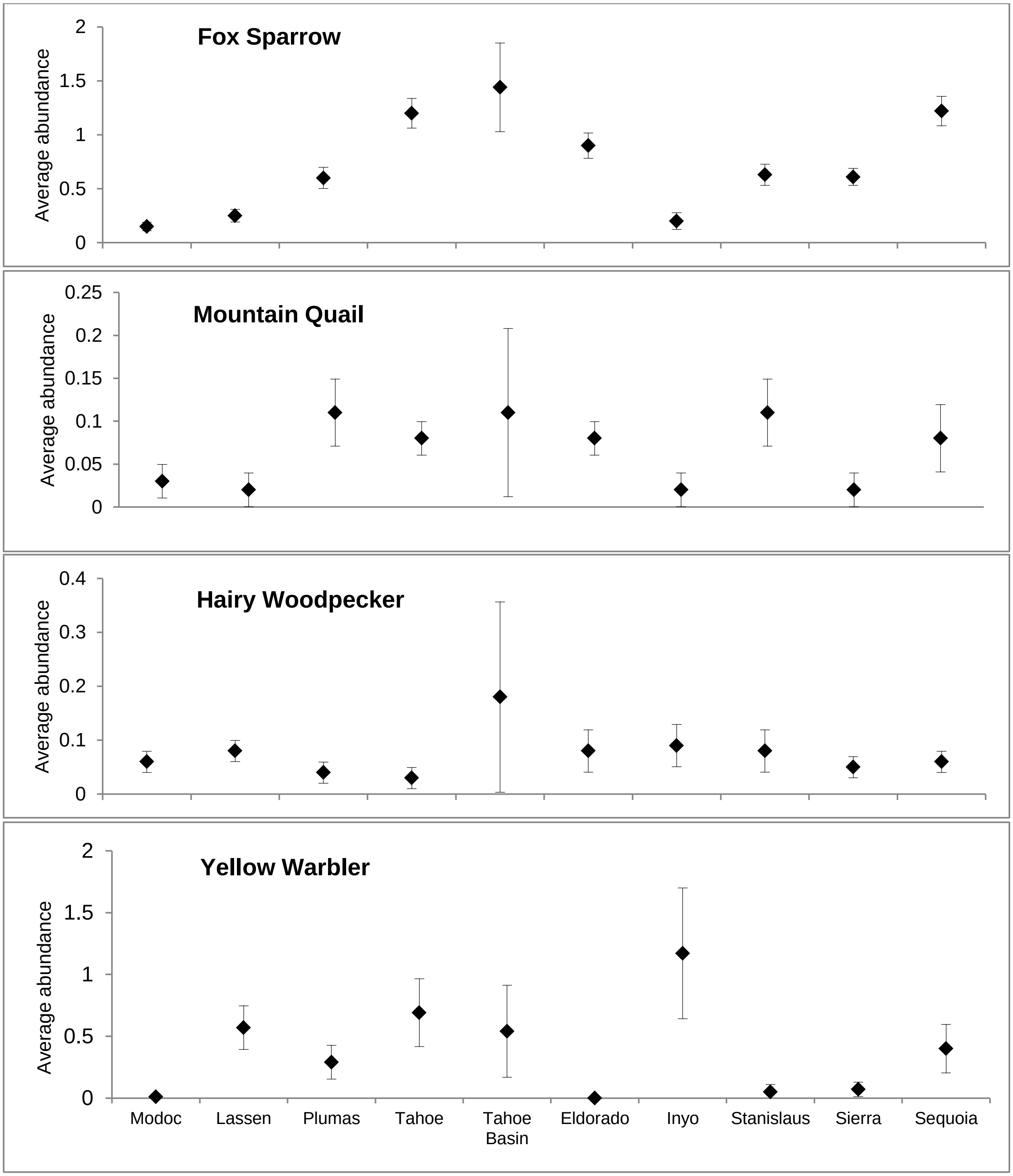
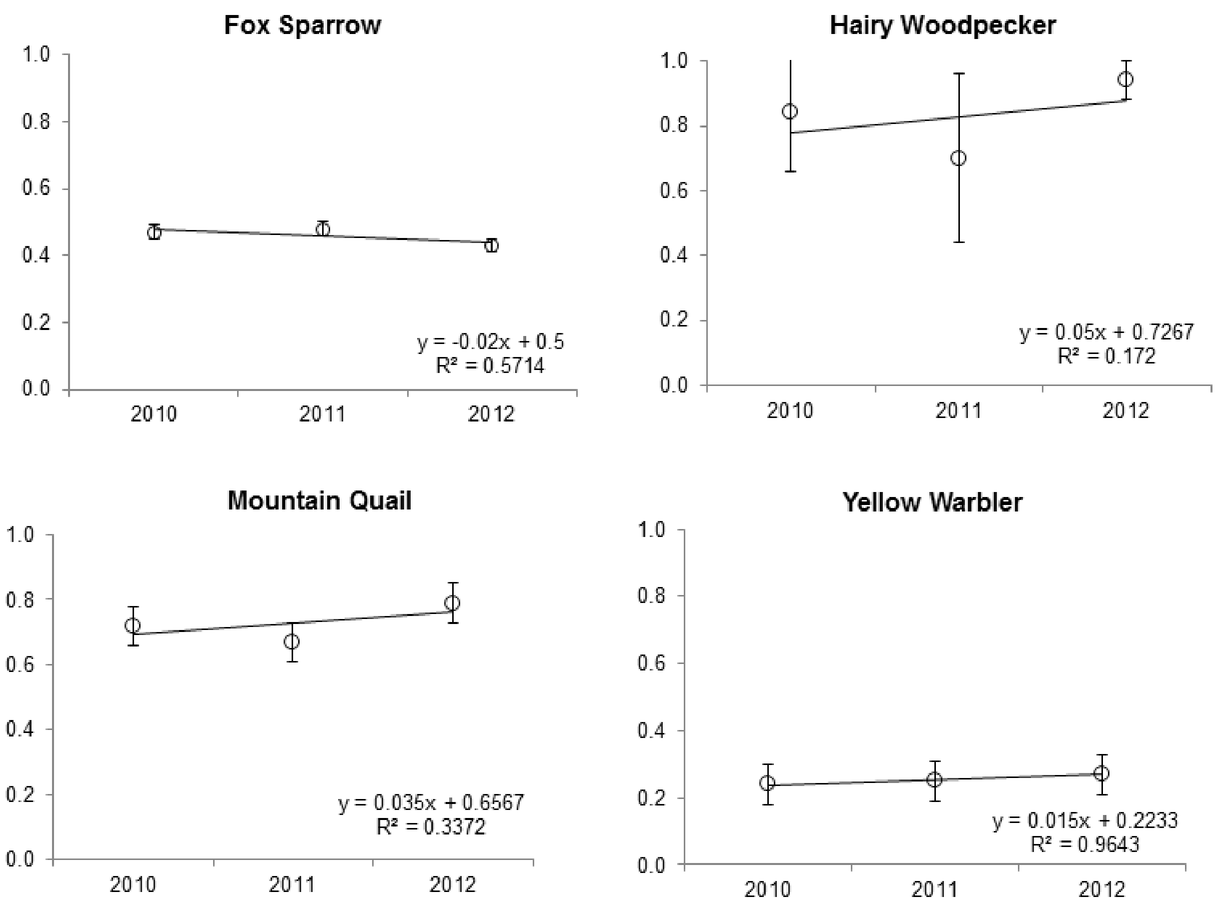


Figure 3. Annual occupancy estimates for MIS species 2010 – 2012 across the Sierra Nevada bioregional monitoring area. Fox Sparrow and Yellow Warbler occupancy are shown at the point scale, and Mountain Quail and Hairy Woodpecker at the transect scale. Hairy Woodpecker occupancy excludes transects in burned forest, Fox Sparrow and Mountain Quail estimates include all upland transects, and Yellow Warbler estimates include only the riparian transects. Occupancy estimates with 95% confidence intervals and a linear regression line and corresponding R^2 value are shown for assessing trends.



2012 Occupancy models and habitat associations

Fox Sparrow. As the indicator for chaparral habitat, Fox Sparrow occupancy models included real shrub cover (excluding all tree species occurring as saplings or seedlings in the shrub layer), in addition to average shrub height, tree cover, elevation and latitude (Table 1). Only shrub height was eliminated from the model with greatest support (lowest AIC, Table 3), but this model had small separation from the global model (ΔAIC = 0.14). We found a strong positive association with elevation and real shrub cover, and weak positive association with average shrub height and a strong negative association with latitude and tree cover (Table 4).

Detection covariates in the most supported model included noise level, percent cloud cover, and day of year, with some support for wind and temperature (ΔAIC = 1.65). Detectability was negatively associated with noise, percent cloud clover, temperature and time of survey, and positively associated with wind (weakly) and day of year (strongly).

Hairy Woodpecker. Global model occupancy covariates included snags per acre, basal area, elevation and latitude (Table 1). The model with greatest support (Table 3) included elevation and basal area, but other low AIC models included latitude (ΔAIC=0.23), or latitude and snags (ΔAIC=1.76). Occupancy was positively associated with all covariates but the strongest association was with basal area (Table 4). The beta coefficient for snags was comparable to those of elevation and basal area, but standard error on the snag coefficient was large indicating that the response was inconsistent. Detection covariates in the top model only included wind, but there was some support for models also including temperature (ΔAIC=0.86), and temperature and noise (ΔAIC=1.71). Detectability was negatively associated with wind, cloud cover, and temperature, and positively associated with noise and day of year though all the effects were fairly weak.

Mountain Quail. For Mountain Quail, the indicator for early and mid-seral forest, we included tree, shrub, and ground cover covariates, tree diameter, elevation, and latitude in transect-scale occupancy models (Table 1). For shrub cover, we initially examined three highly correlated variables: real shrub cover (only shrub species), tree shrub cover (trees < 5 m tall), and raw shrub cover (the sum of real shrub and tree shrub cover). Raw shrub cover had the lowest p-value in a preliminary occupancy model and was thus included in the global model while real shrub and tree shrub were not. For tree variables, we performed a similar test between the highly correlated variables basal area and tree conifer cover (the sum of canopy and subcanopy cover); average basal area had the lowest p-value in a preliminary occupancy model and was selected for the global model. The global model covariates included elevation, latitude, conifer canopy cover, conifer subcanopy cover, basal area, shrub cover, average shrub height, litter ground cover, and average diameter at breast height of canopy trees. The most supported model (Table 3) only eliminated basal area in comparison to the global model (ΔAIC=1.97). Occupancy was strongly positively associated with shrub cover and weakly with subcanopy conifer cover and average dbh. It was strongly negatively associated with elevation, latitude, average shrub height, and litter cover and weakly with conifer canopy cover (Table 4). The top model for detection covariates only included day of year, but another low AIC model also included temperature (ΔAIC=1.31). Detectability was negatively associated with day of year and weakly with noise, wind, and cloud cover, and weakly positively associated with temperature.

Yellow Warbler. Vegetation covariates in the Yellow Warbler riparian occupancy models included basal area, shrub cover, shrub height, willow and alder cover, in addition to elevation and latitude (Table 1). Basal area was correlated with both canopy and subcanopy cover, and selected based on preliminary models. Forb, grass (including sedges and rushes), and litter cover were correlated and grass cover was selected based on preliminary models. The global model consisted of elevation, latitude, basal area, shrub cover, average shrub height, willow cover, alder cover and grass cover. The model with most support (Table 3) included elevation, latitude, basal area and willow cover with some weaker support for grass cover (ΔAIC=1.48). We found a strong negative association with elevation, latitude and basal area and strong positive association with willow cover (Table 4). Detection covariates in the model with the most support were day of year and time of survey, and there was also considerable support for the model that also included wind (ΔAIC=0.51). The effect of day of year on detectability was strong and negative while effects of time of survey, wind, cloud cover, noise, and temperature were weak and positive.

Table 3. Stepwise occupancy model selection results for 2012 detections of MIS. Number of parameters (K), AIC and change in AIC value (ΔAIC) are shown. Model selection was completed on probability of detection first and then parameters from the top model were included in occupancy models. Variables are defined in Table 1.

Fox Sparrow	*K*	AIC	ΔAIC
Detection model selection			
psi(.) p(noise + cloud + day)	5	4416.07	0.00
psi(.) p(noise + temp + cloud + day)	6	4417.10	1.03
psi(.) p(noise + wind + temp + cloud + day)	7	4417.72	1.65
psi(.) p(noise + wind + temp + cloud + day + time)	8	4419.71	3.64
psi(.) p(.)	2	4475.47	59.40
Occupancy model selection			
psi(elev + lat + tree.cov + real.shrub) p(noise + cloud + day)	9	4035.96	0.00
psi(elev + lat + tree.cov + real.shrub + shrub.ht) p(noise+could+day)	10	4036.10	0.14
psi(elev + lat + real.shrub) p(noise + cloud + day)	8	4042.95	6.99
psi(.) p(noise + cloud + day)	5	4416.07	380.11
Hairy Woodpecker			
Detection model selection			
psi(.) p(wind)	3	962.83	0.00
psi(.) p(wind + temp)	4	963.68	0.86
psi(.) p(noise + wind + temp)	5	964.54	1.71
psi(.) p(noise + wind + cloud + temp)	6	966.09	3.26
psi(.) p(.)	2	966.87	4.04
psi(.) p(noise + wind + cloud + temp + day)	7	967.81	4.98
Occupancy model selection			
psi(elev + ba.avg) p(wind)	5	944.73	0.00
psi(elev + lat + ba.avg) p(wind)	6	944.97	0.23
psi(elev + lat + ba.avg + snags) p(wind	7	946.49	1.76
psi(.) p(wind)	3	962.83	18.10
Mountain Quail			
Detection model selection			
psi(.) p(day)	3	1102.01	0.00
psi(.) p(temp + day)	4	1103.32	1.31
psi(.) p(temp + cloud + day)	5	1105.14	3.13
psi(.) p(wind + temp + cloud + day)	6	1107.11	5.10
psi(.) p(noise + wind+ temp + cloud + day)	7	1109.10	7.09
psi(.) p(.)	2	1127.92	25.91
Occupancy model selection			
psi(elev + lat + ca.conif + sub.conif + shrub + shrub.ht + dbh.avg + litter) p(day)	11	1032.61	0.00
psi(elev + lat + ca.conif + sub.conif + shrub + shrub.ht + ba.avg + dbh.avg + litter) p(day)	12	1034.58	1.97
psi(elev + lat + ca.conif + sub.conif + shrub + shrub.ht + litter) p(day)	10	1040.35	7.74
psi(.) p(day)	3	1102.01	69.40

Table 3. Continued.

Yellow Warbler

Detection model selection			
psi(.) p(day + time)	4	518.85	0.00
psi(.) p(wind + day + time)	5	519.37	0.52
psi(.) p(day)	3	519.45	0.60
psi(.) p(noise + wind + day + time)	6	520.27	1.42
psi(.) p(noise + wind + cloud + day + time)	7	521.66	2.81
psi(.) p(noise + wind + temp + cloud + day + time)	8	523.53	4.68
psi(.) p(.)	2	531.72	12.87
Occupancy model selection			
psi(elev + lat + willow + ba.avg)	8	466.09	0.00
psi(elev + lat + willow + ba.avg + grass)	9	467.57	1.48
psi(elev + lat + shrub + willow + ba.avg + grass)	10	468.42	2.33
psi(elev + lat + shrub + alnus + willow + ba.avg + grass)	11	470.38	4.29
psi(elev + lat + shrub + alnus + willow + shrub.ht + ba.avg + grass)	12	472.38	6.29
psi(lat + willow + ba.avg)	7	472.43	6.34
psi(.)	4	518.85	52.76

Table 4. Standardized coefficient estimates, unconditional standard errors, and P-value derived from the 2012 global occupancy models for MIS. Bolded coefficient estimates were included in the final (lowest-AIC) occupancy model.

Fox Sparrow	β	SE	P(>|z|)	Hairy Woodpecker	β	SE	P(>|z|)
Occupancy (ψ)				Occupancy (ψ)			
Intercept	-0.12	0.09	0.22	Intercept	10.89	5.93	0.07
Elevation	**0.41**	0.10	<0.001	**Elevation**	**3.73**	2.20	0.09
Latitude	**-0.41**	0.09	<0.001	Latitude	1.27	0.84	0.13
Tree cover	**-0.18**	0.06	0.004	**Basal area**	**3.72**	1.97	0.06
Real shrub cover	**0.76**	0.09	<0.001	Snags	2.52	3.78	0.50
Shrub height	0.09	0.07	0.18				
Detection Probability (p)				Detection Probability (p)			
Intercept	0.71	0.12	<0.001	Intercept	-0.10	0.23	0.68
Noise	**-0.13**	0.10	0.16	Noise	0.19	0.18	0.28
Wind	0.07	0.06	0.24	**Wind**	**-0.17**	0.10	0.09
Temp	-0.07	0.07	0.40	Cloud	-0.05	0.09	0.56
Cloud	**-0.27**	0.06	<0.001	Temp	-0.11	0.09	0.21
Day	**0.58**	0.07	<0.001	Day	0.05	0.09	0.60
Time	-0.01	0.07	0.91				

Yellow Warbler	β	SE	P(>|z|)	Mountain Quail	β	SE	P(>|z|)
Occupancy (ψ)				Occupancy (ψ)			
Intercept	-1.03	0.33	0.00	**Intercept**	2.628	0.556	<0.001
Elevation	**-1.09**	0.65	0.10	**Elevation**	1.958	0.489	<0.001
Latitude	**-0.47**	0.25	0.06	**Latitude**	1.971	0.502	<0.001
Basal Area	**-0.47**	0.22	0.03	**%conifer (canopy)**	0.079	0.264	0.760
Shrub cover	0.24	0.23	0.29	**%conifer (subcanopy)**	0.350	0.562	0.530
Shrub height	0.01	0.15	0.94	**Shrub cover**	1.279	0.378	<0.001
Willow cover	**0.92**	0.29	0.00	**Shrub height**	0.490	0.247	0.047
Alder cover	-0.04	0.20	0.84	Basal area	0.054	0.307	0.86
Grass cover	0.21	0.21	0.31	**Diameter**	0.058	0.283	0.84
				Litter	0.751	0.303	0.013
Detection Probability (p)				Detection Probability (p)			
Intercept	-0.20	0.40	0.62	Intercept	0.54	0.20	0.01
Noise	0.27	0.21	0.21	Noise	-0.02	0.20	0.92
Wind	0.18	0.22	0.41	Wind	-0.02	0.10	0.85
Temp	0.09	0.26	0.72	Temp	0.07	0.09	0.41
Cloud	0.10	0.16	0.52	Cloud	-0.04	0.09	0.67
Day	-0.99	0.28	<0.001	**Day**	**-0.52**	0.10	<0.001
Time	0.30	0.25	0.23				

Comparisons of MIS and selected habitat guild species

Patterns in abundance from 2010 to 2012 also appear to be mostly stable for MIS and associated habitat guild species (Figure 4). The average chaparral habitat guild species abundance declined slightly across the three years of surveys (Figure 4a), likely driven by the two most abundant species (Fox Sparrow and Dusky Flycatcher). Fox Sparrow abundance was highest in 2011, but many of the other chaparral habitat guild species reached their lowest abundance in 2011, while Dusky Flycatcher appears to be declining across all years. Average conifer habitat guild species abundance increased slightly from 2010 to 2012 (Figure 4b), apparently driven by the dramatic increase in Dark-eyed Junco abundance. Black-throated Gray Warbler appears to be declining slightly, while Golden-crowned Kinglet increased in 2012 following a drop in 2011. The remaining conifer habitat guild species abundances appear to be quite stable across years. Snags in green forest habitat guild species abundances (Figure 4c) are apparently stable over this time period as well, with only a slight decrease in abundance from 2010 – 2011 for Mountain Chickadee, the most abundant of these species. Riparian habitat guild species abundances (Figure 4d) are consistently lowest in 2011 with the exception of Wilson's Warbler which increased each year.

Figure 4. Average point-scale abundance in 2010 – 2012 for MIS and other habitat guild species for each habitat component. MIS are bolded in figure legends. Abundance is calculated as number of individuals detected within 100m per visit, not including playback surveys.

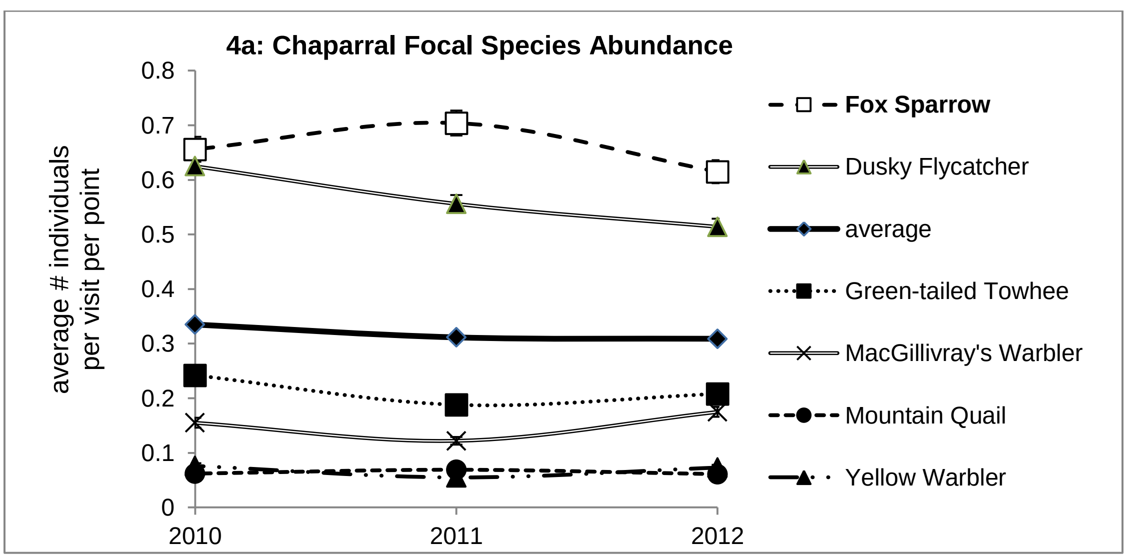
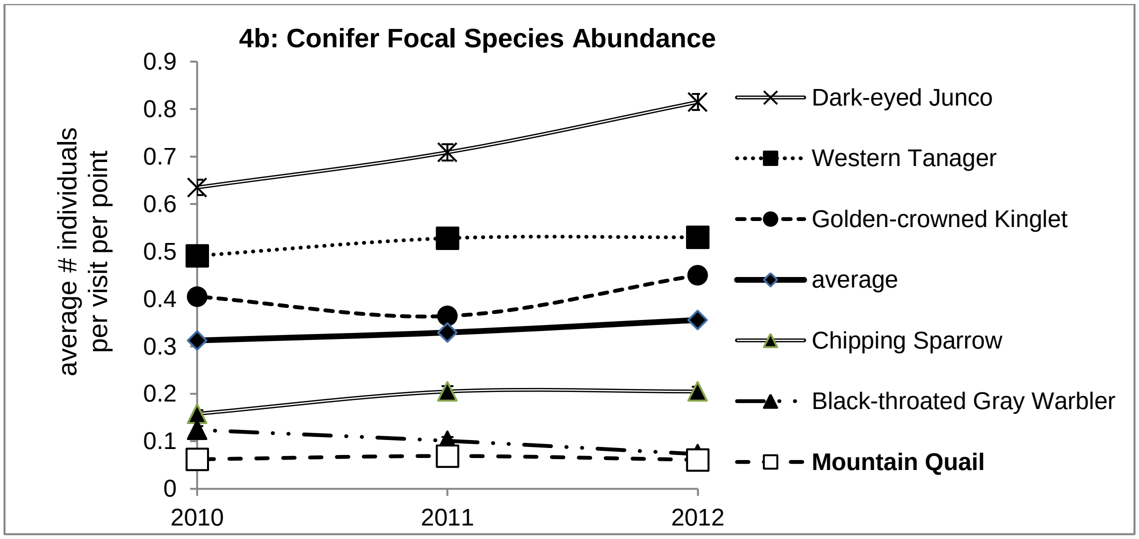
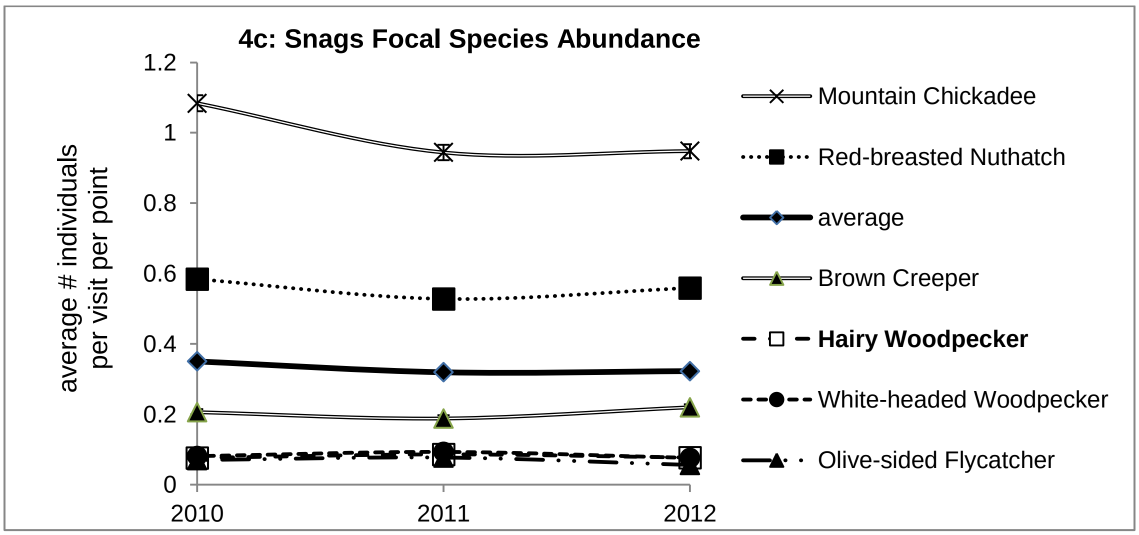
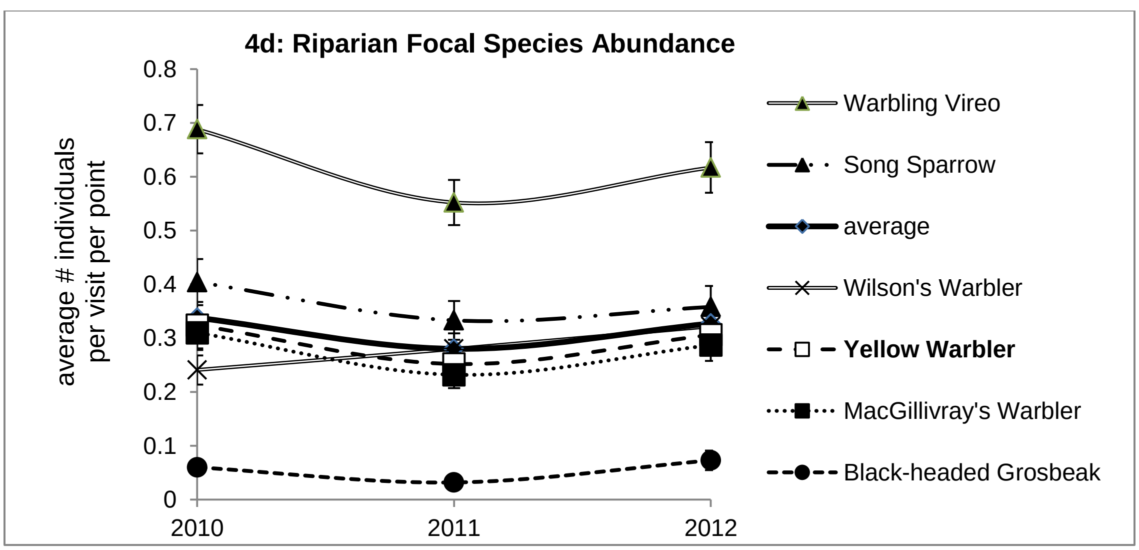


Figure 4, cont'd.







There is a wide range of correlation strengths between the MIS and habitat guild species richness and abundance metrics (Figure 5a-d). For nearly every species, the metric that correlated highest with individual habitat guild species abundance was habitat guild species richness, supporting the idea that the presence of individual habitat guild species has the potential to indicate the presence of other species associated with the same habitats. Habitat guild species richness showed a higher correlation in every case than all species richness. The highest correlations between habitat guild species abundance and habitat guild species richness were for the habitat guild species groups in habitats that are ecologically more distinct, namely riparian and chaparral, and lower for the more broadly-defined early-mid seral conifer and snags in green forest habitat guild groups. In contrast to the relatively high correlations for habitat guild species richness, summed habitat guild species abundance correlations were much lower. For two of the habitat types, chaparral and riparian, correlation between individual habitat guild species abundance and summed habitat guild species abundance approached that of habitat guild species richness, but for snags in green forest, the correlation with habitat guild species abundance was very low, and for early-mid seral conifer species it was near zero or even negative.

The chosen MIS each appear to be among the most highly correlated with habitat guild species richness. Mountain Quail was highest among the early-mid seral conifer habitat guild species with correlation at 0.32 (compared to several of the other habitat guild species at approximately 0.23). Hairy Woodpecker at 0.40 is second only to White-headed Woodpecker at 0.49 among the snags in green forest habitat guild species. All of the chaparral habitat guild species were correlated highly, with Mountain Quail lowest at 0.38 and Fox Sparrow highest at 0.71. And similarly, all the riparian habitat guild species with the exception of Black-headed Grosbeak were highly correlated with habitat guild species richness; Yellow Warbler, Song Sparrow, Wilson’s Warbler, and Warbling Vireo correlations were all greater than 0.55.

Figure 5. Correlations between habitat guild species abundance and richness metrics. Metrics were corrected to per point count visit to account for variable revisit rates. A few slightly negative correlations are not shown. Only points classified as habitat types of interest are included in the correlations, and sample sizes within each habitat are listed in figure subheadings. MIS are listed in the furthest left columns.

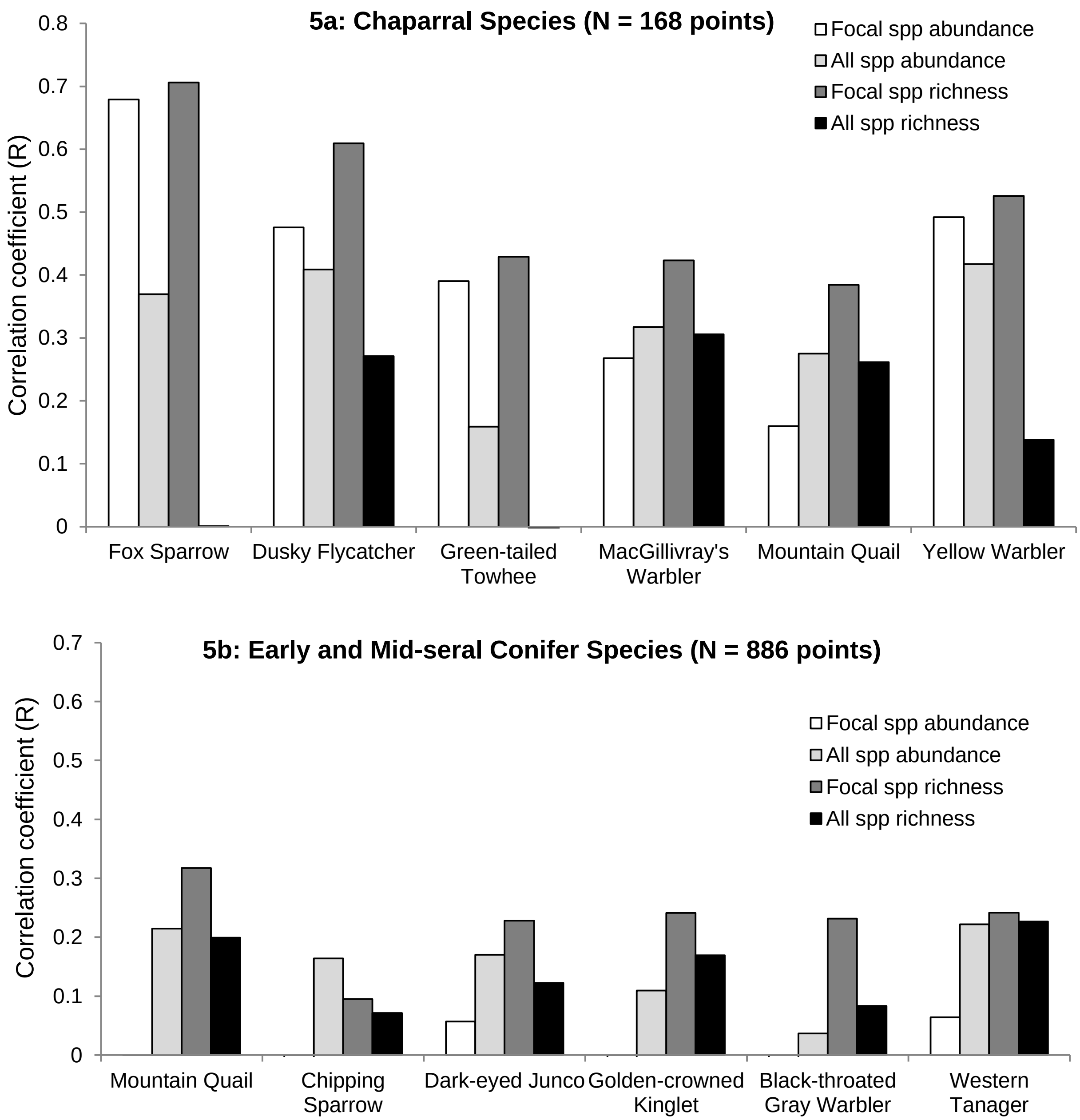
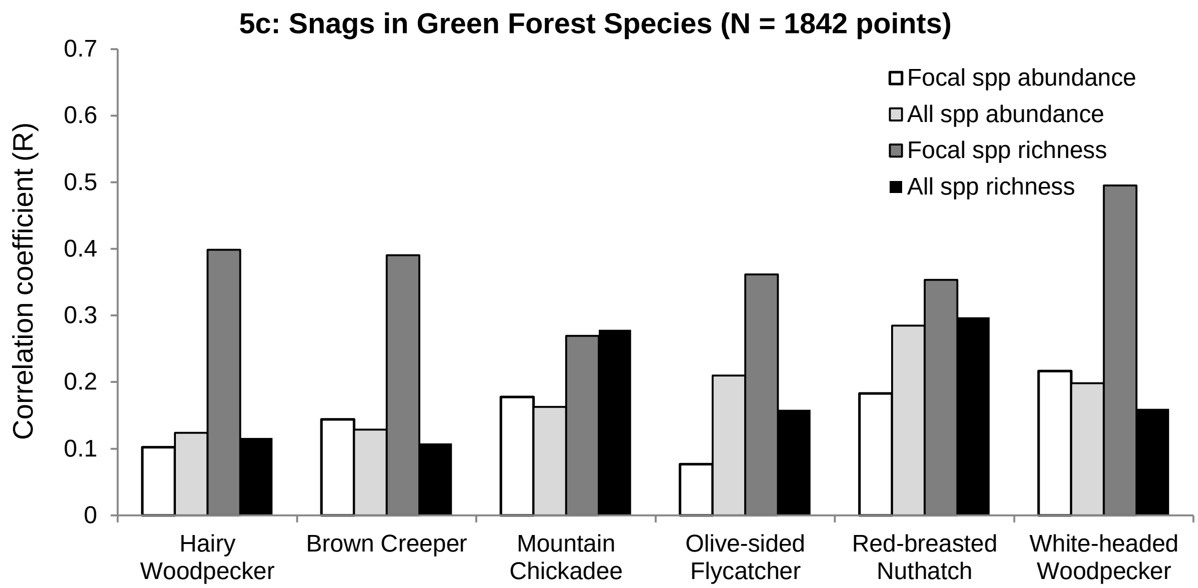
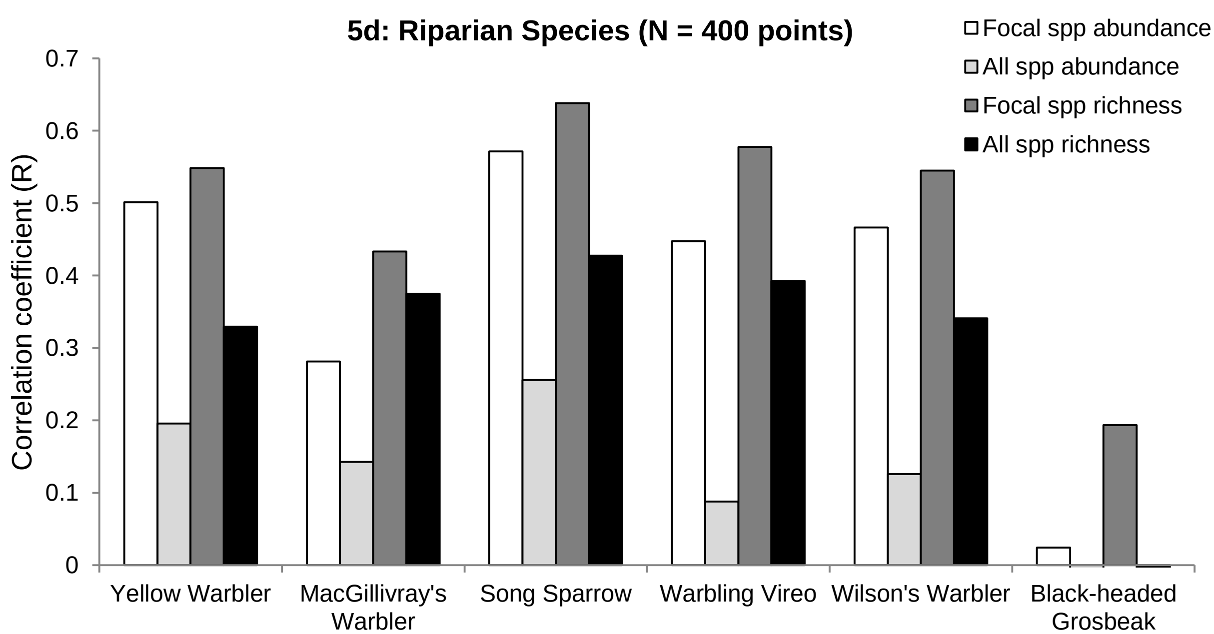


Figure 5, cont'd.





Discussion

Field activities

Our field operations continue to improve in efficiency, and 2012 represents both our largest number of field surveys completed and the highest revisit rate to field sites. This project has benefited each year from more experienced field crew personnel and especially from continuing and consistent oversight by field crew supervisors that have been employed by the project for a minimum of three field seasons. We have completed vegetation surveys at the vast majority of field sites and for the 2013 field season we will transition into concentrating on improving the accuracy of our vegetation database and documenting changes in vegetation composition and structure at our field sites. We will also assess the 20 transects that fall outside of our road stratification (>1 km) and evaluate whether it is a representative sample of the unmanaged roadless and wilderness areas within US Forest Service jurisdiction.

Trend assessments

With only three years of survey data available (not including the 2009 pilot season), we do not have enough data to draw any confident interpretation of population trends for the MIS but abundance and distribution measures indicate generally stable population sizes and distribution. With an additional 3-5 years of data, we will be able to assess trends for the four MIS (and a suite of other relatively abundant species) with suitable power to draw inferences on management activities that might be influencing these populations (Purcell et al. 2005). While there are no obvious directional trends in occupancy for MIS, there does appear to be considerable annual variation. Both Hairy Woodpecker and Mountain Quail occupancy dropped in 2011, potentially due to weather conditions which included heavy winter snowfall and cool spring temperatures. However, this pattern is not evident in the regional abundance measures for these species suggesting that individuals may have temporarily displaced over short distances from certain areas, for example higher to lower elevations.

Distribution and habitat associations: Mountain Quail

Mountain Quail were broadly distributed across both shrub and conifer habitats, preferring sites with high subcanopy conifer cover to those with high canopy cover, supporting an association with young conifer forest. But because Mountain Quail also occupied shrub habitats within our sample and they have such large territory sizes they may respond unpredictably to the amount and distribution of early to mid-seral conifer habitat conditions. They also were detected more frequently at low elevations and southern latitude, and their abundance per point was variable across the forests.

Compared to other early-mid seral conifer habitat guild species, Mountain Quail had the highest correlation with habitat guild species richness. However, the magnitude of Mountain Quail correlations with habitat guild species richness and abundance was small compared to other MIS with their selected habitat guild species. In fact, for each metric Mountain Quail had a stronger correlation with chaparral species than early to mid seral conifer habitat guild species. Due to its stronger association with shrub dominated habitats and weak correlations with other early to mid-seral conifer habitat guild species we conclude Mountain Quail may not be a good indicator of the broad range of habitat types and conditions represented in early to mid-seral conifer forest. Indeed, since none of the species we have selected revealed high correlations ($R > 0.5$) with habitat guild species metrics, it may be that this habitat type is too broadly defined to represent a distinct ecological community. Since we did not separate conifer habitat types but rather only used tree size and conifer tree cover criteria to define the set of points included in this analysis, it is likely that this sample consists of too wide a variety of habitats (e.g. pine, fir, mixed conifer, and east vs. west of the crest differences). Thus using a suite of species that represent the large variety of these habitat types to develop a composite indicator metric would be preferred. Or if a single species based indicator is necessary, a better approach to identifying and monitoring ecosystem integrity of conifer forest would be to define more distinct habitat types and assess unique indicators for each.

Distribution and habitat associations: Hairy Woodpecker

Hairy Woodpecker occupancy was highest at higher elevations and forested sites with high basal area, but overall occupancy estimates were very high, approaching 1.0 in 2010 and 2012. Despite the high occupancy estimates, abundance was relatively low across all forests though there were no obvious patterns of lower abundance in any particular geography. Because snag density was not a strong predictor of Hairy Woodpecker occupancy, we recommend examining whether other snag habitat guild species may prove to be a stronger indicator of snags in green forest. However, at least two factors may explain why our measures of snags may fail to accurately represent the presence of snags at our sampling locations: 1) dying trees that still had green leaves but were infested by beetle larvae (or other food sources for woodpeckers) may not be counted using our field methods, which focused on completely dead trees; 2) the 50 m radius vegetation survey plot may not have adequately characterized snag densities at an appropriate spatial scale relative to the large home range size of many woodpeckers; or, 3) our snag variable, which does not include snags smaller than 30cm, ignores the smaller snags that may be important to Hairy Woodpeckers.

Other snags in green forest habitat guild species revealed similar patterns and magnitude of correlations with those of Hairy Woodpecker. White-headed Woodpecker showed the highest correlation with habitat guild species richness and abundance, and appears to be worthy of consideration as an indicator of snags in green forest. However, a metric combining multiple species that utilize different features and processes involved in snag ecology (e.g. primary excavators, secondary cavity nesters, and species that use different decay classes) would be prudent. Through our vegetation surveys we will be able to track changes in snag densities across the bioregion to help inform the management of this important wildlife resource.

Distribution and habitat associations: Fox Sparrow

Fox Sparrow occupancy was highest on points at higher elevations and southern latitudes with high shrub and low tree cover. Although Fox Sparrow habitat preferences align very well with its role as a chaparral management indicator species, it may not be representative of chaparral at lower elevations. Our data show that Fox Sparrows are uncommon from elevations below 1400 m (4500 ft), especially in the central and southern Sierra Nevada (Roberts et al. 2012). Average abundance was lowest on Modoc, Lassen, and Inyo National Forests where montane chaparral habitat is less common. The inclusion of real shrub cover (% cover of small woody vegetation not including saplings of tree species) in the habitat association model and its high strength in relation to other covariates supports Fox Sparrow as an appropriate MIS for Sierra Nevada west-slope chaparral habitat, but the elevation range restrictions may limit its utility as an indicator for chaparral habitat at lowest elevations.

The correlations among chaparral habitat guild species overall were much higher than either early to mid-seral conifer forest species or green forest snag species. Correlations with habitat guild species abundance were nearly as high as with habitat guild species richness. These data support the continued consideration of Fox Sparrow as an indicator of chaparral habitat distribution and ecosystem integrity, although the elevation restrictions should be taken into consideration and a composite metric of multiple habitat guild species that spans a larger elevation range may still be preferable.

Distribution and habitat associations: Yellow Warbler

At riparian points, Yellow Warbler occupancy was higher at low elevation, southern latitudes, low basal area, and high willow cover. Point-scale occupancy was low indicating the majority of riparian areas we sampled were not suitable habitat for this species. This may result largely because most of our riparian locations do not contain willows. While not all of these sites have the potential to support willows, we believe many of them once did. Over-grazing, widespread willow abatement efforts, fire suppression, and loss of floodplain connectivity have denuded Yellow Warbler habitat over the past century in the Sierra Nevada. Yellow Warbler abundance per point was variable across forests, but we suspect this is due largely to sampling effects of the particular stream channels chosen for sampling. For example on Eldorado National Forest, we did not detect any Yellow Warblers, but most of our riparian transects by chance occur at high elevation or contain a large amount of mountain alder (*Alnus incana*) where other species such as Wilson's Warbler were more common. Yellow Warbler appear to be somewhat specialized on willow riparian habitats rather than in the broader range of mixed-vegetation riparian habitats. This highlights the need to consider a suite of riparian and meadow habitat guild species to guide management, as we and others have employed in effectiveness monitoring throughout the Sierra Nevada (Loffland et al. 2011, Campos and Burnett 2012).

Similar to chaparral habitat guild species, there was a general pattern of high correlation among the riparian habitat guild species for all the metrics except all species richness. In light of these data, Yellow Warbler appears to be a good choice as an indicator, but we suggest only for a specific type of riparian habitat containing willow species. Again, using a suite of species that represent multiple distinct riparian habitat types and differences associated with elevation and other landscape attributes to fully inform riparian habitat management across the region would be preferred.

General considerations for selecting Sierra Nevada habitat guild species

The use of indicator species in forest management is inherently limited by a number of factors. Chief among these is that single or small suites of species will inevitably ignore some portion of the ecological complexity within the area under management (Dale and Beyeler 2001).

The challenge in selecting useful indicators then is to carefully evaluate the mechanism that correlates the change in abundance and distribution of a species with changes in the ecosystem component for which that species is intended to indicate. Ecosystems are intrinsically complex, and as a result these mechanisms should be thoroughly evaluated and understood prior to the selection and application of indicator species approaches to management. Multiple species indicators, therefore, are more likely to elucidate the effects of management because more mechanisms within the complex ecological systems will be reflected by changes in indicator species abundance, richness, and distribution.

These four MIS targeted in this monitoring program may not be the ideal choices for all of the forests in the Sierra Nevada, specifically those on which they are uncommon. In particular, Modoc, Lassen, and Inyo have relatively low abundance for more than one of these MIS and therefore the monitoring targets may not adequately represent the integrity of those habitats. Alternatively, the reason why an MIS is uncommon on any individual forest may be because there are relatively few acres of the habitat for which they are indicators.

Correlation analysis is a rudimentary first step towards evaluating indicators, but our data indicate that Fox Sparrow and Yellow Warbler have the potential to reflect major changes in distribution of their selected habitats. Since the correlations between abundance of individual species was nearly always most highly correlated with habitat guild species richness, and if tracking changes in species richness represents similar changes in ecological integrity, then monitoring the presence and abundance of these species across a representative set of survey locations should be a reasonable metric to reflect ecosystem function. The reason for relatively low correlations in conifer and snags habitat guild species may be a result of the wide variety of habitats included in those habitat types (e.g. fir, Sierra mixed conifer, pine, and east vs. west side of the Sierra crest differences for conifer habitats, and including hardwood and other forest types for snags). Selecting more appropriate indicators to replace these MIS will necessitate at least one of two strategies: 1) choose a composite index of multiple species that each are sensitive to particular portions of these habitat types; or 2) define more distinct habitat targets, each with a different indicator species or suite of species - for example by separating conifer into more distinct groups including yellow pine, true fir, mixed, and east-west conifer types.

Through the use of multi-species point counts we are able to gather occurrence data for a broad range of species, including the MIS and associated habitat guild species. The utility of this dataset to inform a broad range of forest management questions at the bioregional scale will continue to grow with additional years of data collection. Long term data is especially important for evaluating indicators (Favreau et al. 2006) and we hope that this project continues to be funded into the future so that this important baseline database can be used to monitor multiple indicators of ecosystem integrity into the future and provide data for the adaptive management of Sierra Nevada National Forests.

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Appendix 1. Presentations, outreach activities and publications

Presentations completed:
Fogg AM. June 2, 2012 International Migratory Bird Day, South Lake Tahoe, CA.

Fogg AM. June 17, 2012. Mono Lake Chautaqua bird festival, Lee Vining, CA.

Fogg AM. June 22, 2012. Long Fire field trip with Eldorado National Forest staff.

Fogg AM, Roberts LJ, Burnett RD. October 17, 2012. Black-backed Woodpecker occupancy and habitat associations in unburned forest of the Sierra Nevada, California. 2012 Wildlife Society Conference, Portland, OR.

Roberts LJ, Burnett RD, Fogg AM. February 21, 2013. Poster: Using Birds to Guide Climate Smart Conservation in the Sierra Nevada. Southern Sierra Nevada Change Adaptation Workshop. Visalia, CA.

Publications:
Fogg AM, Roberts LJ, Burnett RD (in review). Occurrence Patterns of Black-backed Woodpeckers in Green Forest of the Sierra Nevada Mountains, California, U.S.A. Avian Conservation and Ecology.

Fogg AM, Roberts LJ, Burnett RD (in review). Playback field survey methods increase detectability of avian species and improve confidence in occupancy estimates. Journal of Field Ornithology.

Appendix 2: Detections of Species of Conservation Concern

The PRBO Sierra Nevada bioregional MIS monitoring program is also valuable for generating detections of a wide variety of avian species, many of which are listed on state, federal, and international conservation concern lists. Appendix 2 lists the number of detections over all four years of surveys (2009-2012) for species identified as species of conservation concern lists by California, USDA Forest Service, American Bird Conservancy, or Nature Serve. Some of these species are not consistently identified using our field survey methods (e.g. raptors, shorebirds, and water birds) and thus would not be appropriate targets for analyses such as trend estimation or habitat distribution models. But many of the passerine, hummingbird, and woodpecker species are adequately detected using the field methods in this project and thus our data could be used to generate trend information for these species with reasonable confidence.

Table A1. List of bird species and number of detections (excluding playback surveys) from PRBO MIS survey sites between 2009 and 2012. Status is shown according to governmental and conservation organizations. There are no currently listed federally endangered or threatened bird species in the Sierra Nevada bioregion.

	Number of detections				Status					
Common Name	2009	2010	2011	2012	SE or ST or SC[1]	USFS R5 FSS[2]	CA BSSC[3]	CDFW Watch List[4]	USFWS BCC BCR 15[5]	Nature Serve[6]
Greater Sandhill Crane	15	62	73	83	ST	X				G5 S2
Peregrine Falcon	0	0	0	1					X	G4 S2
Prairie Falcon	1	1	0	0				X		G5 S3
Swainson's Hawk	0	0	0	0	ST	X				G5 S2
Northern Goshawk	3	14	7	12		X	X	X		G5 S3
Cooper's Hawk	7	4	5	14				X		G5 S3
Sharp-shinned Hawk	4	8	1	1				X		G5 S3
Bald Eagle	2	1	0	5	SE	X			X	G5 S2
Osprey	6	4	14	15				X		G5 S3
Northern Harrier	4	1	1	5			X			G5 S3
California Gull	0	65	15	4						G5 S2
California Spotted Owl	0	1	0	1		X	X	X	X	G3 S3
Great Gray Owl	0	0	0	0	SE	X				G5 S1
Long-eared Owl	0	0	1	0			X			G5 S3
Flammulated Owl	0	0	0	0					X	G4 S2S4
Black Swift	0	0	0	0			X		X	G4 S2
Vaux's Swift	2	1	1	13			X			G5 S3
Calliope Hummingbird	38	45	63	67					X	G5 SNR
Rufous Hummingbird	22	9	30	16						G5 S1S2
Lewis' Woodpecker	16	15	6	13					X	G4 SNR
Black-backed Woodpecker	6	17	45	59	SC					G5 SNR
Williamson's Sapsucker	68	132	158	310					X	G5 SNR
Olive-sided Flycatcher	482	715	693	874			X		X	G4 S4
Willow Flycatcher	7	10	19	19	SE	X			X	G5 S1S2
Yellow Warbler	149	440	416	509			X			G5 SNR
Yellow-headed Blackbird	2	13	8	19			X			G5 S3S4
Cassin's Finch	246	624	1187	1120					X	G5 SNR

[1]SE = CA state endangered, ST = CA state threatened, SC = CA state candidate for threatened or endangered

[2]US Forest Service Pacific Southwest Region 5 Forest Sensitive Species

[3]CA Bird Species of Special Concern http://www.dfg.ca.gov/wildlife/nongame/ssc/birds.html

[4]CA Department of Fish and Wildlife Watch List (http://www.dfg.ca.gov/biogeodata/cnddb/pdfs/SPAnimals.pdf)
[5]USFWS Birds of Conservation Concern (http://www.fws.gov/migratorybirds/NewReportsPublications/SpecialTopics/BCC2008/BCC2008.pdf)
[6]Nature Serve classifications (http://www.natureserve.org/explorer/index.htm); G = global scale 1-5; S = state of CA scale 1-5; NR=not ranked