



Bird-Habitat Associations at Five National Park Units in Southern Oregon and Northern California

Natural Resource Technical Report NPS/KLMN/NRTR—2013/793



Golden-crowned Kinglet
12/22/06, Denman Wildlife Area Ore.
Photo by James Livaudais

ON THE COVER

Golden-crowned Kinglet

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Abstract

As part of the Inventory and Monitoring Program of the National Park Service, the Klamath Network and Klamath Bird Observatory established a protocol to monitor long-term trends in landbird populations at National Park units in southern Oregon and northern California. This report uses data from the first sequence of surveys to examine bird-habitat associations at the five larger park units in the network: Crater Lake National Park, Lassen Volcanic National Park, Lava Beds National Monument, Redwood National and State Parks, and Whiskeytown National Recreation Area. These parks include a diversity of ecosystems from high elevation coniferous forest to shrub-steppe, temperate rainforest, chaparral, and oak woodlands. At each park 25–35 sites were established using a stratified random approach that consisted of 3 designated sampling frames. Breeding season point counts were conducted at each park from 2008–2010, along with collection of vegetation data. For this analysis we estimated breeding density of 39 bird species (8–16 species per park) in Program DISTANCE. We used a model selection approach to compare the influence of different habitat features on bird density at each park, including topography, vegetation structure, and floristics. For species occurring at several parks, we examined similarity of associations across parks. Densities of individual bird species were related to a range of factors including elevation and habitat features important for foraging and nest sites. For example, across parks Mountain Chickadees (*Poecile gambeli*) were less abundant at high elevation subalpine sites, Brown Creepers (*Certhia americana*) were associated with snags which are used for both nesting and foraging, and Wilson’s Warblers (*Cardellina pusilla*) were associated with shrub cover in riparian areas. Several bird species showed strong floristic preferences, and were found in specific plant communities within the park. For example Black-throated Gray Warblers (*Setophaga nigrescens*) were associated with canyon live oak (*Quercus chrysolepis*) at Whiskeytown National Recreation Area. Results support information on bird-habitat associations in the region and are presented in the context of park management and Partner’s in Flight conservation objectives.

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Introduction

The mission of the National Park Service (NPS) is to preserve natural resources unimpaired for future generations. In an effort to ensure this mission is met, the NPS developed the Inventory and Monitoring (I&M) Program. As part of this program, national park units (parks) containing significant natural resources were organized into 32 networks for environmental inventory and monitoring. The distribution, abundance, and dynamics of landbird communities were recognized during this inventory program, when preliminary work was completed to assess landbirds in most parks. The Networks were also tasked with monitoring vital signs (key elements of the park ecosystem) to help provide scientific information to park managers about the resources they manage.

In 2002, the Klamath Network (KLMN), working with park resources staff and outside experts, implemented an elaborate process for selecting the 10 vital signs that the Network is currently monitoring which are described in Odion et al. (2005). The goal of the KLMN was to select a suite of vital signs that could be examined in concert with each other to provide accurate, ecologically meaningful, and defensible estimates of park ecosystem integrity (Sarr et al. 2007). As part of this selection process, bird communities were ranked number four in importance because populations and compositions of bird communities can be easily monitored and can be related to changing environmental conditions.

Beginning in 2008, the KLMN and Klamath Bird Observatory (KBO) established a long-term monitoring protocol to examine status and trends of landbird populations at six national park units in southern Oregon and northern California (Stephens et al. 2010a, b). The landbird monitoring program was designed to contribute to the vital signs monitoring program of the KLMN (Sarr et al. 2007), and meet objectives for both the NPS as a whole (Fancy and Sauer 2000), as well as regional and national bird monitoring goals identified by Partners in Flight (PIF) (Altman 1999, 2000, CalPIF 2002a, b, 2004, Rich et al. 2004, CalPIF 2005). The Network encompasses a diverse area centered on the Klamath-Siskiyou and Cascades-Modoc regions, and includes a broad range of topography, elevation, and corresponding climate and vegetation. The region is recognized for its rich biodiversity, including a diverse avifauna (Trail et al. 1997, DellaSala et al. 1999).

The Network in southern Oregon and northern California includes six national park units, which cover a broad range of ecosystems. Two parks, Crater Lake National Park (CRLA) and Lassen Volcanic National Park (LAVO), are characterized by high elevation coniferous forests of the Cascade Range with elevations up to 3,000 m. At slightly lower elevation on the dry Modoc Plateau, Lava Beds National Monument (LBE) is dominated by open shrub-steppe sagebrush. Near sea level, temperate maritime forest at Redwood National and State Parks (RNSP) supports areas of old-growth coastal redwoods (*Sequoia sempervirens*). Whiskeytown National Recreation Area (WHIS) includes mixed conifer forest, oak woodland and chaparral centered on Whiskeytown Lake. Because of a limited number of sites (n=4) at Oregon Caves National Monument (ORCA), only the five larger parks in the Network have been included in this report.

Relationships between bird abundance and habitat may help to explain long-term bird population trends, as well as aid in development of park management and conservation strategies. Although

habitat associations often vary regionally (e.g., Wiens et al. 1987, Field and Haworth 1995), identifying key habitat features for bird species, as well as species with narrow habitat requirements within the parks that makeup the KLMN, may provide insight into future population trends as they relate to changes in vegetation structure, surrounding land cover, and regional climate. The KLMN identified understanding the relationship between bird abundance and habitat characteristics as a key component of the long-term monitoring plan (Stephens et al. 2010a). Park specific habitat associations provide a better understanding of how birds can serve as indicators of ecosystems characteristics. In addition to assessing bird population trends, the long-term monitoring will provide insight into changes in vegetation structure and composition over time. Surveys at each park are planned every three years on a rotating basis, and the first sequence of bird surveys was completed in 2010. The objectives of this KLMN analysis and synthesis report are to relate bird abundance within each park to specific habitat features. We used a model selection approach to compare the relative importance of three habitat components (topography, vegetation structure, and floristics) to explain density of individual bird species at each park. These results will be informative to park managers who are faced with addressing diverse management challenges.

Methods

Study Sites and Sampling Design

We are using standard bird monitoring techniques to sample breeding birds within the parks. A brief description of the site selection process and sampling design are described below, a detailed description can be found in the KLMN Landbird Monitoring Protocol (Stephens et al. 2010a).

Sampling Frame

At each of the five parks included in this analysis, 25–35 sites were established using a stratified random sampling design based on 3 designated sampling frames (Stephens 2010b). Sampling frames were selected based on a variety of criteria including focal species, logistical, safety, statistical, and funding constraints, as well as co-location with sites associated with other KLMN monitoring protocols. To facilitate access and allow increased sampling, sampling frames were identified within 100–1,000 m of roads and trails, with the exception of WHIS. At WHIS the sampling frame was limited to roads, trails, and power lines for safety reasons. At all parks, areas with steep slopes (>30 degrees), talus slopes, and lava flows were excluded because of safety concerns, as well as to avoid damage to understory vegetation (Stephens et al. 2010b). At the majority of parks, the sampling frame included a matrix of available habitat types that excluded high elevation and riparian areas. A second sampling frame specific to high elevation was also sampled at CRLA, but excluded from this analysis because of limited sample size. At LAVO, sites were located in a riparian sampling frame with linear routes established along streams and wetlands.

Site Locations

The Generalized Random Tessellation Stratified (GRTS) method (Stevens and Olsen 2004) was used to develop spatially balanced sampling locations of sites within each sampling frame. These GRTS points were used to co-locate monitoring for landbirds, vegetation, and aquatic monitoring protocols. Point count sites included a series of 12 point count stations established as closely as possible around the GRTS point using a systematic approach. Mobility and time constraints limited the number of point count stations which could be surveyed in a morning at RNSP, so sampling sites were comprised of 4–9 points at this park. Stations were placed 250 m apart, which minimizes the likelihood of double counting birds (Scott et al. 1981). Generally, sites sample approximately 30 hectares with 3–23% of the sampling frame surveyed at each park (Table 1).

Table 1. Sampling frame and sites at each park included in this analysis. Sites continue to be surveyed every three years as part of the Klamath Network Landbird Monitoring Protocol.

Park	Code	Sampling Frame	Frame Area (ha)	Sites	Stations
Crater Lake National Park	CRLA	matrix	28,261	31	372
Lassen Volcanic National Park	LAVO	riparian	3,368	25	300
Lava Beds National Monument	LABE	matrix	10,831	25	300
Redwood National and State Parks	RNSP	matrix	32,284	30	193
Whiskeytown National Recreation Area	WHIS	matrix	6,269	30	360

Bird Surveys

For each park, one survey was conducted at a total of 1,618 points at 149 sites during the first sequence of visits. Two parks were surveyed in 2008 (RNSP and LABE), one in 2009 (WHIS),

and two in 2010 (CRLA and LAVO). Using standard protocols (Stephens 2010a), point count stations were sampled during the breeding season (early May through July) following the variable circular plot methodology that incorporates distance sampling (Reynolds et al. 1980, Fancy 1997, Nelson and Fancy 1999). Each park was surveyed by two experienced observers trained on bird identification and distance estimation. Counts were conducted within the first 4 hours after sunrise, and surveys were not conducted during inclement weather. All birds seen or heard during a 5-minute count period were identified to species. Distance to the nearest meter and type of detection (e.g. song, call, visual) were recorded, as well as any evidence of breeding.

Vegetation Surveys

Vegetation at each point count station was assessed using the Relevé method (Ralph et al. 1993), which allows efficient estimation of vegetation composition and structure over a wide range of habitat types. Vegetation was described using ocular estimates within a 50 m radius (Stephens et al. 2010a). Overall cover in different vegetation layers, as well as cover of individual plant species, was scored into several cover classes (<5%, 5–25%, 25–50%, 50–75%, and >75% cover); the midpoint of each cover class was used for analysis. Vegetation layers were defined as tree, shrub, and ground cover for analysis (maximum cover of any sub-layers); ground cover included both herbaceous and woody vegetation. For cover of individual tree species we used maximum cover in the tree layer, and for shrub species we used maximum cover in the shrub layer. Snags were counted by size classes within a 50 m radius, and we used snags ≥ 15 cm dbh for this analysis. Slope, elevation, and aspect were obtained from 10 m digital elevation models (DEM) using ArcGIS; data were interpolated for each point. Aspect was transformed to a xeric to mesic scale (0–2) for analysis using Beer's equation (Beers 1966).

Data Analysis

Density Estimates

Program DISTANCE 6.0 was used to estimate landbird densities (Thompson et al. 2010). This method allows examination of detection probability based on distance from the observer, and adjusts counts to the effective area surveyed (Buckland et al. 2001, Buckland et al. 2004). Comprehensive analysis of detection showed that overall density estimates for all detection types, or song alone were highly correlated, although detection of songs and calls may differ (Stephens et al. 2013). However, examination of boxplots showed extreme outliers in density distributions for a number of species, which can complicate regression-type analyses such as bird-habitat associations (Zuur et al. 2010). Generally for breeding landbirds, the metric of interest is territories/ha (e.g. spot-mapping). During the breeding season, males predominantly defend a territory while females focus on raising young. For many species, males have a loud distinctive song, while both males and females vocalize using calls. Thus, combining songs and calls can be problematic given that male song represents a territory, but two individuals can vocalize within the territory.

For this analysis, we used an approach based on species-specific biology (Newell and Rodewald *In Press*). For species predominantly detected by song, we used detections by song to represent territories per hectare. For other territorial species predominantly detected by calling or visual cues, density estimates were divided by two to represent territories per hectare (we pooled a few visual cues with calls, because of more similar detection). If sufficient birds were detected (> 60 detections by detection type), we analyzed both songs and calls/visual detections separately, and

added densities for analysis. For non-territorial flocking species, we used all detections to estimate number of individuals/ha. A species-specific approach may prove useful for future trend analyses with increased number of detections. Although some outliers remained, this approach generally improved density distributions.

For this multi-species habitat-association analysis, we used the same detection function in Program DISTANCE for each species. Data were truncated at 5% to minimize the effect of outliers, and we used a hazard-rate cosine model as the most robust to issues such as observer avoidance, heaping, or other violations of assumptions (Stephens et al. 2013, Buckland et al. 2001, Alldredge 2008). With limited detections by species across parks in this first analysis, we erred on the side of caution and used separate detection functions by park when possible and because of potential differences in vegetation structure among parks. However, preliminary examination suggested strong differences in the detection function for songs and calls, but limited differences among parks (Stephens et al. 2013). To include additional species we pooled detection functions across parks for species with a mix of detection types (i.e. there were not enough detections in a given park). Pooling of the detection functions across parks should be examined further after additional data collection. Since the majority of detections are vocalizations, type and loudness may be more important than vegetation structure. We used multiple covariates distance sampling (MCDS) with observer as a covariate, because variation among observers appeared to be an important factor influencing detection probability (Stephens et al. 2013, Buckland et al. 2004). For this analysis we doubled distances at CRLA for one observer who appeared to be consistently underestimating distances. This issue may need to be considered in future population trend estimates for the park. Density was estimated for each point and for each park.

Model Selection

For the bird-habitat association analysis, we used an information theoretic approach (Burnham and Anderson 2002) to examine a set of topographic, structural, and floristic models to explain bird species density at each park. Akaike's information criterion adjusted for small sample size (AIC_c) was used to rank models. Models with $\Delta AIC < 10$ were considered to have some support, and models $\Delta AIC < 2$ were considered to be equivalent (Burnham and Anderson 2002). For each park we selected a set of topographic and structural variables to include in our models (Table 2). The same set of topographic variables (elevation, slope, and aspect) and vegetation structure (snags, tree, shrub and ground cover) were used at all parks (snags were excluded from the analysis at LABE because of limited numbers). We selected dominant plant species at each park that occurred at more than 20% of plots (Table 2); plant species with limited variation in cover were dropped from the analysis. Boxplots were examined for normality and homogeneity of variance, and we examined Spearman rank-order correlation coefficients among variables at each park; with a sample size of 30 or less, relationships based on rank scores may be more robust to outliers. Because of issues with collinearity among habitat variables, our analysis was restricted to univariate models to examine the relative importance of different habitat features to explain bird density.

Bird density may be spatially autocorrelated within 500–1,000 m (Lichstein et al. 2002). Examination of Moran's I showed significant spatial autocorrelation at all the parks, generally within 1 km (Figure 1). Although several approaches may be used to analyze correlated data such as mixed models (Dormann et al. 2007), debate remains over inference from model

selection (Vaida et al. 2005, Greven 2008) and examination of leverage is not always available. The KLMN study design and number of sites at each park allowed a more standard statistical approach, and we averaged bird density and habitat variables by site to examine habitat associations. We used the same approach at all parks, although this may be less appropriate for lines of points (LAVO and WHIS). We used linear regression with habitat as the independent variable and bird density (either territories/ha or number of individuals/ha) as the dependent variable. We used Cook's Distance to examine leverage (Fox 2008), and removed outliers that were unduly influencing associations. Outliers may have resulted from several factors including: 1) detection issues such as observer or weather (sites were surveyed on one day by the same observer) or 2) habitat differences (one site may have sampled habitat atypical for the park). Normality and heterogeneity in density data tended to be issues for less abundant bird species. Data transformations generally failed to solve the problem (Zuur et al. 2010), and regression results for less abundant species should be considered with caution.

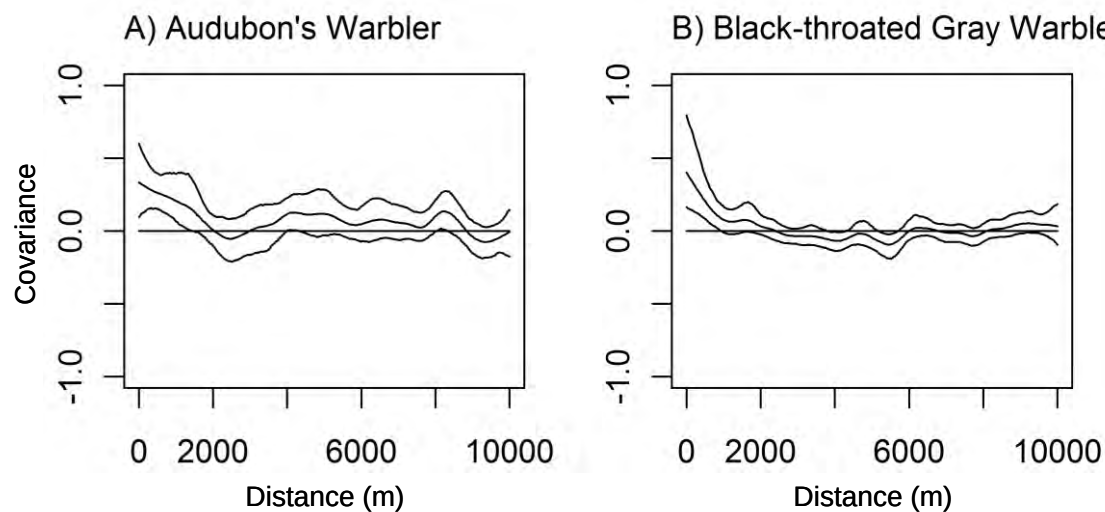


Figure 1. Examples of spatial autocorrelation in bird density for Audubon' Warblers at Crater Lake National Park (A) and Black-throated Gray Warblers at Whiskeytown National Recreation Area (B).

Table 2. Candidate models at each park included the same seven variables for topography and vegetation structure. At each park we included additional floristic models which represented common plant species at the park (occurring at >20% of points). We only ran univariate models because of issues with collinearity among variables.

Model		Code
Topography		
	Elevation (m)	ELEVATION
	Slope (degrees)	SLOPE
	Beer's aspect (0–2 scale)	ASPECT
Vegetation structure		
	Canopy cover (% cover class)	TRCOV
	Shrub cover (% cover class)	SHCOV
	Ground cover (% cover class)	GRCOV
	Snags in 50 m radius	SNAGS
Floristics (% cover class)		
CRLA	Lodgepole Pine (<i>Pinus contorta</i>)	PICO
	Mountain Hemlock (<i>Tsuga mertensiana</i>)	TSME
	Shasta Red Fir (<i>Abies magnifica</i> var. <i>shastensis</i>)	ABMA
LAVO	Lodgepole Pine (<i>Pinus contorta</i>)	PICO
	Shasta Red Fir (<i>Abies magnifica</i> var. <i>shastensis</i>)	ABMA
	Western White Pine (<i>Pinus monticola</i>)	PIMO
RNSP	California Huckleberry (<i>Vaccinium ovatum</i>)	VAOV
	California Rose-Bay (<i>Rhododendron macrophyllum</i>)	RHMA
	Coastal Redwood (<i>Sequoia sempervirens</i>)	SESE
	Douglas-fir (<i>Pseudotsuga menziesii</i>)	PSME
	Salal (<i>Gaultheria shallon</i>)	GASH
	Tanbark Oak (<i>Lithocarpus densiflora</i>)	LIDE
	Western Hemlock (<i>Tsuga heterophylla</i>)	TSHE
	California Black Oak (<i>Quercus kelloggii</i>)	QUKE
	Canyon Live Oak (<i>Quercus chrysolepis</i>)	QUCH
WHIS	Douglas-fir (<i>Pseudotsuga menziesii</i>)	PSME
	Knobcone Pine (<i>Pinus attenuata</i>)	PIAT
	Poison Oak (<i>Toxicodendron diversiloba</i>)	TODI
	Ponderosa or Yellow Pine (<i>Pinus ponderosa</i>)	PIPO
	Toyon (<i>Heteromeles arbutifolia</i>)	HEAR
	Whiteleaf Manzanita (<i>Arctostaphylos viscida</i>)	ARVI
	Whitethorn (<i>Ceanothus incanus</i>)	CEIN
LABE	Big Sage (<i>Artemisia tridentata</i>)	ARTR
	Bitterbrush (<i>Purshia tridentata</i>)	PUTR
	Rabbit-brush Spp (<i>Chrysothamnus</i> spp.)	CHRY
	Sierra Juniper (<i>Juniperus occidentalis</i>)	JUOC

Results

Habitat

Sampling at each park surveyed a range of elevation (Figure 2) and vegetation cover (Figure 3). Sites at WHIS surveyed the widest range of elevation with several sites located in higher elevation mixed conifer forest. At RNSP stations sampled a high proportion of closed canopy forest, whereas canopy cover was limited at LABE. Only a few stations sampled areas with dense shrub cover at the two parks with high elevation coniferous forest, CRLA and LAVO, and ground cover was highest at LABE. At each park the majority of stations were located in 3–4 vegetation types (Table 3).

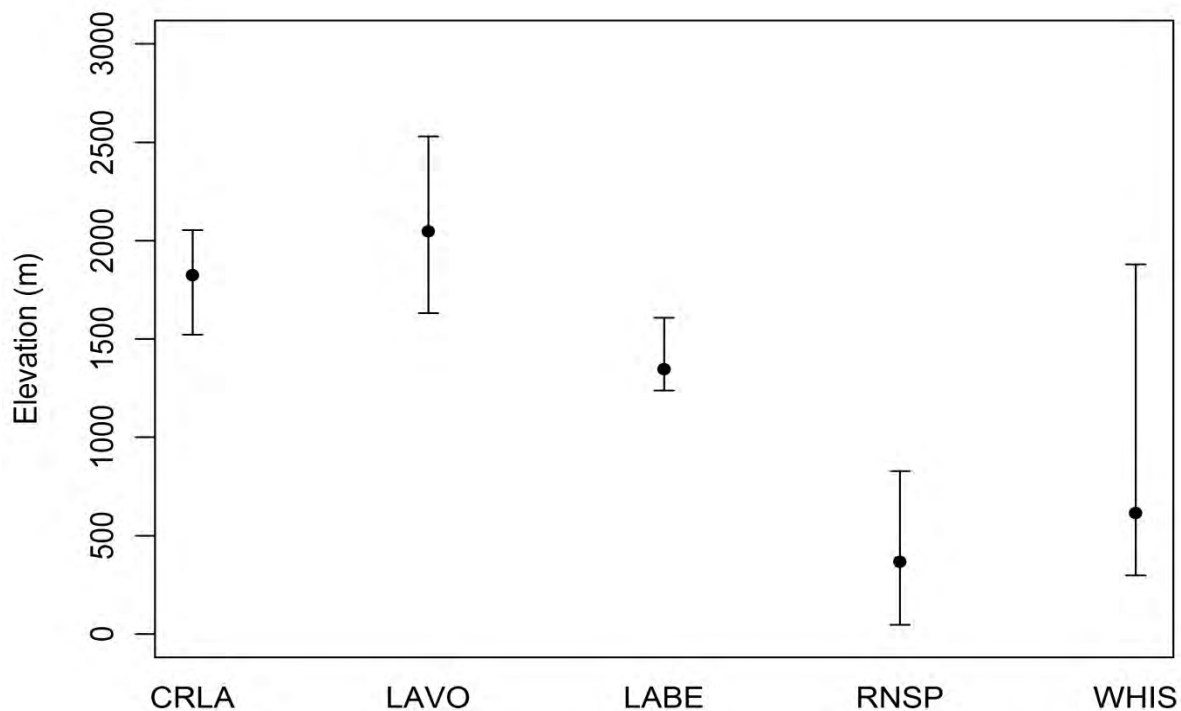


Figure 2. National park units in the Klamath Network include a broad range of elevation. Bars indicate minimum and maximum elevation sampled at each park.

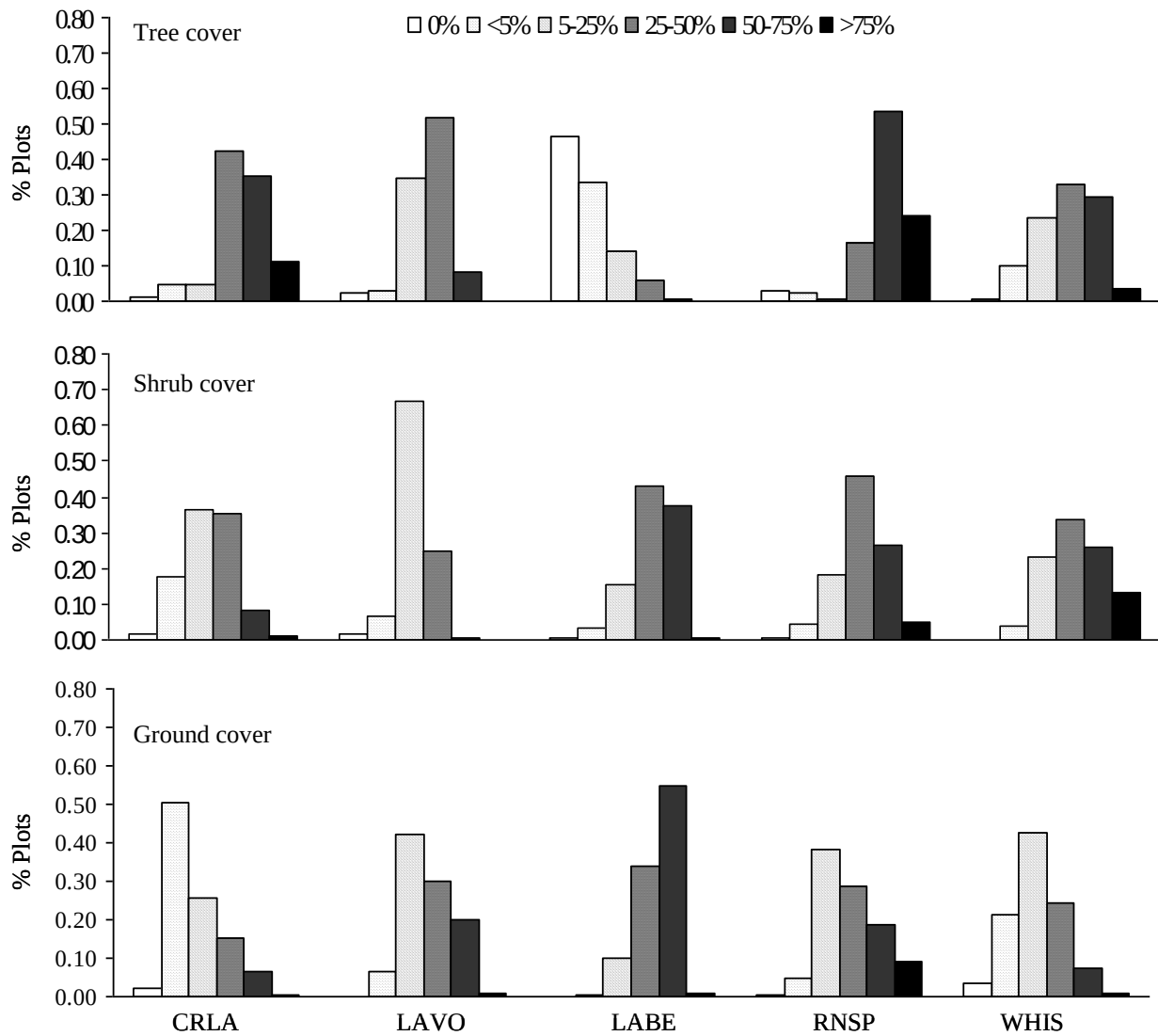


Figure 3. Long-term avian monitoring sites survey a range of vegetation cover at national park units in the Klamath Network.

Table 3. GAP landcover vegetation types sampled at long-term avian monitoring sites in the Klamath Network. Categories presented in which >20 stations were surveyed.

GAP Landcover Level 3 Categories	Sites¹	Stations
Crater Lake National Park		
North Pacific Mountain Hemlock Forest	19	121
Northern California Mesic Subalpine Woodland	23	104
Mediterranean California Red Fir Forest	6	44
Rocky Mountain Poor-Site Lodgepole Pine Forest	12	26
Lassen Volcanic National Park		
Mediterranean California Red Fir Forest	20	102
Mediterranean California Foothill and Lower Montane Riparian Woodland	16	86
Mediterranean California Mesic Mixed Conifer Forest	16	54
Redwood National and State Parks		
California Coastal Redwood Forest	23	95
Mediterranean California Mixed Evergreen Forest	18	45
Mediterranean California Dry-Mesic Mixed Conifer Forest	10	25
Whiskeytown National Recreation Area		
Developed, Open Space	24	126
California Lower Montane Blue Oak-Foothill Pine Woodland	22	103
Mediterranean California Dry-Mesic Mixed Conifer Forest	18	64
Mediterranean California Mixed Evergreen Forest	13	25
Lava Beds National Monument		
Inter-Mountain Basins Big Sagebrush Steppe	19	125
Columbia Plateau Steppe and Grassland	7	59
North Pacific Wooded Volcanic Flowage	14	55

¹Sites containing at least one point in the GAP landcover category

Breeding Density

We were able to estimate breeding density for a total of 39 bird species, 26 of which have been identified as PIF focal species in the region (Table 4). This represented 10–27% of the species detected on point counts at each park; with more data collected in future years additional species may be analyzed. We present models with some support ($\Delta AIC_c < 10$) and better than a null model. Equally well supported models with $\Delta AIC_c < 2$ that explained >20% of the variation in the data are presented graphically. Habitat associations were examined by park for 8–16 species and we summarize results by park. For several species occurring at multiple parks, we examine consistency of habitat associations across parks.

Table 4. Initial examination of bird density at parks in the Klamath Network indicate a number of Partners in Flight focal species may be included in long-term monitoring. Bird-habitat associations in this report include 26 species identified by conservation plans as important for monitoring different habitats in the region.

Species	Continental Pacific ¹	Continental Intermountain West ¹	OR/WA Coniferous Forest ²	California Riparian ³	California Coniferous Forest ⁴	California Oak Woodlands ⁵	California Scrub and Chaparral ⁶	California Sagebrush ⁷
Black-headed Grosbeak				X				
Brown Creeper			X		X			
Brewer's Sparrow		X						X
Black-throated Gray Warbler	X		X		X			
Chestnut-backed Chickadee	X							
Clark's Nutcracker		X						
Golden-crowned Kinglet					X			
Hermit Warbler	X		X					
Hutton's Vireo			X			X		
Lincoln's Sparrow			X					
Orange-crowned Warbler			X					
Oregon Junco					X			
Pacific-slope Flycatcher	X		X					
Pacific Wren	X		X					
Red-breasted Nuthatch					X			
Red Crossbill			X					
Spotted Towhee							X	
Steller's Jay	X							
Swainson's Thrush				X				
Varied Thrush	X		X					
Warbling Vireo				X				
Western Meadowlark								X
Western Scrub-Jay	X					X	X	
Western Tanager					X			
Wilson's Warbler			X	X				
Wrentit	X						X	

¹Rich et al. 2004, ²Altman 1999, ³RHJV 2004, ⁴CalPIF 2002a, ⁵CalPIF 2002b, ⁶CalPIF 2004, ⁷CalPIF 2005

Crater Lake National Park

Sites at CRLA, one of the high elevation parks, included both open subalpine meadow, and forest dominated by Shasta red fir (*Abies magnifica* var. *shastensis*), mountain hemlock (*Tsuga mertensiana*), and lodgepole pine (*Pinus contorta*). A total of 60 species were detected on point counts at CRLA in 2010 and we were able to estimate breeding density for 16 species (Table 5). An analysis of the correlation between variables showed strong correlations between slope and mountain hemlock, shrub cover and snags, and mountain hemlock and Shasta red fir (Table 6). These correlations were considered in our interpretation of the results. Six PIF coniferous forest focal species were included in the analysis: Brown Creeper (*Certhia americana*), Clark's Nutcracker (*Nucifraga columbiana*), Golden-crowned Kinglet (*Regulus satrapa*), Hermit Warbler (*Setophaga occidentalis*), Oregon Junco (*Junco hyemalis oregonus*), and Red Crossbill (*Loxia curvirostra*) (Altman 1999); the Clark's Nutcracker is also an Intermountain West stewardship species, and the Hermit Warbler and Steller's Jay (*Cyanocitta stelleri*) are Pacific stewardship species (Rich et al. 2004).

At CRLA, models containing vegetation structure had stronger predictive ability than topographic or floristic models. Only Townsend's Solitaires (*Myadestes townsendi*) were positively associated with elevation, while Hermit Thrushes (*Catharus guttatus*) and Mountain Chickadees (*Poecile gambeli*) were negatively associated with elevation (Table 7). Sampling a limited range of elevation which excluded alpine sites, we did not find strong associations with elevation for species such as the Clark's Nutcracker, known to be more abundant at higher elevation. An open canopy species, the Pine Siskin (*Spinus pinus*), was strongly associated with snags (Figure 4A). A coniferous forest generalist, the Audubon's Warbler (*Setophaga coronata auduboni*), was strongly associated with tree cover (Figure 4B); whereas the ground-foraging American Robin (*Turdus migratorius*) was negatively associated with shrub as well as tree cover (Figure 4C). Apparently related to regeneration post-disturbance, snags and shrub cover were strongly correlated at the park, and Oregon Juncos and Brown Creepers were positively associated with both variables (Figure 5A, B). There was weak support for relationships between bird density and specific plant species (floristic models). Golden-crowned Kinglets (*Regulus satrapa*) and Red-breasted Nuthatches (*Sitta canadensis*) were positively associated with Shasta red fir, and kinglets also tended to be negatively associated with lodgepole pine (Table 7). Based on Gap landcover data, no Golden-crowned Kinglets were detected at stations located in the lodgepole pine vegetation type. Mountain Chickadees tended to be negatively associated with mountain hemlock, a high elevation tree species. None of the models examined explained density of Clark's Nutcrackers, Hermit Warblers, Red Crossbills, or Steller's Jays.

Table 5. Density estimates with confidence intervals of bird species included in the habitat analysis at Crater Lake National Park, 2010. Densities were estimated in Program DISTANCE 6.0 using a species-specific approach separating songs and calls to estimate territories/ha. Species with an asterisk indicate flocking species estimated as individuals/ha. Distances were adjusted for observer error and estimates should be considered with caution.

Species	Analysis	Detections	% Song	Density	95% CI		% Points
American Robin	Song+Call ¹	143	0.43	0.11	0.07	0.16	0.23
Audubon's Warbler	Song	325	0.93	0.25	0.19	0.31	0.52
Brown Creeper	Song+Call ¹	108	0.37	0.28	0.16	0.39	0.20
Clark's Nutcracker	Call	165	0.00	0.03	0.02	0.05	0.16
Golden-crowned Kinglet	Song+Call ¹	89	0.48	0.21	0.13	0.29	0.21
Gray Jay	Call	112	0.00	0.04	0.03	0.05	0.24
Hermit Thrush	Song	256	0.95	0.08	0.06	0.10	0.47
Hermit Warbler	Song ¹	54	0.98	0.06	0.00	0.12	0.08
Mountain Chickadee	Call	279	0.16	0.28	0.19	0.37	0.37
Oregon Junco	Song	222	0.82	0.20	0.12	0.27	0.48
Pine Siskin*	Individuals	1070	0.03	2.74	2.11	3.37	0.87
Red-breasted Nuthatch	Song+Call ¹	551	0.33	0.25	0.20	0.29	0.79
Red Crossbill*	Individuals	61	0.02	0.16	0.07	0.26	0.12
Steller's Jay	Call	83	0.00	0.03	0.02	0.04	0.16
Townsend's Solitaire	Song*	51	0.82	0.02	0.01	0.04	0.12
Western Tanager	Song	161	0.80	0.03	0.02	0.04	0.29

¹Detections pooled across park

Table 6. Spearman rank-order correlation coefficients for habitat variables at Crater Lake National Park, 2010. Correlations >0.60 highlighted in **bold**. See Table 2 for variable codes.

Variable	ELEVATION	SLOPE	ASPECT	TRCOV	SHCOV	GRCOV	SNAGS	TSME	PICO	ABMA
ELEVATION	1.00									
SLOPE	0.30	1.00								
ASPECT	-0.02	0.02	1.00							
TRCOV	0.00	0.29	0.04	1.00						
SHCOV	-0.07	0.01	0.11	0.57	1.00					
GRCOV	-0.14	0.31	0.26	0.42	0.48	1.00				
SNAGS	0.05	-0.28	0.27	0.19	0.71	0.44	1.00			
TSME	0.39	0.62	0.07	-0.02	-0.05	-0.03	-0.20	1.00		
PICO	-0.02	-0.58	0.02	-0.29	-0.20	-0.46	0.10	-0.27	1.00	
ABMA	-0.05	0.59	0.00	0.24	0.11	0.06	-0.26	0.64	-0.55	1.00

Table 7. Univariate bird-habitat model selection results for 16 species at Crater Lake National Park, 2010, including number of parameters (k), Akaike's Information Criterion corrected for small sample size (AIC_c), model weight, slope of the parameter (β) with confidence intervals (CI), and adjusted R-squared values. Models with $\Delta AIC_c < 10$ and better than a null model are presented. See Table 2 for variable codes.

Model	k	AIC _c	ΔAIC _c	weight	β	95% CI		Adj. R ²
American Robin ¹								
SHCOV	2	-71.4056	0.0000	0.8157	-0.2910	-0.4526	-0.1293	0.3028
SNAGS	2	-66.2131	5.1925	0.0608	-0.0008	-0.0015	-0.0002	0.1710
TRCOV	2	-65.8151	5.5905	0.0498	-0.2271	-0.4092	-0.0449	0.1600
SLOPE	2	-65.3564	6.0492	0.0396	0.0103	0.0017	0.0189	0.1470
PICO	2	-62.1399	9.2657	0.0079	-0.2003	-0.4576	0.0570	0.0505
NULL	1	-61.7049	9.7006	0.0064	-	-	-	-
Audubon's Warbler								
TRCOV	2	-29.8561	0.0000	0.9709	0.7751	0.4410	1.1092	0.4176
SHCOV	2	-22.5330	7.3232	0.0249	0.6171	0.2477	0.9865	0.2625
Brown Creeper ¹								
SHCOV	2	-15.1823	0.0000	0.6603	0.7675	0.3549	1.1802	0.3447
SNAGS	2	-13.6833	1.4990	0.3121	0.0034	0.0014	0.0054	0.3073
TRCOV	2	-6.1794	9.0028	0.0073	0.4663	-0.0526	0.9853	0.0853
Clark's Nutcracker								
GRCOV	2	-105.9466	0.0000	0.2785	-0.1180	-0.2389	0.0028	0.0906
ELEVATION	2	-104.8945	1.0521	0.1646	0.0001	0.0000	0.0002	0.0592
SHCOV	2	-104.2803	1.6663	0.1210	-0.0727	-0.1715	0.0261	0.0404
NULL	1	-104.1234	1.8232	0.1119	-	-	-	-
Golden-crowned Kinglet								
GRCOV	2	-6.1455	0.0000	0.4776	0.8326	0.2281	1.4370	0.1878
ABMA	2	-4.2526	1.8929	0.1854	0.8600	0.1264	1.5936	0.1367
PICO	2	-3.3897	2.7558	0.1204	-0.7190	-1.3905	-0.0474	0.1123
SLOPE	2	-1.6815	4.4640	0.0513	0.0197	-0.0036	0.0429	0.0620
TRCOV	2	-1.4287	4.7167	0.0452	0.4264	-0.1021	0.9548	0.0543
NULL	1	-0.8184	5.3271	0.0333	-	-	-	-
Gray Jay								
SHCOV	2	-114.0708	0.0000	0.7100	0.1177	0.0333	0.2021	0.1921
TRCOV	2	-109.5346	4.5362	0.0735	0.0793	-0.0131	0.1717	0.0649
NULL	1	-108.5771	5.4937	0.0455	-	-	-	-
Hermit Thrush								
ELEVATION	2	-87.3930	0.0000	0.6235	-0.0002	-0.0004	-0.0001	0.1718
ABMA	2	-83.4772	3.9158	0.0880	0.1709	-0.0335	0.3753	0.0603
NULL	1	-82.6708	4.7222	0.0588	-	-	-	-
Hermit Warbler								
ELEVATION	2	-139.2964	0.0000	0.2878	-0.0001	-0.0001	0.0000	0.0803
NULL	1	-138.0686	1.2278	0.1558	-	-	-	-
Mountain Chickadee								
TSME	2	1.1623	0.0000	0.6906	-1.0543	-1.7960	-0.3127	0.1990
ELEVATION	2	5.0282	3.8659	0.0999	-0.0008	-0.0016	0.0000	0.0926
SLOPE	2	6.7387	5.5764	0.0425	-0.0197	-0.0464	0.0069	0.0411
NULL	1	6.9203	5.7580	0.0388	-	-	-	-

¹Outlier(s) with Cooks distance > 0.5 removed from model

Table 7 (continued). Univariate bird-habitat model selection results for 16 species at Crater Lake National Park, 2010, including number of parameters (k), Akaike's Information Criterion corrected for small sample size (AIC_c), model weight, slope of the parameter (β) with confidence intervals (CI), and adjusted R-squared values. Models with $\Delta AIC_c < 10$ and better than a null model are presented. See Table 2 for variable codes.

Model	k	AIC _c	ΔAIC _c	weight	β	95% CI		Adj. R ²
Oregon Junco								
SNAGS	2	-19.3092	0.0000	0.4669	0.0035	0.0017	0.0053	0.3394
SHCOV	2	-19.0461	0.2631	0.4094	0.7499	0.3599	1.1399	0.3335
TSME	2	-15.8977	3.4114	0.0848	-0.9183	-1.4810	-0.3557	0.2598
TRCOV	2	-13.1254	6.1838	0.0212	0.5902	0.1551	1.0253	0.1881
ELEVATION	2	-11.1403	8.1688	0.0079	-0.0007	-0.0013	-0.0001	0.1326
GRCOV	2	-9.8220	9.4871	0.0041	0.5530	-0.0137	1.1196	0.0936
Pine Siskin								
SNAGS	2	99.0970	0.0000	1.0000	0.0332	0.0234	0.0430	0.6120
Red-breasted Nuthatch								
SHCOV	2	-37.7634	0.0000	0.2684	-0.3716	-0.6605	-0.0826	0.1648
ABMA	2	-37.4915	0.2719	0.2343	0.5393	0.1101	0.9684	0.1574
SNAGS	2	-36.7762	0.9872	0.1639	0.4733	0.0711	0.8755	0.1377
TSME	2	-36.6503	1.1131	0.1539	-0.0013	-0.0024	-0.0002	0.1342
GRCOV	2	-35.3547	2.4087	0.0805	-0.3796	-0.7570	-0.0023	0.0973
NULL	1	-33.3028	4.4605	0.0289	-	-	-	-
Red Crossbill								
GRCOV	2	9.2070	0.0000	0.2621	-0.7102	-1.4844	0.0641	0.0775
NULL	1	10.5854	1.3783	0.1316	-	-	-	-
Steller's Jay								
ELEVATION	2	-135.9410	0.0000	0.2632	-0.0001	-0.0001	0.0000	0.0904
PICO	2	-135.2289	0.7121	0.1843	-0.0655	-0.1413	0.0103	0.0685
NULL	1	-134.2182	1.7228	0.1112	-	-	-	-
Townsend's Solitaire								
ELEVATION	2	-127.4022	0.0000	0.3747	0.0001	0.0000	0.0002	0.1077
TRCOV	2	-125.2479	2.1543	0.1276	0.0539	-0.0178	0.1256	0.0435
NULL	1	-124.9900	2.4122	0.1122	-	-	-	-
Western Tanager								
SNAGS	2	-129.6273	0.0000	0.3416	0.0002	0.0000	0.0005	0.1003
NULL	1	-127.4711	2.1562	0.1162	-	-	-	-

¹Outlier(s) with Cooks distance > 0.5 removed from model

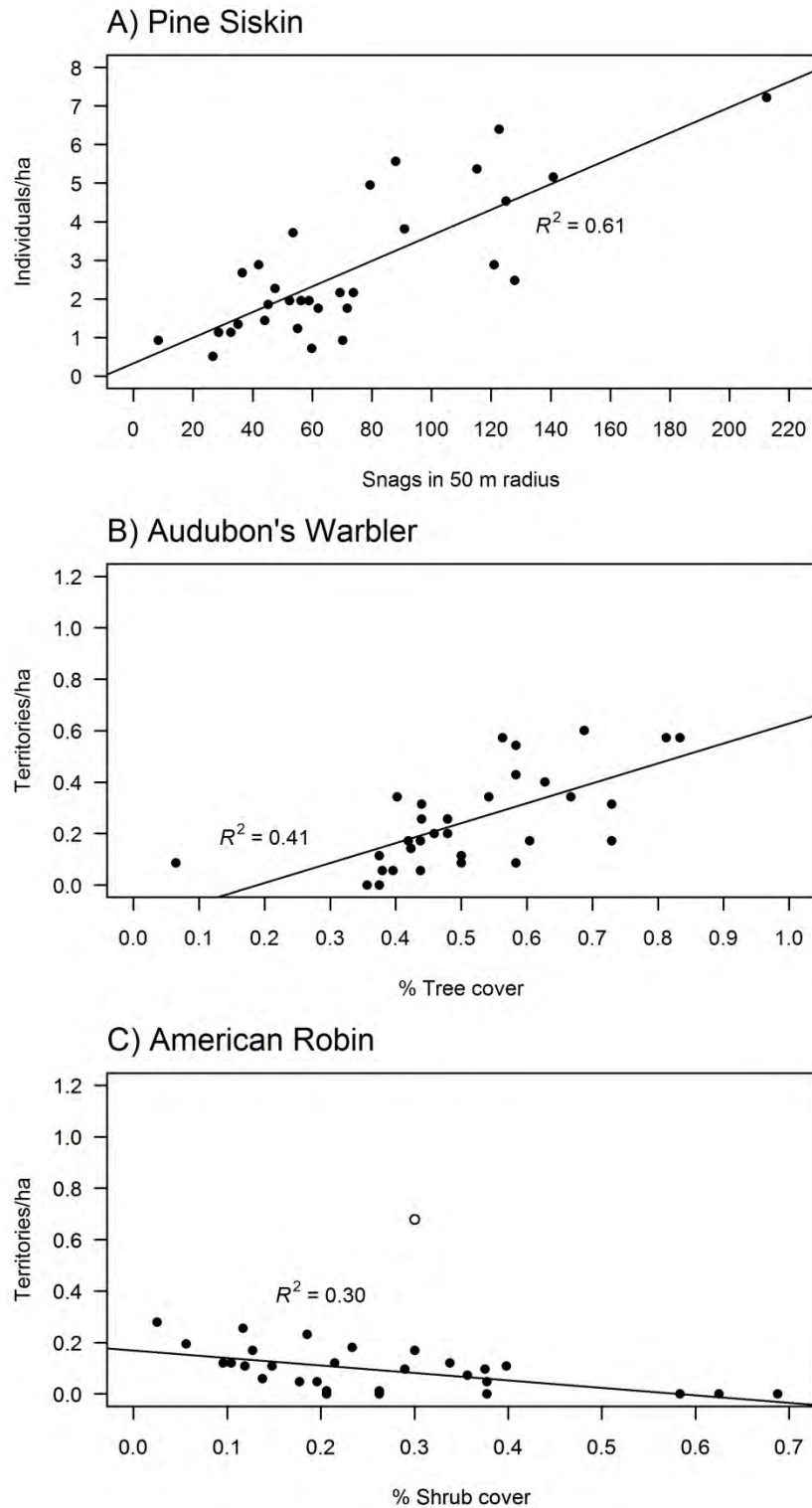


Figure 4. Models containing vegetation structure had the greatest predictive ability at Crater Lake National Park in 2010 as shown by the Pine Siskins (A), Audubon's Warbler (B), and American Robins (C). Open circles indicate outliers excluded from the regression.

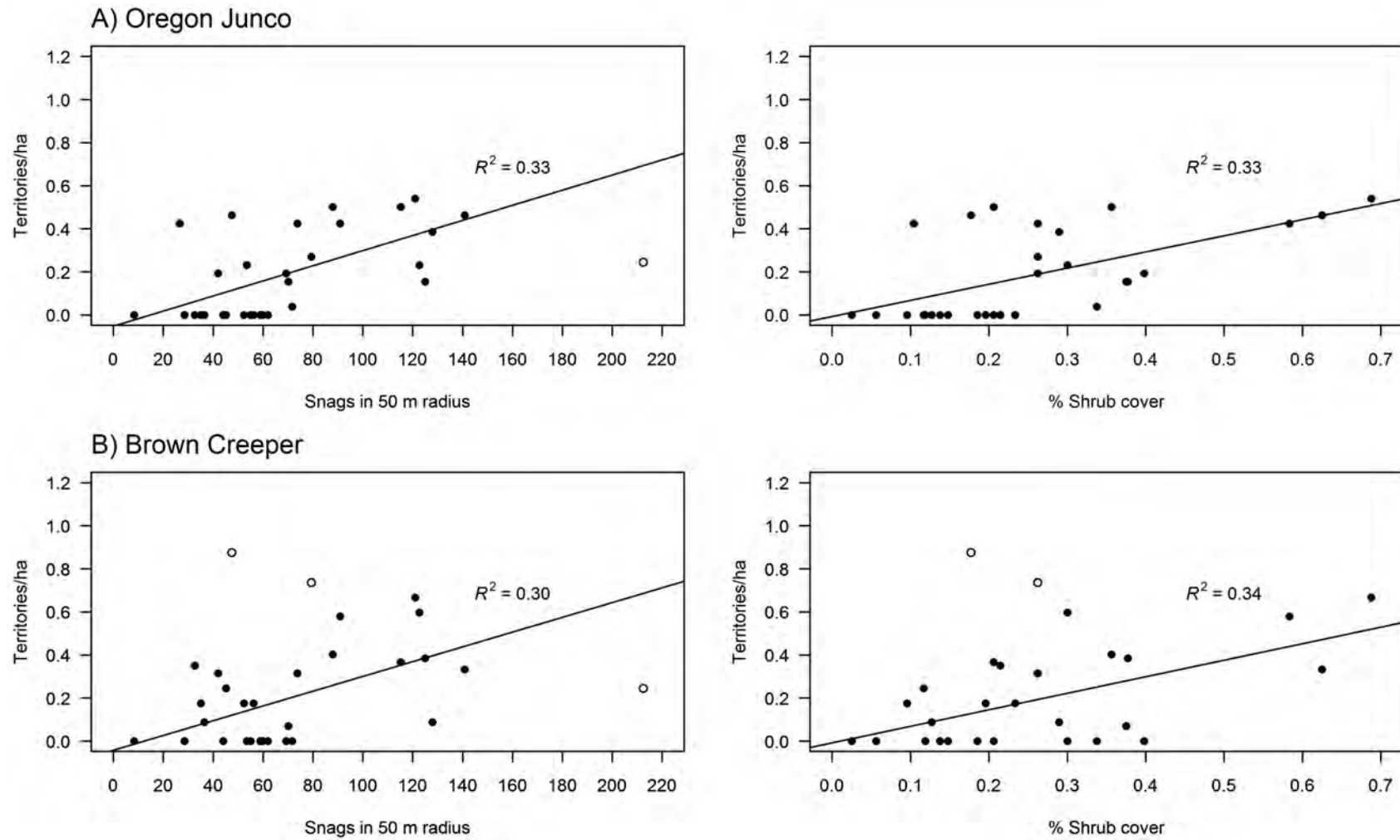


Figure 5. Several species at Crater Lake National Park, 2010, showed positive associations with multiple variables such as the Oregon Juncos (A) and Brown Creepers (B). Open circles indicate outliers excluded from the regression.

Lassen Volcanic National Park

Sites at LAVO sampled similar high elevation forest as at CRLA, but were limited to stations near streams and wetlands. Shasta red fir and lodgepole pine were dominant along with western white pine (*Pinus monticola*), mountain hemlock, and white fir (*Abies concolor*). Mountain alder (*Alnus incana* spp *tenuifolia*) and willow spp (*Salix* spp) were found in the riparian areas. A total of 68 species were detected on point counts at LAVO in 2010 and we were able to estimate densities for 15 species within our riparian sampling frame (Table 8). An analysis of the correlation between variables showed strong negative correlations between elevation, tree cover, shrub cover, and snags. Slope was negatively correlated with snags and lodgepole pine (Table 9). These correlations were considered in the interpretation of the results. Four PIF coniferous forest focal species were included in the analysis: Brown Creeper, Golden-crowned Kinglet, Oregon Junco, and Western Tanager (*Piranga ludoviciana*) (CalPIF 2002a); and two riparian focal species: Warbling Vireo (*Vireo gilvus*) and Wilson's Warbler (*Cardellina pusilla*) (RHJV 2004).

Both elevation and vegetation structure provided important models at LAVO. In this riparian sampling frame, two riparian species, the Wilson's Warbler and Warbling Vireo, were negatively associated with elevation (Figure 6A, B), whereas two conifer associated species, the Audubon's Warbler and Pine Siskin, were positively associated with elevation (Figure 6C, D); the Mountain Chickadee also tended to be negatively associated with elevation at the park (Table 10). American Robins were negatively associated with tree cover, and positively associated with elevation (Figure 7A); perhaps because tree cover decreased at high elevation subalpine sites (Table 9). An aerial flycatcher, the Western Wood-Pewee (*Contopus sordidulus*), was positively associated with snags (Figure 7B). Two ground foraging and nesting species, the Oregon Junco and Lincoln's Sparrow (*Melospiza lincolnii*) were positively associated with ground cover (Figure 8A, B). The Western Tanager was also associated with ground cover, although counts for this species were low at this park (Figure 8C). None of the models examined explained density of Golden-crowned Kinglets, Red-breasted Nuthatches, Townsend's Solitaires, or Steller's Jays.

Table 8. Density estimates with confidence intervals of bird species included in the habitat analysis at Lassen Volcanic National Park, 2010. Densities were estimated in Program DISTANCE 6.0 using a species-specific approach separating songs and calls to estimate territories/ha. Species with an asterisk indicate flocking species estimated as individuals/ha.

Species	Analysis	Detections	% Song	Density	95% CI		% Points
American Robin	Song+Call ¹	122	0.25	0.19	0.13	0.25	0.32
Audubon's Warbler	Song	244	0.88	0.15	0.12	0.18	0.61
Brown Creeper	Song+Call ¹	71	0.45	0.21	0.14	0.28	0.21
Golden-crowned Kinglet	Song+Call ¹	89	0.45	0.27	0.17	0.36	0.25
Lincoln's Sparrow	Song	174	0.82	0.16	0.10	0.21	0.32
Mountain Chickadee	Call	210	0.09	0.13	0.11	0.15	0.49
Oregon Junco	Song+Call ¹	284	0.54	0.32	0.26	0.38	0.62
Pine Siskin*	Call	138	0.04	0.33	0.19	0.46	0.28
Red-breasted Nuthatch	Song+Call ¹	81	0.72	0.03	0.02	0.05	0.24
Steller's Jay	Call	131	0.01	0.06	0.04	0.07	0.34
Townsend's Solitaire	Song ¹	63	0.76	0.03	0.02	0.04	0.20
Warbling Vireo	Song	135	0.89	0.12	0.08	0.16	0.31
Western Tanager	Song	138	0.83	0.03	0.02	0.04	0.39
Western Wood-Pewee	Call	144	0.01	0.05	0.04	0.07	0.35
Wilson's Warbler	Song ¹	152	0.76	0.23	0.14	0.32	0.34

¹Detections pooled across park

Table 9. Spearman rank-order correlation coefficients for habitat variables at Lassen Volcanic National Park, 2010. Correlations >0.60 highlighted in bold. See Table 2 for variable codes.

Variables	ELEVATION	SLOPE	ASPECT	TRCOV	SHCOV	GRCOV	SNAGS	ABMA	PICO	PIMO
ELEVATION	1.00									
SLOPE	0.50	1.00								
ASPECT	0.23	0.10	1.00							
TRCOV	-0.63	-0.44	-0.23	1.00						
SHCOV	-0.59	-0.05	-0.08	0.57	1.00					
GRCOV	0.14	0.00	0.42	-0.33	-0.07	1.00				
SNAGS	-0.64	-0.59	-0.02	0.55	0.35	0.11	1.00			
ABMA	0.57	0.48	0.27	-0.20	-0.08	0.09	-0.20	1.00		
PICO	-0.43	-0.66	-0.36	0.37	0.21	0.13	0.58	-0.44	1.00	
PIMO	0.42	0.45	0.13	-0.13	-0.01	-0.07	-0.11	0.83	-0.24	1.00

Table 10. Univariate bird-habitat model selection results for 15 species at Lassen Volcanic National Park, 2010, including number of parameters (k), Akaike's Information Criterion corrected for small sample size (AIC_c), model weight, slope of the parameter (β) with confidence intervals (CI), and adjusted R-squared values. Models with $\Delta AIC_c < 10$ and better than a null model are presented. See Table 2 for variable codes.

Model	k	AIC _c	ΔAIC _c	weight	β	95% CI		Adj. R ²
American Robin								
TRCOV	2	-27.1563	0.0000	0.3833	-0.8116	-1.3647	-0.2584	0.2549
ELEVATION	2	-27.0720	0.0843	0.3675	0.0004	0.0001	0.0007	0.2524
GRCOV	2	-24.2992	2.8571	0.0919	0.4994	0.0679	0.9309	0.1647
SHCOV	2	-23.2007	3.9556	0.0530	-0.9865	-1.9488	-0.0242	0.1272
SNAGS	2	-21.2132	5.9431	0.0196	-0.0051	-0.0119	0.0017	0.0550
ASPECT	2	-20.9149	6.2414	0.0169	0.3008	-0.1291	0.7307	0.0436
NULL	1	-20.9078	6.2485	0.0169	-	-	-	-
Audubon's Warbler								
ELEVATION	2	-61.0591	0.0000	0.5510	0.0002	0.0000	0.0003	0.2016
GRCOV	2	-57.8183	3.2408	0.1090	0.1969	-0.0238	0.4176	0.0911
SHCOV	2	-56.5923	4.4669	0.0590	-0.3490	-0.8425	0.1444	0.0454
NULL	1	-56.5392	4.5200	0.0575	-	-	-	-
Brown Creeper								
GRCOV	2	-12.2564	0.0000	0.1824	0.4422	-0.1067	0.9912	0.0689
SNAGS	2	-11.8389	0.4175	0.1481	0.0061	-0.0021	0.0143	0.0533
SLOPE	2	-11.6488	0.6077	0.1346	-0.0123	-0.0297	0.0050	0.0460
NULL	1	-11.5788	0.6777	0.1300	-	-	-	-
Golden-crowned Kinglet								
ASPECT	2	1.2666	0.0000	0.2802	0.6149	-0.0550	1.2849	0.0979
NULL	1	2.7352	1.4687	0.1344	-	-	-	-
Lincoln's Sparrow								
GRCOV	2	-38.3910	0.0000	0.9939	0.7931	0.4676	1.1186	0.5042
Mountain Chickadee								
ELEVATION	2	-70.3226	0.0000	0.4227	-0.0002	-0.0003	0.0000	0.1821
SHCOV	2	-68.0804	2.2423	0.1378	0.3708	-0.0214	0.7630	0.1053
ABMA	2	-67.1231	3.1996	0.0854	-0.3708	-0.8277	0.0861	0.0704
SNAGS	2	-67.0560	3.2666	0.0825	0.0022	-0.0005	0.0049	0.0679
SLOPE	2	-66.5827	3.7399	0.0651	-0.0042	-0.0100	0.0016	0.0501
NULL	1	-66.4055	3.9172	0.0596	-	-	-	-
Oregon Junco								
GRCOV	2	-23.8137	0.0000	0.7531	0.6039	0.1682	1.0396	0.2313
NULL	1	-18.3454	5.4683	0.0489	-	-	-	-
Pine Siskin								
ELEVATION	2	-38.3910	0.0000	0.9939	0.7931	0.4676	1.1186	0.5459
Red-breasted Nuthatch								
GRCOV	2	-85.5092	0.0000	0.2152	0.1100	-0.0168	0.2369	0.0846
TRCOV	2	-85.3536	0.1556	0.1991	0.1460	-0.0268	0.3187	0.0789
NULL	1	-84.4070	1.1021	0.1240	-	-	-	-
Steller's Jay								
ELEVATION	2	-100.8713	0.0000	0.1513	0.0000	-0.0001	0.0000	0.0501
NULL	1	-100.6938	0.1774	0.1385	-	-	-	-

Table 10 (continued). Univariate bird-habitat model selection results for 15 species at Lassen Volcanic National Park, 2010, including number of parameters (k), Akaike's Information Criterion corrected for small sample size (AIC_c), model weight, slope of the parameter (β) with confidence intervals (CI), and adjusted R-squared values. Models with $\Delta AIC_c < 10$ and better than a null model are presented. See Table 2 for variable codes.

Model	k	AIC _C	ΔAIC _C	weight	β	95% CI		Adj. R ²
Townsend's Solitaire								
TRCOV	2	-101.8093	0.0000	0.1755	-0.1177	-0.2419	0.0066	0.1057
SNAGS	2	-101.4846	0.3246	0.1492	-0.0012	-0.0026	0.0001	0.0940
PICO	2	-101.3222	0.4871	0.1376	-0.1175	-0.2510	0.0160	0.0881
ASPECT	2	-100.9956	0.8136	0.1169	0.0723	-0.0144	0.1589	0.0761
SLOPE	2	-100.6691	1.1402	0.0993	0.0023	-0.0006	0.0052	0.0639
ELEVATION	2	-100.2239	1.5853	0.0795	0.0000	0.0000	0.0001	0.0471
NULL	1	-100.1256	1.6837	0.0756	-	-	-	-
Warbling Vireo								
ELEVATION	2	-51.2962	0.0000	0.9629	-0.0004	-0.0006	-0.0002	0.4733
SNAGS	2	-43.6542	7.6420	0.0211	0.0068	0.0025	0.0112	0.2849
TRCOV	2	-41.9272	9.3690	0.0089	0.5741	0.1625	0.9858	0.2338
Western Tanager								
-937.7612	2	-937.7612	0.0000	0.6993	0.0385	0.0106	0.0664	0.0211
NULL	1	-932.6028	5.1584	0.0530	-	-	-	-
Western Wood-Pewee								
SNAGS	2	-109.8274	0.0000	0.9014	0.0030	0.0018	0.0041	0.5343
PICO	2	-104.4625	5.3649	0.0617	0.2612	0.1358	0.3866	0.4228
ELEVATION	2	-102.8528	6.9745	0.0276	-0.0001	-0.0002	-0.0001	0.3844
SLOPE	2	-100.1216	9.7058	0.0070	-0.0049	-0.0079	-0.0020	0.3133
Wilson's Warbler								
ELEVATION	2	-7.0657	0.0000	0.6919	-0.0007	-0.0011	-0.0002	0.2678
SHCOV	2	-3.9188	3.1469	0.1435	1.6618	0.2468	3.0769	0.1696
SNAGS	2	-2.3209	4.7447	0.0645	0.0097	-0.0002	0.0196	0.1148
NULL	1	-0.3803	6.6854	0.0245	-	-	-	-

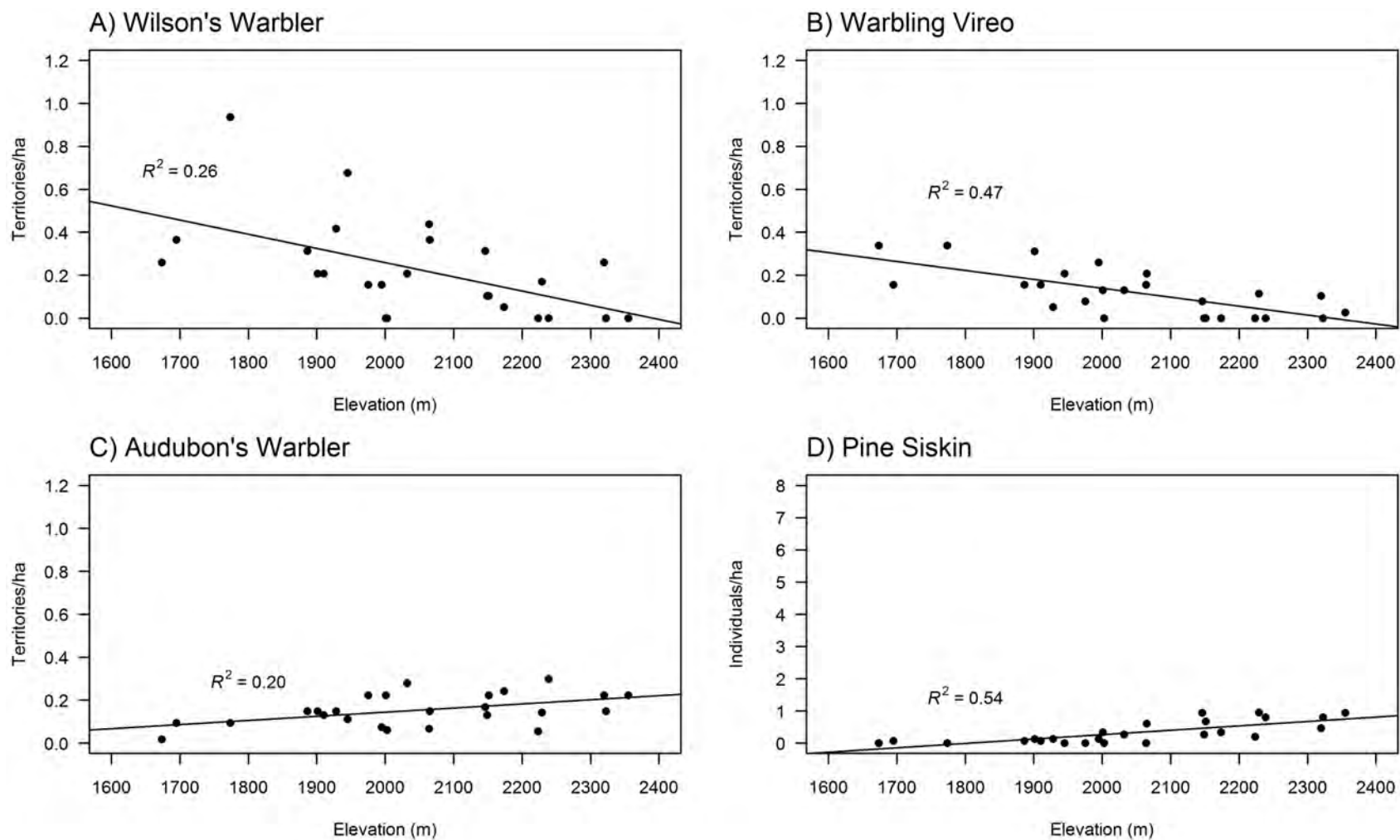


Figure 6. Elevation was important in the riparian sampling frame at Lassen Volcanic National Park, 2010 to several species such as the Wilson's Warbler (A), Warbling Vireo (B), Audubon's Warbler (C) and Pine Siskin (D).

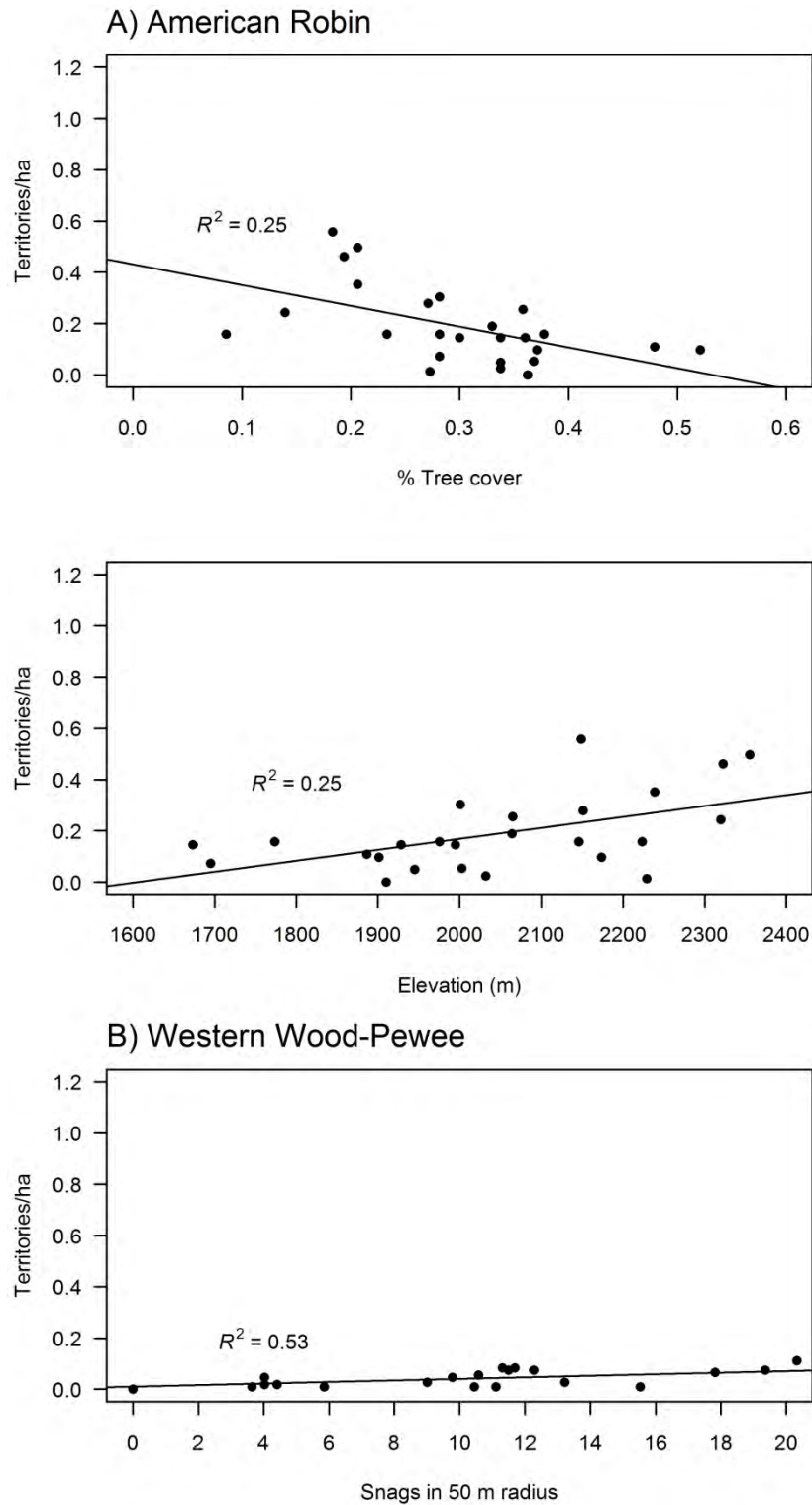


Figure 7. Vegetation structure was important for several open canopy species at Lassen Volcanic National Park, 2010 including the American Robins (A) and the Western Wood-Pewee (B).

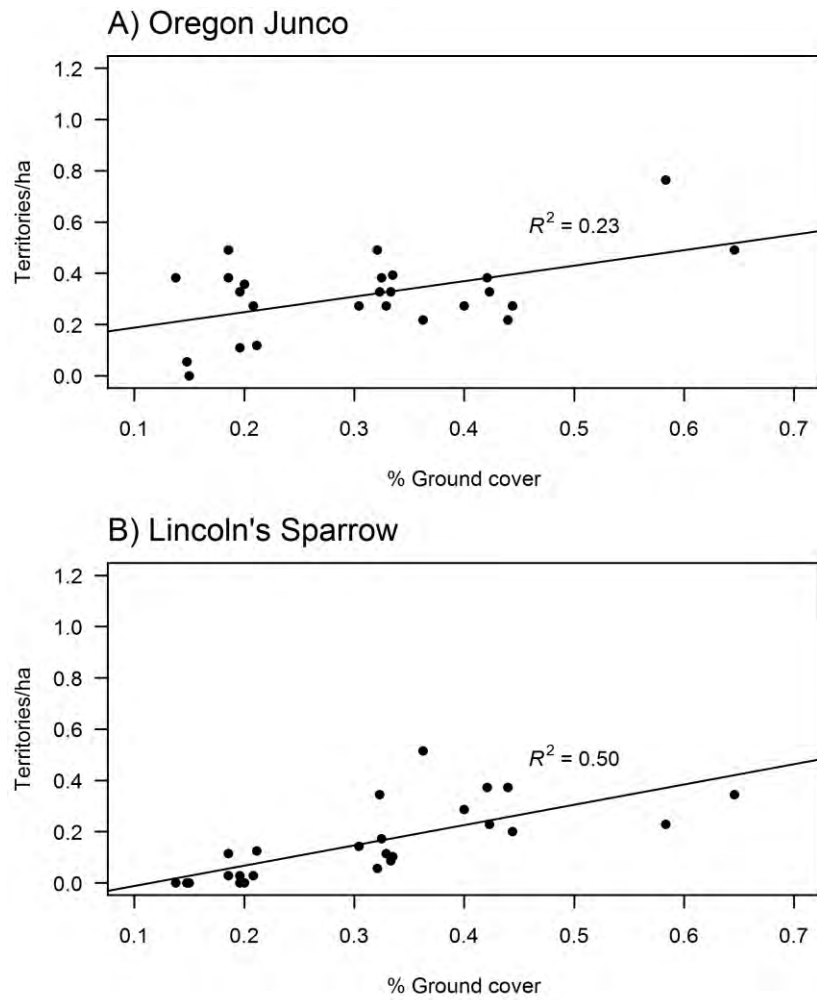


Figure 8. Two ground-nesting species, the Oregon Junco and Lincoln's Sparrow, were positively associated with ground cover at Lassen Volcanic National Park, 2010.

Lava Beds National Monument

Sites at LABE included shrub-steppe habitat of the Great Basin region dominated by big sage (*Artemisia tridentata*), bitterbrush (*Purshia tridentata*), and several rabbitbrush (*Haplopappus* spp) and currant (*Ribes* spp.) species. Habitat ranged from open grassland to areas with greater tree cover including sierra juniper (*Juniperus occidentalis*) and mountain mahogany (*Cercocarpus ledifolius*) at higher elevations. A total of 77 species were detected on point counts at LABE, and we were able to estimate density for 8 species (Table 11). An analysis of the correlation between variables showed strong positive correlations between elevation, tree cover, and sierra juniper; these variables were negatively correlated with big sage. Shrub cover was positively correlated with big sage the dominant shrub at LAVO, while ground cover was negatively correlated with tree cover (Table 12). These correlations were considered in our interpretation of the results. Two PIF sagebrush focal species were included in the analysis: Brewer's Sparrow (*Spizella breweri*) and Western Meadowlark (*Sturnella neglecta*) (CalPif 2005); the Brewer's Sparrow is also an intermountain west stewardship species (Rich et al. 2004).

Overall shrub and grassland bird species dominated at LABE. Lazuli Buntings (*Passerina amoena*) were positively associated with shrubs (Figure 9A); Spotted Towhees (*Pipilo maculatus*) were positively associated with the dominant shrub species at the park, bitterbrush (Figure 9B); and the Brewer's Sparrow was positively associated with big sage (Figure 9C). With sagebrush tending to occur at lower elevations in the park, Western Scrub-Jays (*Aphelocoma californica*) were more abundant at higher elevation sites as part of the transition between shrubland and forest habitat (Figure 10A). Mourning Doves (*Zenaida macroura*) showed a weak negative association with xeric southwest-facing slopes. (Table 13). For Western Meadowlarks models containing ground cover and grass were equally well supported (Figure 10C, D). None of the models examined explained density of Brown-headed Cowbirds (*Molothrus ater*) or Rock Wrens (*Salpinctes obsoletus*).

Table 11. Density estimates with confidence intervals of bird species included in the habitat analysis at Lava Beds National Monument, 2008. Densities were estimated in Program DISTANCE 6.0 using a species-specific approach separating songs and calls to estimate territories/ha.

Species	Analysis	Detections	% Song	Density	95% CI		% Points
Brown-headed Cowbird	Individuals	122	0.26	0.16	0.12	0.20	0.34
Brewer's Sparrow	Song	86	0.93	0.07	0.03	0.11	0.22
Lazuli Bunting	Song	166	0.82	0.14	0.08	0.20	0.38
Mourning Dove	Song	177	0.81	0.04	0.03	0.05	0.45
Rock Wren	Song	204	0.91	0.10	0.06	0.15	0.43
Spotted Towhee	Song+Call ¹	444	0.75	0.64	0.53	0.75	0.76
Western Meadowlark	Song+Call	652	0.89	0.23	0.16	0.30	0.79
Western Scrub-Jay	Call	139	0.00	0.05	0.03	0.07	0.31

¹Detections pooled across park

Table 12. Spearman rank-order correlation coefficients for habitat variables at Lava Beds National Monument, 2008. Correlations >0.60 highlighted in bold. See Table 2 for variable codes.

Variables	ELEVATION	SLOPE	ASPECT	TRCOV	SHCOV	GRCOV	SNAGS ¹	GRAS	ARTR	PUTR	CHRY	JUOC
ELEVATION	1.00											
SLOPE	0.56	1.00										
ASPECT	-0.23	0.21	1.00									
TRCOV	0.84	0.36	-0.17	1.00								
SHCOV	-0.18	-0.08	0.25	-0.25	1.00							
GRCOV	-0.51	-0.24	-0.06	-0.70	0.21	1.00						
SNAGS ¹	0.73	0.55	0.05	0.70	-0.31	-0.61	1.00					
GRAS	-0.36	-0.21	-0.12	-0.47	-0.30	0.51	-0.17	1.00				
ARTR	-0.68	-0.35	0.28	-0.69	0.59	0.55	-0.58	0.19	1.00			
PUTR	-0.10	-0.18	-0.23	0.09	0.22	-0.13	-0.36	-0.11	0.07	1.00		
CHRY	-0.19	0.14	0.01	0.02	0.12	0.22	-0.21	-0.18	0.11	0.09	1.00	
JUOC	0.83	0.37	-0.14	0.99	-0.20	-0.65	0.67	-0.47	-0.65	0.13	0.07	1.00

¹Snags dropped from analysis because of limited variation

Table 13. Univariate bird-habitat model selection results for 8 bird species at Lava Beds National Monument, 2008, including number of parameters (k), Akaike's Information Criterion corrected for small sample size (AIC_c), model weight, slope of the parameter (β) with confidence intervals (CI), and adjusted R-squared values. Models with $\Delta AIC_c < 10$ and better than a null model are presented. See Table 2 for variable codes.

Model	k	AIC _c	ΔAIC _c	weight	β	95% CI		Adj. R ²
Brown-headed Cowbird								
JUOC	2	-39.8702	0.0000	0.2542	0.7002	-0.0653	1.4657	0.0971
NULL	1	-38.4257	1.4446	0.1234	-	-	-	-
Brewer's Sparrow								
ARTR	2	-65.9791	0.0000	0.9109	0.3694	0.1770	0.5618	0.3924
ELEVATION	2	-59.6147	6.3644	0.0378	-0.0003	-0.0006	-0.0001	0.2079
GRCOV	2	-57.3287	8.6505	0.0121	0.2233	0.0025	0.4441	0.1288
JUOC	2	-56.7798	9.1994	0.0092	-0.4905	-1.0121	0.0312	0.1086
TRCOV	2	-56.6572	9.3220	0.0086	-0.3178	-0.6617	0.0262	0.1040
SLOPE	2	-56.4597	9.5194	0.0078	-0.0247	-0.0523	0.0028	0.0966
Lazuli Bunting								
SHCOV	2	-26.6793	0.0000	0.7024	0.6436	0.1856	1.1016	0.2369
TRCOV	2	-21.0689	5.6104	0.0425	-0.5165	-1.2489	0.2160	0.0449
NULL	1	-21.0289	5.6504	0.0417	-	-	-	-
Mourning Dove								
ASPECT	2	-114.2247	0.0000	0.3194	0.0312	0.0000	0.0624	0.1205
NULL	1	-112.1227	2.1020	0.1117	-	-	-	-
Rock Wren								
JUOC	2	-39.1354	0.0000	0.1667	-0.7020	-1.4789	0.0748	0.0942
TRCOV	2	-39.0329	0.1025	0.1584	-0.4549	-0.9663	0.0565	0.0904
ARTR	2	-38.9677	0.1677	0.1533	0.3070	-0.0417	0.6557	0.0881
NULL	1	-37.7710	1.3643	0.0843	-	-	-	-
Spotted Towhee								
PUTR	2	5.5910	0.0000	0.5677	2.3986	0.5890	4.2082	0.2136
SHCOV	2	8.5453	2.9543	0.1296	0.9087	-0.0178	1.8352	0.1149
NULL	1	9.2517	3.6607	0.0910	-	-	-	-
Western Meadowlark								
GRCOV	2	-26.5289	0.0000	0.3825	0.8938	0.4653	1.3224	0.4233
GRAS	2	-26.4956	0.0333	0.3762	1.0867	0.5649	1.6084	0.4226
TRCOV	2	-23.6543	2.8746	0.0909	-1.2625	-1.9580	-0.5669	0.3531
JUOC	2	-23.3133	3.2157	0.0766	-1.9001	-2.9662	-0.8341	0.3442
ELEVATION	2	-21.6733	4.8556	0.0338	-0.0009	-0.0015	-0.0004	0.2997
ARTR	2	-21.3218	5.2072	0.0283	0.7881	0.2919	1.2844	0.2898
CHRY	2	-19.0512	7.4777	0.0091	2.9770	0.7804	5.1736	0.2223
Western Scrub-Jay								
ELEVATION	2	-79.0320	0.0000	0.8879	0.0003	0.0001	0.0005	0.3022
SLOPE	2	-71.5123	7.5197	0.0207	0.0162	-0.0052	0.0376	0.0574
NULL	1	-71.1429	7.8891	0.0172	-	-	-	-

¹Outlier(s) with Cooks distance > 0.5 removed from model

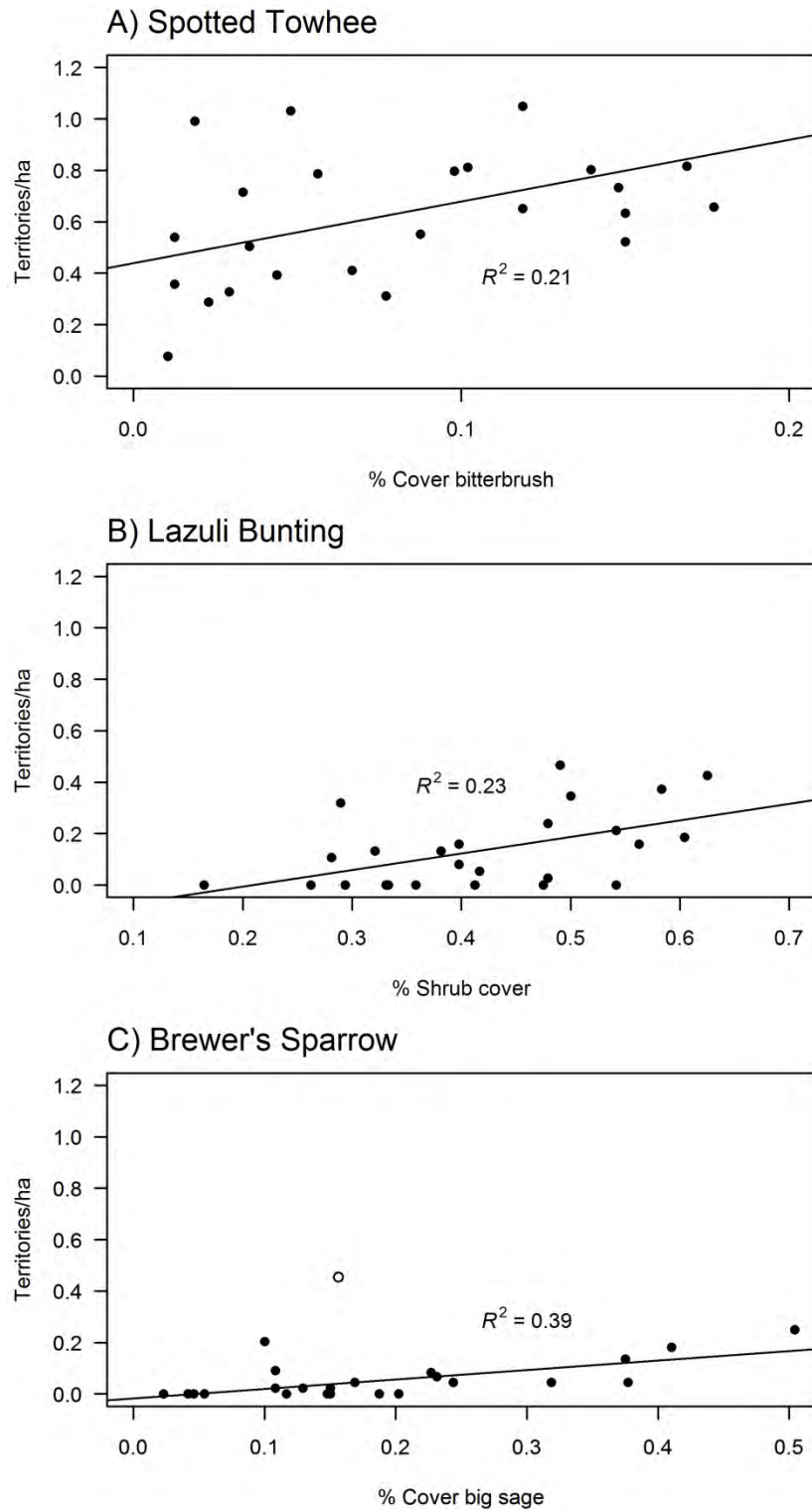


Figure 9. Spotted Towhee (A), Lazuli Bunting (B), and Brewer's Sparrow (C) were positively associated with shrubs as well as individual shrub species at Lava Beds National Monument, 2008 (A, B, C).

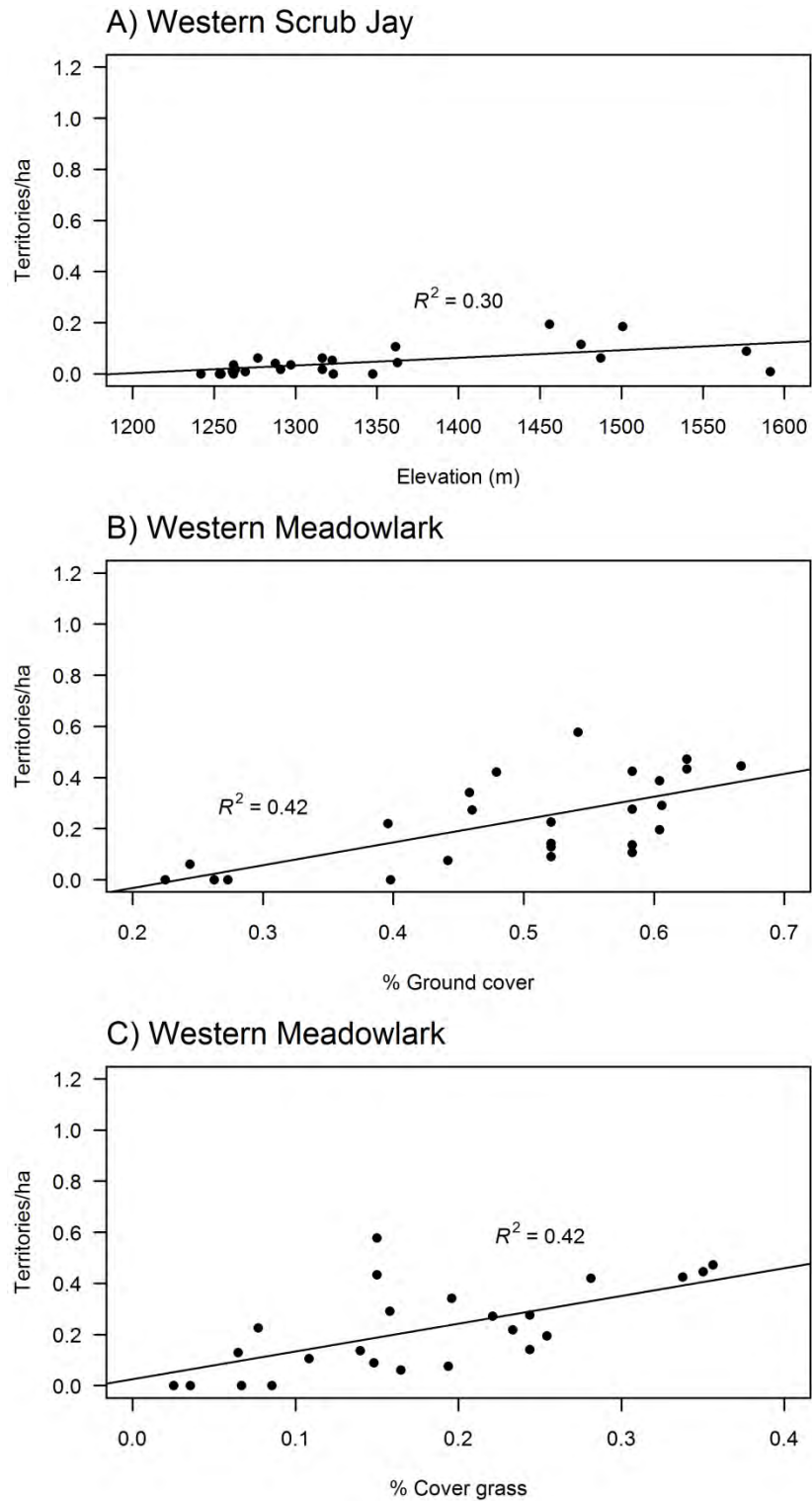


Figure 10. Western Scrub Jays were more abundant at higher elevation (A) and Western Meadowlarks were associated with ground vegetation at Lava Beds National Monument, 2008 (B, C).

Redwood National and State Parks

Sites at RNSP sampled coastal rainforest at the lowest elevations and mixed conifer forest at more interior and higher elevation sites. The lower elevation forests were dominated by the coastal redwood; other tree species included Douglas-fir (*Pseudotsuga menziesii*), western hemlock, and tanbark oak (*Lithocarpus densiflora*). Douglas-fir and tanbark oak are major components of the somewhat drier and more species rich mixed evergreen forest. The understory was dominated by sword fern (*Polystichum munitum*) and California huckleberry (*Vaccinium ovatum*), along with California rose-bay (*Rhododendron macrophyllum*), salal (*Gaultheria shallon*), and some red huckleberry (*Vaccinium parvifolium*). A total of 69 species were detected on point counts at RNSP and density was estimated for 11 species (Table 14). An analysis of the correlation between variables showed strong negative correlations between elevation, and coastal redwoods, and strong positive correlations between elevation, tanbark oak and California rose-bay. Tree cover was positively correlated with Douglas-fir, shrub cover was positively correlated with California huckleberry, and ground cover was positively correlated with ferns. These correlations were considered in our interpretation of the results. Two PIF coniferous forest focal species were included in the analysis: Brown Creeper and Golden-crowned Kinglet (CalPIF 2002a), and two riparian focal species: Swainson's Thrush (*Catharus ustulatus*) and Wilson's Warbler (RHJV 2004). Six species are pacific stewardship species: Chestnut-backed Chickadee (*Poecile rufescens*), Hermit Warbler, Pacific-slope Flycatcher (*Empidonax difficilis*), Pacific Wren (*Troglodytes pacificus*), Stellar's Jay, and Varied Thrush (*Ixoreus naevius*) (Rich et al. 2004).

At RNSP models that incorporated topography or vegetation structure showed low predictive ability, and only the Hutton's Vireo (*Vireo huttoni*) showed a weak positive association with slope and tree cover (Table 16). Overall models containing floristics had the strongest support. Four abundant bird species at the park, Pacific-slope Flycatcher, Chestnut-backed Chickadee, Pacific Wren, and Varied Thrush were all positively associated with cover of coastal redwoods (Figure 11). Wilson's Warblers were positively associated with the dominant shrub at the park, California huckleberry (Figure 12A), as well as ferns, shrub cover, and salal (Table 16). At this elevation Chestnut-backed Chickadees were negatively associated with drier Douglas-fir forest (Figure 12B), while Swainson's Thrushes showed a weak positive association with Douglas-fir (Table 16). Whereas Varied Thrushes were positively associated with mesic areas containing ferns (Figure 12C). None of the models examined explained density of Golden-crowned Kinglets, Hermit Warblers, or Stellar's Jays.

Table 14. Density estimates with confidence intervals of bird species included in the habitat analysis at Redwood National and State Parks, 2008. Densities were estimated in Program DISTANCE 6.0 using a species-specific approach separating songs and calls to estimate territories/ha.

Species	Analysis	Detections	% Song	Density	95% CI	% Points	Species
Brown Creeper	Song+Call ¹	57	0.68	0.28	0.19	0.37	0.00
Chestnut-backed Chickadee	Call	107	0.02	0.36	0.28	0.44	0.41
Golden-crowned Kinglet	Song+Call ¹	63	0.32	0.31	0.21	0.42	0.26
Hermit Warbler	Song ¹	61	0.97	0.13	0.07	0.18	0.24
Hutton's Vireo	Song ¹	66	0.79	0.09	0.07	0.12	0.30
Pacific-slope Flycatcher	Call	252	0.50	0.78	0.65	0.92	0.74
Pacific Wren	Song	181	0.89	0.38	0.30	0.46	0.59
Steller's Jay	Call	144	0.01	0.12	0.10	0.15	0.52
Swainson's Thrush	Song	106	0.71	0.04	0.03	0.05	0.32
Varied Thrush	Song	110	0.89	0.12	0.07	0.17	0.33
Wilson's Warbler	Song ¹	134	0.95	0.41	0.31	0.50	0.50

¹Detections pooled across park

Table 15. Spearman rank-order correlation coefficients for habitat variables at Redwood National and State Parks, 2008. Correlations >0.60 highlighted in bold. See Table 2 for variable codes.

Variables	ELEVATION	SLOPE	ASPECT	TRCOV	SHCOV	GRCOV	SNAGS	SESE	VAOV	FERN	PSME	TSHE	LIDE	RHMA	GASH
ELEVATION	1.00														
SLOPE	0.16	1.00													
ASPECT	0.24	-0.24	1.00												
TRCOV	0.28	0.27	-0.23	1.00											
SHCOV	-0.09	-0.07	0.12	-0.15	1.00										
GRCOV	-0.22	-0.24	0.19	-0.56	0.26	1.00									
SNAGS	0.22	-0.15	-0.06	0.25	-0.25	-0.02	1.00								
SESE	-0.64	-0.33	-0.27	-0.17	0.06	0.17	-0.13	1.00							
VAOV	0.09	0.05	0.10	0.20	0.65	0.00	0.19	-0.08	1.00						
FERN	-0.60	-0.35	-0.22	-0.38	0.29	0.63	-0.10	0.57	0.00	1.00					
PSME	0.54	0.29	-0.02	0.60	-0.11	-0.37	0.07	-0.52	0.08	-0.51	1.00				
TSHE	-0.33	-0.31	-0.16	0.12	0.14	-0.03	0.12	0.25	0.19	0.30	-0.19	1.00			
LIDE	0.73	0.29	0.24	0.35	-0.16	-0.59	0.07	-0.47	0.07	-0.68	0.54	-0.16	1.00		
RHMA	0.60	-0.06	0.01	0.35	0.15	-0.30	0.16	-0.20	0.22	-0.24	0.50	0.06	0.65	1.00	
GASH	0.18	0.19	-0.04	0.22	0.57	0.16	0.20	-0.19	0.59	0.11	0.18	0.03	-0.05	0.29	1.00

Table 16. Univariate bird-habitat model selection results for 11 bird species at Redwood National and State Parks, 2008, including number of parameters (k), Akaike's Information Criterion corrected for small sample size (AIC_c), model weight, slope of the parameter (β) with confidence intervals (CI), and adjusted R-squared values. Models with $\Delta AIC_c < 10$ and better than a null model are presented. See Table 2 for variable codes.

Model	k	AIC _c	ΔAIC _c	weight	β	95% CI		Adj. R ²
Brown Creeper								
FERN	2	2.9069	0.0000	0.2813	0.6601	0.1674	1.1529	0.1838
TSHE	2	3.1571	0.2502	0.2482	2.0326	0.4849	3.5803	0.1770
PSME	2	4.2275	1.3206	0.1453	-0.7515	-1.3798	-0.1231	0.1471
SESE	2	4.2802	1.3733	0.1416	0.8965	0.1431	1.6499	0.1456
ELEVATION	2	6.5634	3.6565	0.0452	-0.0004	-0.0009	0.0000	0.0780
NULL	1	7.8817	4.9748	0.0234	-	-	-	-
Chestnut-backed Chickadee								
SESE	2	-9.7949	0.0000	0.6499	1.0623	0.4665	1.6582	0.2985
PSME	2	-8.1325	1.6624	0.2831	-0.8321	-1.3435	-0.3207	0.2585
ELEVATION	2	-3.1180	6.6769	0.0231	-0.0005	-0.0009	0.0000	0.1236
GASH	2	-1.4630	8.3319	0.0101	2.2701	-0.2843	4.8244	0.0739
NULL	1	-0.4124	9.3825	0.0060	-	-	-	-
Golden-crowned Kinglet								
ASPECT	2	13.3462	0.0000	0.2295	-0.3190	-0.6539	0.0159	0.0882
TSHE	2	14.5652	1.2190	0.1248	1.4564	-0.4154	3.3282	0.0504
NULL	1	14.9983	1.6521	0.1005	-	-	-	-
Hermit Warbler								
NULL	1	-29.4000	0.0000	0.1657	-	-	-	-
Hutton's Vireo								
SLOPE	2	-70.3614	0.0000	0.4884	0.0081	0.0018	0.0144	0.1679
TRCOV	2	-68.3555	2.0059	0.1791	0.1894	0.0085	0.3703	0.1104
NULL	1	-65.9662	4.3952	0.0543	-	-	-	-
Pacific-slope Flycatcher								
SESE	2	1.8471	0.0000	0.9960	2.5043	1.7809	3.2277	0.6296
Pacific Wren								
SESE	2	-13.7446	0.0000	0.8867	1.0940	0.5361	1.6518	0.3429
ELEVATION	2	-8.8353	4.9093	0.0762	-0.0006	-0.0009	-0.0002	0.2261
FERN	2	-5.7994	7.9451	0.0167	0.5039	0.0777	0.9301	0.1437
Steller's Jay								
NULL	1	-72.6536	0.0000	0.1439	-	-	-	-
Swainson's Thrush								
PSME	2	-113.6994	0.0000	0.5730	0.1186	0.0305	0.2066	0.1857
SHCOV	2	-110.9208	2.7787	0.1428	0.1080	0.0033	0.2127	0.1067
NULL	1	-108.6567	5.0428	0.0460	-	-	-	-
Varied Thrush								
SESE	2	-37.4953	0.0000	0.5189	0.7193	0.3438	1.0948	0.3317
FERN	2	-36.7673	0.7280	0.3606	0.4705	0.2161	0.7248	0.3153
ELEVATION	2	-34.2558	3.2395	0.1027	-0.0004	-0.0006	-0.0002	0.2555

Table 16 (continued). Univariate bird-habitat model selection results for 11 bird species at Redwood National and State Parks, 2008, including number of parameters (k), Akaike's Information Criterion corrected for small sample size (AIC_c), model weight, slope of the parameter (β) with confidence intervals (CI), and adjusted R-squared values. Models with $\Delta AIC_c < 10$ and better than a null model are presented. See Table 2 for variable codes.

Model	k	AIC _C	ΔAIC _C	weight	β	95% CI		Adj. R ²
Wilson's Warbler								
VAOV	2	2.3214	0.0000	0.3005	1.0342	0.2979	1.7705	0.2006
FERN	2	2.9102	0.5889	0.2239	0.6619	0.1692	1.1547	0.1848
SHCOV	2	3.7578	1.4364	0.1465	3.4898	0.7033	6.2764	0.1614
GASH	2	4.0313	1.7099	0.1278	0.8694	0.1580	1.5807	0.1537
SESE	2	5.7086	3.3872	0.0553	0.7904	0.0189	1.5619	0.1051
ELEVATION	2	5.8456	3.5242	0.0516	-0.0005	-0.0010	0.0000	0.1010
GRCOV	2	7.2012	4.8798	0.0262	0.3966	-0.0862	0.8794	0.0594
NULL	1	7.9191	5.5977	0.0183	-	-	-	-

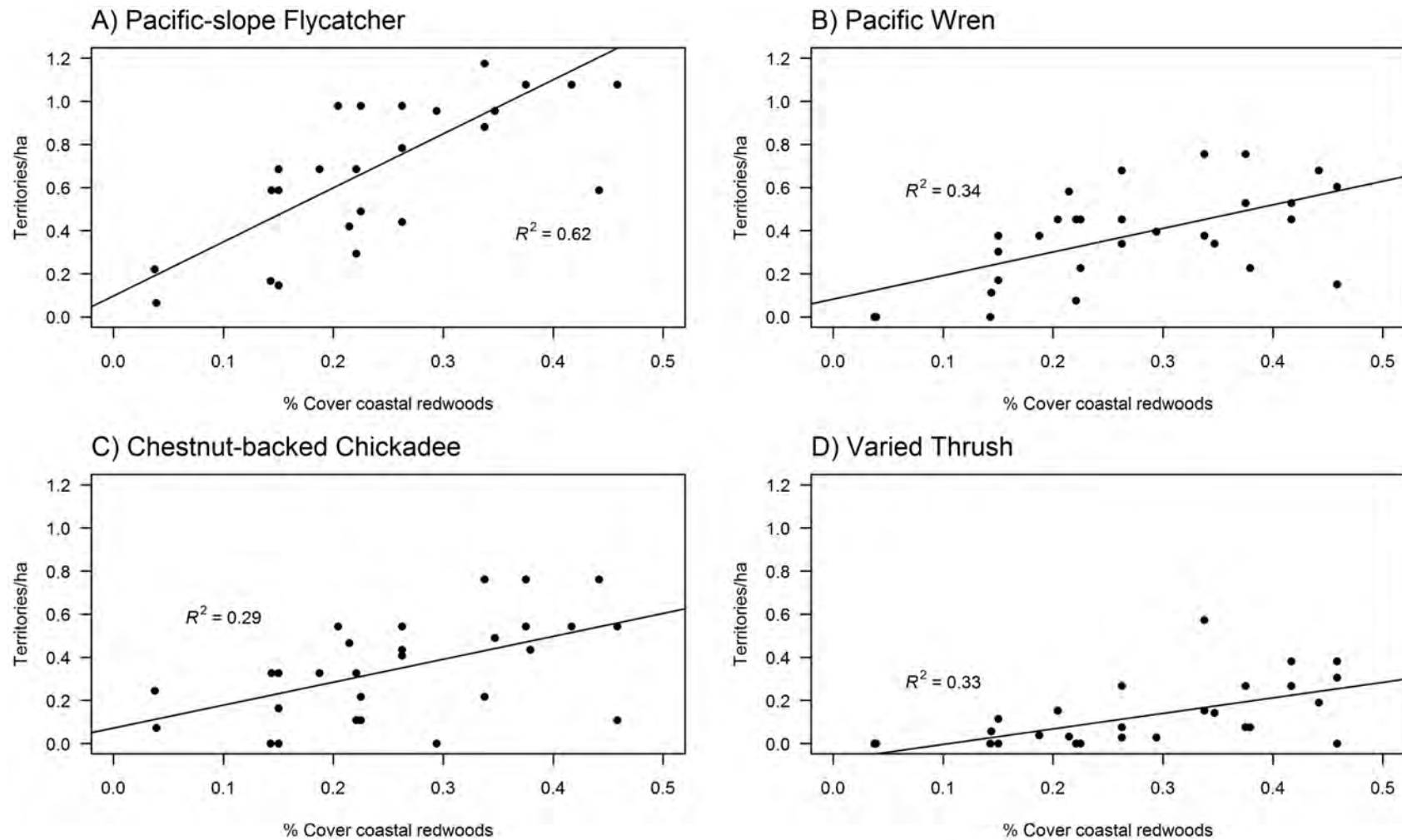


Figure 11. Four bird species, the Pacific-slope Flycatcher, Pacific Wren, Chestnut-backed Chickadee and Varied Thrush, were positively associated with coastal redwoods at Redwood National and State Parks, 2008 (A, B, C, D).

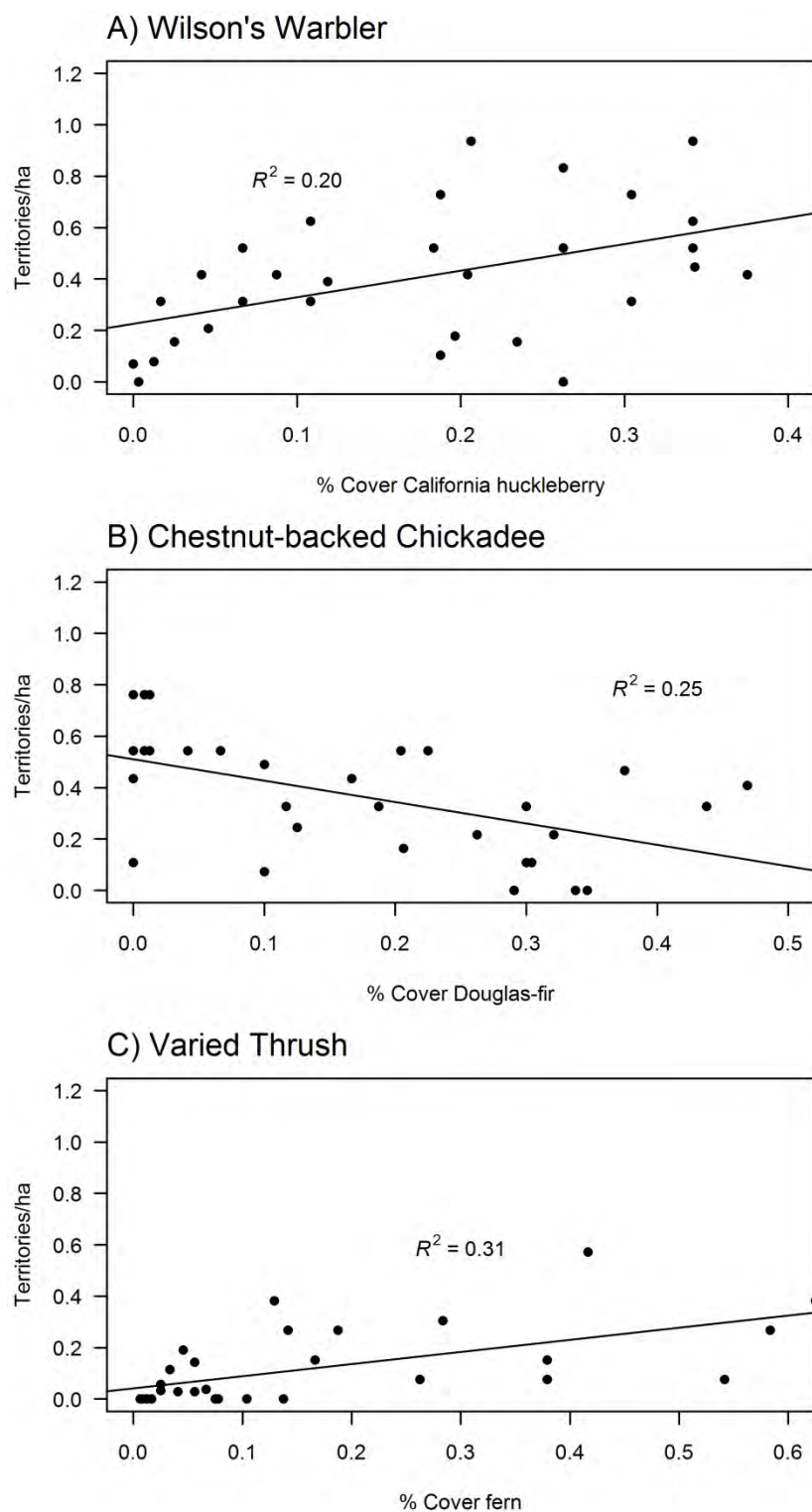


Figure 12. Models containing floristics received the strongest predictive power for species such as the Wilson's Warbler (A), Chestnut-backed Chickadee (B), and Varied Thrush (C) at Redwood National and State Parks, 2008.

Whiskeytown National Recreation Area

Sites at WHIS were predominantly in mixed conifer forest, mixed oak woodland, and chaparral. Dominant tree species included canyon live oak (*Quercus chrysolepis*) and California black oak (*Quercus kelloggii*), ponderosa and knobcone pines (*Pinus attenuate*), and Douglas-fir. Whiteleaf manzanita (*Arctostaphylos viscida*), toyon (*Heteromeles arbutifolia*), and whitethorn (*Ceanothus incanus*) composed the shrub layer. A total of 97 species were detected on point counts in 2009, and density was estimated for 11 species (Table 17). An analysis of the correlation between variables showed strong negative correlations between elevation, and ground cover, knobcone pine, and toyon; and positive correlations between elevation and slope. Tree cover was positively correlated with Douglas-fir, and ground cover was positively correlated with poison oak (*Toxicodendron diversiloba*). Toyon was positively correlated with manzanita. PIF focal species analyzed included three scrub and chaparral species, the Spotted Towhee, Western Scrub Jay and Wrentit (*Chamaea fasciata*) (CalPIF 2004); two coniferous forest species, the Black-throated Gray Warbler and Oregon Junco (CalPif 2002a); and one oak woodland species, the Hutton's Vireo (CalPIF 2002b). Three species are Pacific Stewardship species: the Black-throated Gray Warbler, Western Scrub Jay, and Wrentit (Rich et al. 2004).

At WHIS a transition between habitat types appeared to be related to elevation, affecting bird density patterns. Brown-headed Cowbirds tended to be negatively associated with elevation, whereas Steller's Jays tended to be positively associated with elevation (Table 19). Steller's Jays were also negatively associated with whitethorn, and although overall cover was low this common *Ceanothus* spp generally occurred in the lower elevation chaparral areas of the park. Generally not found above 800 m in the park, Orange-crowned Warblers (*Oreothlypis celata*) and Wrentits were positively associated with whitethorn (Figure 15A, B). Both vegetation structure and floristics were important predictors of landbird densities at the park. Canopy species were positively associated with tree cover, including the Black-headed Grosbeak (*Pheucticus melanocephalus*) and Cassin's Vireo (*Vireo cassinii*) (Figure 13A, B), and shrub-associated species, the Spotted Towhee and Wrentit, were negatively associated with tree cover (Figure 13C, D). Individual tree species provided the best model for several species, and Black-throated Gray Warblers were strongly associated with canyon live oak (Figure 14A). Although not abundant at the park, Hutton's Vireos were positively associated with California black oak (Figure 14C). Cassin's Vireos were also positively associated with canyon live oak and Douglas-fir (Figure 14B, 15C). Western Tanagers were also positively associated with canyon live oak (Figure 14D). None of the models examined explained density of Oregon Juncos at the park.

Table 17. Density estimates with confidence intervals for bird species included in the habitat analysis at Whiskeytown National Recreation Area, 2009. Densities were estimated in Program DISTANCE 6.0 using a species-specific approach separating songs and calls to estimate territories/ha. Species with an asterisk indicate flocking species estimated as individuals/ha.

Species	Analysis	Detections	% Song	Density	95% CI		% Points
Brown-headed Cowbird*	Individuals	71	0.35	0.12	0.08	0.17	0.17
Black-headed Grosbeak	Song	241	0.82	0.13	0.10	0.16	0.47
Black-throated Gray Warbler	Song+Call	360	0.89	0.52	0.38	0.66	0.60
Cassin's Vireo	Song	140	0.91	0.17	0.12	0.21	0.34
Hutton's Vireo	Song ¹	57	0.91	0.05	0.03	0.06	0.15
Orange-crowned Warbler	Song	240	0.88	0.18	0.14	0.23	0.47
Oregon Junco	Song	115	0.80	0.09	0.05	0.13	0.25
Spotted Towhee	Song+Call ¹	231	0.78	0.25	0.18	0.33	0.42
Steller's Jay	Call	104	0.01	0.03	0.02	0.04	0.26
Western Tanager	Song	150	0.70	0.06	0.04	0.08	0.35
Wrentit	Song	121	0.90	0.05	0.02	0.08	0.23

¹Detections pooled across parks

Table 18. Spearman rank-order correlation coefficients for habitat variables at Whiskeytown National Recreation Area, 2009. Correlations >0.60 highlighted in bold. See Table 2 for variable codes.

Variables	ELEVATION	SLOPE	ASPECT	TRCOV	SHCOV	GRCOV	SNAGS	QUCH	TODI	QUKE	ARVI	PIPO	PIAT	HEAR	PSME	CEIN
ELEVATION	1.00															
SLOPE	0.64	1.00														
ASPECT	0.29	0.21	1.00													
TRCOV	0.45	0.28	0.12	1.00												
SHCOV	-0.13	-0.01	-0.20	-0.53	1.00											
GRCOV	-0.66	-0.23	-0.36	-0.35	0.35	1.00										
SNAGS	0.02	-0.29	-0.03	0.03	-0.14	-0.14	1.00									
QUCH	0.04	0.17	-0.19	0.54	-0.50	0.05	-0.16	1.00								
TODI	-0.55	-0.10	-0.48	-0.21	0.32	0.77	-0.12	0.21	1.00							
QUKE	-0.07	0.01	0.07	0.40	-0.17	0.11	-0.01	0.48	0.21	1.00						
ARVI	-0.50	-0.14	-0.12	-0.42	0.39	0.57	-0.31	0.05	0.51	0.41	1.00					
PIPO	-0.21	-0.11	-0.27	0.44	-0.29	0.26	0.19	0.53	0.30	0.57	0.16	1.00				
PIAT	-0.86	-0.55	-0.24	-0.34	0.15	0.50	0.05	0.05	0.41	0.33	0.59	0.31	1.00			
HEAR	-0.71	-0.32	-0.19	-0.55	0.41	0.69	-0.18	-0.13	0.56	0.28	0.81	0.08	0.76	1.00		
PSME	0.32	0.33	-0.05	0.75	-0.49	-0.31	0.06	0.37	-0.16	0.19	-0.37	0.27	-0.32	-0.48	1.00	
CEIN	-0.46	-0.07	-0.48	-0.24	0.10	0.51	-0.15	0.27	0.60	0.34	0.43	0.35	0.48	0.50	-0.30	1.00

Table 19. Univariate bird-habitat model selection results for 11 bird species at Whiskeytown National Recreation Area, 2009, including number of parameters (k), Akaike's Information Criterion corrected for small sample size (AIC_c), model weight, slope of the parameter (β) with confidence intervals (CI), and adjusted R-squared values. Models with $\Delta AIC_c < 10$ and better than a null model are presented. See Table 2 for variable codes.

Model	k	AIC _c	ΔAIC _c	weight	β	95% CI		Adj. R ²
Brown-headed Cowbird								
ELEVATION	2	-38.1007	0.0000	0.2862	-0.0002	-0.0003	0.0000	0.1406
GRCOV	2	-37.3555	0.7452	0.1972	0.3895	0.0296	0.7493	0.1190
QUCH	2	-36.4298	1.6709	0.1241	0.7496	-0.0264	1.5255	0.0914
HEAR	2	-35.6764	2.4243	0.0852	0.9986	-0.1587	2.1559	0.0682
NULL	1	-34.6751	3.4256	0.0516	-	-	-	-
Black-headed Grosbeak								
TRCOV	2	-72.1382	0.0000	0.9536	0.5255	0.3436	0.7073	0.5495
PIPO	2	-65.0422	7.0960	0.0274	1.9233	1.0753	2.7712	0.4246
QUCH	2	-63.8111	8.3271	0.0148	1.0386	0.5577	1.5194	0.3996
Black-throated Gray Warbler								
QUCH	2	16.9374	0.0000	0.9784	4.3293	2.4408	6.2178	0.4206
SHCOV	2	25.2526	8.3153	0.0153	-1.1612	-1.9158	-0.4066	0.2355
Cassin's Vireo								
PSME	2	-47.2392	0.0000	0.3684	1.7686	0.9777	2.5595	0.4173
TRCOV	2	-47.0503	0.1890	0.3352	0.6220	0.3418	0.9023	0.4135
QUCH	2	-46.3534	0.8859	0.2366	1.4021	0.7524	2.0519	0.3992
PIPO	2	-42.8248	4.4144	0.0405	2.2894	1.0457	3.5330	0.3215
SHCOV	2	-40.9807	6.2585	0.0161	-0.4307	-0.6888	-0.1726	0.2769
Hutton's Vireo								
QUKE	2	-111.9295	0.0000	0.9821	0.6981	0.3883	1.0080	0.4211
QUCH	2	-102.6640	9.2655	0.0096	0.3422	0.0962	0.5883	0.2032
Orange-crowned Warbler								
CEIN	2	-62.7064	0.0000	0.9993	6.4415	4.4571	8.4258	0.5984
Spotted Towhee								
TRCOV	2	-20.3519	0.0000	0.9204	-0.8098	-1.1943	-0.4252	0.3777
PSME	2	-14.3668	5.9851	0.0462	-2.0877	-3.4285	-0.7468	0.2403
HEAR	2	-10.7823	9.5696	0.0077	2.0732	0.3209	3.8256	0.1439
PIPO	2	-10.3342	10.0177	0.0061	5.3741	0.6241	10.1241	0.1310
CEIN	2	-9.3825	10.9695	0.0038	0.4303	0.0067	0.8540	0.1030
GRCOV	2	-9.1548	11.1971	0.0034	0.5681	-0.0077	1.1438	0.0961
Oregon Junco								
SLOPE	2	-45.3619	0.0000	0.1314	0.0074	-0.0013	0.0160	0.0663
TRCOV	2	-44.8385	0.5234	0.1011	0.1982	-0.0575	0.4539	0.0498
TODI	2	-44.7718	0.5901	0.0978	0.7996	-0.2462	1.8454	0.0477
PSME	2	-44.6622	0.6997	0.0926	0.6046	-0.2047	1.4138	0.0442
ASPECT	2	-44.6215	0.7405	0.0907	-0.1065	-0.2503	0.0373	0.0429
NULL	1	-44.4245	0.9374	0.0822	-	-	-	-

Table 19 (continued). Univariate bird-habitat model selection results for 11 bird species at Whiskeytown National Recreation Area, 2009, including number of parameters (k), Akaike's Information Criterion corrected for small sample size (AIC_c), model weight, slope of the parameter (β) with confidence intervals (CI), and adjusted R-squared values. Models with $\Delta AIC_c < 10$ and better than a null model are presented. See Table 2 for variable codes.

Model	k	AIC _c	ΔAIC _c	weight	β	95% CI		Adj. R ²
Steller's Jay								
SLOPE	2	-134.4358	0.0000	0.3542	0.0025	0.0006	0.0045	0.1690
CEIN	2	-132.9640	1.4718	0.1697	-0.6867	-1.3020	-0.0715	0.1272
ELEVATION	2	-132.2733	2.1625	0.1201	0.0000	0.0000	0.0001	0.1069
PIAT	2	-130.8393	3.5965	0.0587	-0.4067	-0.8913	0.0779	0.0632
PSME	2	-130.5962	3.8396	0.0519	0.1552	-0.0381	0.3484	0.0555
GRCOV	2	-130.4670	3.9687	0.0487	-0.0597	-0.1359	0.0165	0.0515
NULL	1	-130.0011	4.4346	0.0386	-	-	-	-
Western Tanager ¹								
QUCH	2	-112.2743	0.0000	0.5613	0.3016	0.0986	0.5045	0.2433
TRCOV	2	-109.6903	2.5839	0.1542	0.1051	0.0183	0.1918	0.1673
SHCOV	2	-107.4432	4.8311	0.0501	-0.0706	-0.1458	0.0047	0.0951
HEAR	2	-106.7496	5.5247	0.0354	-0.2543	-0.5565	0.0480	0.0715
QUKE	2	-106.6188	5.6555	0.0332	0.2481	-0.0537	0.5499	0.0670
SLOPE	2	-105.8908	6.3834	0.0231	0.0021	-0.0009	0.0051	0.0415
NULL	1	-105.8593	6.4149	0.0227	-	-	-	-
Wrentit ¹								
CEIN	2	-91.9993	0.0000	0.6268	2.4558	1.3473	3.5642	0.4223
TRCOV	2	-90.2595	1.7398	0.2626	-0.2805	-0.4167	-0.1443	0.3853
ARVI	2	-86.3907	5.6086	0.0380	0.3022	0.1248	0.4796	0.2942
HEAR	2	-86.1571	5.8422	0.0338	1.0077	0.4082	1.6073	0.2883
GRCOV	2	-85.7800	6.2193	0.0280	0.2625	0.1029	0.4221	0.2787

¹Outlier(s) with Cooks distance > 0.5 removed from model

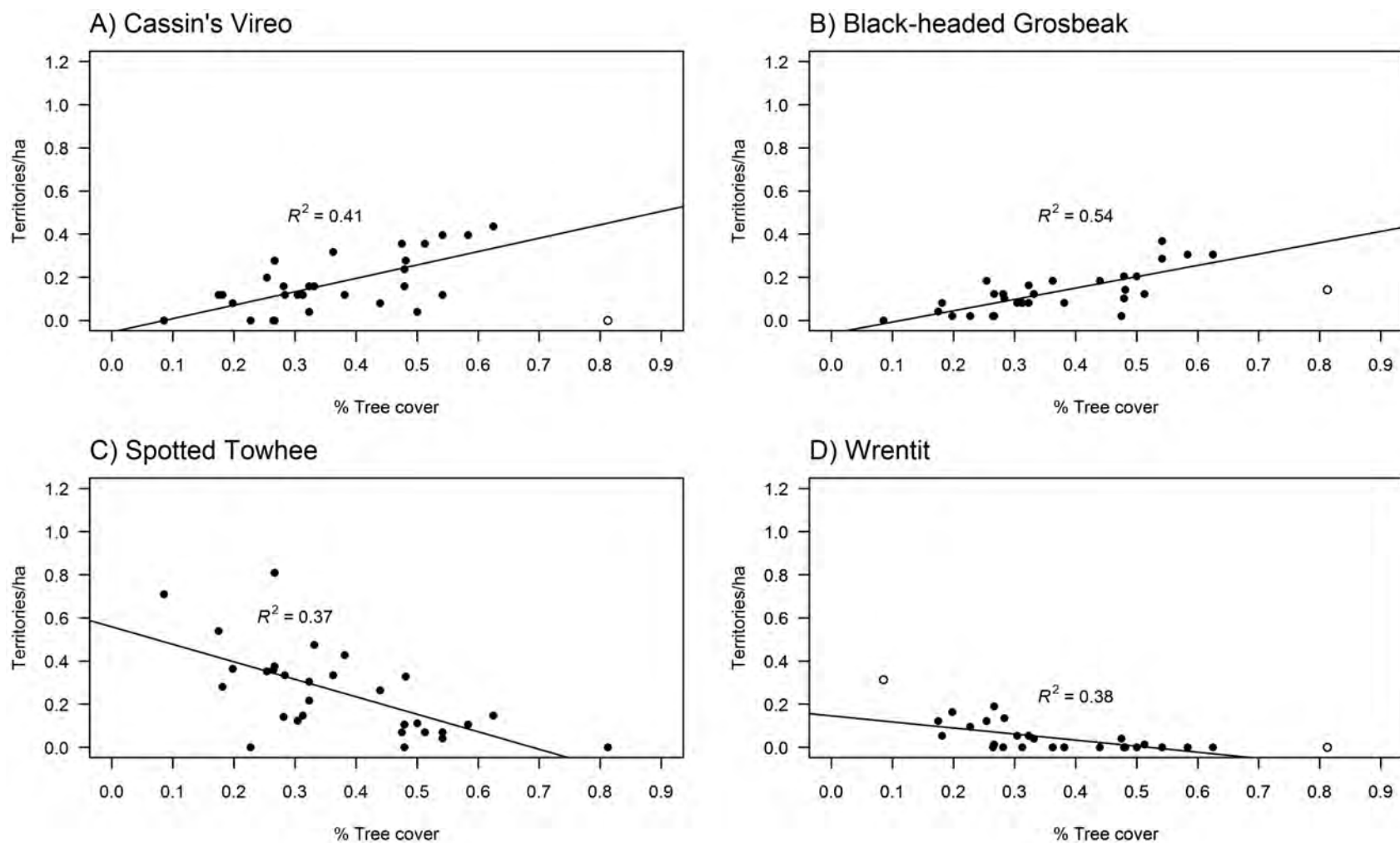


Figure 13. Vegetation structure was important for four species at Whiskeytown National Recreation Area, 2009. Cassin's Vireo and Black-headed Grosbeak were positively associated with tree cover (A, B) and Spotted Towhee and Wrentit, were negatively associated with tree cover (C, D). Open circles indicate outliers excluded from the regression.

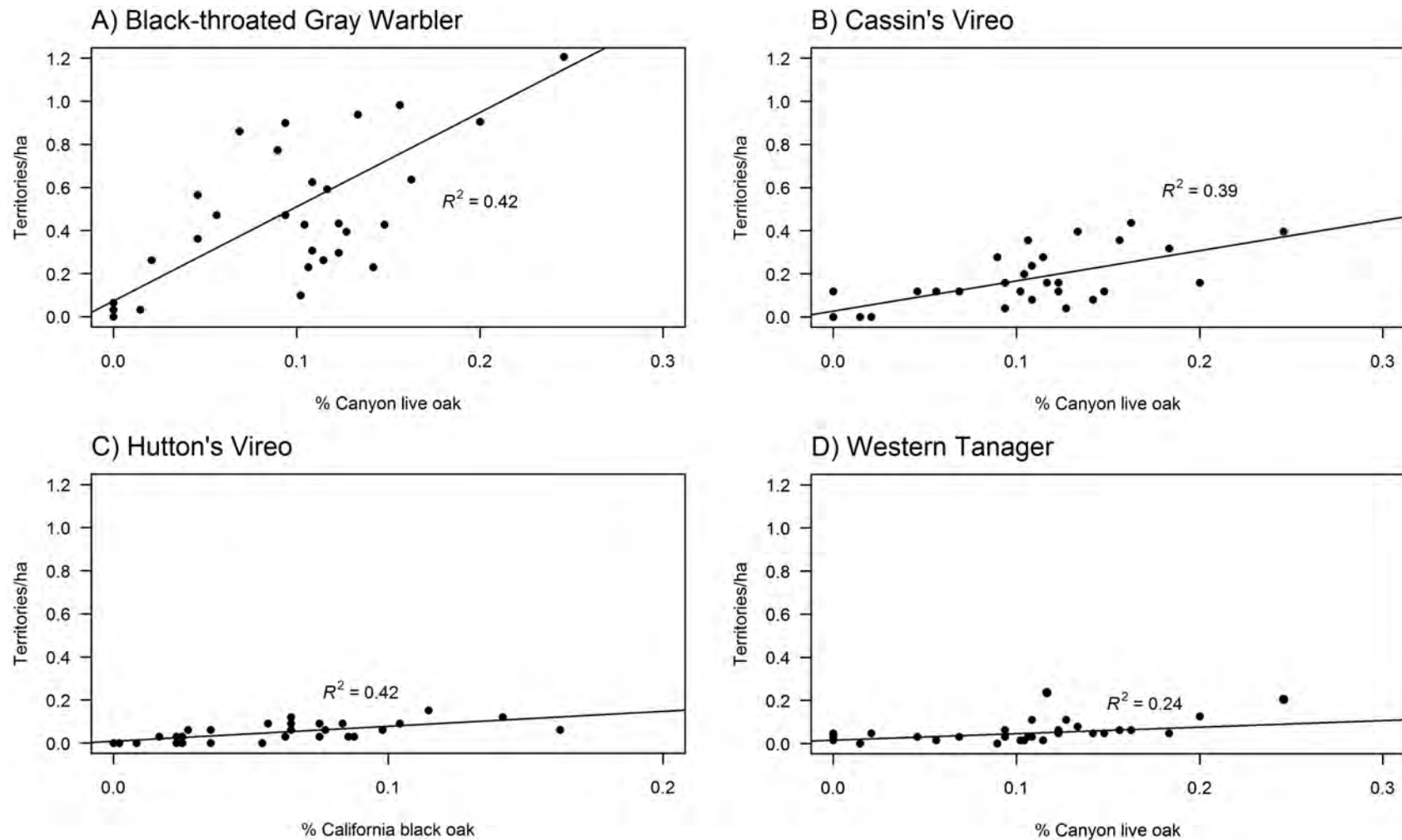


Figure 14. Four species, the Black-throated Gray Warbler (A), Cassin's Vireo (B), Hutton's Vireo (C), and Western Tanager (D), were positively associated with oak species at Whiskeytown National Recreation Area, 2009.

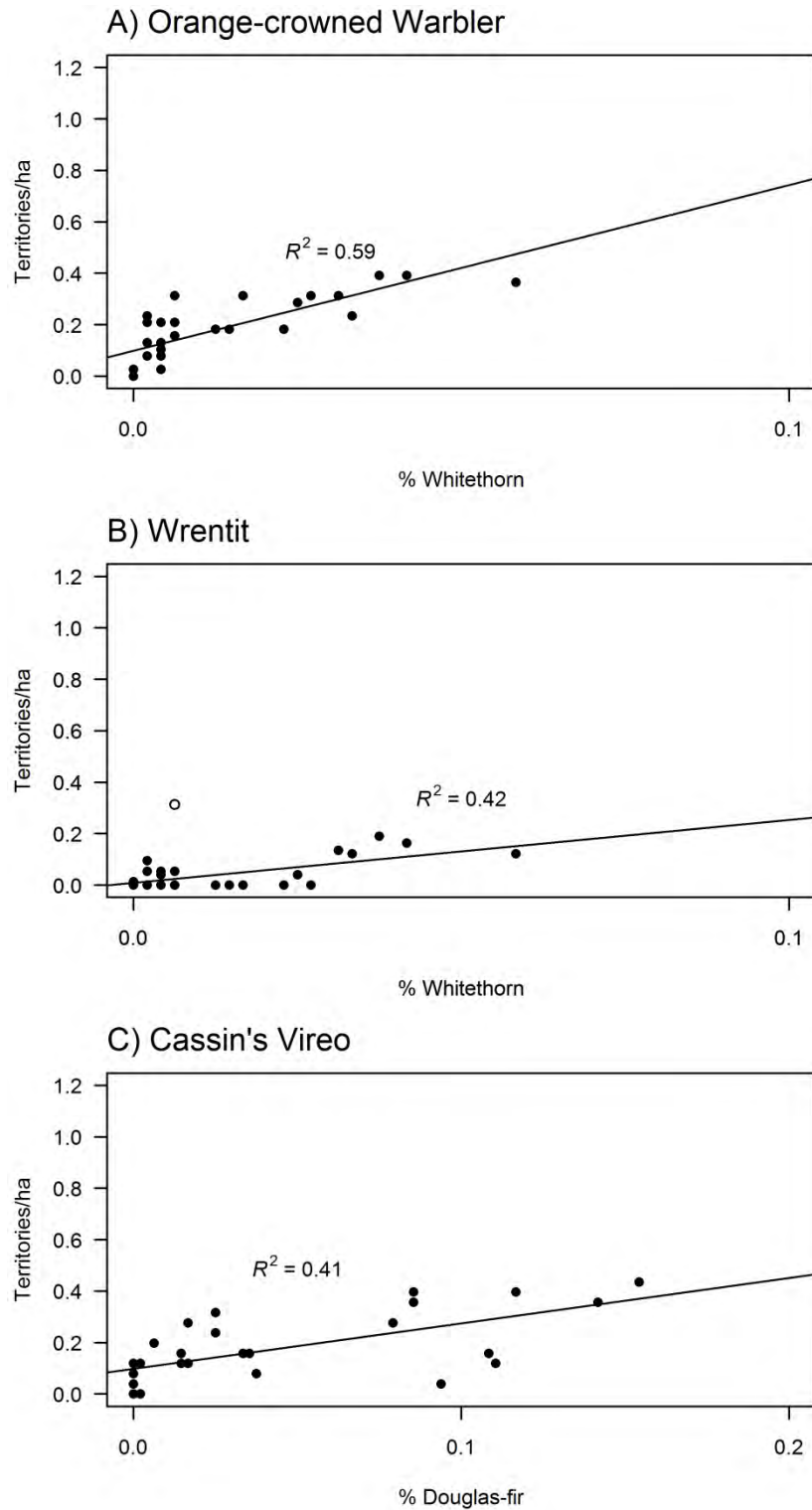


Figure 15. Orange-crowned Warbler and Wrentit had a positive association with whitethorn (A, B). Equally well supported as tree cover and oak, Cassin's Vireos were positively associated with conifer species (C). Open circles indicate outliers excluded from the regression.

Synthesis Across Parks

Several species occurred at more than one park, and we examined similarity of habitat associations across different parks. At both LAVO and RNSP, Wilson's Warblers showed positive associations with shrub cover (Figure 16). Indicative of a similar habitat selection, Spotted Towhees were negatively associated with tree cover at WHIS and positively associated with shrub cover at LABE. At both high elevation parks, CRLA and LAVO, Mountain Chickadees were negatively associated with elevation (Figure 17A). American Robins were negatively associated with tree cover (Figure 17B), and Brown Creepers were positively associated with snags (Figure 17C). Other, species such as the Audubon's Warbler and Oregon Junco, showed different habitat associations at CRLA and LAVO, perhaps related to different sampling frames. The majority of species showed no clear habitat associations across parks, including Brown-headed Cowbirds, Golden-crowned Kinglets, Hermit Warblers, Red-breasted Nuthatches, Steller's Jays, Townsend's Solitaires, and Western Tanagers.

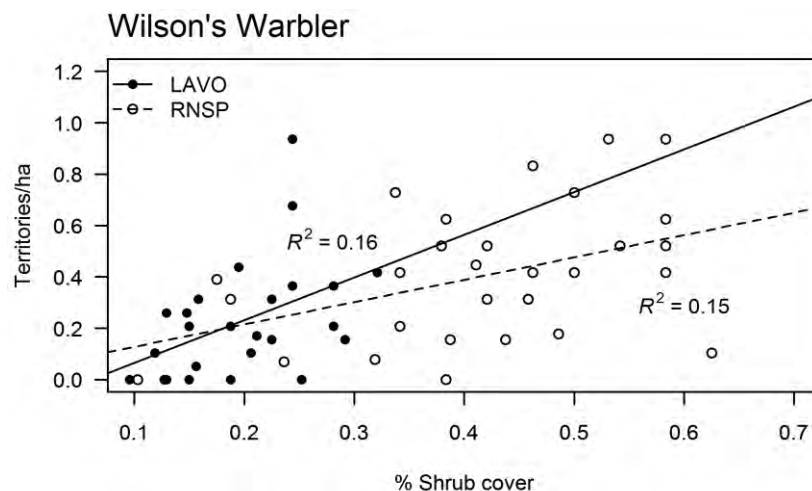


Figure 16. Wilson's Warblers were positively associated with shrub cover at parks that surveyed riparian or mesic coniferous forest.

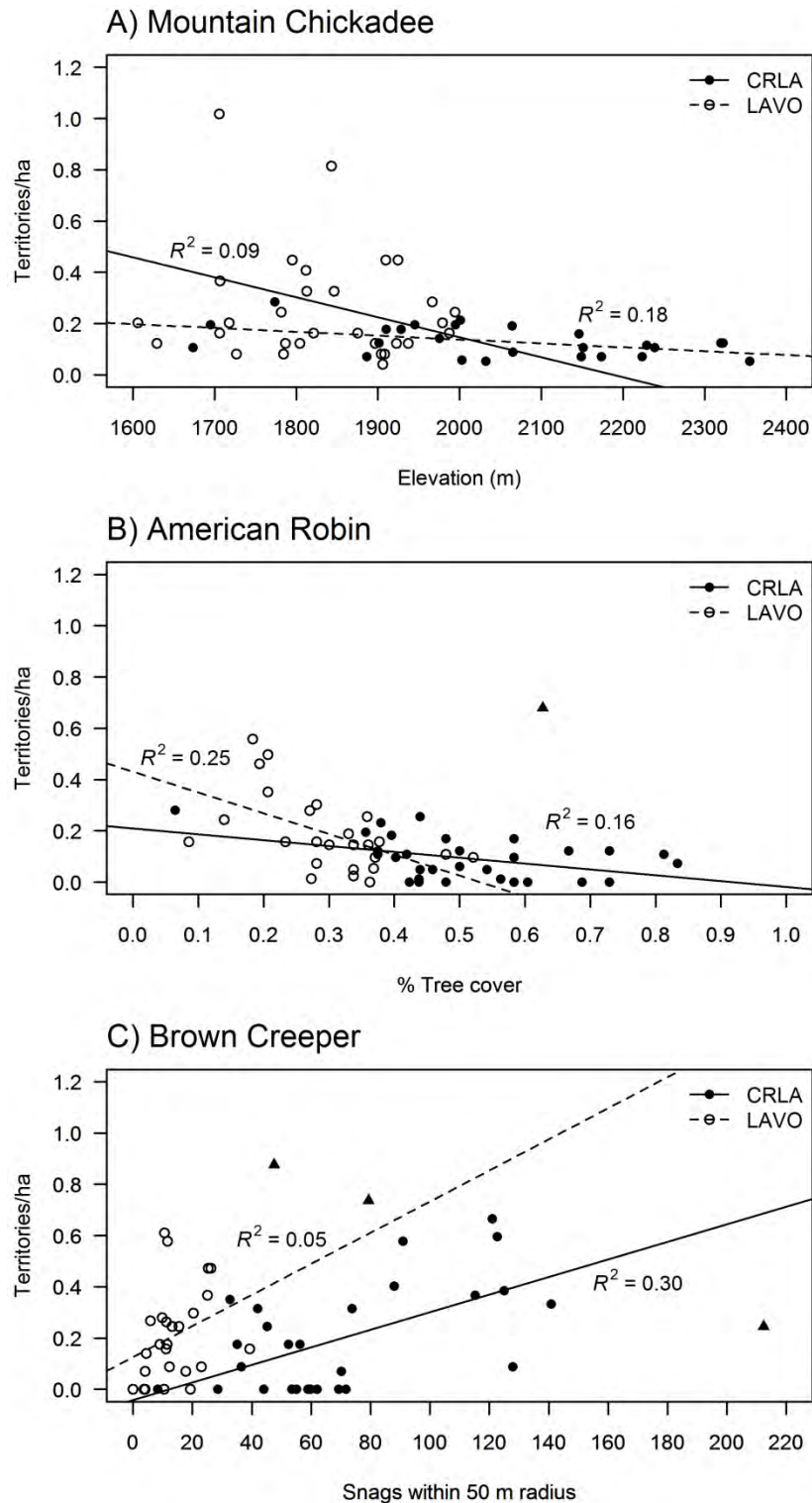


Figure 17. At both high elevation parks, Mountain Chickadees were less abundant at high elevation subalpine sites (A). An open canopy species, American Robins were negatively associated with tree cover (B), and Brown Creepers tended to be positively associated with snags (C), which this species uses for both nesting and foraging. Triangles indicate outliers excluded from the regression.

Discussion

Bird-habitat associations identified for parks in the Klamath Network generally agree with existing information on species-specific habitat requirements in the region (Table 20). Densities of individual bird species at five parks showed site-specific relationships with topographical, structural, and floristic parameters, relating to characteristics important for foraging and nest sites. In this analysis we examined bird associations with specific on-site topographic and microhabitat features; although, overall occurrence of different habitat types at the landscape scale may have been an additional factor structuring spatial patterns in populations, and therefore, density (e.g. Betts et al. 2010).

Of the topographical features included in analyses, elevation was among the important factors structuring bird (and plant) communities among parks. Elevation can be a proxy for large scale differences in climate as well as smaller scale differences in vegetation from relatively wet valley bottoms to drier ridges. The effect of elevation was especially apparent at LAVO where coniferous forest species were associated with higher elevation areas, and riparian species were found at lower elevation. At LABE, density of Western Scrub-Jays increased at higher elevations with the transition from shrub-steppe to juniper in the park. Orange-crowned Warblers, Wrentits, and Brown-headed Cowbirds were only found at lower elevation chaparral sites in WHIS, and not at higher elevation mixed conifer areas of the park. The Mountain Chickadee is generally considered a montane forest bird, but this species was less abundant at high elevation subalpine sites at CRLA and LAVO. Selecting nest-sites in warmer locations (Wachob 1996), this chickadee species could be limited by low temperatures at high elevation, although decreased tree cover could also be a confounding factor. In any case, current conditions appear to limit its abundance at the highest elevations. Long-term monitoring at parks might help track any altitudinal shifts in this or other high elevation bird species as climate changes over time. Northward range expansions have been documented in a number of North American landbird species (Hitch and Leberg 2007), and extensive community reshuffling is predicted for areas with high diversity such as the Klamath Mountains (Stralberg et al. 2009).

Foraging and nest sites are both important components of habitat selection (Martin 1995) which may explain many of the structural habitat associations of birds at the parks. Several canopy-nesting and foraging species were associated with tree cover in both coniferous forest and oak woodland, including the Audubon's Warbler, Cassin's Vireo, and Black-headed Grosbeak. In shrub-steppe and chaparral, total shrub cover, and cover of individual shrub species were important for several shrub-nesting and foraging species, including the Spotted Towhee, Lazuli Bunting, Wrentit, and Wilson's Warbler. Ground cover was important for ground-nesting and foraging species, including the Lincoln's Sparrow and Oregon Junco. Few woodpecker species were abundant enough to examine in this analysis, but the Brown Creeper, which nests in loose bark on snags or older trees, was positively associated with numbers of snags at both high elevation parks. Interestingly, American Robins were negatively associated with tree cover, and also negatively associated with shrub cover. This ground foraging but tree nesting generalist species seems adapted to open parkland from high elevation subalpine woodland to open lawns and gardens.

Table 20. Summary of habitat associations found in this study and conservation focus for Partner's in Flight focal species in the region.

Focal species	Habitat association (this study)	Conservation focus
Brown Creeper	Snags (CRLA, LAVO)	Large trees, snags
Brewer's Sparrow ¹	Rabbitbrush, sagebrush (LABE)	Depends on big sagebrush habitats
Black-throated Gray Warbler ¹	Canyon live oak (WHIS)	>20% deciduous canopy cover
Hutton's Vireo	California black oak (WHIS)	>20% deciduous cover in subcanopy/understory (trees and shrubs)
Lincoln's Sparrow	Ground cover (LAVO)	Montane wet meadows, interspersed of herbaceous and woody
Oregon Junco	Ground cover (LAVO)	Herbaceous understory
Pacific-slope Flycatcher ¹	Coastal redwood (RNSP)	>20% deciduous canopy cover; riparian buffer >40 m
Pacific Wren ¹	Coastal redwoods (RNSP)	Late-successional forest, forest floor complexity
Red-breasted Nuthatch	Tree cover (CRLA)	Large trees
Spotted Towhee	Bitterbrush (LABE), Tree cover (negative WHIS)	Prefers tall, dense shrublands
Varied Thrush ¹	Coastal redwood, ferns (RNSP)	Multi-layered, structural diversity
Warbling Vireo	Elevation (LAVO)	Large deciduous trees associated with streams, semi-open canopy
Western Meadowlark	Ground cover, grass (LABE)	Sagebrush - grasslands
Western Scrub-Jay ¹	Elevation (LABE)	Acorns
Wilson's Warbler	California huckleberry (RNSP), elevation (LAVO)	>40% cover in deciduous shrub layer; riparian buffer >40 m
Wrentit ¹	Whitethorn (WHIS)	Shrubs (including chaparral, coastal scrub, and riparian)

¹Also a stewardship species with >50% of the population in the region

For open cup nesters, associations with snags may be related to disturbance. Snags at CRLA and LAVO may be indicative of a range of disturbance from large-scale episodic events such as fire and pine-bark beetle mortality (e.g. Morrison and Raphael 1993) to small-scale individual tree death in gap-phase dynamics (e.g. Lertzman and Krebs 1991). Bird species associated with snags at the parks, such as the Pine Siskin and Western Wood-Pewee, are known to prefer open canopies (Dawson 1997, Bernis and Rising 1999). Similar to our results at CRLA, numbers of Pine Siskins may be high with up to 50 individuals of this loosely colonial breeding species recorded on high elevation Breeding Bird Survey routes (Dawson 1997). Oregon Junco associations with snags at CRLA might suggest this species also benefits from disturbance, and juncos have been found to respond positively to harvest openings in high elevation coniferous forest (Leupin et al. 2007). However, we did not find the same associations at LAVO, where this species was positively associated with ground cover.

Floristics may also be a factor in habitat selection (Seavy and Alexander 2007, Hewson et al. 2011) and in a number of parks species density was associated with floristics. Several species, such as the Black-throated Gray Warbler, showed strong floristic preferences. Black-throated Gray Warblers have been found in association with a number of tree species in different regions (Guzy and Lowther 1997), perhaps related to foraging preferences. Four species, the Pacific-Slope Flycatcher, Pacific Wren, Chestnut-backed Chickadee, and Varied Thrush, were positively associated with coastal redwoods, highlighting their importance as habitat for mesic coniferous forest associated birds. At higher elevations Chestnut-backed Chickadees are actually known to forage on Douglas-fir (Dahlsten. et al. 2002), and negative associations with Douglas-fir at RNSP in this study may have been related to elevation. Typically a shrub-steppe species, Brewer's Sparrows were associated with big sage at LABE.

Models presented best explain bird density based on the data collected, but the strength of different habitat associations depends on the availability and heterogeneity of habitats sampled within the park. Inferences from these models to other areas may be limited in scope because of the scale of sampling (e.g. Wiens et al. 1987, Fielding and Haworth 1995). Within each park a number of environmental gradients are less well reflected. For example, Golden-crowned Kinglets are known to avoid fire-dependent lodgepole pine (Ingold and Galati 1997), although in our analysis this was a relatively weak association likely because of limited sampling of lodgepole pine forest. Similarly, while Rock Wrens (*Salpinctes obsoletus*) were abundant at LABE the lack of association was likely because rocky outcrops from lava flows, a characteristic they are presumably associated with, were not quantified. In addition, with only one year of data for each park, the temporal consistency of habitat associations identified in this report remains to be determined. Overall bird-habitat associations should be considered with caution based on a clear ecological interpretation, and results from other studies. Ultimately studies across broad spatial scales or experimental studies are needed in order to make inference outside of the parks.

Providing a foundation for understanding population trends from long-term monitoring at the parks, these results describe baseline habitat conditions, bird species, and habitat requirements of those species at each park. Results from this work can be used to identify key habitat features for birds within the parks, as well as help to inform management decisions and conservation strategies. The relationship of individual bird species with floristics may provide new

information that is park specific, which could be particularly informative in the context of land management decisions. Integration of bird monitoring and intensive vegetation data collection in the future may be used to refine these habitat models to include more detailed parameters (e.g. stand density, tree height, and dbh, wood debris, etc).

Partners in Flight focal species for which habitat associations were found are particularly useful in understanding habitat availability within a park, as well as the value of the park to preserve habitat for suites of species. When facing management decisions, park managers can use results to understand current conditions, and within the context of Partner's in Flight conservation plans, understand both bird and habitat implications from management actions. Brown Creepers provide an excellent example; a Partner's in Flight focal species generally quite flexible in forest type preferences but strongly associated with large trees and snags. Dependent on bark for both foraging and nesting, creepers are sensitive to management that reduces this habitat attribute. Our results are consistent with this established habitat association, showing density positively correlated with number of snags at both CRLA and LAVO. Management of forests at both parks should maintain snags and large trees to the extent possible while meeting management goals. For example, when planning fuel reduction or prescribed burning in coniferous forests, selecting treatments that preserve snags would be particularly important for a suite of species that nests in cavities and forage on bark. Monitoring a suite of species, including Brown Creepers, before and after management provides a metric to evaluate whether treatments accomplished the desired effect.

Although multiple complex factors influence avian habitat selection, identifying important features for individual species as well as groups of species remains critical to protecting and managing important areas for conservation, such as National Parks. Results can be used to inform park specific management decisions, such as fuel management, invasive species removal, and restoration. In addition, results will be helpful in interpreting potential causal factors associated with long-term population trends.

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Appendix A

Common and scientific names of species included in this report and parks for which habitat associations were examined.

Common Name	Scientific Name	CRLA	LAVO	LABE	RNSP	WHIS
American Robin	<i>Turdus migratorius</i>	X	X			
Audubon's Warbler	<i>Setophaga coronata auduboni</i>	X	X			
Brown-headed Cowbird	<i>Molothrus ater</i>			X		X
Black-headed Grosbeak	<i>Pheucticus melanocephalus</i>					X
Brown Creeper	<i>Certhia americana</i>	X	X		X	
Brewer's Sparrow	<i>Spizella breweri</i>			X		
Black-throated Gray Warbler	<i>Setophaga nigrescens</i>					X
Cassin's Vireo	<i>Vireo cassinii</i>					X
Chestnut-backed Chickadee	<i>Poecile rufescens</i>				X	
Clark's Nutcracker	<i>Nucifraga columbiana</i>	X				
Golden-crowned Kinglet	<i>Regulus satrapa</i>	X	X		X	
Gray Jay	<i>Perisoreus canadensis</i>	X				
Hermit Thrush	<i>Catharus guttatus</i>	X				
Hermit Warbler	<i>Setophaga occidentalis</i>	X			X	
Hutton's Vireo	<i>Vireo huttoni</i>				X	X
Lazuli Bunting	<i>Passerina amoena</i>			X		
Lincoln's Sparrow	<i>Melospiza lincolnii</i>		X			
Mountain Chickadee	<i>Poecile gambeli</i>	X	X			
Mourning Dove	<i>Zenaidura macroura</i>			X		
Orange-crowned Warbler	<i>Oreothlypis celata</i>					X
Oregon Junco	<i>Junco hyemalis oregonus</i>	X	X			X
Pine Siskin	<i>Spinus pinus</i>	X	X			
Pacific-slope Flycatcher	<i>Empidonax difficilis</i>				X	
Red-breasted Nuthatch	<i>Sitta Canadensis</i>	X	X			
Red Crossbill	<i>Loxia curvirostra</i>	X				
Rock Wren	<i>Salpinctes obsoletus</i>			X		
Spotted Towhee	<i>Pipilo maculatus</i>			X		X
Steller's Jay	<i>Cyanocitta stelleri</i>	X	X		X	X
Swainson's Thrush	<i>Catharus ustulatus</i>				X	
Townsend's Solitaire	<i>Myadestes townsendi</i>	X	X			
Varied Thrush	<i>Ixoreus naevius</i>				X	
Warbling Vireo	<i>Vireo gilvus</i>		X			
Western Meadowlark	<i>Sturnella neglecta</i>			X		
Western Scrub-Jay	<i>Aphelocoma californica</i>			X		
Western Tanager	<i>Piranga ludoviciana</i>	X	X			X
Western Wood-Pewee	<i>Contopus sordidulus</i>		X			
Wilson's Warbler	<i>Cardellina pusilla</i>		X		X	
Pacific Wren	<i>Troglodytes pacificus</i>				X	
Wrentit	<i>Chamaea fasciata</i>					X

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