WESTERN BIRDS

Volume 42, Number 1, 2011

ELEVATION RANGES OF BIRDS ON THE SIERRA NEVADA'S WEST SLOPE

RODNEY B. SIEGEL, ROBERT L. WILKERSON, JAMES F. SARACCO, and ZACHARY L. STEEL, The Institute for Bird Populations, P. O. Box 1346, Point Reyes Station, California 94956; rsiegel@birdpop.org

ABSTRACT: Published estimates of elevation ranges of Sierra Nevada birds are based primarily on anecdotal observations and professional opinion rather than systematic surveys. Continuing climate change is likely to alter the elevation ranges of Sierra bird species, and is perhaps already doing so, but published data are inadequate for describing elevation ranges rigorously. We present elevation ranges of 75 common Sierra Nevada birds based on data from Sequoia and Kings Canyon national parks in the southern Sierra Nevada and Yosemite National Park in the central Sierra Nevada. The mean elevation of a species was significantly higher at Sequoia/Kings Canyon than at Yosemite, by an average of 103 m. When we excluded species restricted to low-elevation habitats that are better represented at Sequoia/Kings Canyon than at Yosemite, and species that disperse upslope and we detected well above their likely breeding ranges, the mean difference between the two areas in the mean elevation of the remaining 59 species was even greater, 219 m. These descriptions of elevation ranges will facilitate future assessments of range shifts, and, more immediately, will provide managers of more intensively managed lands in the Sierra Nevada outside the parks with reference information from the relatively pristine parks.

Climate-change models suggest that by late in the 21st century, the average annual temperature in the Sierra Nevada of California could increase by as much as 3.8°C beyond that at the beginning of the century (Snyder et al. 2002). More precipitation will fall as rain rather than as snow, and the spring snowpack may decline by up to 30–70% (Hayhoe et al. 2004, Franco et al. 2006). Some scenarios suggest that the frequency of wildfire, which has already increased over the past several decades (Westerling 2006), may increase in northern California as much as 90% over that from 1961 to 1990 (Franco et al. 2006). Throughout the Sierra, the composition of plant communities is projected to change substantially, with losses of 60–80% of the subalpine and alpine ecosystems over the same time period (Hayhoe et al. 2004, Franco et al. 2006). These interrelated phenomena—increased temperature, decreased snowpack, altered fire regimes, and shifting plant communities—will likely alter the ranges of Sierran bird species and restructure bird assemblages (Stralberg et al. 2009).

Around the world, the ranges of many species of plants and animals that are restricted to mountaintops have contracted severely, and the first populations and even species that have been extirpated because of climate change are of mountaintop biota (Parmesan 2006). Mountain-dwelling birds have already responded to climate change in many parts of the world by shifting their ranges upslope (Pounds et al. 1999, Root et al. 2003, 2005). In the Sierra Nevada, Tingley et al. (2009) found evidence that the distributions of many bird species have changed during the past century, with distributions generally tracking species' preferred temperature and/or precipitation conditions over time.

The boundaries of many birds' ranges are correlated with climatic factors (Bohning-Gaese and Lemoine 2004), particularly at the upper latitudinal and elevational boundaries, where cold temperatures may impose physiological constraints (Root 1988, Root and Schneider 1993, Newton 2003). At lower latitudinal and elevational limits biotic factors such as competition and predation may be more important than abiotic factors, but physiological constraints associated with heat stress or water limitation may play a role there as well (Bohning-Gaese and Lemoine 2004).

Occurrence data can yield important insights into historical change (Tingley and Beissinger 2009), and a clear snapshot of the current occurrence patterns and elevational distributions of Sierra birds will facilitate understanding how birds respond to current and future climate change in the Sierra Nevada. Existing characterizations of the elevation ranges of Sierra Nevada birds (Gaines 1992, Siegel and DeSante 1999, Stock and Espinoza 2009) are based primarily on anecdotal observations and professional opinion rather than systematic surveys. Here we describe the elevation ranges of common Sierra Nevada birds on the basis of recent data from national parks on the west slope of the southern and central Sierra Nevada. These descriptions will facilitate future assessments of shifts in these elevation ranges and, more immediately, will provide managers of more intensively managed Sierra lands outside the parks with better reference information from more pristine park ecosystems. Serving as "reference sites" for assessing the effects of regional land-use and land-cover changes is a major role of the national park system (Silsbee and Peterson 1991, Simons et al. 1999).

METHODS

Study Area

We studied the distribution of birds in Yosemite and Sequoia and Kings Canyon national parks. Sequoia and Kings Canyon are contiguous and managed as one unit by the National Park Service. Both areas lie on the western slope of the Sierra Nevada, and both contain large tracts of mid-elevation and subalpine conifer forest, as well as substantial acreage of chaparral, oak woodland, meadows, and alpine plant communities. Yosemite's total area is 308,074 ha, extending from the upper foothill zone to the Sierra crest. Sequoia/Kings Canyon is slightly larger, comprising 350,843 ha, and also extends from the foothills to the Sierra crest but differs from Yosemite in that its western boundary is considerably lower, and it includes more area dominated by foothill plant communities.

The Sierra Nevada extends over 600 km from north to south and so has a substantial north–south gradient in the elevational boundaries of various forest types. On the basis of data from Yosemite in the central Sierra and Sequoia/Kings Canyon in the southern Sierra, we were able to characterize birds' elevation ranges in two distant areas spanning a large swath of this gradient.

Sample Design

As part of the National Park Service's Inventory and Monitoring Program, we counted birds at points away from trails in Yosemite in 1999 and 2000 and in Sequoia/Kings Canyon in 2003 and 2004. We established count points in a geographic information system (GIS) by randomly selecting starting points for transects of point counts. We constrained the starting points to within 2 km of a trail or road, a buffer that encompassed 71% and 83% of the park's total area at Sequoia/Kings Canyon and Yosemite, respectively. Observers hiked to starting points, where they counted birds, then randomly selected a cardinal or semi-cardinal direction of travel. The observer made up to 11 additional point counts (as many as he or she could complete within 3.5 hours of local sunrise), spaced 250 m apart, along the direction of travel, unless the route was blocked by an obstacle such as a cliff or uncrossable stream. When the observer encountered such an obstacle, he returned to the previous count point, then changed his direction of travel clockwise to the next cardinal or semi-cardinal direction that would permit continued travel.

Data Recording

Prior to the start of the field season each year, all observers participated in a rigorous 2-week training program in bird identification and point-count methods and were required to pass a certification exam that tested their ability to identify virtually all birds occurring regularly in the Sierra Nevada by sight and sound.

At Sequoia/Kings Canyon, our surveys took place from 14 May to 20 July, at Yosemite from 18 May to 28 July. Within each park, we surveyed lower-elevation transects first, moving to higher-elevation transects as the season progressed and most snow melted. Point counts lasted 5 min, during which observers recorded all birds detected by sight or sound at any distance. Distances to each bird were estimated and recorded but were not used in the analysis we report here.

Observers used hand-held Global Positioning System units and topographic maps to determine the coordinates of each count point. Later, using GIS, we extracted elevations of count points from digital elevation models of the parks (resolution 10 m). Coordinates described the points' locations rather than the birds' actual locations, likely introducing a small amount of random error into our results, as individual birds could have been upslope or downslope from the point.

Data Analysis

We used data from 2599 point counts along 273 transects at Yosemite (Figure 1) and 1732 point counts along 224 transects at Sequoia/Kings Canyon (Figure 2). Elevation of count points ranged from 1146 to 3673 m (mean 2382 m) at Yosemite and from 314 to 3880 m (mean 2527 m) at Sequoia/Kings Canyon. Transects were well distributed across the area and elevation gradient within each park (Figures 1 and 2).

We categorized each species detected at least 20 times at either Yosemite or Sequoia/Kings Canyon, as either detected or not detected at each count point, then calculated summary statistics to describe the range of elevations at which the species was detected in each park: the mean elevation of detection and its standard deviation, as well as the upper and lower quantiles encompassing 95% of detections. Our threshold of 20 detections was somewhat arbitrary, but inspection of the data indicated that species with at least 20 detections had distributions that consistently spanned the range of elevations where our field experience in the parks suggests they occur. We estimated quantiles by interpolation with method 7 (the default method) of the quantile function in R (see Hyndman and Fan 1996 for details). We used two-tailed paired *t* tests to compare the mean elevation of count points where a species was detected in the two parks, with mean elevations of detection of each species representing matched pairs.

We graphed the distribution of stations with and without detections of each species by means of bean plots, which we generated with the "beanplot" package (Kampstra 2008) in R version 2.9.2 (R Development Core Team 2009). Bean plots facilitate comparison of distributions of data points by displaying the data simultaneously with density traces of the data. Here we used asymmetrical bean plots to show elevational distributions of points with detections of each species alongside the distributions of points without detections at each park. Individual data points (i.e., count points) in the bean plots were represented by short line segments displayed as a one-dimensional scatterplot, or strip chart. Elevations represented by multiple points were displayed as longer lines representing the summed lengths of the line segments for the various count points. The sizes and shapes of density traces in bean plots reflect the distributions of data along the elevation gradients and a bandwidth (smoothing) parameter whose value we determined by the Shaether–Jones method (Shaether and Jones 1991). The width of the density trace (along the *x* axis) is selected by an algorithm that incorporates the sample size and the distribution of values to generate a shape that illustrates relative differences (within a species) in density of detections (or non-detections) at various elevations. The shape of the density trace reflects not the ratio between detections and non-detections at a given elevation but the proportion of detections or non-detections at that elevation with respect to the entire elevational distribution of points of detection or non-detection—the reason why the traces for detection and non-detection are not exactly complementary. See Venables and Ripley (2002:126–129) for additional detail on density traces and their implementation in R.

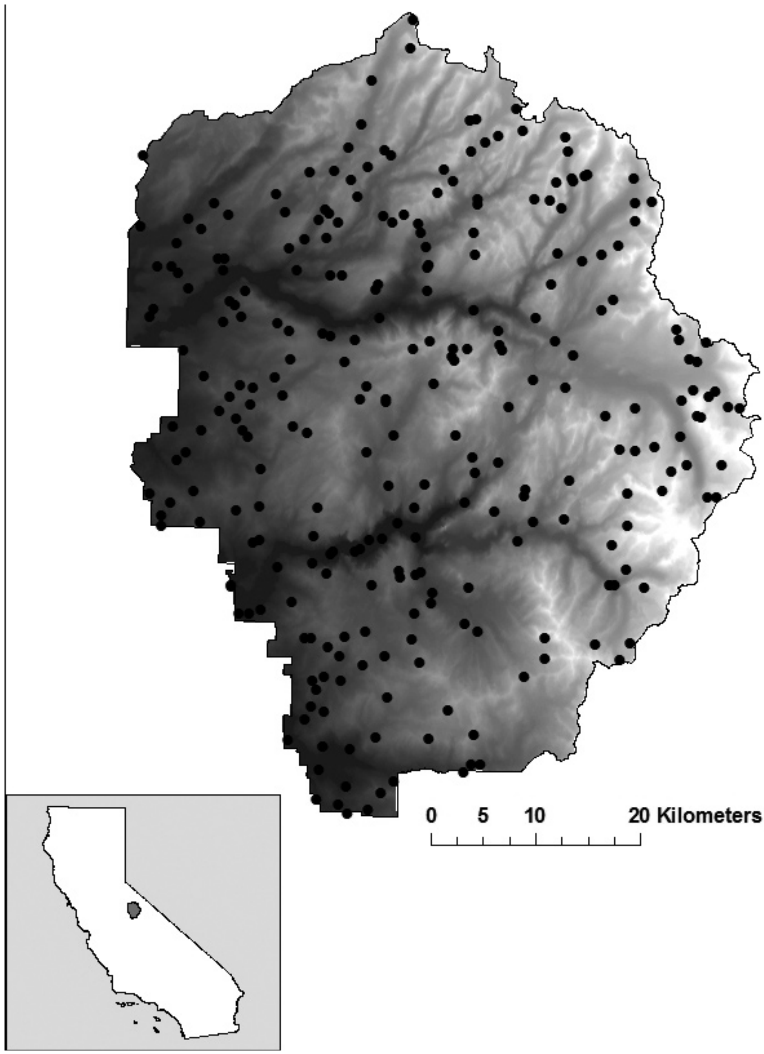


Figure 1. Locations of 273 point-count transects (black circles) surveyed at Yosemite National Park in 1999 and 2000. Each transect comprised 7–12 point counts spaced 250 m apart. Background shading indicates elevation, with lowest elevations in the park indicated with dark gray and highest elevations indicated with white. Inset map shows the location of Yosemite National Park within California.

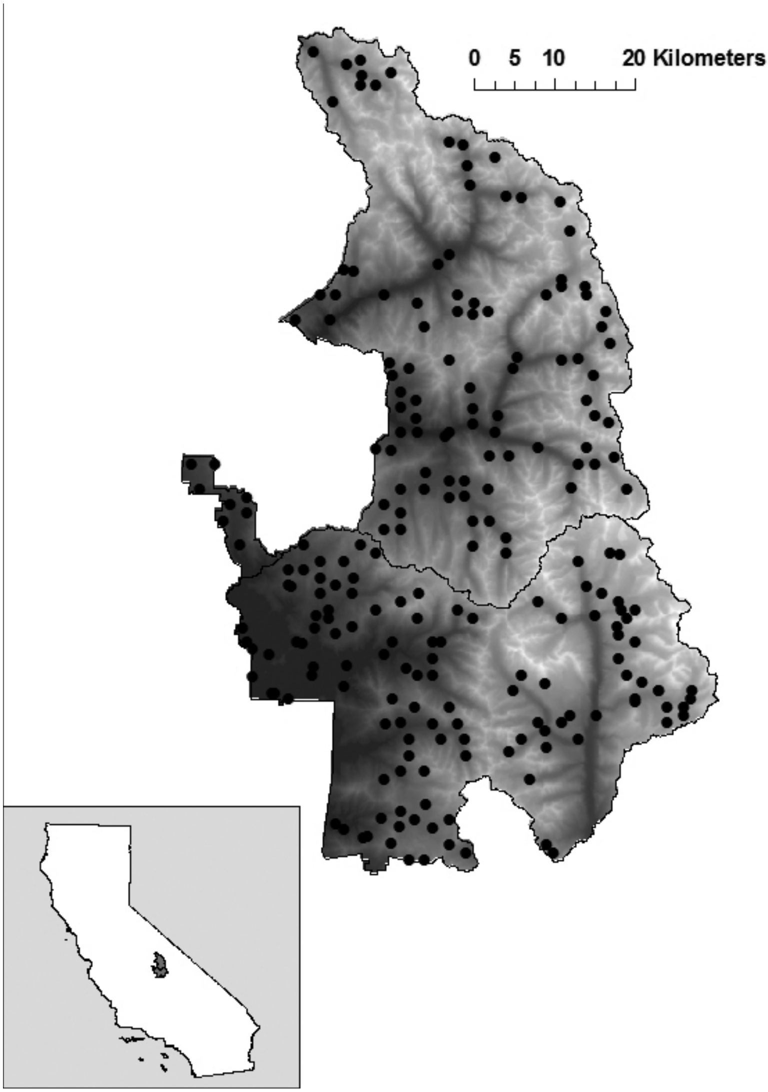


Figure 2. Locations of 224 point-count transects (black circles) surveyed at Sequoia and Kings Canyon national parks in 2003–2004. Each transect comprised 7–12 point counts spaced 250 m apart. Background shading indicates elevation, with lowest elevations in the park indicated with dark gray and highest elevations indicated with white. Inset map shows the location of Sequoia and Kings Canyon national parks within California.

RESULTS

Seventy-five species met our threshold of at least 20 point counts with detections in either Yosemite or Sequoia/Kings Canyon. Table 1 presents the summary statistics describing the observed elevation ranges of each. Figure 3 contains the bean plots indicating actual detections and density traces of distributions of each species at each park.

The mean elevation of detection of the 74 species detected at both Yosemite and Sequoia/Kings Canyon (the California Quail was not detected during surveys at Yosemite) was significantly higher at Sequoia/Kings Canyon than at Yosemite (two-tailed paired t test; $t = 2.38$, df = 73, $P = 0.02$), by an average of 103 m (standard error 43 m). This difference cannot be explained simply by the mountain peaks at Sequoia/Kings Canyon being higher than at Yosemite, as only a few species were detected at Sequoia/Kings Canyon at elevations higher than the highest survey stations at Yosemite, and those only in low numbers. However, two groups of species, described below, may present special cases that could confound the comparison of elevation ranges in the two parks.

Low-Elevation Species

Because Sequoia/Kings Canyon has much more extensive (and lower-elevation) foothill habitat than does Yosemite, several species (California Quail, Acorn Woodpecker, Ash-throated Flycatcher, Western Scrub-Jay, Oak Titmouse, Bewick's Wren, Wrentit, and California Towhee; see Table 1 for scientific names) had mean elevations of detection at Sequoia/Kings Canyon that were lower than the lowest count point at Yosemite (Figure 3).

Upslope Migrants

In the Sierra Nevada, many species of birds disperse upslope in mid-to-late summer after nesting (Gaines 1992). We made no attempt to verify that the individual birds detected during point counts were local breeders. Most of our detections were of singing birds that, on the basis of the seasonal timing of our surveys, were likely still on breeding territories. However, individuals of some species can remain fairly conspicuous as they move upslope from their breeding territories and could have been counted by surveyors. Elevation profiles of eight species that are known (e.g., Gaines 1992) to move well upslope of the breeding range in the late summer after the breeding season—the Band-tailed Pigeon, Anna's Hummingbird, House Wren, Orange-crowned Warbler, Nashville Warbler, Lazuli Bunting, Lesser Goldfinch, and Evening Grosbeak—show substantial numbers of detections hundreds of meters higher than previous descriptions of breeding ranges based on expert opinion and known nest records (e.g., Gaines 1992). These high-elevation detections likely represent post-breeding individuals that had already moved upslope beyond their usual breeding ranges. Another species, the Rufous Hummingbird, does not breed anywhere in the Sierra Nevada (Healy and Calder 2006) but is conspicuous during its southbound migration through the Sierra in mid and late summer. For each of these species our results should be interpreted broadly as describing ranges during early and mid-summer rather than strictly breeding ranges.

Table 1 Summary Statistics of Data on Elevational Distribution of the 75 Species[a] Most Frequently Detected during Point Count surveys at Sequoia and Kings Canyon National Parks 2003–2004 and Yosemite National Park 1999–2000

	Elevation (m) of count stations with detections					
	Sequoia/Kings Canyon			Yosemite		
Species	*n*[b]	Mean (SD)	2.5–97.5% quantiles[c]	*n*[b]	Mean (SD)	2.5–97.5% quantiles
Sooty Grouse, *Dendragapus fuliginosus*	55	2523 (451)	1795–3155	50	2404 (298)	1950–2925
Mountain Quail, *Oreortyx pictus*	194	2082 (627)	665–3084	421	2010 (390)	1308–2740
California Quail, *Callipepla californica*	21	708 (117)	525–901	0	—	—
Spotted Sandpiper, *Actitis macularius*	15	2932 (279)	2540–3389	35	2381 (629)	1200–3073
Band-tailed Pigeon, *Patagioenas fasciata*	10	2331 (786)	810–3209	22	2039 (488)	1208–2831
White-throated Swift, *Aeronautes saxatalis*	25	1539 (593)	521–2734	58	1640 (465)	1200–2706
Anna's Hummingbird, *Calypte anna*	36	1709 (963)	478–3395	67	1952 (543)	1200–2970
Rufous Hummingbird, *Selasphorus rufus*	56	2977 (284)	2599–3467	32	2822 (254)	2367–3238
Acorn Woodpecker, *Melanerpes formicivorus*	23	832 (411)	495–1724	55	1474 (210)	1200–1862
Williamson's Sapsucker, *Sphyrapicus thyroideus*	38	2870 (277)	2388–3373	21	2679 (216)	2302–2967
Red-breasted Sapsucker, *Sphyrapicus ruber*	29	2143 (260)	1763–2641	13	2245 (262)	1776–2493
Hairy Woodpecker, *Picoides villosus*	63	2502 (508)	1620–3319	189	2043 (446)	1219–2912
White-headed Woodpecker, *Picoides albolarvatus*	73	2217 (318)	1762–2907	144	1964 (362)	1207–2601
Northern Flicker, *Colaptes auratus*	163	2325 (633)	727–3347	233	1978 (471)	1200–2913
Pileated Woodpecker, *Dryocopus pileatus*	17	2018 (375)	1528–2850	53	1845 (272)	1369–2295
Olive-sided Flycatcher, *Contopus cooperi*	175	2558 (317)	1895–3050	240	2133 (350)	1251–2719
Western Wood-Pewee, *Contopus sordidulus*	213	2155 (511)	719–2888	282	1957 (440)	1200–2680

(continued)

Table 1 (*Continued*).

	Elevation (m) of count stations with detections					
	Sequoia/Kings Canyon			Yosemite		
Species	*n*[b]	Mean (SD)	2.5–97.5% quantiles[c]	*n*[b]	Mean (SD)	2.5–97.5% quantiles
Hammond's Flycatcher, *Empidonax hammondii*	43	2240 (481)	1649–3310	81	1873 (346)	1258–2605
Dusky Flycatcher, *Empidonax oberholseri*	456	2820 (485)	1836–3436	524	2512 (443)	1612–3194
Pacific-slope Flycatcher, *Empidonax difficilis*	42	1513 (420)	707–2135	26	1744 (360)	1260–2446
Ash-throated Flycatcher, *Myiarchus cinerascens*	43	780 (238)	490–1318	4	1386 (69)	1331–1468
Cassin's Vireo, *Vireo cassinii*	52	1883 (642)	732–3029	206	1750 (367)	1200–2592
Warbling Vireo, *Vireo gilvus*	223	2232 (481)	1121–2963	190	1912 (415)	1200–2640
Steller's Jay, *Cyanocitta stelleri*	387	2207 (527)	1092–3160	634	2038 (463)	1200–2920
Western Scrub-Jay, *Aphelocoma californica*	43	877 (307)	534–1496	20	1475 (144)	1200–1738
Clark's Nutcracker, *Nucifraga columbiana*	239	3123 (330)	2439–3491	290	2951 (261)	2359–3446
Common Raven, *Corvus corax*	65	2182 (674)	678–3415	45	1929 (491)	1211–3023
Mountain Chickadee, *Poecile gambeli*	687	2665 (500)	1725–3380	1011	2420 (430)	1545–3155
Oak Titmouse, *Baeolophus inornatus*	28	725 (254)	435–1242	1	1413 (0)	1413–1413
Red-breasted Nuthatch, *Sitta canadensis*	383	2316 (398)	1624–3115	567	2093 (370)	1364–2760
White-breasted Nuthatch, *Sitta carolinensis*	105	2940 (702)	610–3404	98	2532 (443)	1575–3215
Brown Creeper, *Certhia americana*	223	2472 (515)	1476–3296	326	2159 (463)	1208–2939
Rock Wren, *Salpinctes obsoletus*	54	3232 (282)	2614–3578	44	2692 (582)	1582–3376
Bewick's Wren, *Thryomanes bewickii*	34	970 (397)	590–1691	25	1648 (367)	1235–2353
House Wren, *Troglodytes aedon*	42	1286 (843)	574–2935	30	1732 (364)	1291–2463
Pacific Wren, *Troglodytes pacificus*	64	2096 (334)	1533–2743	77	1790 (328)	1200–2351
Golden-crowned Kinglet, *Regulus satrapa*	371	2268 (330)	1727–2923	478	2154 (334)	1452–2768
Ruby-crowned Kinglet, *Regulus calendula*	96	2963 (267)	2529–3393	19	2838 (220)	2331–3124

Mountain Bluebird, *Sialia currucoides*	37	3301 (227)	2872–3673	21	2880 (289)	2340–3310
Townsend's Solitaire, *Myadestes townsendi*	141	2655 (475)	1427–3331	305	2332 (447)	1483–3051
Hermit Thrush, *Catharus guttatus*	336	2942 (440)	1963–3449	289	2608 (402)	1718–3172
American Robin, *Turdus migratorius*	311	2382 (615)	1064–3348	440	2154 (553)	1200–3083
Wrentit, *Chamaea fasciata*	80	1085 (420)	621–2012	35	1488 (205)	1183–1850
American Pipit, *Anthus rubescens*	37	3456 (331)	3156–3651	16	3322 (216)	3003–3625
Orange-crowned Warbler, *Oreothlypis celata*	30	1150 (692)	646–3001	5	1992 (730)	1328–3018
Nashville Warbler, *Oreothlypis ruficapilla*	196	1962 (522)	963–2903	385	1872 (365)	1303–2576
Yellow Warbler, *Dendroica petechia*	13	2073 (483)	1343–2843	36	1461 (392)	1199–2323
Yellow-rumped Warbler, *Dendroica coronata*	707	2678 (500)	1727–3360	985	2439 (444)	1433–3136
Black-throated Gray Warbler, *Dendroica nigrescens*	46	1426 (408)	708–2201	119	1679 (253)	1223–2222
Hermit Warbler, *Dendroica occidentalis*	117	2186 (344)	1677–3062	284	1881 (313)	1252–2459
MacGillivray's Warbler, *Oporornis tolmiei*	210	2332 (503)	1363–2998	186	2070 (381)	1200–2801
Wilson's Warbler, *Wilsonia pusilla*	97	2508 (582)	759–3284	63	2213 (461)	1335–3201
Western Tanager, *Piranga ludoviciana*	344	1994 (483)	688–2760	446	1943 (404)	1200–2652
Green-tailed Towhee, *Pipilo chlorurus*	114	2608 (385)	1944–2992	50	2421 (229)	1949–2783
Spotted Towhee, *Pipilo maculatus*	178	1363 (542)	546–2207	215	1711 (299)	1218–2358
California Towhee, *Melozone crissalis*	29	755 (229)	471–1246	1	1267 (0)	1267–1267
Chipping Sparrow, *Spizella passerina*	56	2659 (649)	955–3341	53	2191 (431)	1537–2927
Fox Sparrow, *Passerella iliaca*	324	2407 (364)	1823–3138	440	2266 (293)	1676–2786
Song Sparrow, *Melospiza melodia*	21	2246 (445)	1494–2918	44	1639 (627)	1184–2788
Lincoln's Sparrow, *Melospiza lincolnii*	48	2564 (393)	1889–3101	46	2281 (374)	1851–3232

(continued)

Table 1 (*Continued*).

Species	Elevation (m) of count stations with detections: Sequoia/Kings Canyon n^b	Mean (SD)	2.5–97.5% quantiles[c]	Yosemite n^b	Mean (SD)	2.5–97.5% quantiles
White-crowned Sparrow, *Zonotrichia leucophrys*	196	3203 (327)	2488–3590	164	2993 (262)	2560–3377
Dark-eyed Junco, *Junco hyemalis*	800	2620 (554)	1433–3427	1245	2457 (505)	1337–3230
Black-headed Grosbeak, *Pheucticus melanocephalus*	149	1301 (452)	595–2032	226	1598 (302)	1200–2268
Lazuli Bunting, *Passerina amoena*	58	1523 (705)	594–2787	75	1722 (401)	1195–2714
Red-winged Blackbird, *Agelaius phoeniceus*	4	2685 (125)	2525–2800	40	1722 (635)	1200–2794
Brewer's Blackbird, *Euphagus cyanocephalus*	13	2854 (454)	2385–3535	48	1880 (772)	1200–2998
Brown-headed Cowbird, *Molothrus ater*	26	1143 (574)	531–2243	12	1536 (335)	1200–2245
Gray-crowned Rosy-Finch, *Leucosticte tephrocotis*	52	3408 (142)	3134–3570	41	3228 (217)	2875–3653
Pine Grosbeak, *Pinicola enucleator*	8	2939 (332)	2502–3388	26	2772 (354)	1920–3191
Purple Finch, *Carpodacus purpureus*	52	1952 (693)	633–3298	63	1930 (510)	1263–2911
Cassin's Finch, *Carpodacus cassinii*	239	2910 (434)	1883–3431	479	2727 (393)	1606–3234
Red Crossbill, *Loxia curvirostra*	34	2987 (470)	1488–3355	38	2638 (461)	1687–3210
Pine Siskin, *Carduelis pinus*	102	2875 (380)	2014–3340	379	2715 (417)	1459–3255
Lesser Goldfinch, *Carduelis psaltria*	38	1060 (674)	430–2747	31	1714 (475)	1202–2905
Evening Grosbeak, *Coccothraustes vespertinus*	59	2392 (337)	1860–3145	50	2087 (445)	1213–2986

[a]≥20 detections in at least one park.

[b]Numbers of count points at which we detected the species in the park.

Data for three additional species—Hammond's Flycatcher and Hermit Warbler at Sequoia/Kings Canyon and the Purple Finch at both parks—yielded upper quantiles that appear surprisingly higher than previous (albeit unsystematically determined) range descriptions (e.g., Gaines 1992) in one or both parks, even though the species are not generally thought of as upslope migrants (Figure 3). Misidentification of the species is a possibility for Hammond's Flycatcher, which can easily be confused with the higher-ranging Dusky Flycatcher, but our results suggest the other two species, which we detected repeatedly well above their previously described elevation ranges, could have recently colonized these higher elevations.

Overall, individual species were detected at higher mean elevations at Sequoia/Kings Canyon than at Yosemite with remarkable consistency (Figure 4). However the low-elevation species and the upslope migrants listed above did not adhere well to this pattern (Figure 4). The low-elevation species and the upslope migrants excluded, the mean difference between the two parks in the mean elevation of detection of the remaining 59 species was even greater (two-tailed paired t test; $t = 6.55$, df = 58, $P = 0.0001$), averaging 222 m (standard error 34 m) higher at Sequoia/Kings Canyon.

DISCUSSION

We report here the first quantitative data on elevation distributions of Sierra Nevada birds, on the basis of a rigorous sampling design involving extensive point counts in two protected areas that span a large latitudinal swath of the region. We show important differences in the elevational distributions of species between parks, and by extension, between the southern Sierra and the central Sierra. In part, these differences reflect differing elevation ranges of the parks; Sequoia/Kings Canyon boundaries extend farther downslope into foothill habitats than Yosemite boundaries, and the high mountain peaks at Sequoia/Kings Canyon are higher than the peaks at Yosemite. But even without these factors, most species occur at higher elevations at Sequoia/Kings Canyon than at Yosemite, presumably because of the tendency for similar plant communities to occur at higher elevations with decreasing latitude.

Our results may be useful for assessing bird assemblages in less pristine and more heavily managed habitats throughout the west slope of the central and southern Sierra. Bird survey results from such lands can be compared with assemblages from the appropriate elevation zones at Yosemite and Sequoia/Kings Canyon to identify species that may be missing, perhaps due to unfavorable management regimes.

Perhaps more importantly, these data will serve as an important baseline for documenting future changes in bird distributions and assemblages in the Sierra Nevada due to climate change. Many bird species' distributions in the Sierra have already changed in historical times, apparently in response to climate change (Tingley et al. 2009), and larger changes are expected in the coming decades (Stralberg et al. 2009). Breadth of elevation range is a major predictor of birds' risk of extinction in the context of climate change (Sekercioglu et al. 2008), and better data are needed on both elevation ranges and elevation-range shifts of birds worldwide (Sekercioglu et al. 2008).

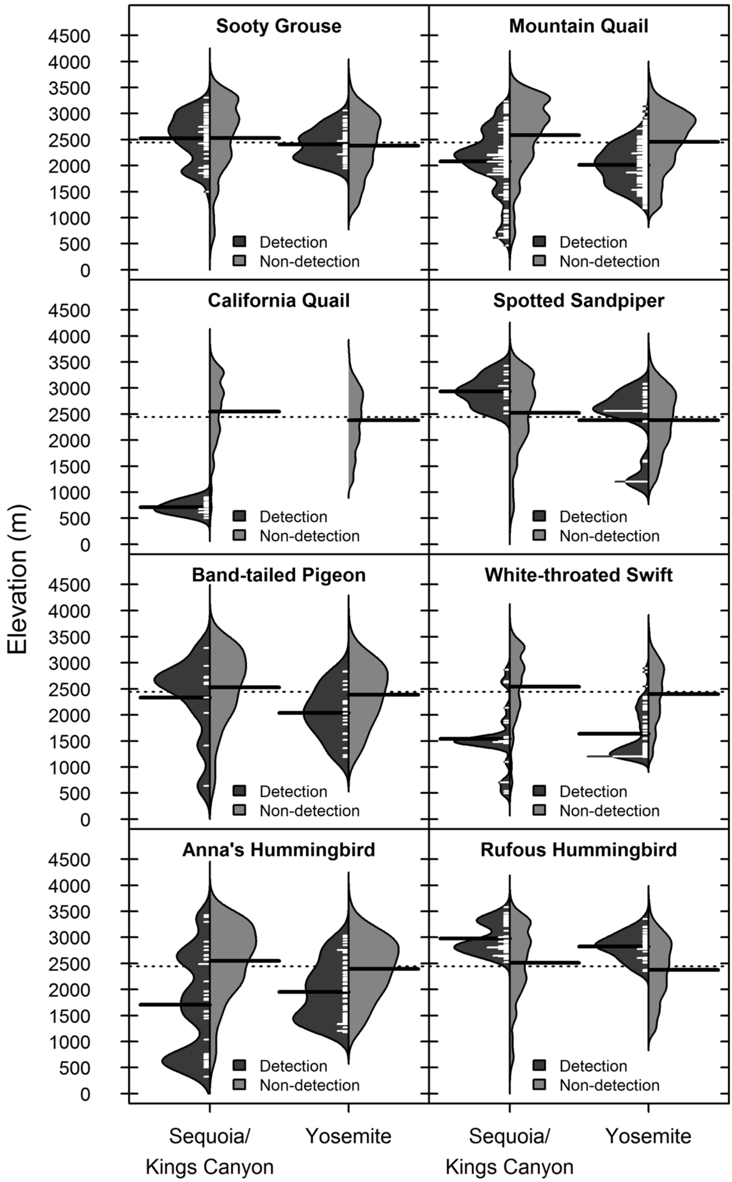
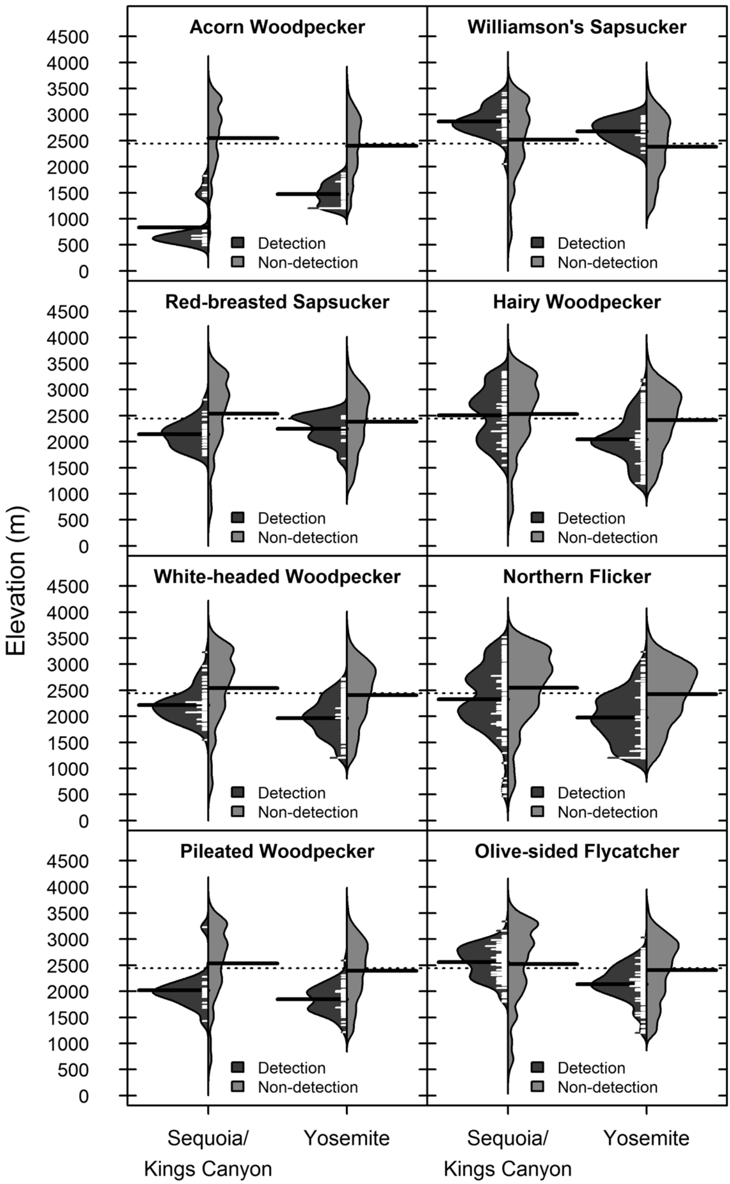


Figure 3. Elevational distributions of count points where birds listed in Table 1 were detected and not detected during bird surveys at Sequoia/Kings Canyon and Yosemite national parks. White tick marks left of the vertical center line represent single points where the species was detected; longer tick marks represent multiple points at the same elevation. Shaded regions delineate density traces of the data. For each park,



sites of detection are shown to the left of vertical center lines and are described by dark gray density traces; density traces of sites of non-detection are shown to the right of vertical center lines in lighter gray. Black horizontal lines show mean elevations of count points where the species was detected (left of center) and not detected (right of center). The dashed line shows the mean elevation of all stations surveyed across both parks.

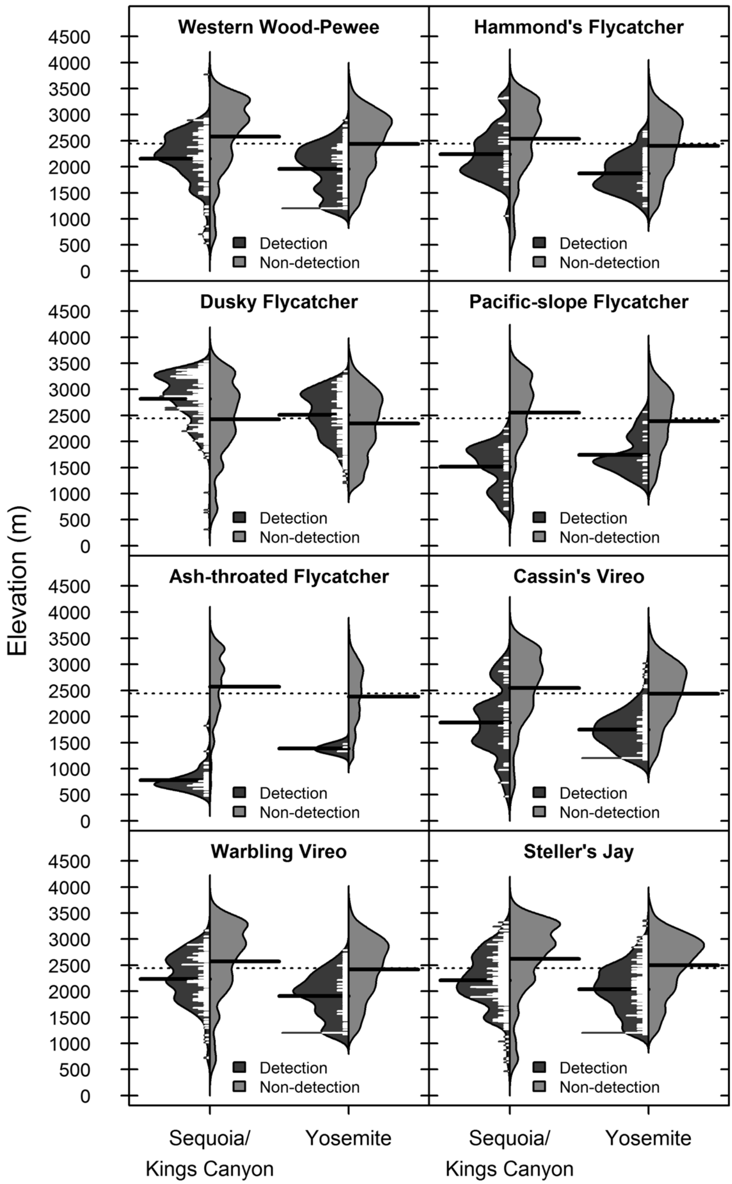


Figure 3 (*Continued*).

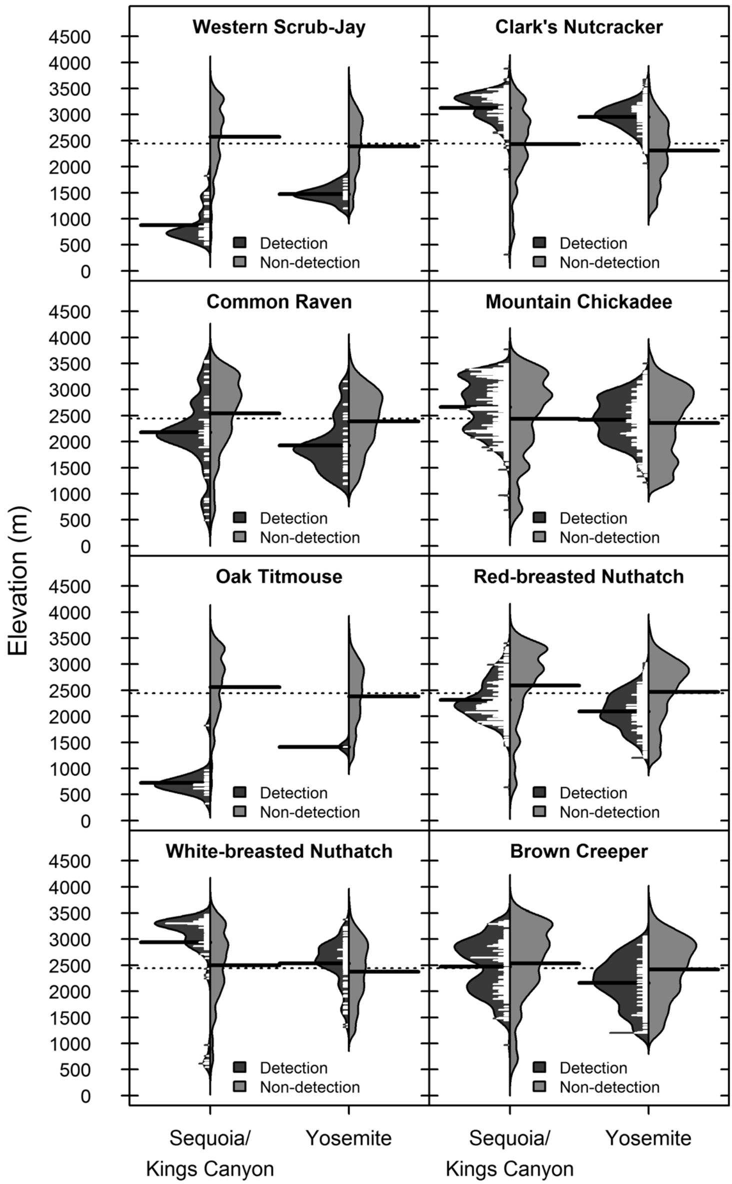


Figure 3 (*Continued*).

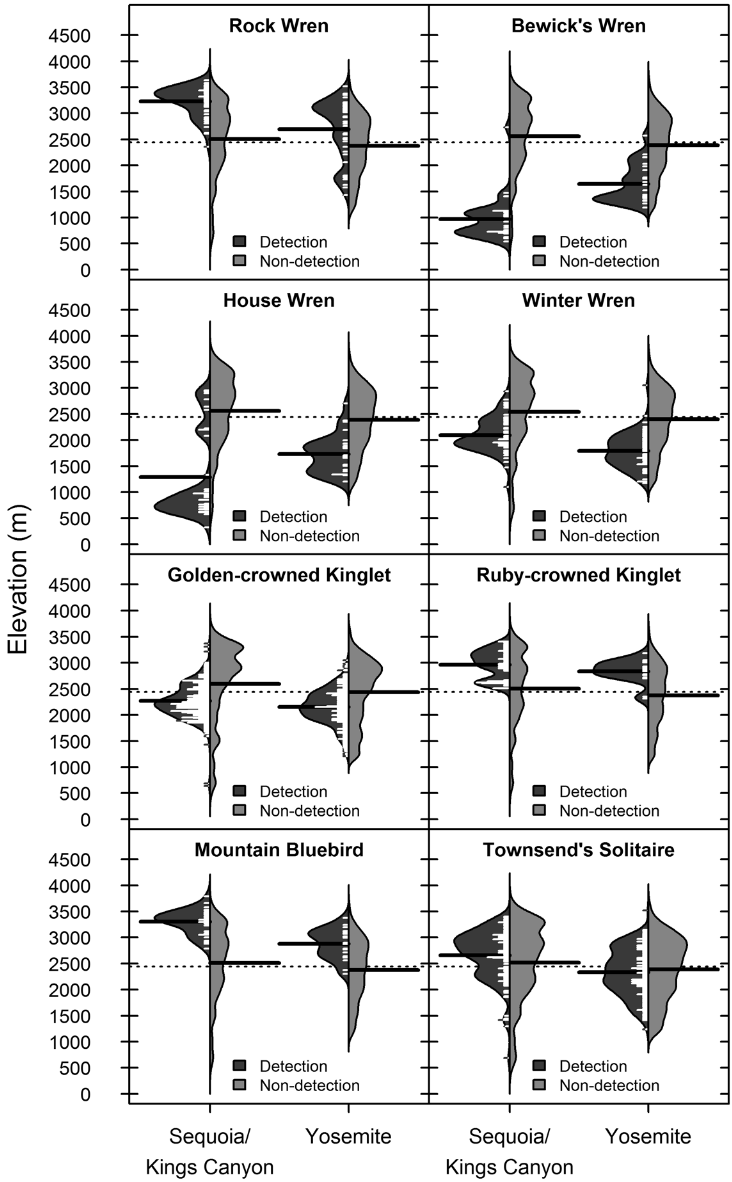


Figure 3 (*Continued*).

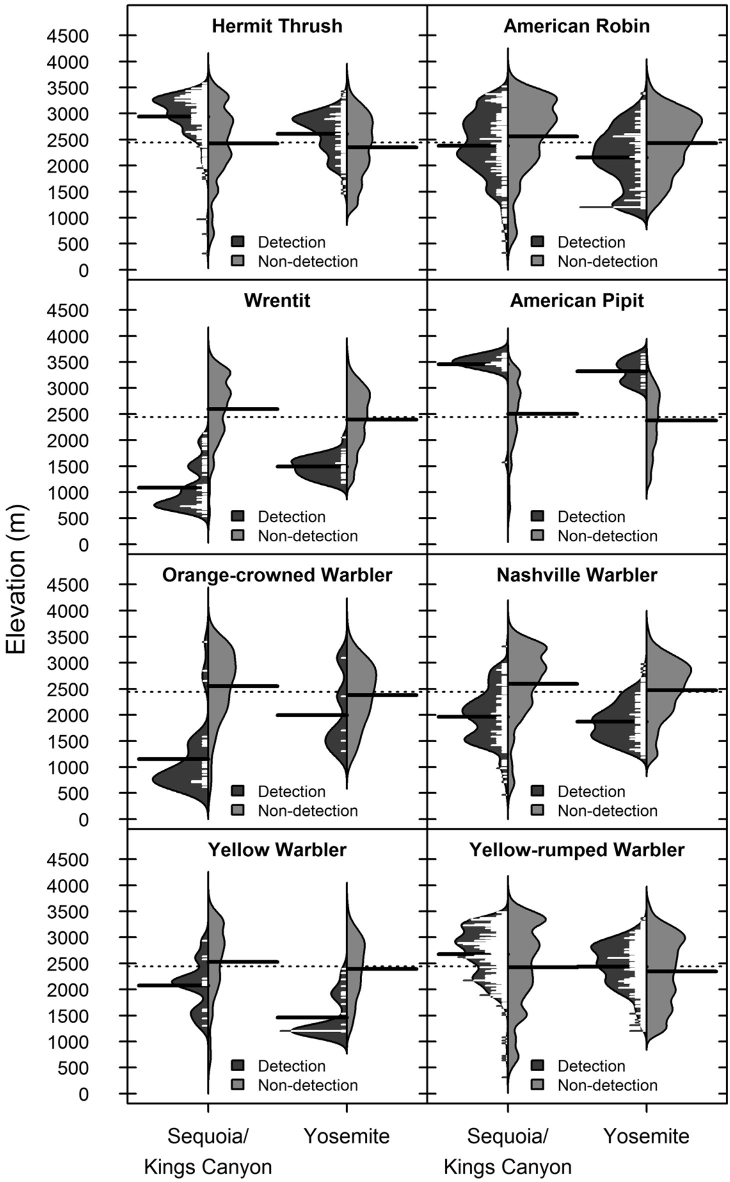


Figure 3 (*Continued*).

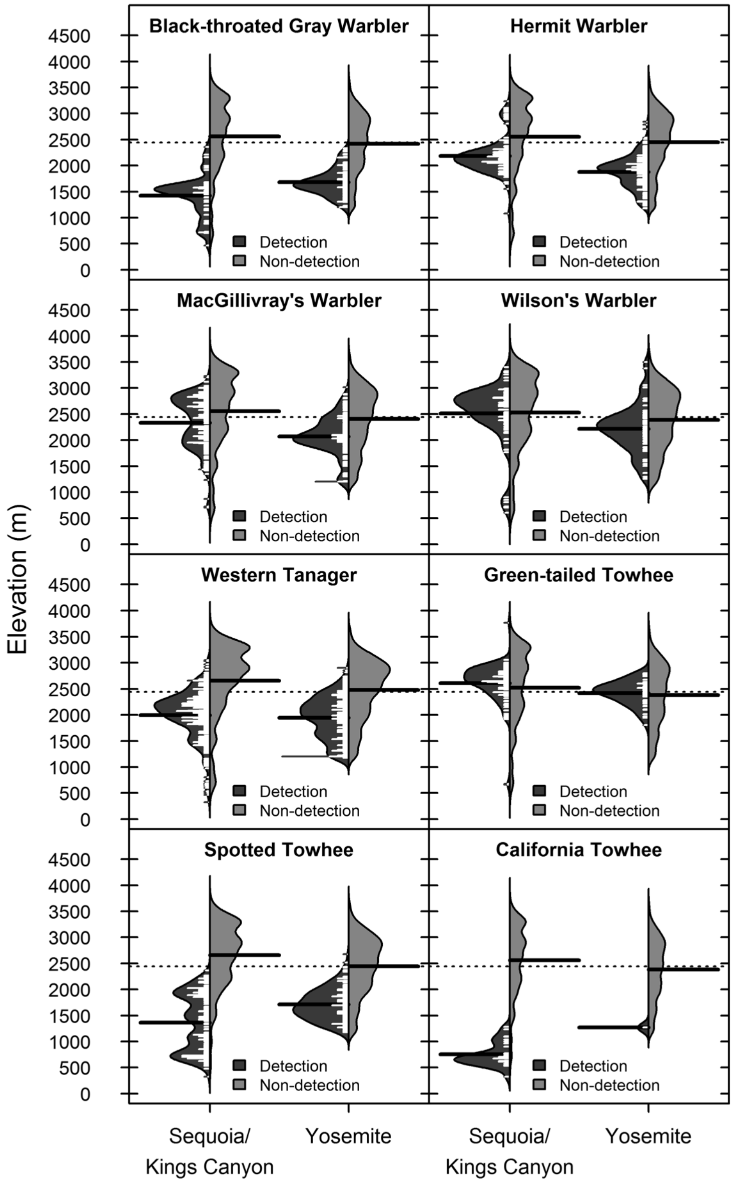


Figure 3 (*Continued*).

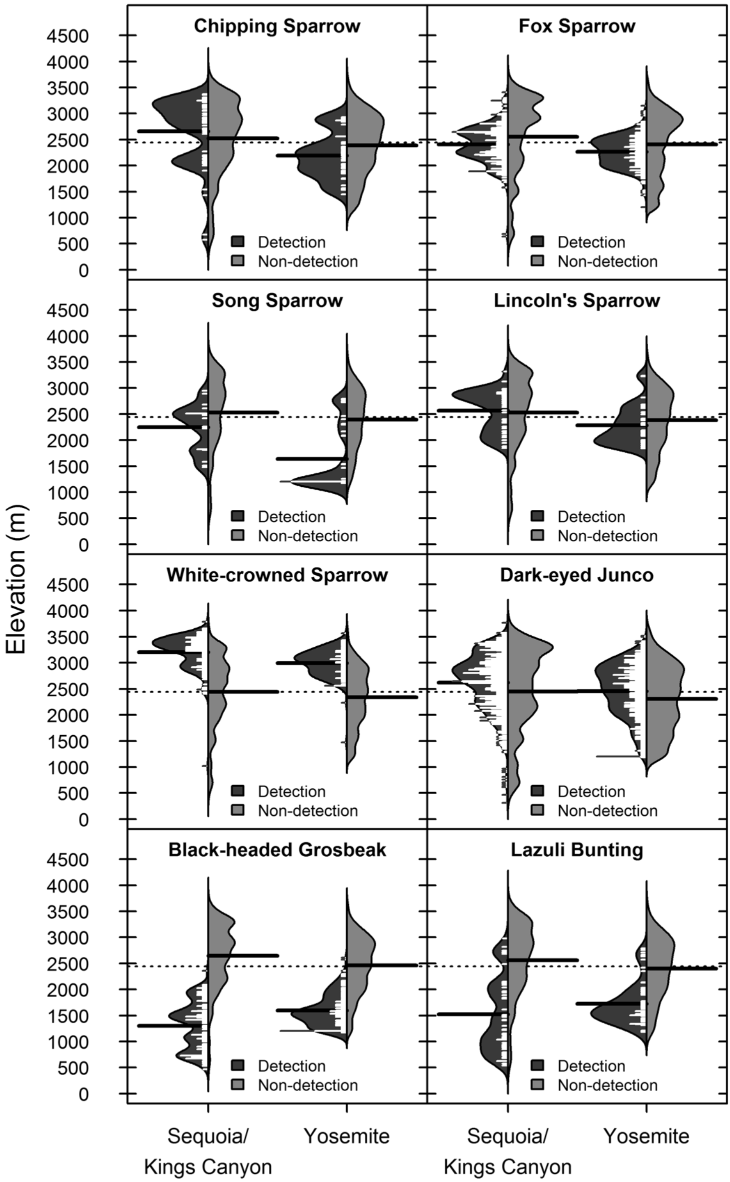


Figure 3 (*Continued*).

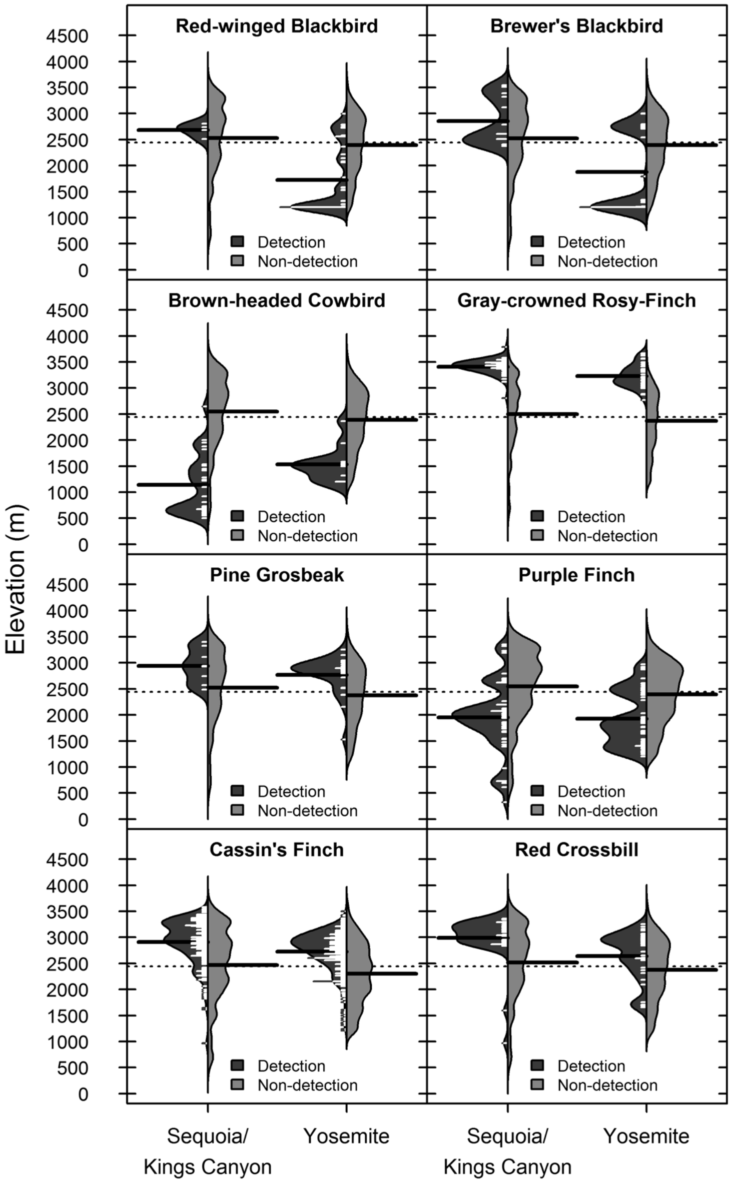


Figure 3 (*Continued*).

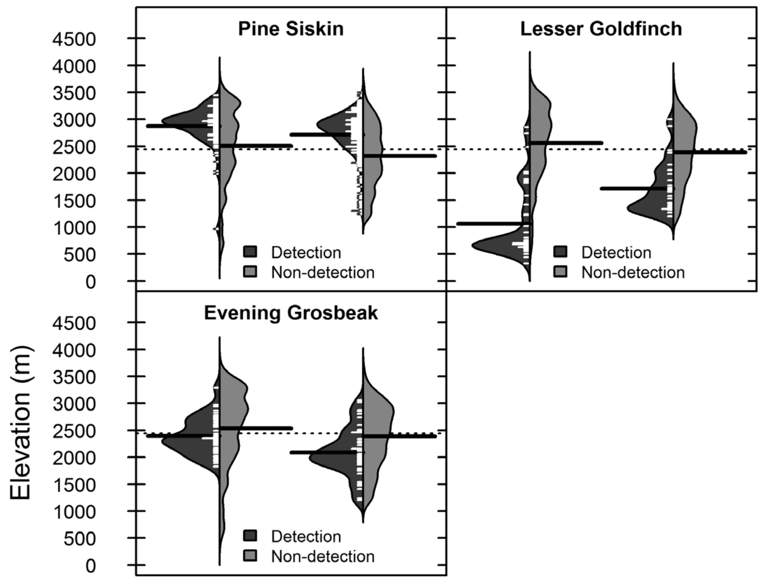


Figure 3 (*Continued*).

For the species we considered, our results can thus help assess the risk of climate-driven local extirpations within the Sierra Nevada's national parks, as well as their broader regional and rangewide risks. The utility of these results from the southern and central Sierra Nevada could be further extended with similar data from the northern end of the Sierra Nevada.

ACKNOWLEDGMENTS

This project was made possible by funding from the National Park Service Sierra Nevada Network's Inventory and Monitoring Program and Sequoia and Kings Canyon National Parks' Natural Resources Condition Assessment. We thank numerous National Park Service personnel at Yosemite and Sequoia/Kings Canyon for assistance, support, and collegiality, particularly Jennifer Akin, Les Chow, Alice Chung-MacCoubrey, Angela Evenden, David Graber, Sylvia Haultain, Rachel Mazur, Joe Meyer, Linda Mutch, Sarah Stock, Charisse Sydoriak, Steve Thompson, Jan van Wagtendonk, and Harold Werner. We are especially grateful to our outstanding field crews: Clay Anderson, Katie Christie, Neil Clipperton, Stephanie Dolrenry, Diony Gamoso, Liz Guillorn, Dan Hernandez, Eric Hollingstad, Katie Hughes, Susan Jackson, Juliette Juillerat, Kristin Kusic, Chad Landrum, Jonah Liebes, Annie McMillan, Ron Melzer, Lauren Mork, Susan Mortenson, Kevin Pietrzak, Eric Sawtelle, Victor Sepulveda, and Arden Thomas. We thank David DeSante at The Institute for Bird Populations for developing the original study design at Yosemite and providing helpful comments on an earlier draft of the manuscript. Helpful comments were also provided by Tom Gardali, L. Jay Roberts, Morgan Tingley, and Philip Unitt. Finally, we thank Lauren and Bill Nickell for their warm hospitality at the Sunset Inn during our fieldwork at Yosemite. This study was completed by The Institute for Bird Populations' Sierra Nevada Bird Observatory and is contribution 399 of The Institute for Bird Populations.

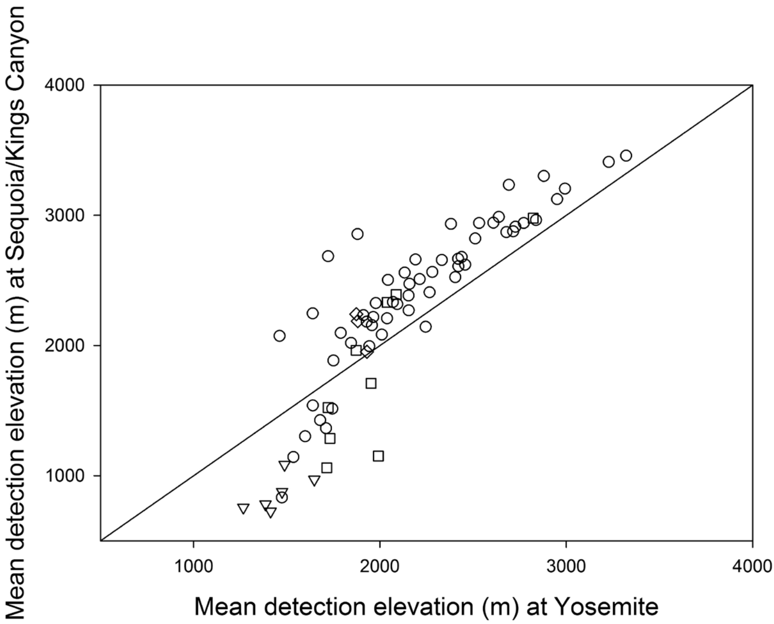


Figure 4. Mean elevation of detection of 74 bird species (all species in Table 2 except for the California Quail, which we did not detect at Yosemite) at Yosemite National Park plotted against the species' mean elevation of detection at Sequoia and Kings Canyon national parks. Triangles, species restricted to lower-elevation habitats in the parks; squares, species that disperse upslope after breeding and for which we may have detected substantial numbers of individuals higher than their breeding range; diamonds, three species for which our results diverge from previous descriptions of the species' elevational range (Hammond's Flycatcher, Hermit Warbler, Purple Finch); circles, the remaining 56 species.

LITERATURE CITED

Bohning-Gaese, K., and Lemoine, N. 2004. Importance of climate change for the ranges, communities and conservation of birds, in Birds and Climate Change (A. P. Møller, W. Fiedler, and P. Berthold, eds.), pp. 211–236. Elsevier, Amsterdam.

Franco, G., Cayan, D. R., and Lynd Luers, A. 2006. Our changing climate: Assessing the risks to California. California Climate Change Center report CEC-500-2006-077. http://meteora.ucsd.edu/cap/pdffiles/CA_climate_Scenarios.pdf.

Gaines, D. 1992. Birds of Yosemite and the East Slope. Artemisia Press, Lee Vining, CA.

Hayhoe, K., Cayan, D., Field, C. B., Frumhoff, P. C., Maurer, E. P., Miller, N. L., Moser, S. C., Schneider, S. H., Cahill, K. N., Cleland, E. F., Dale, L., Drapek, R., Hanemann, R. M., Kalkstein, L. S., Lenihan, J., Lunch, C. K., Neilson, R. P., Sheridan, S. C., and Verville, J. H. 2004. Emissions pathways, climate change, and impacts on California. Proc. Natl. Acad. Sci. 101:12422–12427.

Healy, S., and Calder, W. A. 2006. Rufous Hummingbird (*Selasphorus rufus*), in

The Birds of North America Online (A. Poole, and F. Gill, eds.), no. 53. http://bna.birds.cornell.edu/bna/species/053.

Hyndman, R. J., and Fan, Y. 1996. Sample quantiles in statistical packages. Am. Statistician 50:361–365.

Kampstra, P. 2008. Beanplot: A boxplot alternative to visual comparisons of distributions. J. Statistical Software 28:1–9.

Newton, I. 2003. The Speciation and Biogeography of Birds. Academic Press, London.

Parmesan, C. 2006. Ecological and evolutionary responses to recent climate change. Annu. Rev. Ecol. Evol. Syst. 37:637–669.

Pounds, J. A., Fogden, M. P. L. and Campbell, J. H. 1999. Biological response to climate change on a tropical mountain. Nature 398:611–615.

R Development Core Team. 2009. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. www.R-project.org.

Root, T. L. 1988. Energy constraints on avian distributions and abundances. Ecology 69:330–339.

Root, T. L., MacMynowski, D. P., Mastrandrea, M. D., and Schneider, S. H. 2005. Human modified temperatures induce species changes: Joint attribution. Proc. Natl. Acad. Sci. 102:7465–7469.

Root, T. L., Price, J. T., Hall, K. R., Schneider, S. H., Rosenzweig, C., and Pounds, J. A. 2003. Fingerprints of global warming on wild animals and plants. Nature 421:57–60.

Root, T. L., and Schneider, S. H. 1993. Can large-scale climatic models be linked with multi-scale ecological studies? Cons. Biol. 7:256–270.

Sekercioglu, C. H., Schneider, S. H., Fay, J. P., and Loarie, S. R. 2008. Climate change, elevational range shifts, and bird extinctions. Cons. Biol. 22:140–150.

Shaether, S. J., and Jones, M. C. 1991. A reliable data-based bandwidth selection method for kernal density estimation. J. Royal Statistical Soc. B 53:683–690.

Siegel, R. B., and D. F. DeSante. 1999. Draft avian conservation plan for the Sierra Nevada Bioregion: A report to California Partners in Flight. The Institute for Bird Populations, P. O. Box 1346, Point Reyes Station, CA 94956.

Silsbee, G. G., and Peterson, D. L. 1991. Designing and implementing comprehensive long-term inventory and monitoring programs for National Park System lands. Natural Resources Report NPS/NRUW/NRR-91/04, Denver, CO. http://science.nature.nps.gov/im/monitor/docs/silsbee.pdf.

Simons, T. R., Rabenold, K. N., Buehler, D. A., Collazo, J. A., and Franzreb, K. E. 1999. The role of indicator species: Neotropical migratory song birds, in Ecosystem Management for Sustainability: Principles and Practices Illustrated by a Regional Biosphere Reserve Cooperative (J. D. Peine, ed.), pp. 187–208. Lewis, New York.

Snyder, M. A., Bell, J. L., Sloan, L. C., Duffy, P. B., and Govindasamy, B. 2002. Climate responses to a doubling of atmospheric carbon dioxide for a climatically vulnerable region. Geophys. Res. Lett. 29(11):1514, doi:10.1029/2001GL014431.

Stralberg, D., Jongsomjit, D., Howell, C. A., Snyder, M. A., Alexander, J. D., Wiens, J. A., and Snyder, T. L. 2009. Re-shuffling of species with climate disruption: A no-analog future for California birds? PLoS One 4(9):e6825, doi:10.1371/journal.pone.0006825.

Stock, S., and Espinoza, T. 2009. Yosemite Bird Checklist. National Park Service, El Portal, CA. www.nps.gov/yose/naturescience/upload/Bird%20Checklist.8.5x11.pdf.

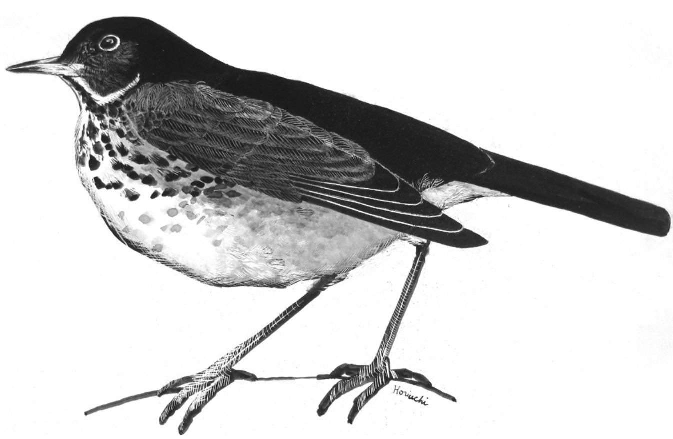
Tingley, M. W., and Beissinger, S. R. 2009. Detecting range shifts from historical species occurrences: New perspectives on old data. Trends in Ecology and Evolution 24: 625–633.

Tingley, M. W., Monahan, W. B., Beissinger, S. R., and Moritz, C. 2009. Birds track their Grinnellian niche through a century of climate change. Proc. Natl. Acad. Sci. 106 (suppl. 2):19637–19643.

Venables, W. N., and Ripley, B. D. 2002. Modern Applied Statistics with S. 4th edition. Springer-Verlag, New York.

Westerling, A. L., Hidalgo, H. G., Cayan, D. R., and Swetnam, T. W. 2006. Warming and earlier spring increase western U.S. forest wildfire activity. Science 313:940–943.

Accepted 17 December 2010



Hermit Thrush

Sketch by Irene Horiuchi