THE INSTITUTE FOR BIRD POPULATIONS

Assessing climate change vulnerability and developing a climate change adaptation strategy for Sierra Nevada birds

Summary of progress to date

March 27, 2012

Project partners

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Project objectives

1) Use the NatureServe Climate Change Vulnerability Index (CCVI) to assess vulnerability of regularly breeding bird species in the Sierra Nevada. The Index is a tool that incorporates data about species' natural history and distribution with spatially explicit temperature and precipitation projections, to assess species' vulnerability to range contractions, or population reductions due to climate change during the coming years.

2) Develop a Climate Change Adaptation Strategy for Sierra Nevada bird species that are most vulnerable to climate change. The Strategy will provide recommendations for actions that managers can take now and in the future to bolster resilience to climate change.

3) Conduct outreach efforts targeting Sierra Nevada land managers (particularly Forest Service and National Park Service personnel), the California Partners in Flight community, and the general public to publicize the existence of the plan and the importance of proactive management to minimize negative consequence of climate change on Sierra Nevada birds.

Accomplishments to date

a) Develop species list

We developed a comprehensive list of bird species a) that regularly breed in the Jepson Sierra Nevada Region (Figure 1), hereafter referred to as simply the Sierra Nevada, and b) for which digital breeding range maps are available from California Department of Fish and Game. The intersection of these two criteria yielded a list of 167 species, which we then augmented with one additional species, Rufous Hummingbird, which does not breed in the region but migrates through it during the summer, when most of the other bird species are breeding. Our total list of bird species to be assessed thus includes 168 species (Table 1).

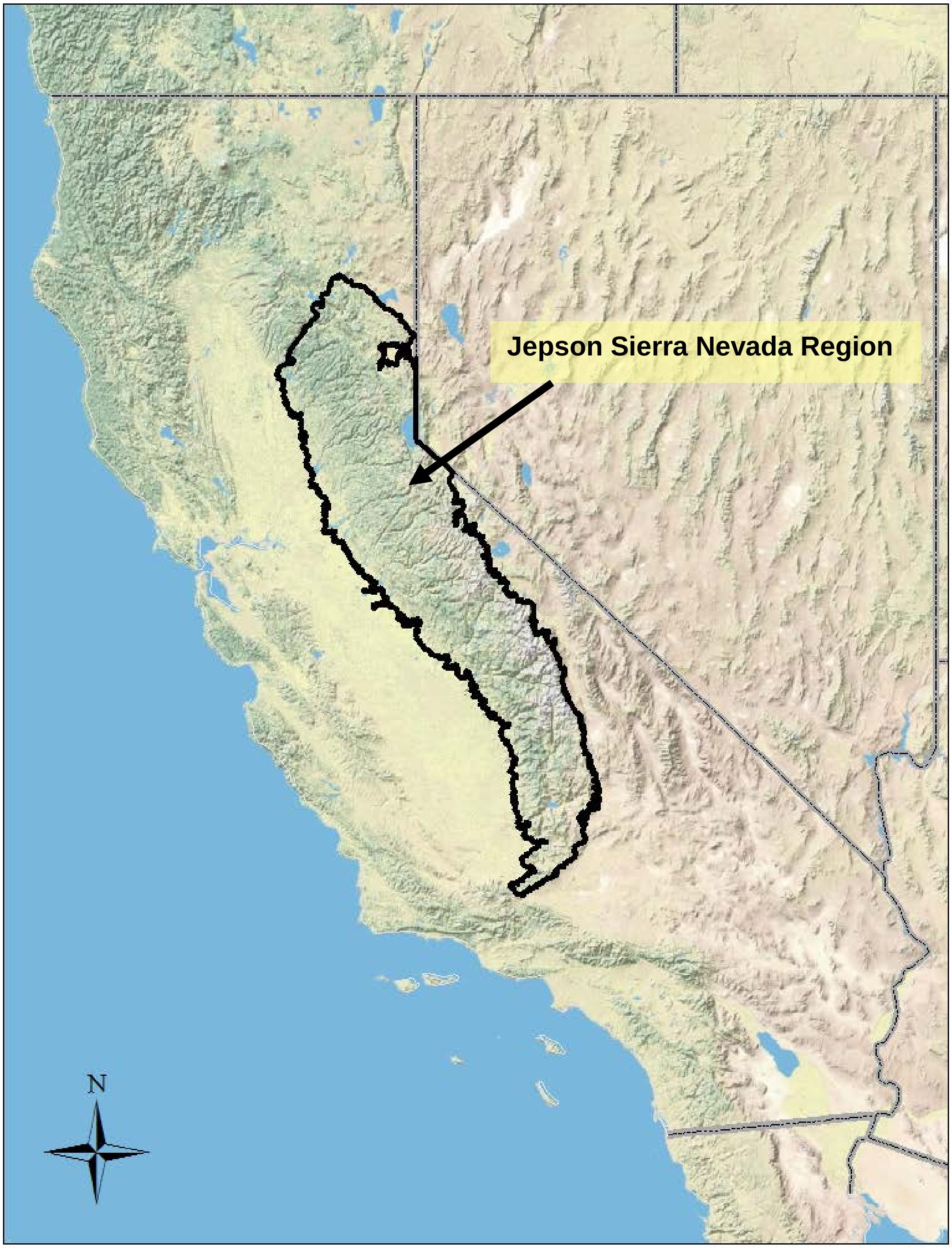


Figure 1. Numerous competing delineations of the Sierra Nevada region exist, but we are using the Jepson Sierra Nevada Region (outlined in black) as the domain for this project.

Table 1. Species under evaluation for climate change vulnerability in the Sierra Nevada.

Wood Duck	Black Swift	Oak Titmouse
Mallard	Vaux's Swift	Bushtit
Harlequin Duck	White-throated Swift	Red-breasted Nuthatch
Bufflehead	Black-chinned Hummingbir	White-breasted Nuthatch
Common Merganser	Anna's Hummingbird	Pygmy Nuthatch
Mountain Quail	Calliope Hummingbird	Brown Creeper
California Quail	Rufous Hummingbird	Rock Wren
White-tailed Ptarmigan	Belted Kingfisher	Canyon Wren
Sooty Grouse	Lewis's Woodpecker	Bewick's Wren
Wild Turkey	Acorn Woodpecker	House Wren
Pied-billed Grebe	Williamson's Sapsucker	Pacific Wren
Great Blue Heron	Red-breasted Sapsucker	Marsh Wren
Turkey Vulture	Nuttall's Woodpecker	Blue-gray Gnatcatcher
Osprey	Downy Woodpecker	American Dipper
Bald Eagle	Hairy Woodpecker	Golden-crowned Kinglet
Northern Harrier	White-headed Woodpecker	Ruby-crowned Kinglet
Sharp-shinned Hawk	Black-backed Woodpecker	Wrentit
Cooper's Hawk	Northern Flicker	Western Bluebird
Northern Goshawk	Pileated Woodpecker	Mountain Bluebird
Red-shouldered Hawk	Olive-sided Flycatcher	Townsend's Solitaire
Red-tailed Hawk	Western Wood-Pewee	Swainson's Thrush
Golden Eagle	Willow Flycatcher	Hermit Thrush
American Kestrel	Hammond's Flycatcher	American Robin
Peregrine Falcon	Gray Flycatcher	California Thrasher
Prairie Falcon	Dusky Flycatcher	European Starling
Virginia Rail	Pacific-slope Flycatcher	American Pipit
Sora	Black Phoebe	Phainopepla
American Coot	Say's Phoebe	Orange-crowned Warbler
Sandhill Crane	Ash-throated Flycatcher	Nashville Warbler
Killdeer	Western Kingbird	MacGillivray's Warbler
Spotted Sandpiper	Cassin's Vireo	Common Yellowthroat
Wilson's Snipe	Hutton's Vireo	Yellow Warbler
Black Tern	Warbling Vireo	Yellow-rumped Warbler
Band-tailed Pigeon	Pinyon Jay	Black-throated Gray Warb
Mourning Dove	Steller's Jay	Hermit Warbler
Yellow-billed Cuckoo	Western Scrub-Jay	Wilson's Warbler
Greater Roadrunner	Clark's Nutcracker	Green-tailed Towhee
Barn Owl	Black-billed Magpie	Spotted Towhee
Flammulated Owl	Common Raven	Rufous-crowned Sparrow
Western Screech-Owl	Horned Lark	California Towhee
Great Horned Owl	Purple Martin	Chipping Sparrow
Northern Pygmy-Owl	Tree Swallow	Brewer's Sparrow
Spotted Owl	Violet-green Swallow	Black-chinned Sparrow
Great Gray Owl	Northern Rough-winged Sw	Vesper Sparrow
Long-eared Owl	Cliff Swallow	Lark Sparrow
Northern Saw-whet Owl	Barn Swallow	Sage Sparrow
Common Nighthawk	Mountain Chickadee	Savannah Sparrow
Common Poorwill	Chestnut-backed Chickade	Fox Sparrow

Table 1, continued.

Song Sparrow	Western Meadowlark	Cassin's Finch
Lincoln's Sparrow	Yellow-headed Blackbird	House Finch
White-crowned Sparrow	Brewer's Blackbird	Red Crossbill
Dark-eyed Junco	Brown-headed Cowbird	Pine Siskin
Western Tanager	Bullock's Oriole	Lesser Goldfinch
Black-headed Grosbeak	Gray-crowned Rosy-Finch	Lawrence's Goldfinch
Lazuli Bunting	Pine Grosbeak	Evening Grosbeak
Red-winged Blackbird	Purple Finch	House Sparrow

b) Quantify historic climatic conditions across the Sierra Nevada

The NatureServe CCVI requires an assessment of the historic variation in temperature and precipitation experienced by individual species in the region of interest.

We used historical temperature and derivative hydrologic moisture data at a 270-meter grid-scale (developed by Thorne et al., in review) within the Sierra Nevada between 1970-2000 as a basis for quantifying the amount of historic variation in temperature and moisture across the entire Sierra Nevada region (Figure 2).

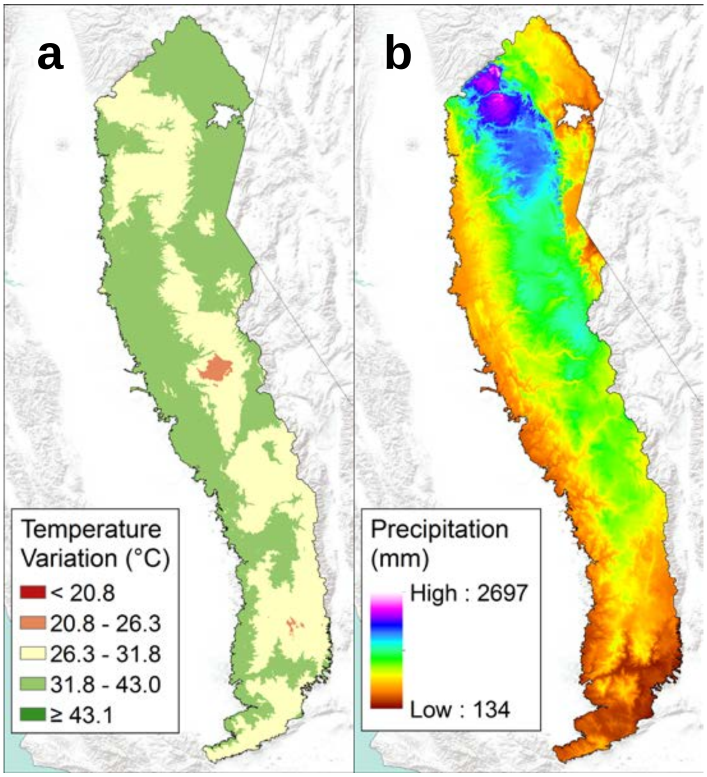


Figure 2. Historic (1970-2000) variation in (a) temperature and (b) moisture within the Sierra Nevada. For temperature, bins represent the average annual difference between monthly mean July maximum temperatures and monthly mean January minimum temperatures within each 270-m grid cell. Moisture is represented as the difference between the highest and lowest annual precipitation (mm) values for each cell during the 30-year period. Note that lowland areas of the Sierra Nevada are generally exposed to greater annual temperature variation than high-elevation areas, and that northern areas are generally exposed to greater annual variation in precipitation.

c) Predict future climatic conditions across the Sierra Nevada

The NatureServe CCVI requires spatially explicit predictions of changes in temperature and moisture regimes across the area of interest. We derived these predicted changes for temperature (Figure 3) and moisture (Figure 4) from models predicting future temperature (°C) and moisture data represented as Climate Water Deficit (CWD), which integrating actual and potential evapotranspiration metrics and represents the amount of drying predicted to occur, independent the amount of precipitation. These data were incorporated into Basin Characterization Models (BCM) which calculated mean values for historic (1971-2000) and future (2040–2069) 30-year temporal ranges for each 270-m grid cell in the Sierra Nevada. Calculations were based on a medium-high (A2) emissions scenario, predicting medium-high temperature increases, and two climate models, Geophysical Fluid Dynamics Laboratory (GFDL) and Parallel Climate Model (PCM), representing warmer/drier and cooler/wetter future scenarios, respectively, though both models predict drying and warming compared to current conditions.

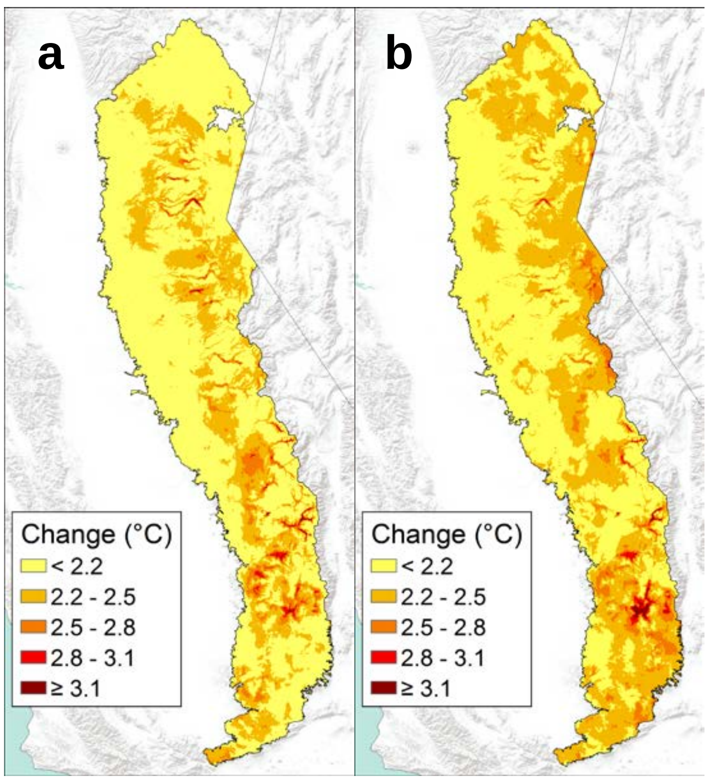


Figure 3. Differences between current and future temperature based on (a) PCM and (b) GFDL circulation models within the Sierra Nevada. For each 270 m grid cell, monthly mean temperature was calculated as *mean of the monthly maximum temperature + the monthly minimum temperature divided by two* during historical (1971-2000) and future (2040-2069) 30-year periods. The maps represent the differences between the values from the two 30-year periods, using the two climate-change models, PCM and GFDL. Note that a greater amount of warming is predicted by the GFDL than by the PCM models, and that generally more warming is anticipated in higher-elevation and eastern sections than in lower-elevation and western sections of the Sierra Nevada.

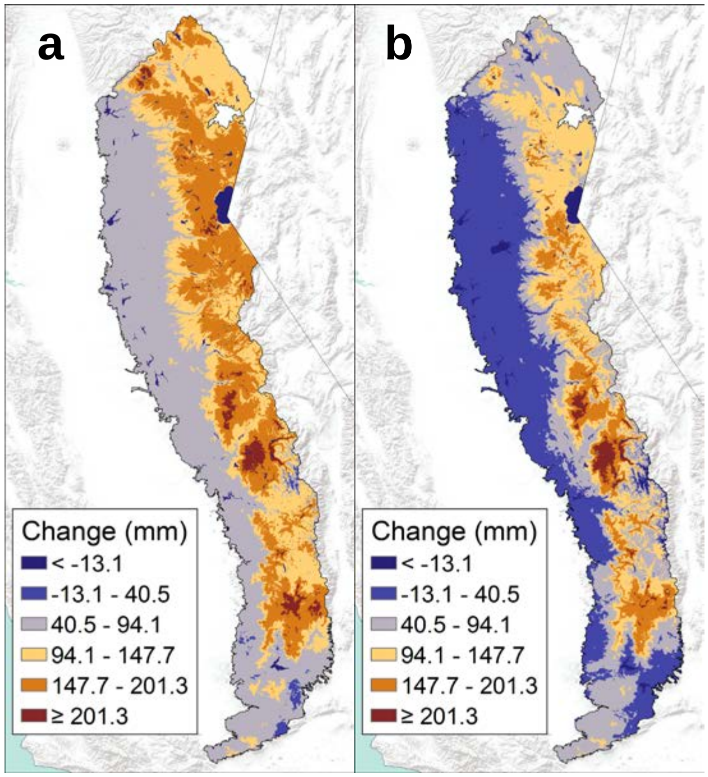


Figure 4. Differences between current and future moisture based on (a) PCM and (b) GFDL circulation models within the Sierra Nevada. For each 270 m grid cell, monthly mean climatic water deficit (CWD) evapotranspiration values were calculated as *mean of the annual CWD values* during historical (1971-2000) and future (2040-2069) 30-year periods. Higher CWD values represent drier conditions. The maps represent the differences between the CWD values from the two 30-year periods for each circulation model. Note that much more drying is predicted by the GFDL than by the PCM models, and that more drying is anticipated in higher-elevation and eastern sections than in lower-elevation and western sections of the Sierra Nevada.

d) Quantify historic climatic variation and predicted climatic conditions within each species' current Sierra Nevada range, under each climate circulation model

Our next step was to calculate (following specific guidelines provided by NatureServe), for each individual species, statistics on the amount of historic climatic variation within its current Sierra Nevada range, and statistics on the amount of anticipated climate change within its current Sierra Nevada range. We started with the maps presented in Figures 2, 3 and 4, but then clipped them to the extent of each individual species' breeding range within the Sierra Nevada. Figures 5-8 provide sample results for four species (California Thrasher, Green-tailed Towhee, Brewer's Sparrow, and Gray-crowned Rosy-Finch) with diverse breeding ranges in the Sierra Nevada, but present only the predictions based on the GFDL circulation model, for brevity. We then calculated summary statistics for each species based on the clipped maps, using each circulation model.

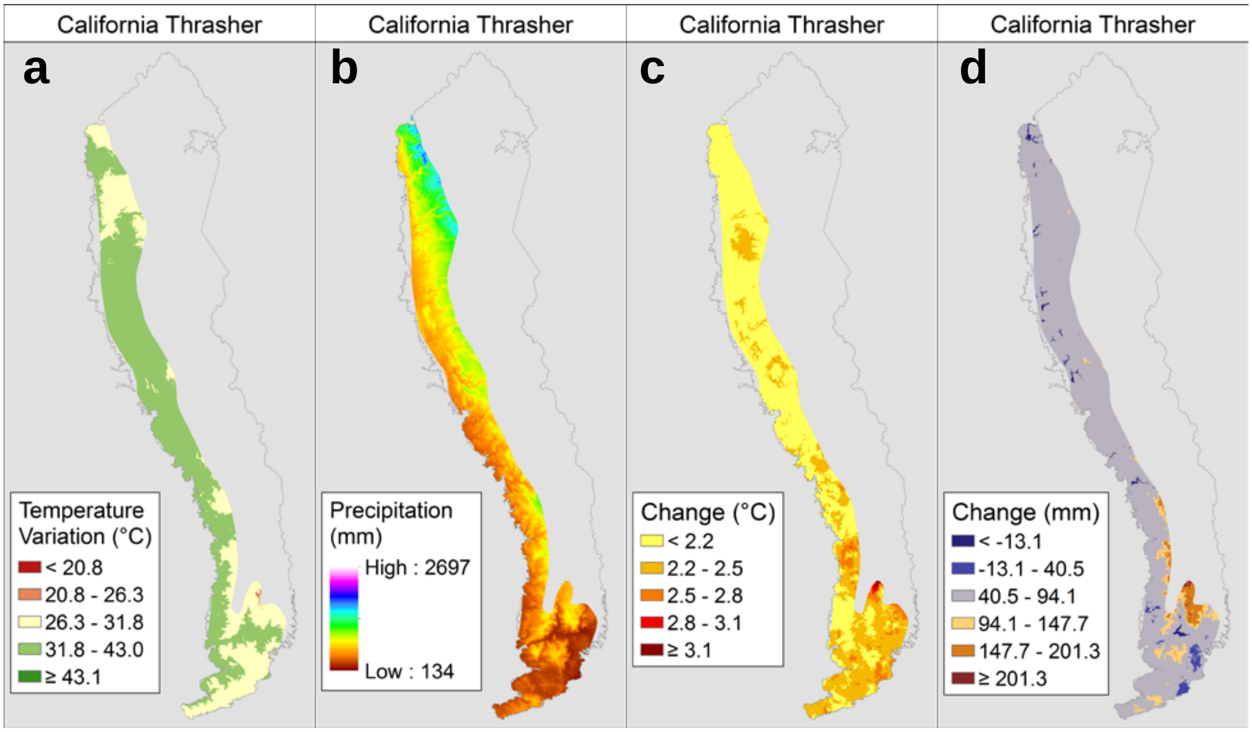


Figure 5. Exposure of California Thrasher to historic climatic variation and predicted climate change in the Sierra Nevada. These figures represent exposure to variation in (a) temperature and (b) precipitation based on observed variation during 1971-2000 (see Fig. 2), and predicted changes in (c) temperature and (d) moisture between1971-2000 and 2040-2069 (see Figs. 3 and 4), in the current range of California Thrasher, a species restricted to lower-elevation habitats on the Sierra Nevada's western slope. In this portion of the Sierra Nevada, historic exposure to temperature variation is relatively high, historic exposure to precipitation variation is relatively low, and predicted changes in temperature and moisture are relatively low compared to other portions of the Sierra Nevada region. The predictions pictured here are based on GFDL models – predictions based on PCM models (which predict relatively less warming and drying) were also made but are not shown here.

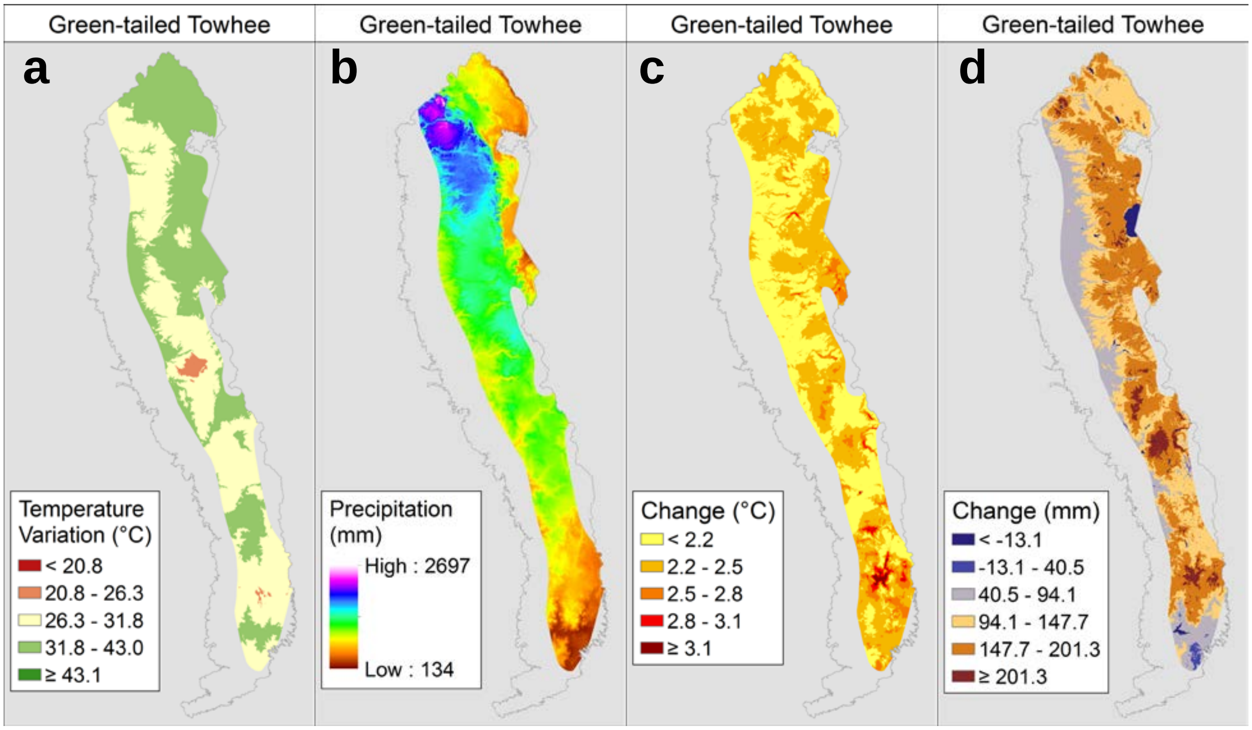


Figure 6. Exposure of Green-tailed Towhee to historic climatic variation and predicted climate change in the Sierra Nevada. These figures represent exposure to variation in (a) temperature and (b) precipitation based on observed variation during 1971-2000 (see Fig. 2), and predicted changes in (c) temperature and (d) moisture between1971-2000 and 2040-2069 (see Figs. 3 and 4), in the current range of Green-tailed Towhee, a species restricted to mid-elevation areas within the Sierra Nevada. In this portion of the Sierra Nevada, exposure to historic temperature and precipitation variation and predicted changes in temperature and moisture are all moderately high compared to other portions of the Sierra Nevada region. The predictions pictured here are based on GFDL models – predictions based on PCM models (which predict relatively less warming and drying) were also made but are not shown here.

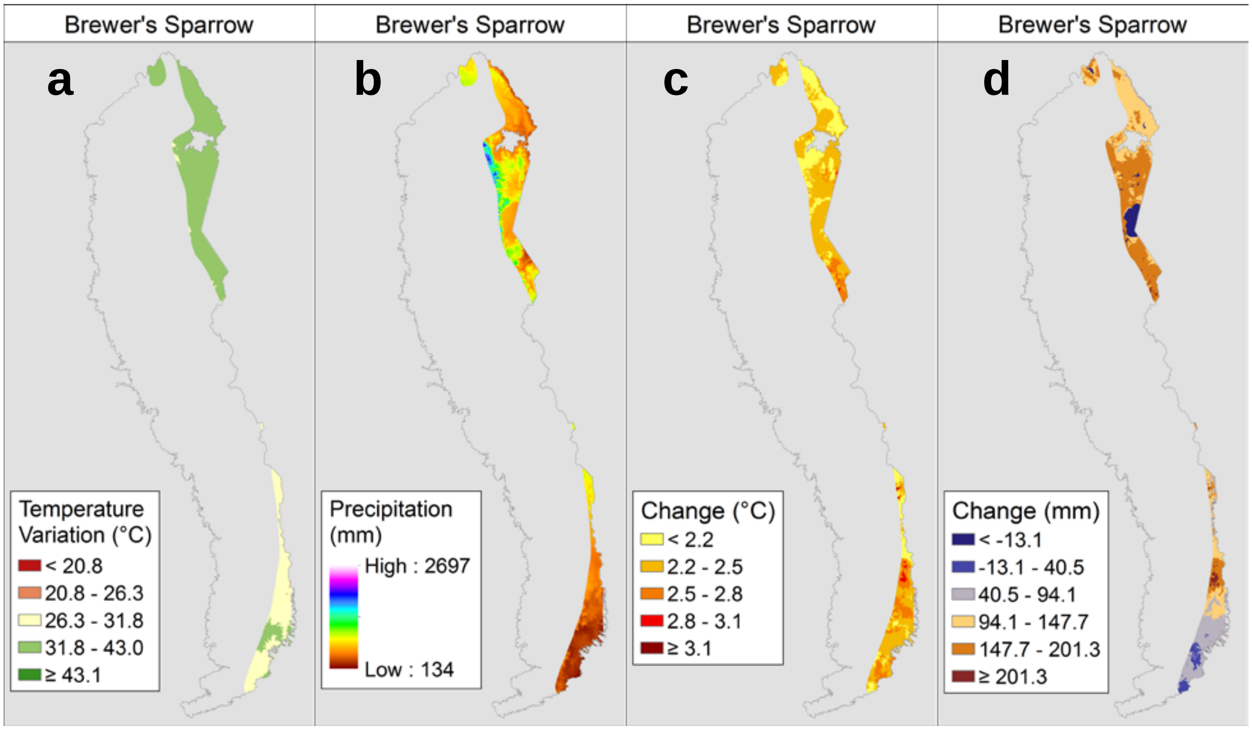


Figure 7. Exposure of Brewer's Sparrow to historic climatic variation and predicted climate change in the Sierra Nevada. These figures represent exposure to variation in (a) temperature and (b) precipitation based on observed variation during 1971-2000 (see Fig. 2), and predicted changes in (c) temperature and (d) moisture between1971-2000 and 2040-2069 (see Figs. 3 and 4), in the current range of Brewer's Sparrow, a species restricted to mid-elevation areas at the northern and southern extremes of the Sierra Nevada's eastern slope. In these portions of the Sierra Nevada, exposure to historic temperature and precipitation variation is relatively low, and predicted changes in temperature and moisture are moderate compared to other portions of the Sierra Nevada region. The predictions pictured here are based on GFDL models – predictions based on PCM models (which predict relatively less warming and drying) were also made but are not shown here.

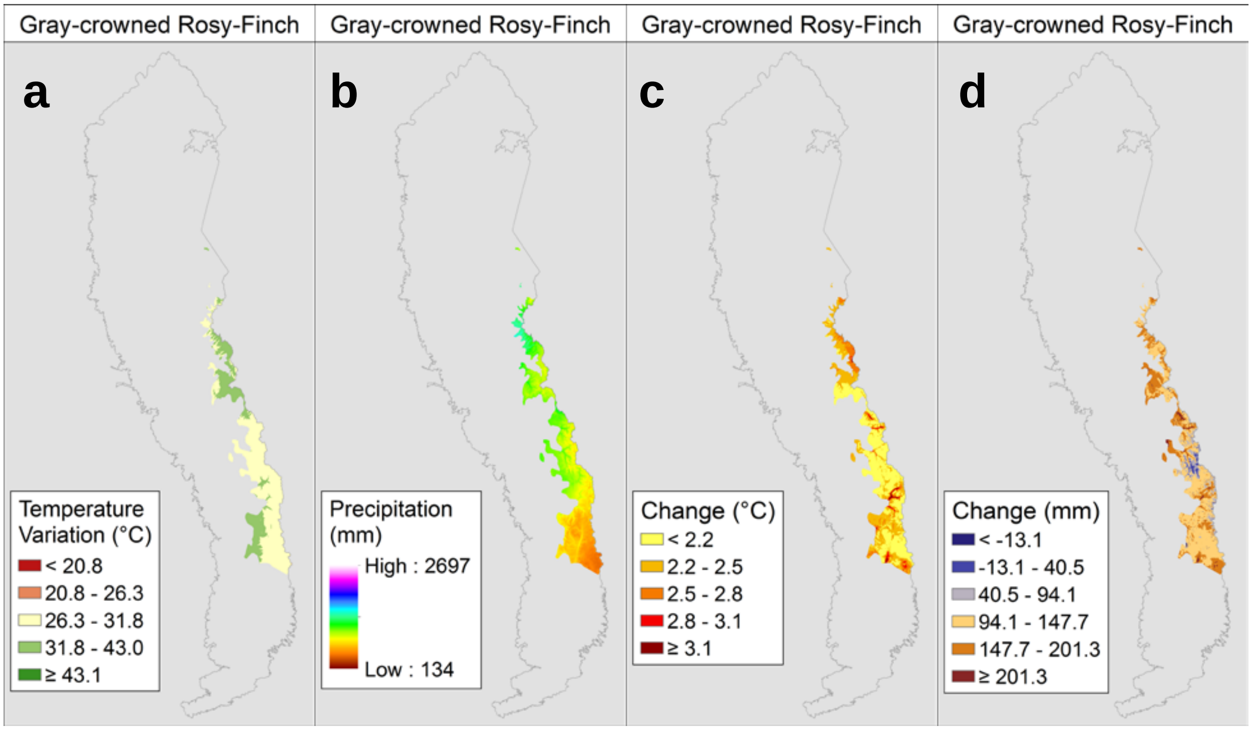


Figure 8. Exposure of Gray-crowned Rosy-Finch to historic climatic variation and predicted climate change in the Sierra Nevada. These figures represent exposure to variation in (a) temperature and (b) precipitation based on observed variation during 1971-2000 (see Fig. 2), and predicted changes in (c) temperature and (d) moisture between1971-2000 and 2040-2069 (see Figs. 3 and 4), in the current range of Gray-crowned Rosy-Finch, a species largely restricted to the highest-elevation areas of the Sierra Nevada. In these portions of the Sierra Nevada, exposure to historic temperature and precipitation variation is moderate, and predicted changes in temperature and moisture are high compared to other portions of the Sierra Nevada region. The predictions pictured here are based on GFDL models – predictions based on PCM models (which predict relatively less warming and drying) were also made but are not shown here).

e) Use literature and expert opinion to assess 20 attributes of each species conservation status, natural history and ecology

Following NatureServe guidelines, we scored each of the 168 species' relative vulnerability to climate change according to 20 distinct traits relating to conservation status, natural history, and ecological interactions. Scores were based on published and unpublished literature, as well as expert opinion of the various project partners.

f) Process the results of steps (d) and (e) through the algorithm provided by NatureServe's Climate Change Vulnerability Index to yield an overall assessment of each species' vulnerability

After compiling all of the vulnerability rankings and statistics on historical climate variation and predicted climate change, we processed the results through the algorithm provided by NatureServe's Climate Change Vulnerability Index to yield an overall assessment of each species' vulnerability – which was scored as one of the following:

Extremely Vulnerable: Abundance and/or range extent within geographical area assessed extremely likely to substantially decrease or disappear by 2050.

Highly Vulnerable: Abundance and/or range extent within geographical area assessed likely to decrease significantly by 2050.

Moderately Vulnerable: Abundance and/or range extent within geographical area assessed likely to decrease by 2050.

Not Vulnerable/Presumed Stable: Available evidence does not suggest that abundance and/or range extent within the geographical area assessed will change (increase/decrease) substantially by 2050. Actual range boundaries may change.

Not Vulnerable/Increase Likely: Available evidence suggests that abundance and/or range extent within geographical area assessed is likely to increase by 2050.

g) Ancillary analysis of the effects of climatic variation on avian demography in the Sierra Nevada

Central to this project is predicting the effects that climate change will have on Sierra Nevada bird species in the coming decades. Although we have used NatureServe's Climate Change Index as our primary tool for doing this, we also conducted a secondary analysis that was not explicitly part of the CCVI-based assessment. IBP and Yosemite National Park have been collaborating since the early 1990s to operate Monitoring Avian Productivity and Survivorship (MAPS) bird banding stations annually in Yosemite (Figure 9).

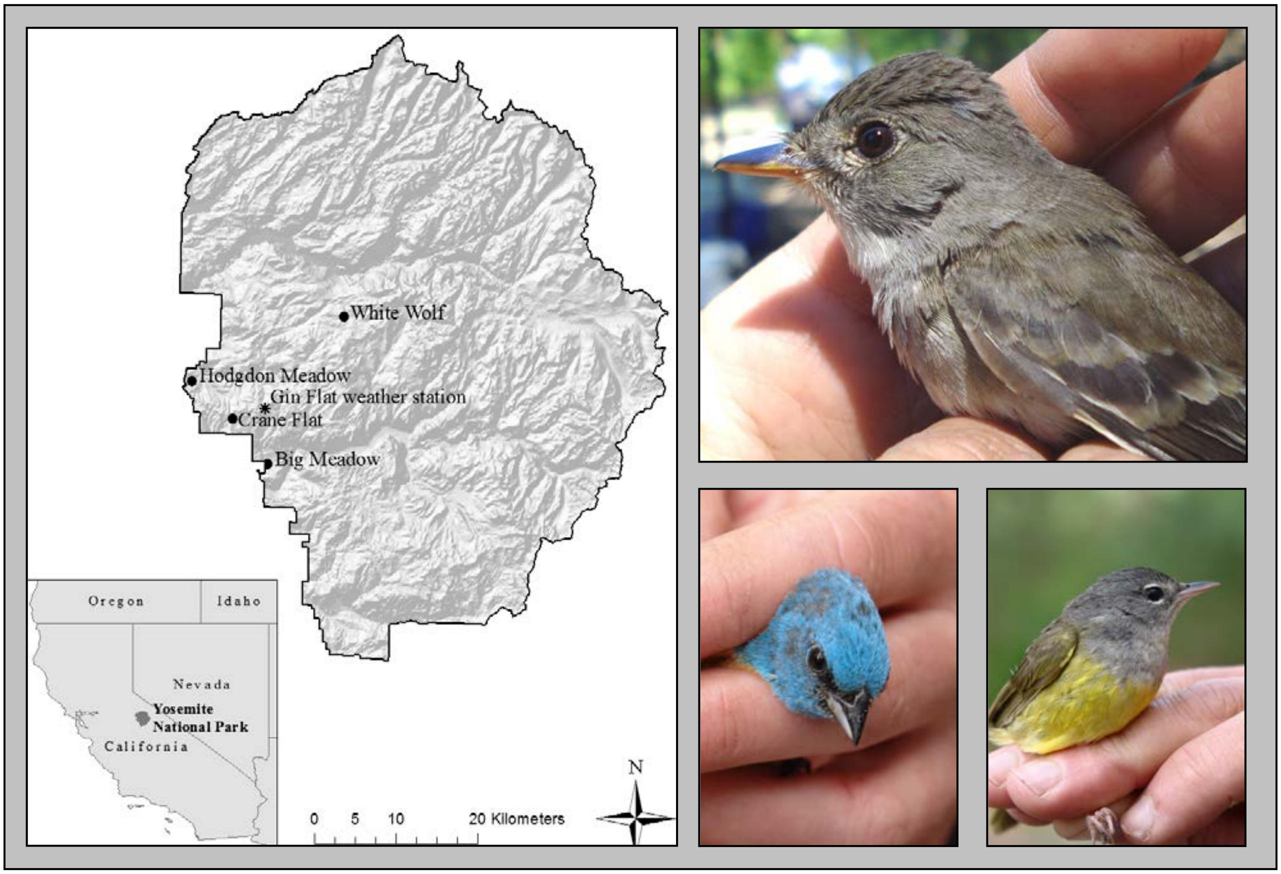


Figure 9. Locations of Monitoring Avian Productivity and Survivorship (MAPS) stations at Yosemite National Park, and three focal species (Willow Flycatcher, MacGillivray's Warbler, and Lazuli Bunting) captured at those stations.

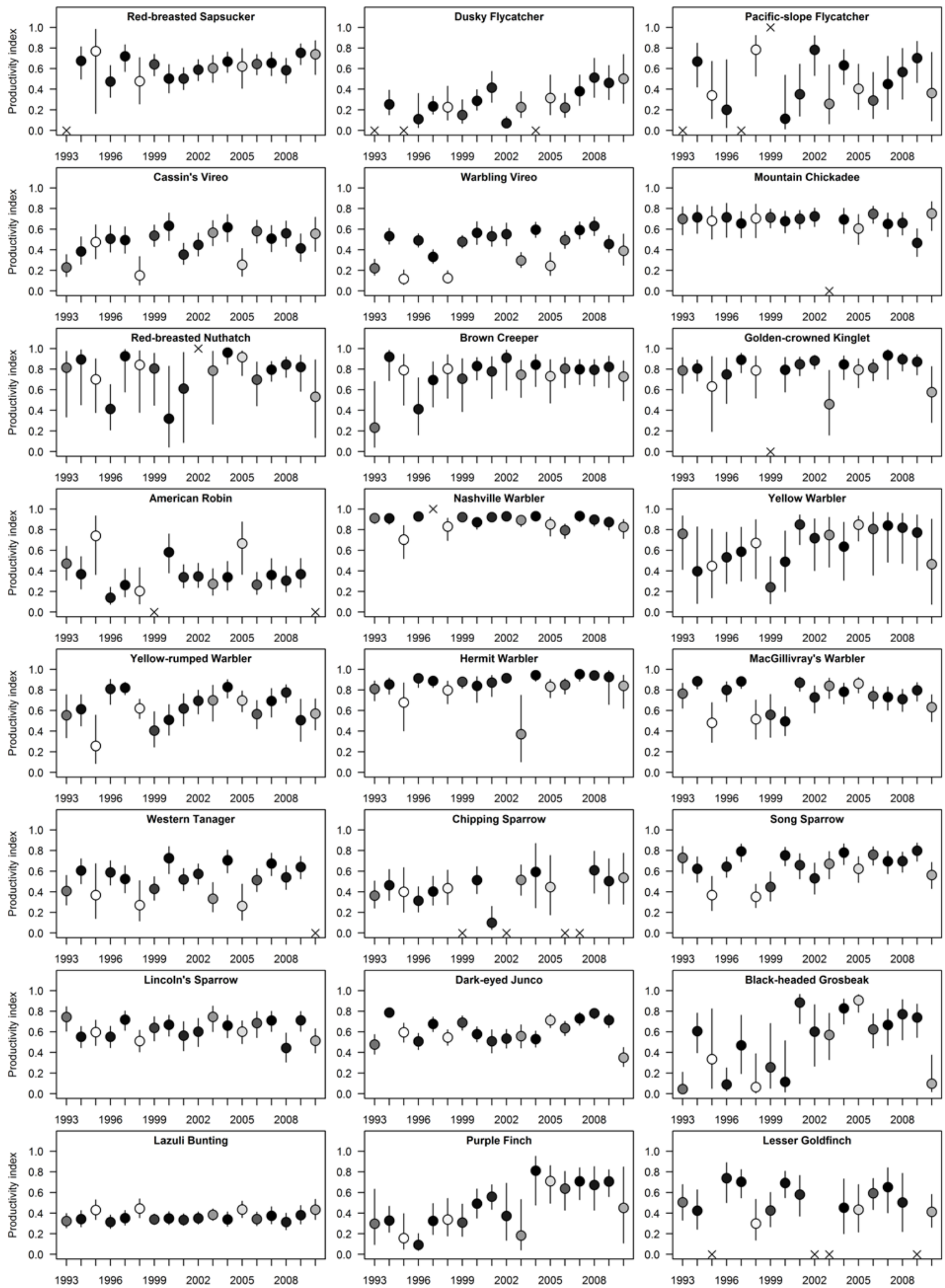
We used 18 years of mark-recapture data from these stations to assess the effect of annual variation in spring snowpack on annual productivity indices derived from data collected at these MAPS stations. Winter snowpack and timing of snowmelt in the Sierra Nevada vary dramatically from year to year, and snow cover can persist at higher elevations well into spring and summer months following severe winters. Spring snowpack is expected to increase in the coming decades, as snowmelt occurs earlier in the spring - a pattern already being observed across much of western North America and other montane regions of the world.

We used logit-linear models to examine annual variation and temporal trend in productivity as well as the relationship between spring snowpack (measured as snow water equivalent) and productivity, and then used Aikaike's Information Criterion adjusted for small samples, AIC_c, and AIC_c model weights,, to select among competing models. Overall, the relationship between productivity and snowpack was negative, with 22 of 24 species having negative regression coefficients for snowpack (all species except Yellow Warbler and Lazuli Bunting) (Figure 10).

Twenty of 24 target species showed some degree of support for the hypothesis that productivity is related to snowpack. Thirteen of these species had models with snowpack effects as among the most strongly supported models. Sixteen species had statistically significant negative relationships with spring snowpack and only one species (Yellow Warbler) had a statistically significant positive relationship with spring snowpack. These results suggest that one aspect of Sierra Nevada climate change in the coming decades – decreased spring snowpack, may actually boost productivity for many landbird species. Of course, effects of climate change are likely to be numerous and complex – earlier snowmelt, for example, is likely to lead to drier mid-summer meadow conditions, which might mean reduced food resources or other negative consequences for meadow-nesting birds, including many of the target species at the Yosemite MAPS stations. It is unclear how such effects might weigh against one another, and ecological consequences of climate change may be numerous and complex.

We are currently preparing these results for publication.

Figure 10 (next page). Annual productivity index estimates, for 24 bird species across four Monitoring Avian Productivity and Survivorship (MAPS) stations in Yosemite National Park, 1993-2010. Estimates represent the probability of a captured bird being a young (hatching-year) bird on the mean capture date for young birds in that year; they are model-averaged back-transformed predictions from logit-linear models. **Symbol shading follows a gradient from low (black) to high (white) May snowpack.** Productivity was not estimable in years for which no young birds were captured are shown with × symbols at a probability value of zero. Years with no adults, but more than one young bird captured, are denoted with × symbols at a probability value of one.


Red-breasted Sapsucker
Dusky Flycatcher
Pacific-slope Flycatcher
Cassin's Vireo
Warbling Vireo
Mountain Chickadee
Red-breasted Nuthatch
Brown Creeper
Golden-crowned Kinglet
American Robin
Nashville Warbler
Yellow Warbler
Yellow-rumped Warbler
Hermit Warbler
MacGillivray's Warbler
Western Tanager
Chipping Sparrow
Song Sparrow
Lincoln's Sparrow
Dark-eyed Junco
Black-headed Grosbeak
Lazuli Bunting
Purple Finch
Lesser Goldfinch
Productivity index
0.0
0.2
0.4
0.6
0.8
1.0
1993
1996
1999
2002
2005
2008

f) Produce an adaptation strategy for the most vulnerable species, as determined in step (e).

Based on results of the Climate Change Vulnerability work described above, we are now developing our Adaptation Strategy. Chapters under development include:

- Introduction to the Sierra Nevada Region and its Avifauna
- Climate Change in the Sierra Nevada
- Climate Change Vulnerability Assessment for Sierra Nevada birds
- Adaptation Approaches and Priorities
- Adaptation Recommendations

The Adaptation Recommendations Chapter places particular emphasis on steps to protect bird species dependent on rivers, streams, lakes, and wetland habitats; interior forest bird species; and high-elevation bird species.

Remaining tasks

Major tasks that remain include:

- Complete the Adaptation Strategy.
- Obtain peer review of the Adaptation Strategy and make appropriate revisions.
- Conduct outreach efforts targeting Sierra Nevada land managers (particularly Forest Service and National Park Service personnel), the California Partners in Flight community, and the general public to publicize the existence of the plan and the importance of proactive management to minimize negative consequence of climate change on Sierra Nevada birds. One of the planned outreach activities is the creation of a high-quality web-video about Sierra Nevada birds and climate change in collaboration with our partners at Yosemite National Park.