Audubon CALIFORNIA

Mapping Avian Responses to Climate Change in California

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Cover: California Quail (*Callipepla californica*) by John James Audubon.

Summary

Global climate change threatens our wildlife with extinction, and only science-based planning and careful stewardship will ensure a lasting protection. The coming Century brings new challenges that require bold solutions. These challenges include a shifting landscape, an uncertain future climate, and a potential de-coupling of species from their complex ecosystems. To minimize uncertainty about how best to protect California's birds, we combine the latest in science with old-fashioned bird watching to generate future range maps for each species. By using the many years of bird data, collected by volunteers each winter and spring, in combination with detailed climate information, we can understand the relationship between a bird's range and its climate. Armed with this relationship, we can project likely responses to all future climate scenarios and look for areas of stability and loss within a species' range. Knowing which parts of the range are most likely to remain constant, most in need of new habitat, or doomed to disappear, we can promote conservation actions that balance risk and opportunity. The present document, *Mapping Avian Responses to Climate Change in California*, serves as a general technical report describing our mapping methodology and basic summary results. It accompanies Version 1.0 of our new Geographic Information Systems (GIS) library containing over 100,000 spatially explicit predictions of the past, present, and future distributions of California's birds.

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While too many people to name, we thank all Audubon California chapters, local birders, and climatologists who contributed data to the present study. Integrative research of this sort would simply not be possible without their collective efforts.

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Aims and Purpose

Audubon California has developed a geographic information system (GIS) for purposes of forecasting how bird species will respond geographically to future climate change. We are using the new GIS library to inform land-based conservation around the state, specifically by mapping (1) Areas and habitats in California that will continue to remain important to birds, (2) Areas where bird species of special concern will benefit from habitat restoration, (3) Movement corridors that will enable particular species to track changes in climate, (4) Areas where assisted migration of birds and habitats will be required to ensure future survival, (5) Areas and habitats where bird species will be physiologically doomed to extirpation, and (6) Areas where additional study will be needed to make recommendations for adaptive land management.

The Importance of Scale

It is widely recognized that species' distributions are influenced by a variety of biotic and abiotic factors, including habitat and resource availability, species interactions, and physiology (Brown *et al.* 1996). However, the respective influences of these factors are highly dependent on the spatial and temporal scales of analysis (Wiens 1989). One of the major challenges for understanding the effects of climate change on species' distributions thus lies in identifying the appropriate spatiotemporal scales at which species' distributions can and cannot be reliably predicted from a mechanistic knowledge of climate dependence (Guisan & Thuiller 2005). As a first approximation, species' distributions considered at small scales tend to be mostly influenced by biotic interactions (Nicholson & Bailey 1935), mid scales by habitat and resource availability (Orians & Wittenberger 1991), and large scales by climate, putatively through interactions with the physiological limits of the organism (Andrewartha & Birch 1954).

Classic examples of such scale-dependencies in California include: (1) Small scale: Competition between the Golden-crowned Sparrow and Dark-eyed Junco, where junco foraging distributions are constrained spatially by aggressive interactions with the sparrow (Davis 1973). (2) Mid scale: Oak woodland specialists like the Acorn Woodpecker, where distributional limits are determined by the number of oak species in the community (Koenig & Haydock 1999). (3) Large scale: Lifezone icons like the California Thrasher, where statewide range limits are largely defined by climatic attributes of the Upper Sonoran lifezone (Grinnell 1917).

Here, we use correlative models to predict the geographic responses of California's avifauna to past and future changes in climate. We intentionally focus on a large geographic region (all of California) and a coarse spatial resolution (4 x 4 km) because these two factors combined likely approximate the spatial scale at which many bird distributions are proximately shaped by climate. However, non-modeled factors such as habitat dependencies, biotic interactions, and dispersal limitations may in some cases prove highly important even at this coarse scale. Because it is impossible to incorporate all of these "non-climatic" variables into an analysis, the correlative distribution models presented here are best described as capturing the bioclimatic envelope of each species. In this sense, the "null climate models" should be seen as delineating areas where a species could occur in the future if suitable habitats are present, biotic interactions remain unchanged, and dispersal is non-limiting. Hence, the models are not intended to provide a passive answer to the question of how bird species will respond to future climate change. They are instead meant to identify conservation opportunities that can only be realized if we proactively plan for biological change.

Climate Change Models and Uncertainty

All interpretations of the future must be based on models, and all models entail uncertainty. In the case of climate change, our best hope for making sound conservation decisions is to reduce as much uncertainty as possible. There are three major sources of uncertainty to consider when forecasting species' distributional responses to climate change: computational, biological, and future climate. In this analysis, we have gone to great lengths to reduce all three sources of uncertainty.

Computational uncertainty stems from the quality of the data used to develop the model, as well as the limits of the modeling technique. Data quality is tied to both the validity and spatial scale of the geographic coordinate data used to formulate the model. Starting data sources might be perfectly suited to make projections in one case and poorly suited in another. Ideally, the models that are eventually projected to the future are first validated using historical time series data. Such validation provides users with a sense of how well the models correctly predict known historical changes in distribution, thereby giving an indication of how well the models might continue to perform in the future. Computational uncertainty is further propagated by the fact that different modeling techniques often yield different predictions. To deal with this, we use three different modeling methods that bracket the range of expected outcomes. We then ensemble the models and – coupled with the historic validation just

described – show that ensembled models are superior overall at predicting observed changes in distribution.

Biological uncertainty means that we are not sure if a species can persist or move under future climate change. Much of the last 100 years of ecology has dealt with understanding how populations and species persist. Birth rates, death rates, immigration, emigration, competition, foraging, lifespan, *et cetera*. These key biological factors are challenging to measure and each estimate has sources of uncertainty, too. Our models do not incorporate any of these measures directly, but we can still consider them *post hoc* when issuing conservation recommendations. Here, biological uncertainty is minimized in areas where a species occurs today and is predicted to occur after accounting for both future climate change and computational uncertainty.

Future climate uncertainty is obvious: we don't know yet how much climate will change in the future, and at what rate. To deal with this uncertainty, we base our analysis on all major climate change models and scenarios available for North America. We then look for areas in each species' range that show agreement across models. For example, where do the majority of models predict range stability? Range contraction? Or range expansion? We identify these changes in distribution using combinations of the current range and projected future range under all species models, climate models, and emission scenarios. In essence, we are calculating the odds of a given outcome across the potential range of outcomes.

Some conservation leaders will be uncomfortable making decisions based on models. It is worth noting, however, that assuming species will not shift their distributions in response to climate change is also a model of the future. This *status quo* model also has all the same uncertainties associated with change models, except that there is no formal attempt to bracket or measure the uncertainty. A *status quo* model may, in fact, be the riskiest approach of all.

MATERIAL AND METHODS

Focal bird species

We focused our analysis on all 312 common coastal and terrestrial bird species in California (Appendix 1). Focal species have parallel representation in the California Wildlife Habitat Relationships (CWHR) range map classification system (California Department of Fish and Game 2002).

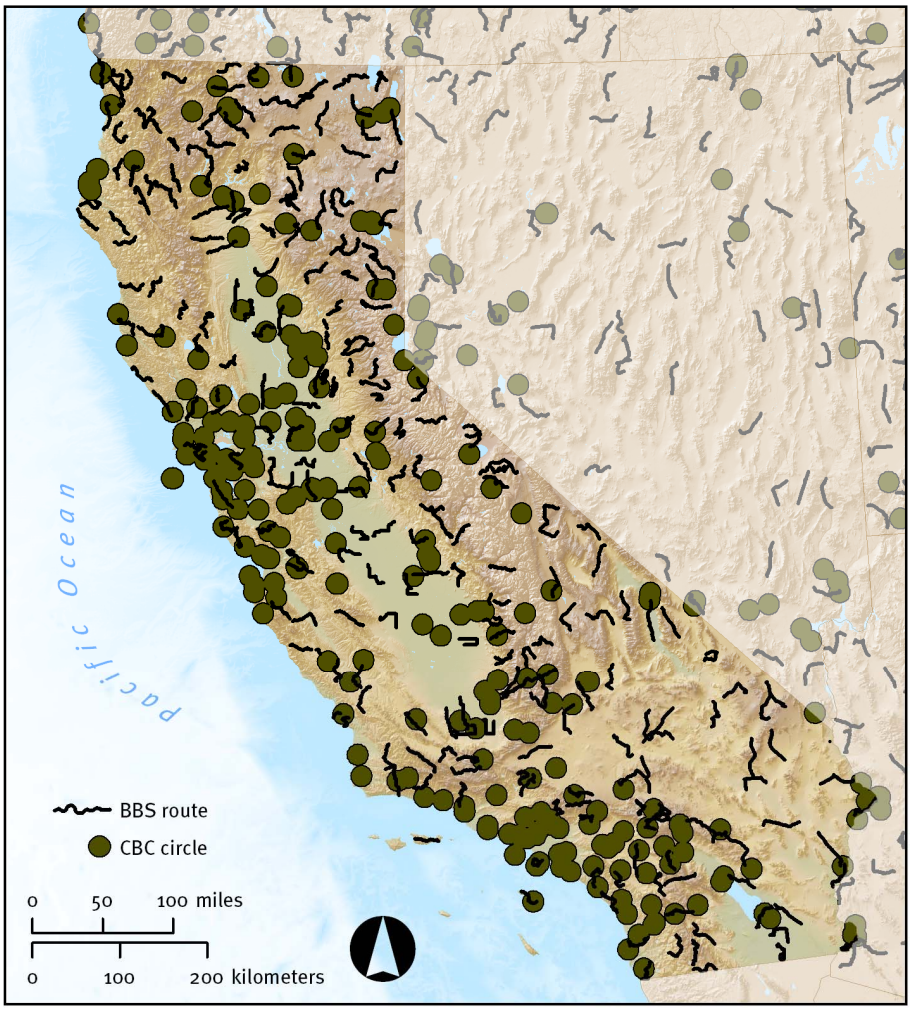

Figure 1. Distribution of Audubon Christmas Bird Count circles (n = 128) and North American Breeding Bird Survey routes (n = 191) in California.

Bird distribution

Bird distribution data were primarily obtained from the Audubon Christmas Bird Count (CBC, Butcher 1990) and the North American Breeding Bird Survey (BBS, Sauer *et al.* 2001) (Fig. 1). In these datasets, a species was considered present at a site if it was detected in 5% or more of survey years (1967–2006). Absence was defined for the same time period as sites where a species was never observed. Geographic coordinates of sites were obtained from georeferenced circle centroids (CBC) and route start-points (BBS). We only included BBS observations from the first 10 stations on each route. Three special classes of species required that we obtain locality data from sources other than the CBC and BBS: (1) Species that have recently undergone taxonomic revisions, (2) Species that are exceedingly difficult to reliably identify in field

surveys, and (3) Species that are either rare or rarely detected in field surveys. In these cases, we obtained georeferenced locality data from the Ornithological Information System (ORNIS). ORNIS is an online data portal that facilitates easy access to over 35 million unique bird records (specimen and observational) housed by 45 different providers. We primarily used ORNIS to assemble specimen records from museum collections. See Appendix 1 for a list of data sources and sample sizes used in the present study.

Contemporary climate interpolation

Monthly mean minimum temperature, mean maximum temperature, and total precipitation were obtained from PRISM: Parameter-elevation Regressions on Independent Slopes Model. PRISM is a knowledge-based system that generates monthly x yearly climate surfaces using mathematical interpolation and expert knowledge (Daly *et al.* 2002). PRISM data are made freely available for every month x year (1895–2007) at 4 x 4 km spatial resolution. We limited our use of PRISM data to the years for which we had bird data (1967–2006). Monthly climate variables were used to compute standard bioclimatic variables.

Future climate models and scenarios

Future climate surfaces were derived from the World Climate Research Programme's (WCRP) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset referenced in the Intergovernmental Panel on Climate Change Fourth Assessment Report (Intergovernmental Panel on Climate Change 2007). This climate dataset encompasses 3 major emission scenarios (SRES: A1B, B1, A2) and 16 different climate models, some with multiple runs, yielding a total of 112 different predictions of the future (Appendix 2).

In brief, the A2 scenario represents a relatively "high" emissions pathway shaped by fragmented technological and economic growth. A1B is a relatively "middle-of-the-road" scenario where technological change is balanced across fossil and non-fossil energy sources. Finally, B1 is a relatively "low" emissions trajectory that emphasizes clean and sustainable technology. These and other major emission scenarios are illustrated in Figure 2.

Future climate surfaces were computed as means for 2060–2099 (late 21st Century), a period in which major emission scenarios exhibit pronounced differences (Figure 2). To calculate these surfaces, we first used the WCRP-CMIP3 data archive to derive mean monthly climate grids (mean temperature and total precipitation; monthly estimates of minimum and maximum temperature were not available) for our historic (1967–2006) and future (2060–

2099) time periods. We then subtracted historic from future for each month x variable to derive delta grids. The monthly temperature and precipitation delta grids were then statistically downscaled (re-sampled using bilinear interpolation to 4 x 4 km) and added to our historic PRISM climate surfaces (1967–2006). Finally, we used these new PRISM-adjusted future monthly climate surfaces to compute bioclimatic variables.

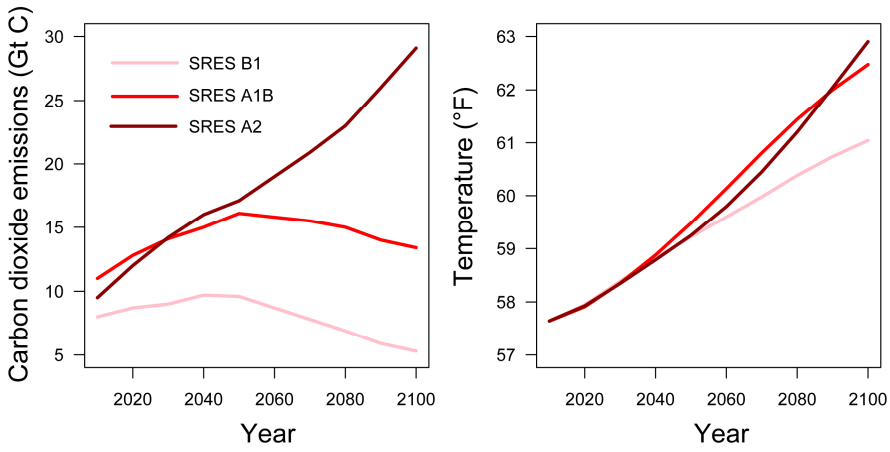

Figure 2. Possible Carbon dioxide emission scenarios for the 21st Century. The present study considers 3 scenarios: A1B, B1, and A2 (left), with corresponding increases in annual mean temperature (right).

Bioclimatic variables

Correlative distribution models were developed using standard bioclimatic variables that represent more biologically meaningful combinations of the original monthly climate variables (Nix 1986). Bioclimatic variables broadly encompass temperature, precipitation, and seasonality (Table 1).

Correlative distribution models

We developed our models in two separate yet equally important phases. In phase I, we developed historic time series models using the observed climatic associations of each species. In phase II, we developed contemporary models that could be projected to the future using all 112 different climate models and scenarios described above. Phase I is broadly termed historical validation and phase II is referred to as ensemble forecasting.

Table 1. Bioclimatic variables used to model bird distribution. These 19 variables represent more biologically meaningful versions of the original monthly climate variables obtained from PRISM and WCRP-CMIP3.

Bioclimatic Variable	**Units**
Annual Mean Temperature	°C
Mean Diurnal Range (Mean of monthly [max temp - min temp])	°C
Isothermality	None
Temperature Seasonality (standard deviation)	°C
Max Temperature of Warmest Month	°C
Min Temperature of Coldest Month	°C
Temperature Annual Range	°C
Mean Temperature of Wettest Quarter	°C
Mean Temperature of Driest Quarter	°C
Mean Temperature of Warmest Quarter	°C
Mean Temperature of Coldest Quarter	°C
Annual Precipitation	mm
Precipitation of Wettest Month	mm
Precipitation of Driest Month	mm
Precipitation Seasonality (Coefficient of Variation)	None
Precipitation of Wettest Quarter	mm
Precipitation of Driest Quarter	mm
Precipitation of Warmest Quarter	mm
Precipitation of Coldest Quarter	mm

Phase I historical validation

We took advantage of the rich time series information of the CBC, BBS, and PRISM datasets to develop historical time series distribution models for most species that did not rely on ORNIS data (n = 261, Appendix 1). The historical models allowed us to (1) Quantify how species have already been responding geographically to historical changes in climate and (2) Assess how well our models accurately predicted known changes in distribution.

We accomplished this task by first splitting our combined CBC and BBS data, as well as the bioclimatic variables derived from PRISM, into 4 decadal time periods corresponding to cool, warm, and mixed cool-warm phases of the Pacific Decadal Oscillation (PDO, Fig. 3): 1967–1976 (cool), 1977–1986 (warm), 1987–1996 (mixed), and 1997–2006 (mixed). The PDO is an El Niño-like pattern describing climate variability in the Pacific region; it is an oceanic phenomenon that also exerts a considerable influence on weather and climate in western North America. To the extent to which species' distributions are proximately shaped by climate, efforts to model changes in distribution need to take cycles like the PDO into account so that they do not confound cyclical change with directional change.

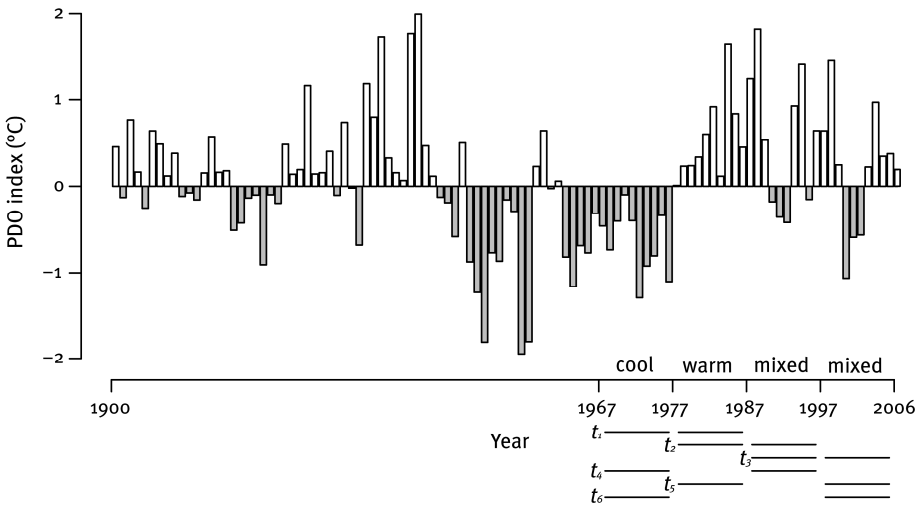

Figure 3. The Pacific Decadal Oscillation (PDO) as determined by mean annual sea surface temperature, 1900-2006. Our study considers six major transition states (t_1 through t_6). Source: http://www.atmos.washington.edu/~mantua/abst.PDO.html

We used the PDO to partition our combined CBC and BBS data into decadal training and testing subsets. In general, "training" refers to the data used to develop the model, and "testing" describes the data used to assess how well the model performed. The species distribution model is formulated using the climatic attributes of the training data (Fig. 4a). While the model itself is mathematical (Fig. 4b), it can be projected back onto the original bioclimatic variables to derive what is commonly termed the predictive distribution map (PDM, Fig. 4c). Models may be projected back onto the original gridded bioclimatic variables used to formulate the model, or onto the same bioclimatic variables encompassing different times or places; the latter approach is used in historical validation and ensemble forecasting.

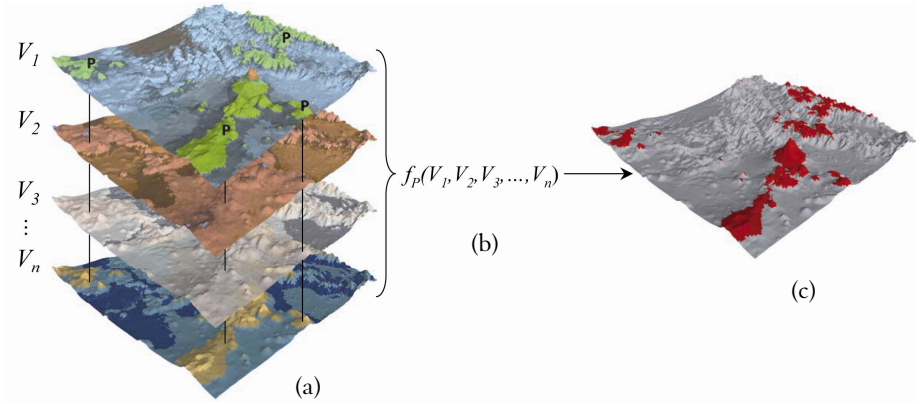

Figure 4. Correlative distribution modeling combines species coordinate data (P) and bioclimatic variables (V_1, V_2, V_3, …, V_n) (a) to formulate a mathematical model (f) (b). The resulting species distribution model may then be projected back into geographic space to generate a predictive distribution map (c).

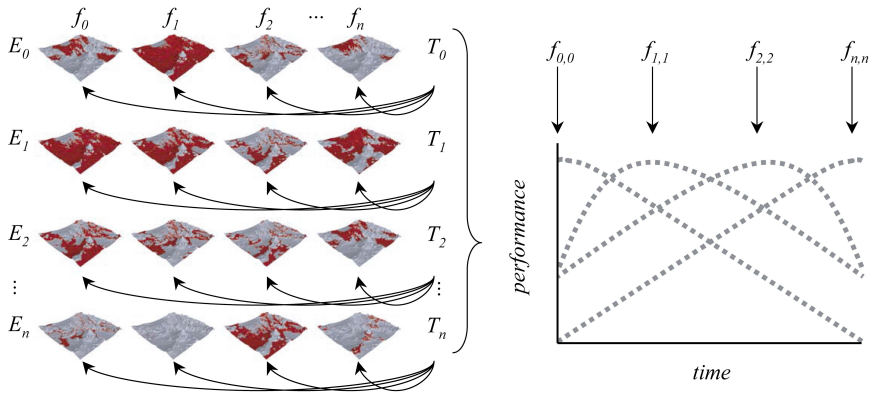

Figure 5. Direct validation of correlative distribution models ($f_0, f_1, f_2, \ldots, f_n$) projected to other environments ($E_0, E_1, E_2, \ldots, E_n$). Measures of model performance are calculated using testing data ($T_0, T_1, T_2, \ldots, T_n$) that are temporally concomitant with the bioclimatic data. Large time series datasets like the CBC, BBS, and PRISM may be used to estimate how species model performance changes as a function of time (vertical arrows on plot denote training models on the matrix diagonal).

We used Maxent (Phillips *et al.* 2006), Domain (Carpenter *et al.* 1993), and Bioclim (Nix 1986, Busby 1991) to develop historic time series distribution models using the 19 bioclimatic attributes (decadal means) of each species' spatially unique localities sampled at 4 x 4 km (i.e., the native resolution of PRISM). A maximum of 4 time series models were possible for each species (corresponding to the 4 training species data subsets). These were developed using the three modeling algorithms (Maxent, Domain, and Bioclim), yielding a total of 12 different models encompassing computational uncertainty in modeling technique. Each training model was then projected to the remaining 3 decadal time periods, meaning that each of our starting 261 species' distributions was captured by a total of 48 training and testing PDMs (Fig. 5).

Phase II ensemble forecasting

Forecasts were developed using models that collapsed the species and climate data from the 4 historic decades into a single contemporary time slice (1967–2006). This was done to accommodate the remaining 51 species that could not be included in the time series analysis. Thus, all 312 bird species were included in phase II of analysis (Appendix 1). Species localities were rendered spatially unique based on the entire 40 year time period. Bioclimatic variables were recomputed as 40-year means. We then redeveloped the species models using the same modeling algorithms (Maxent, Domain, and Bioclim). For each species and algorithm, we iteratively projected the contemporary models onto the bioclimatic variables computed for the 112 future climate models and scenarios (Appendix 2). This resulted in a total of 336 future PDMs for each species.

Thresholding

For purposes of calculating measures of historic model performance, and to standardize visualization of all historic, contemporary, and future PDMs across different modeling techniques (which generate different types of probability surfaces), we rendered each PDM binary using a ≥95% sensitivity threshold on the training PDM. This ensured that our models minimally recovered the training data, a behavior we considered important given our high confidence in the species locality data.

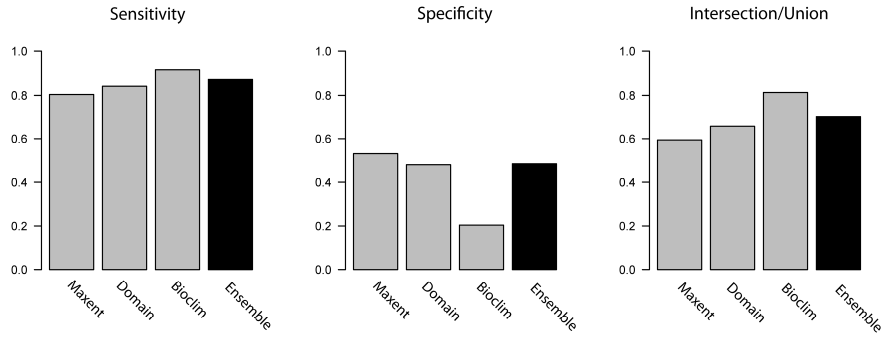

Figure 6. Results of historic model validation for Maxent, Domain, Bioclim, and the ensemble of all three algorithms. Models evaluated using three measures of performance (sensitivity, specificity, and intersection/union or spatial concordance), reported here as means for 261 bird species modeled over 4 decades. Each bar is thus comprised of 4 x 261 = 1,044 data points.

Historic model validation

We considered three measures of model performance, all calculated on the testing PDMs generated in phase I of analysis: (1) Sensitivity, which describes the model's ability to correctly predict where a species is known to occur, (2) Specificity, the inverse of sensitivity, which describes the model's ability to correctly predict where a species is known to be absent, and (3) Spatial concordance, a measure that quantifies overall model agreement by dividing the intersection of the testing and training PDMs through by their union. We calculated these three measures for each model individually (Maxent, Domain, and Bioclim), as well as for the ensemble of all three models (Figure 6). Historic ensembling was achieved by applying a two-thirds rule, meaning that model concordance was defined by areas where at least two out of three model predictions were in agreement. For historic training models, this meant that we reclassified areas as present if at least 2/3 training PDMs predicted bioclimatic suitability in a given decade. Similarly, for historic testing models, we reclassified areas as present if at least 6/9 testing PDMs predicted bioclimatic

suitability in a given decade. The results of phase I show that, on average, ensemble models outperformed the individual models. Phase I results further show that predictions obtained from Maxent, Domain, and Bioclim entail performance tradeoffs, meaning that no one algorithm is superior at fully maximizing model accuracy.

Mapping future changes in bird distribution

Our goal was to consolidate all of the future model predictions into a single grid or map for each bird species. Specifically, we wanted the results to furnish spatially explicit recommendations for adaptive land management in the face of climate change and model uncertainty. We accomplished this through further processing of the contemporary and future PDMs derived from ensemble forecasting. For each species, we first subtracted the contemporary PDM from each future PDM to generate 336 new delta surfaces describing areas of predicted range stability, expansion, and contraction. Because the species distribution models were unable to explicitly incorporate other potentially important variables such as habitat dependencies, we then combined each species' delta grid with its corresponding expert delineated CWHR range map (California Department of Fish and Game 2002). Third, we reclassified the hybrid PDM-CWHR maps into five possible distributional transition states, with recommended conservation actions in parentheses: (1) Range stability or persistence predicted within the CWHR extent ("preserve"), (2) Range expansion predicted beyond the CWHR extent but range persistence predicted within the extent of the contemporary PDM ("restore"), (3) Range uncertainty predicted within both the CWHR and contemporary PDM ("study"), (4) Range expansion predicted beyond both the CWHR and contemporary PDM ("assist"), and (5) Range contraction predicted within the CWHR extent ("avoid"). Categories 1, 2, 4, and 5 were defined based on a one-third rule, meaning that we only assigned each map pixel to a particular transition state if it was predicted by >33% of the 336 transition grids. Category 3 was then assigned to all remaining pixels with model predictions; this category identifies areas where a consensus was not obtained across the different models.

Data Availability

Our raw data and results, consisting of over 100,000 gridded model predictions from phases I and II of analysis, are made freely available to encourage further research. Information and updates forthcoming through the Audubon California website (http://www.ca.audubon.org).

References

Andrewartha, H. G. & L. C. Birch. 1954. *The Distribution and Abundance of Animals*. University of Chicago Press, Chicago, IL.

Brown, J. H., G. C. Stevens, & D. M. Kaufman. 1996. The geographic range: size, shape, boundaries, and internal structure. *Annual Review of Ecology and Systematics* 27, 597-623.

Busby, J. R. 1991. BIOCLIM – a bioclimate analysis and prediction system. In: Margules, C. R. & M. P. Austin (Eds.), *Nature Conservation: Cost Effective Biological Surveys and Data Analysis*. CSIRO, Australia, pp. 64-68.

California Department of Fish and Game (CDFG) and California Interagency Wildlife Task Group (CIWTG). 2002. *California Wildlife Habitat Relationships System*. Wildlife and Habitat Data Analysis Branch. Sacramento, California.

Carpenter, G., A. N. Gillison, & J. Winter. 1993. DOMAIN: a flexible modelling procedure for mapping potential distributions of plants and animals. *Biodiversity and Conservation* 2, 667-680.

Daly, C., W. P. Gibson, G. H. Taylor, G. L. Johnson, & P. Pasteris. 2002. A knowledge-based approach to the statistical mapping of climate. *Climate Research* 22, 99-113.

Davis, J. 1973. Habitat preferences and competition of wintering juncos and Golden-crowned Sparrows. *Ecology* 54, 174-180.

Grinnell, J. 1917. The niche-relationships of the California Thrasher. *The Auk* 34, 427-433.

Guisan, A. & W. Thuiller. 2005. Predicting species distribution: offering more than simple habitat models. *Ecology Letters* 8, 993-1009.

Intergovernmental Panel on Climate Change. 2007. Contribution of Working Group I to the fourth assessment report of the Intergovernmental Panel on Climate Change. In: Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, & H. L. Miller (Eds.), *Climate Change 2007: The Physical Science Basis*. Cambridge University Press, Cambridge, UK and New York.

Koenig, W. D. & J. Haydock. 1999. Oaks, acorns, and the geographical ecology of Acorn Woodpeckers. *Journal of Biogeography* 26, 159-165.

Nicholson, A. J. & V. A. Bailey. 1935. The balance of animal populations – part 1. *Proceedings of the Zoological Society of London* 3, 551-598.

Nix, H. A. 1986. A biogeographic analysis of Australian Elapid snakes. In: Longmore, R. (Ed.), *Atlas of Australian Elapid Snakes*. Australian Government Publishing Service, Canberra, pp. 4-15.

Orians, G. H. & J. F. Wittenberger. 1991. Spatial and temporal scales in habitat selection. *The American Naturalist* 137, S29-S49.

Phillips, S. J., R. P. Anderson, & R. E. Schapire. 2006. Maximum entropy modeling of species geographic distributions. *Ecological Modelling* 190, 231-259.

Wiens, J. A. 1989. Spatial scaling in ecology. *Functional Ecology* 3, 385-397.

Appendix 1

Focal bird species, sample sizes, and data sources used in the present analysis. Sample sizes (number of unique localities where a species was observed; NA = missing data): n_1 = 1967 – 1976, n_2 = 1977 – 1986, n_3 = 1987 – 1996, n_4 = 1997 – 2006, n_{All} = 1967 – 2006. Data source (alphabetical by code): BBS = North American Breeding Bird Survey, BIOS = California Department of Fish and Game Biogeographic Information & Observation System, CBC = Audubon Christmas Bird Count, CMN = Canadian Museum of Nature, EBIRD = eBird, GBBC = Great Backyard Bird Count, MACL = Macaulay Library, MVZ = Museum of Vertebrate Zoology, PFW = Project Feeder Watch, PRBO = PRBO Conservation Science, RSL = Redwood Sciences Laboratory, UMMZ = University of Michigan Museum of Zoology, YPM = Yale Peabody Museum.

Species	n_1	n_2	n_3	n_4	n_{All}	Data Source
Greater White-fronted Goose	42	61	78	89	107	CBC
Snow Goose	46	74	76	94	114	CBC
Ross' Goose	12	42	59	78	86	CBC
Canada Goose	75	111	127	144	173	BBS, CBC
Tundra Swan	37	58	60	58	82	CBC
Wood Duck	49	85	105	108	140	BBS, CBC
Gadwall	NA	NA	NA	NA	140	BBS, CBC
Eurasian Wigeon	16	39	60	65	74	CBC
American Wigeon	72	101	119	118	147	BBS, CBC
Mallard	116	153	180	183	238	BBS, CBC
Blue-winged Teal	22	41	51	54	67	BBS, CBC
Cinnamon Teal	58	79	97	101	129	BBS, CBC
Northern Shoveler	66	95	107	117	138	BBS, CBC
Northern Pintail	80	109	114	117	155	BBS, CBC
Green-winged Teal	70	98	113	117	147	BBS, CBC
Canvasback	69	95	100	102	133	BBS, CBC
Redhead	60	83	93	97	121	BBS, CBC
Ring-necked Duck	66	99	115	117	144	CBC
Greater Scaup	41	53	63	68	86	CBC
Lesser Scaup	69	95	106	112	136	BBS, CBC
Long-tailed Duck	16	21	28	25	36	CBC
Bufflehead	65	95	106	118	141	BBS, CBC
Common Goldeneye	56	83	93	107	129	CBC
Barrow's Goldeneye	10	27	36	36	48	CBC
Hooded Merganser	43	76	93	106	125	CBC
Common Merganser	67	100	117	115	146	BBS, CBC
Red-breasted Merganser	34	48	55	62	76	CBC
Ruddy Duck	77	107	119	119	157	BBS, CBC
Chukar	3	9	10	10	16	BBS, CBC
Ring-necked Pheasant	88	102	105	86	153	BBS, CBC
Ruffed Grouse	NA	NA	NA	NA	90	EBIRD, RSL
Greater Sage-grouse	NA	NA	NA	NA	4	BBS, CBC
Sooty Grouse	NA	NA	NA	NA	77	MVZ

Species	n_1	n_2	n_3	n_4	n_{All}	Data Source
Wild Turkey	4	12	48	72	77	BBS, CBC
Mountain Quail	66	91	106	116	146	BBS, CBC
California Quail	168	208	218	226	303	BBS, CBC
Gambel's Quail	21	22	18	18	30	BBS, CBC
Common Loon	40	65	74	69	93	CBC
Pied-billed Grebe	80	115	125	132	169	BBS, CBC
Horned Grebe	52	70	74	78	101	CBC
Eared Grebe	64	97	107	114	143	BBS, CBC
Western Grebe	56	88	99	100	128	BBS, CBC
Clark's Grebe	0	42	73	80	87	BBS, CBC
American White Pelican	31	39	64	76	90	BBS, CBC
Double-crested Cormorant	49	85	107	115	140	BBS, CBC
American Bittern	55	76	79	68	102	BBS, CBC
Least Bittern	5	8	9	11	13	CBC
Great Blue Heron	102	136	149	156	205	BBS, CBC
Great Egret	59	103	120	124	155	BBS, CBC
Snowy Egret	44	76	89	93	113	BBS, CBC
Cattle Egret	31	68	72	69	93	BBS, CBC
Green Heron	51	95	99	103	131	BBS, CBC
Black-crowned Night-Heron	58	94	104	104	136	BBS, CBC
White-faced Ibis	6	12	27	35	39	BBS, CBC
Turkey Vulture	61	89	102	112	144	BBS, CBC
California Condor	NA	NA	NA	NA	16	MVZ
Osprey	31	63	84	91	112	BBS, CBC
White-tailed Kite	71	110	104	116	156	BBS, CBC
Bald Eagle	35	62	73	92	109	BBS, CBC
Northern Harrier	83	124	142	142	187	BBS, CBC
Sharp-shinned Hawk	74	109	124	126	159	BBS, CBC
Cooper's Hawk	81	114	130	133	170	BBS, CBC
Northern Goshawk	7	16	14	19	29	BBS, CBC
Harris's Hawk	NA	NA	NA	NA	8	EBIRD
Red-shouldered Hawk	68	121	133	146	189	BBS, CBC
Swainson's Hawk	6	4	8	10	15	BBS, CBC
Red-tailed Hawk	146	202	219	219	305	BBS, CBC
Ferruginous Hawk	36	80	103	102	124	CBC
Rough-legged Hawk	51	81	77	67	119	CBC
Golden Eagle	64	102	118	112	152	BBS, CBC
American Kestrel	140	181	189	171	260	BBS, CBC
Merlin	45	84	114	113	138	CBC
Peregrine Falcon	31	47	71	90	97	CBC
Prairie Falcon	53	92	110	110	142	BBS, CBC
Black Rail	4	8	10	13	19	CBC
Clapper Rail	13	15	17	17	23	CBC
Virginia Rail	53	89	97	92	122	CBC
Sora	48	88	96	95	122	CBC
Common Moorhen	50	65	70	81	102	CBC
American Coot	78	108	120	124	156	CBC
Sandhill Crane	11	19	25	22	32	CBC
Black-bellied Plover	38	43	49	51	64	CBC
Pacific Golden-Plover	0	0	10	14	15	CBC
Snowy Plover	27	32	36	39	43	CBC
Semipalmated Plover	26	33	36	33	46	CBC
Killdeer	160	196	200	193	276	BBS, CBC
Mountain Plover	10	14	18	10	21	CBC
Black-necked Stilt	36	59	65	71	93	BBS, CBC
American Avocet	40	58	62	65	89	BBS, CBC
Spotted Sandpiper	69	95	97	102	138	BBS, CBC

Species	n_1	n_2	n_3	n_4	n_{All}	Data Source
Greater Yellowlegs	54	81	100	104	130	CBC
Willet	42	46	48	52	65	BBS, CBC
Lesser Yellowlegs	22	38	50	42	60	CBC
Long-billed Curlew	42	58	66	63	82	BBS, CBC
Red Knot	13	19	16	19	22	CBC
Western Sandpiper	51	58	69	70	91	CBC
Least Sandpiper	63	91	99	99	128	CBC
Dunlin	49	65	74	68	93	CBC
Short-billed Dowitcher	NA	NA	NA	NA	21	MVZ
Long-billed Dowitcher	NA	NA	NA	NA	24	MVZ
Wilson's Snipe	78	115	131	134	166	BBS, CBC
Wilson's Phalarope	6	7	6	8	11	BBS, CBC
Bonaparte's Gull	42	60	67	68	90	CBC
Mew Gull	37	52	60	66	80	CBC
Ring-billed Gull	71	95	108	110	140	BBS, CBC
California Gull	70	102	110	116	150	BBS, CBC
Herring Gull	47	77	83	90	110	BBS, CBC
Thayer's Gull	23	50	54	57	68	CBC
Yellow-footed Gull	NA	NA	NA	NA	35	GBBC, EBIRD
Glaucous-winged Gull	38	52	56	64	80	BBS, CBC
Gull-billed Tern	NA	NA	NA	NA	7	MVZ
Caspian Tern	16	27	35	32	47	BBS, CBC
Black Tern	NA	NA	NA	NA	102	CMN, EBIRD, MACL, YPM
Forster's Tern	NA	NA	NA	NA	33	MVZ
Black Skimmer	1	6	11	12	14	BBS, CBC
Rock Pigeon	83	139	144	140	192	BBS, CBC
Band-tailed Pigeon	87	110	116	130	176	BBS, CBC
Spotted Dove	23	28	29	19	37	BBS, CBC
White-winged Dove	12	14	16	16	26	BBS, CBC
Mourning Dove	233	269	284	300	385	BBS, CBC
Inca Dove	NA	NA	NA	NA	43	GBBC, EBIRD, PFW
Common Ground-Dove	9	16	18	20	23	BBS, CBC
Yellow-billed Cuckoo	NA	NA	NA	NA	15	MVZ
Greater Roadrunner	41	70	72	62	98	BBS, CBC
Barn Owl	63	104	109	114	152	BBS, CBC
Flammulated Owl	NA	NA	NA	NA	21	MVZ
Western Screech-Owl	5	67	89	93	115	BBS, CBC
Great Horned Owl	122	168	191	182	252	BBS, CBC
Northern Pygmy-Owl	38	64	78	81	110	BBS, CBC
Elf Owl	NA	NA	NA	NA	39	BIOS
Burrowing Owl	58	90	88	85	123	BBS, CBC
Spotted Owl	7	22	20	20	29	BBS, CBC
Barred Owl	NA	NA	NA	NA	1179	BIOS
Great Gray Owl	NA	NA	NA	NA	13	EBIRD, MVZ
Long-eared Owl	18	27	40	36	57	CBC
Short-eared Owl	40	53	48	52	75	BBS, CBC
Northern Saw-whet Owl	18	23	30	31	42	CBC
Lesser Nighthawk	15	15	19	23	35	BBS, CBC
Common Nighthawk	27	29	32	40	53	BBS
Common Poorwill	24	29	33	33	56	BBS, CBC
Whip-poor-will	NA	NA	NA	NA	4	EBIRD
Black Swift	NA	NA	NA	NA	73	EBIRD, PRBO
Vaux's Swift	4	12	12	12	21	BBS, CBC
White-throated Swift	58	76	80	88	116	BBS, CBC
Black-chinned Hummingbird	6	5	6	5	12	BBS, CBC
Anna's Hummingbird	105	141	151	170	227	BBS, CBC
Costa's Hummingbird	28	36	47	42	64	BBS, CBC

Appendix 1, continued.

Species	n_1	n_2	n_3	n_4	n_{All}	Data Source
Calliope Hummingbird	NA	NA	NA	NA	96	MACL, MVZ, UMMZ, YPM
Broad-tailed Hummingbird	NA	NA	NA	NA	34	GBBC, EBIRD, PFW, PRBO
Rufous Hummingbird	5	5	6	5	11	BBS, CBC
Allen's Hummingbird	20	20	27	28	46	BBS, CBC
Belted Kingfisher	79	114	126	135	170	BBS, CBC
Lewis's Woodpecker	41	61	68	72	95	BBS, CBC
Acorn Woodpecker	131	150	170	165	222	BBS, CBC
Gila Woodpecker	NA	NA	NA	NA	18	MVZ
Williamson's Sapsucker	11	23	22	26	36	BBS, CBC
Red-naped Sapsucker	NA	NA	NA	NA	54	MVZ
Red-breasted Sapsucker	NA	NA	NA	NA	246	MVZ
Ladder-backed Woodpecker	11	17	25	24	28	BBS, CBC
Nuttall's Woodpecker	98	135	148	145	191	BBS, CBC
Downy Woodpecker	80	121	129	133	181	BBS, CBC
Hairy Woodpecker	86	127	139	155	208	BBS, CBC
White-headed Woodpecker	36	43	48	54	74	BBS, CBC
Black-backed Woodpecker	NA	NA	NA	NA	12	MVZ
Northern Flicker	79	112	125	127	162	BBS, CBC
Gilded Flicker	NA	NA	NA	NA	4	MVZ
Pileated Woodpecker	22	39	40	50	62	BBS, CBC
Olive-sided Flycatcher	50	50	52	59	87	BBS, CBC
Western Wood-Pewee	80	86	87	101	136	BBS
Willow Flycatcher	NA	NA	NA	NA	110	MVZ
Hammond's Flycatcher	9	14	17	29	35	BBS, CBC
Gray Flycatcher	4	14	18	27	28	BBS, CBC
Dusky Flycatcher	8	18	23	34	37	BBS, CBC
Pacific-slope Flycatcher	NA	NA	NA	NA	179	MVZ
Cordilleran Flycatcher	NA	NA	NA	NA	23	MVZ
Black Phoebe	108	158	174	183	245	BBS, CBC
Say's Phoebe	80	114	136	141	182	BBS, CBC
Vermilion Flycatcher	8	16	19	22	29	CBC
Ash-throated Flycatcher	88	106	115	109	152	BBS, CBC
Brown-crested Flycatcher	NA	NA	NA	NA	23	EBIRD
Cassin's Kingbird	16	33	36	42	54	BBS, CBC
Western Kingbird	90	96	100	97	141	BBS, CBC
Loggerhead Shrike	120	156	168	156	230	BBS, CBC
Northern Shrike	12	23	21	22	34	CBC
Bell's Vireo	NA	NA	NA	NA	51	MVZ
Gray Vireo	NA	NA	NA	NA	21	MVZ
Plumbeous Vireo	NA	NA	NA	NA	13	MVZ
Cassin's Vireo	28	33	59	79	93	BBS, CBC
Hutton's Vireo	72	106	117	134	173	BBS, CBC
Warbling Vireo	46	57	66	65	92	BBS, CBC
Gray Jay	NA	NA	NA	NA	19	MVZ
Steller's Jay	115	138	163	191	235	BBS, CBC
Western Scrub-Jay	90	98	102	219	258	BBS, CBC
Pinyon Jay	12	17	18	16	28	BBS, CBC
Clark's Nutcracker	14	19	23	29	38	BBS, CBC
Black-billed Magpie	15	24	30	29	41	BBS, CBC
Yellow-billed Magpie	44	59	57	56	78	BBS, CBC
American Crow	128	161	184	187	247	BBS, CBC
Common Raven	129	187	230	270	338	BBS, CBC
Horned Lark	117	144	155	148	215	BBS, CBC
Purple Martin	NA	NA	NA	NA	26	MVZ
Tree Swallow	55	94	118	131	165	BBS, CBC
Violet-green Swallow	83	98	87	91	146	BBS, CBC
Northern Rough-winged Swallow	26	48	58	57	82	BBS, CBC

Species	n_1	n_2	n_3	n_4	n_{All}	Data Source
Bank Swallow	NA	NA	NA	NA	19	MVZ
Cliff Swallow	63	72	68	70	109	BBS, CBC
Barn Swallow	54	75	65	105	141	BBS, CBC
Black-capped Chickadee	3	6	4	6	11	BBS, CBC
Mountain Chickadee	69	93	113	125	156	BBS, CBC
Chestnut-backed Chickadee	49	57	73	74	102	BBS, CBC
Oak Titmouse	118	142	154	153	212	BBS, CBC
Juniper Titmouse	1	2	4	5	6	BBS, CBC
Verdin	12	14	23	20	27	BBS, CBC
Bushtit	114	164	173	171	240	BBS, CBC
Red-breasted Nuthatch	88	113	137	157	194	BBS, CBC
White-breasted Nuthatch	110	142	164	168	219	BBS, CBC
Pygmy Nuthatch	40	47	57	61	79	BBS, CBC
Brown Creeper	97	140	148	156	209	BBS, CBC
Cactus Wren	35	45	57	51	66	BBS, CBC
Rock Wren	92	124	143	133	192	BBS, CBC
Canyon Wren	50	70	83	69	103	BBS, CBC
Bewick's Wren	152	187	204	207	282	BBS, CBC
House Wren	108	151	173	175	235	BBS, CBC
Winter Wren	52	82	95	108	136	BBS, CBC
Marsh Wren	72	108	124	125	167	BBS, CBC
American Dipper	37	58	55	56	81	BBS, CBC
Golden-crowned Kinglet	74	113	132	134	177	BBS, CBC
Ruby-crowned Kinglet	82	113	126	128	166	BBS, CBC
Blue-gray Gnatcatcher	47	80	104	114	136	BBS, CBC
California Gnatcatcher	NA	NA	NA	NA	28	MVZ
Black-tailed Gnatcatcher	NA	NA	NA	NA	33	MVZ
Western Bluebird	124	158	164	171	230	BBS, CBC
Mountain Bluebird	47	82	89	89	125	BBS, CBC
Townsend's Solitaire	41	58	82	80	113	BBS, CBC
Swainson's Thrush	21	24	22	24	43	BBS, CBC
Hermit Thrush	99	132	151	152	202	BBS, CBC
Varied Thrush	62	89	101	99	136	BBS, CBC
American Robin	171	213	246	262	324	BBS, CBC
Wrentit	111	142	155	165	215	BBS, CBC
Northern Mockingbird	140	174	191	184	261	BBS, CBC
Sage Thrasher	14	24	29	26	39	BBS, CBC
Bendire's Thrasher	NA	NA	NA	NA	11	MVZ
California Thrasher	83	114	124	118	166	BBS, CBC
Crissal Thrasher	3	5	5	4	6	BBS, CBC
Le Conte's Thrasher	17	20	27	21	37	BBS, CBC
European Starling	168	213	226	216	304	BBS, CBC
American Pipit	76	104	118	119	151	CBC
Cedar Waxwing	76	105	122	122	156	BBS, CBC
Phainopepla	46	75	97	88	119	BBS, CBC
Orange-crowned Warbler	90	133	152	162	204	BBS, CBC
Nashville Warbler	35	59	65	76	93	BBS, CBC
Virginia's Warbler	NA	NA	NA	NA	8	MVZ
Lucy's Warbler	NA	NA	NA	NA	11	MVZ
Yellow Warbler	52	76	78	78	122	BBS, CBC
Yellow-rumped Warbler	77	106	121	122	154	CBC
Black-throated Gray Warbler	47	78	79	100	119	BBS, CBC
Townsend's Warbler	40	64	70	72	93	CBC
Hermit Warbler	35	55	56	78	91	BBS, CBC
MacGillivray's Warbler	21	30	32	42	54	BBS, CBC
Common Yellowthroat	60	87	104	108	148	BBS, CBC
Wilson's Warbler	58	76	76	85	122	BBS, CBC

Species	n_1	n_2	n_3	n_4	n_{All}	Data Source
Yellow-breasted Chat	18	29	32	37	49	BBS
Western Tanager	78	92	100	134	160	BBS, CBC
Summer Tanager	6	12	19	22	24	BBS, CBC
Green-tailed Towhee	26	38	38	49	64	BBS, CBC
Spotted Towhee	87	123	223	249	286	BBS, CBC
California Towhee	71	76	168	181	218	BBS, CBC
Abert's Towhee	4	5	4	4	6	BBS, CBC
Rufous-crowned Sparrow	42	77	89	88	114	BBS, CBC
Chipping Sparrow	93	110	124	122	185	BBS, CBC
Brewer's Sparrow	27	39	36	44	58	BBS, CBC
Black-chinned Sparrow	20	17	15	8	28	BBS, CBC
Vesper Sparrow	40	61	63	73	97	BBS, CBC
Lark Sparrow	102	137	149	144	205	BBS, CBC
Black-throated Sparrow	29	39	49	45	65	BBS, CBC
Sage Sparrow	44	65	76	75	101	BBS, CBC
Savannah Sparrow	82	112	130	133	175	BBS, CBC
Grasshopper Sparrow	4	16	19	23	34	BBS, CBC
Fox Sparrow	92	124	127	140	178	BBS, CBC
Song Sparrow	135	173	202	210	279	BBS, CBC
Lincoln's Sparrow	62	100	113	118	147	BBS, CBC
White-throated Sparrow	41	59	75	83	101	CBC
White-crowned Sparrow	93	122	131	135	183	BBS, CBC
Golden-crowned Sparrow	76	109	122	121	157	CBC
Dark-eyed Junco	79	111	124	126	160	CBC
Black-headed Grosbeak	97	99	109	123	166	BBS, CBC
Blue Grosbeak	6	8	13	13	24	BBS
Lazuli Bunting	38	46	55	53	83	BBS
Lapland Longspur	NA	NA	NA	NA	24	BBS, CBC
Red-winged Blackbird	163	193	202	204	285	BBS, CBC
Tricolored Blackbird	56	84	100	105	139	BBS, CBC
Western Meadowlark	176	213	210	206	286	BBS, CBC
Yellow-headed Blackbird	31	40	41	40	65	BBS, CBC
Brewer's Blackbird	192	228	239	234	320	BBS, CBC
Hooded Oriole	20	19	26	21	37	BBS, CBC
Bullock's Oriole	99	118	121	110	166	BBS, CBC
Scott's Oriole	22	24	31	28	42	BBS, CBC
Great-tailed Grackle	NA	NA	NA	NA	884	GBBC, EBIRD, PFW, PRBO
Bronzed Cowbird	NA	NA	NA	NA	13	EBIRD, PFW
Brown-headed Cowbird	148	200	214	216	299	BBS, CBC
Gray-crowned Rosy-finch	NA	NA	NA	NA	69	MVZ
Pine Grosbeak	NA	NA	NA	NA	26	MVZ
Purple Finch	115	146	158	155	219	BBS, CBC
Cassin's Finch	32	46	56	63	85	BBS, CBC
House Finch	208	240	246	251	347	BBS, CBC
Red Crossbill	21	49	59	72	88	BBS, CBC
Pine Siskin	76	110	120	114	168	BBS, CBC
Lesser Goldfinch	134	180	196	204	272	BBS, CBC
Lawrence's Goldfinch	42	49	60	51	85	BBS, CBC
American Goldfinch	89	118	136	134	191	BBS, CBC
Evening Grosbeak	32	47	43	41	69	BBS, CBC
House Sparrow	162	193	200	190	279	BBS, CBC

Appendix 2

Future climate change models and emission scenarios (SRES: A2, A1B, B1) furnished by the World Climate Research Programme's Coupled Model Intercomparison Project phase 3 (WCRP-CMIP3). See the project's main website (http://gdo-dcp.ucllnl.org/) for data access and more detailed information regarding the climate models, emission scenarios, and general statistical methods used to create the data archive.

Modeling Group, Country	WCRP-CMIP3	A2 runs	A1B runs	B1 runs
Bjerknes Centre for Climate Research	BCCR-BCM2.0	1	1	1
Canadian Centre for Climate Modeling & Analysis	CGCM3.1 (T47)	1 to 5	1 to 5	1 to 5
Meteo-France / Centre National de Recherches Meteorologiques, France	CNRM-CM3	1	1	1
CSIRO Atmospheric Research, Australia	CSIRO-Mk3.0	1	1	1
US Dept. of Commerce / NOAA / Geophysical Fluid Dynamics Laboratory, USA	GFDL-CM2.0	1	1	1
US Dept. of Commerce / NOAA / Geophysical Fluid Dynamics Laboratory, USA	GFDL-CM2.1	1	1	1
NASA / Goddard Institute for Space Studies, USA	GISS-ER	1	2, 4	1
Institute for Numerical Mathematics, Russia	INM-CM3.0	1	1	1
Institut Pierre Simon Laplace, France	IPSL-CM4	1	1	1
Center for Climate System Research (The University of Tokyo), National Institute for Environmental Studies, and Frontier Research Center for Global Change (JAMSTEC), Japan	MIROC3.2 (medres)	1 to 3	1 to 3	1 to 3
Meteorological Institute of the University of Bonn, Meteorological Research Institute of KMA	ECHO-G	1 to 3	1 to 3	1 to 3
Max Planck Institute for Meteorology, Germany	ECHAM5/ MPI-OM	1 to 3	1 to 3	1 to 3
Meteorological Research Institute, Japan	MRI-CGCM2.3.2	1 to 5	1 to 5	1 to 5
National Center for Atmospheric Research, USA	CCSM3	1 to 4	1 to 3, 5 to 7	1 to 7
National Center for Atmospheric Research, USA	PCM	1 to 4	1 to 4	2 to 3
Hadley Centre for Climate Prediction and Research / Met Office, UK	UKMO-HadCM3	1	1	1

Appendix 3

Focal bird species and range loss forecasted through the end of the 21st Century under three different emission scenarios. See text for scenario overview. Range loss reported as a percentage of each species' current geographic range.

Species	B1	A1B	A2
Greater White-fronted Goose	0.1	1.4	6.8
Snow Goose	3.0	8.5	11.1
Ross' Goose	2.1	3.7	4.1
Canada Goose	2.2	6.5	10.3
Tundra Swan	2.1	9.9	15.6
Wood Duck	1.7	6.1	8.9
Gadwall	4.3	9.8	14.9
Eurasian Wigeon	2.7	19.5	30.5
American Wigeon	2.4	8.7	14.5
Mallard	3.9	9.6	12.8
Blue-winged Teal	8.3	14.0	17.5
Cinnamon Teal	6.1	13.9	19.6
Northern Shoveler	5.3	10.5	14.9
Northern Pintail	5.3	12.5	15.4
Green-winged Teal	5.1	10.7	14.1
Canvasback	2.7	9.3	15.4
Redhead	3.5	15.3	20.1
Ring-necked Duck	4.6	9.7	12.2
Greater Scaup	1.0	6.7	7.6
Lesser Scaup	4.8	9.5	12.4
Long-tailed Duck	3.2	9.5	12.7
Bufflehead	2.0	5.7	9.3
Common Goldeneye	2.1	5.7	8.4
Barrow's Goldeneye	4.1	49.0	58.5
Hooded Merganser	3.9	8.3	10.1
Common Merganser	3.6	10.3	15.3
Red-breasted Merganser	8.2	35.9	49.9
Ruddy Duck	2.4	9.0	14.2
Chukar	9.0	21.4	23.5
Ring-necked Pheasant	2.3	8.5	15.6
Ruffed Grouse	36.6	55.6	59.8
Greater Sage-grouse	37.0	52.7	57.3
Sooty Grouse	29.5	50.4	57.6
Wild Turkey	7.6	29.9	40.9
Mountain Quail	5.0	18.0	22.4
California Quail	3.6	14.1	21.8
Gambel's Quail	9.0	29.9	36.9
Common Loon	2.4	8.5	11.0
Pied-billed Grebe	3.7	9.9	14.5
Horned Grebe	3.7	11.4	14.8
Eared Grebe	4.6	9.7	12.6
Western Grebe	3.9	12.5	17.6
Clark's Grebe	4.2	11.7	14.8

Appendix 3, continued.

Species	B1	A1B	A2
American White Pelican	13.0	25.6	32.6
Double-crested Cormorant	3.6	12.5	19.0
American Bittern	6.2	13.3	19.7
Least Bittern	9.7	29.1	32.6
Great Blue Heron	4.4	8.8	11.4
Great Egret	2.9	5.2	7.5
Snowy Egret	3.8	8.0	11.3
Cattle Egret	3.8	7.2	10.4
Green Heron	8.2	12.5	14.2
Black-crowned Night-Heron	7.4	11.9	14.4
White-faced Ibis	17.7	32.7	50.6
Turkey Vulture	2.2	4.9	6.4
California Condor	2.2	11.1	16.7
Osprey	2.6	8.9	12.8
White-tailed Kite	2.2	9.6	15.6
Bald Eagle	3.0	15.1	21.4
Northern Harrier	5.0	10.6	13.7
Sharp-shinned Hawk	5.6	13.8	17.6
Cooper's Hawk	4.1	7.7	8.6
Northern Goshawk	4.9	10.1	12.1
Harris's Hawk	7.4	47.6	63.9
Red-shouldered Hawk	5.0	15.3	21.1
Swainson's Hawk	10.0	25.0	30.5
Red-tailed Hawk	3.3	9.4	14.9
Ferruginous Hawk	5.8	10.6	11.6
Rough-legged Hawk	5.1	13.9	19.4
Golden Eagle	5.5	14.6	19.7
American Kestrel	3.4	8.1	10.7
Merlin	4.3	8.4	9.1
Peregrine Falcon	3.0	6.5	8.0
Prairie Falcon	4.9	11.9	15.9
Black Rail	3.7	30.3	36.4
Clapper Rail	13.4	23.4	27.5
Virginia Rail	2.0	5.9	9.0
Sora	2.7	4.5	5.0
Common Moorhen	0.9	3.8	7.4
American Coot	4.2	9.8	12.5
Sandhill Crane	4.1	16.9	27.4
Black-bellied Plover	0.4	6.1	13.4
Pacific Golden-Plover	4.7	10.9	15.3
Snowy Plover	3.0	5.4	6.9
Semipalmated Plover	0.1	1.7	4.6
Killdeer	4.7	9.1	11.9
Mountain Plover	3.6	10.2	14.8
Black-necked Stilt	6.6	7.5	8.1
American Avocet	3.6	8.5	13.1
Spotted Sandpiper	4.6	15.2	20.1
Greater Yellowlegs	1.8	3.8	4.8
Willet	18.2	46.1	55.1
Lesser Yellowlegs	5.1	10.5	20.6
Long-billed Curlew	2.3	7.6	12.8
Red Knot	7.6	27.6	37.1
Western Sandpiper	1.0	5.5	6.5
Least Sandpiper	2.2	4.9	7.2

Species	B1	A1B	A2
Dunlin	0.5	5.5	10.1
Short-billed Dowitcher	10.0	23.2	34.3
Long-billed Dowitcher	18.0	39.5	50.5
Wilson's Snipe	1.5	6.8	9.9
Wilson's Phalarope	17.8	47.0	59.0
Bonaparte's Gull	0.1	4.2	5.4
Mew Gull	0.9	4.8	13.2
Ring-billed Gull	2.1	7.6	9.2
California Gull	1.7	8.2	14.3
Herring Gull	2.9	10.7	15.3
Thayer's Gull	1.3	9.7	30.4
Yellow-footed Gull	79.5	88.0	88.0
Glaucous-winged Gull	4.2	26.5	38.7
Gull-billed Tern	0.0	0.0	0.0
Caspian Tern	16.4	35.3	38.5
Black Tern	17.8	31.0	36.0
Forster's Tern	11.8	30.7	41.6
Black Skimmer	31.8	45.5	45.5
Rock Pigeon	4.6	9.0	11.4
Band-tailed Pigeon	6.5	19.8	26.4
Spotted Dove	4.7	17.8	32.4
White-winged Dove	48.7	65.4	69.9
Mourning Dove	4.2	11.4	14.7
Inca Dove	44.6	96.7	96.7
Common Ground-Dove	40.6	52.7	55.8
Yellow-billed Cuckoo	7.5	7.7	7.5
Greater Roadrunner	7.3	12.0	13.5
Barn Owl	6.1	15.9	20.0
Flammulated Owl	10.9	18.6	20.2
Western Screech-Owl	3.0	12.8	18.9
Great Horned Owl	2.7	6.9	11.0
Northern Pygmy-Owl	4.8	14.2	18.6
Elf Owl	100.0	100.0	100.0
Burrowing Owl	7.2	12.7	16.3
Spotted Owl	13.5	26.6	31.1
Barred Owl	23.8	50.5	58.1
Great Gray Owl	23.4	34.9	36.7
Long-eared Owl	4.3	14.7	19.7
Short-eared Owl	4.7	20.3	29.9
Northern Saw-whet Owl	7.5	17.1	19.4
Lesser Nighthawk	13.6	32.0	40.2
Common Nighthawk	11.7	27.1	32.7
Common Poorwill	19.0	37.0	40.5
Whip-poor-will	16.7	25.6	27.8
Black Swift	10.9	23.0	23.5
Vaux's Swift	8.5	10.1	10.1
White-throated Swift	3.3	8.4	11.5
Black-chinned Hummingbird	7.2	17.0	18.3
Anna's Hummingbird	1.9	8.6	12.4
Costa's Hummingbird	7.7	10.9	12.9
Calliope Hummingbird	15.8	33.1	38.8
Broad-tailed Hummingbird	6.4	13.0	13.5
Rufous Hummingbird	1.8	4.0	4.1
Allen's Hummingbird	4.9	19.1	21.9

Appendix 3, continued.

Species	B1	A1B	A2
Belted Kingfisher	2.1	10.2	16.1
Lewis's Woodpecker	2.1	8.7	10.6
Acorn Woodpecker	4.8	16.8	24.3
Gila Woodpecker	10.5	10.5	11.7
Williamson's Sapsucker	6.5	13.8	18.1
Red-naped Sapsucker	8.1	14.8	17.7
Red-breasted Sapsucker	21.2	44.2	53.0
Ladder-backed Woodpecker	19.4	34.1	41.1
Nuttall's Woodpecker	1.0	6.4	11.0
Downy Woodpecker	1.5	9.1	12.4
Hairy Woodpecker	5.7	19.5	26.6
White-headed Woodpecker	7.4	14.3	16.2
Black-backed Woodpecker	34.7	52.5	54.9
Northern Flicker	5.1	10.6	11.8
Gilded Flicker	9.8	18.0	35.0
Pileated Woodpecker	4.2	18.5	23.7
Olive-sided Flycatcher	22.7	43.2	50.4
Western Wood-Pewee	12.6	34.0	41.3
Willow Flycatcher	11.0	24.3	31.5
Hammond's Flycatcher	18.0	38.8	46.6
Gray Flycatcher	35.1	48.6	52.0
Dusky Flycatcher	20.6	38.8	43.6
Pacific-slope Flycatcher	13.2	28.8	34.2
Cordilleran Flycatcher	23.4	44.2	49.7
Black Phoebe	1.7	5.5	8.1
Say's Phoebe	7.4	12.2	14.6
Vermilion Flycatcher	30.8	40.4	50.0
Ash-throated Flycatcher	3.7	12.6	17.6
Brown-crested Flycatcher	52.6	59.5	60.3
Cassin's Kingbird	1.0	5.5	11.7
Western Kingbird	7.6	17.2	22.1
Loggerhead Shrike	6.1	13.1	16.2
Northern Shrike	7.5	21.2	24.8
Bell's Vireo	11.2	21.3	24.9
Gray Vireo	12.2	22.4	25.9
Plumbeous Vireo	16.7	22.5	25.1
Cassin's Vireo	14.6	31.0	37.4
Hutton's Vireo	6.4	25.6	36.4
Warbling Vireo	23.9	46.0	53.3
Gray Jay	42.4	59.2	63.8
Steller's Jay	5.1	20.0	26.4
Western Scrub-Jay	2.0	12.4	17.9
Pinyon Jay	22.8	39.3	43.6
Clark's Nutcracker	15.3	28.7	32.5
Black-billed Magpie	10.9	30.0	38.8
Yellow-billed Magpie	9.3	53.8	75.3
American Crow	3.7	16.6	24.4
Common Raven	3.1	9.5	13.0
Horned Lark	4.5	9.5	11.9
Purple Martin	16.5	29.0	31.0
Tree Swallow	3.9	17.6	23.4
Violet-green Swallow	3.0	10.0	17.0
Northern Rough-winged Swallow	3.6	9.1	11.6

Appendix 3, continued.

Species	B1	A1B	A2
Bank Swallow	36.3	51.4	54.8
Cliff Swallow	8.4	24.3	32.1
Barn Swallow	2.8	9.3	16.9
Black-capped Chickadee	17.1	41.8	44.9
Mountain Chickadee	5.7	14.6	18.6
Chestnut-backed Chickadee	15.8	41.2	49.2
Oak Titmouse	2.0	13.2	18.8
Juniper Titmouse	31.9	45.4	50.0
Verdin	4.6	22.6	32.5
Bushtit	2.0	11.9	17.5
Red-breasted Nuthatch	2.2	12.6	18.0
White-breasted Nuthatch	1.4	10.6	15.0
Pygmy Nuthatch	6.2	14.5	16.7
Brown Creeper	2.9	12.8	17.9
Cactus Wren	11.8	22.9	29.1
Rock Wren	7.6	16.5	19.5
Canyon Wren	2.7	10.3	15.5
Bewick's Wren	2.0	8.0	11.4
House Wren	1.1	6.8	10.6
Winter Wren	5.1	18.1	22.6
Marsh Wren	1.5	6.4	8.8
American Dipper	3.6	10.6	13.8
Golden-crowned Kinglet	5.8	19.3	25.4
Ruby-crowned Kinglet	4.2	8.6	10.8
Blue-gray Gnatcatcher	4.6	9.9	12.1
California Gnatcatcher	7.3	36.5	56.2
Black-tailed Gnatcatcher	26.0	32.8	35.0
Western Bluebird	3.5	9.9	14.3
Mountain Bluebird	3.7	11.1	14.2
Townsend's Solitaire	4.1	15.5	20.9
Swainson's Thrush	18.1	30.2	34.5
Hermit Thrush	4.3	14.2	18.5
Varied Thrush	1.3	8.7	14.4
American Robin	4.0	13.1	18.2
Wrentit	11.0	32.7	41.4
Northern Mockingbird	9.0	14.3	17.6
Sage Thrasher	11.7	28.6	35.9
Bendire's Thrasher	31.3	44.3	46.7
California Thrasher	2.6	13.7	19.5
Crissal Thrasher	6.6	22.2	33.9
Le Conte's Thrasher	21.6	37.0	42.9
European Starling	5.7	10.8	14.5
American Pipit	4.3	9.7	12.5
Cedar Waxwing	2.0	10.7	16.3
Phainopepla	6.2	15.1	20.9
Orange-crowned Warbler	1.3	7.6	11.4
Nashville Warbler	11.3	33.0	40.4
Virginia's Warbler	9.5	14.4	14.6
Lucy's Warbler	38.7	54.8	58.1
Yellow Warbler	5.8	19.5	29.1
Yellow-rumped Warbler	4.7	9.1	11.4
Black-throated Gray Warbler	2.9	10.6	14.3
Townsend's Warbler	0.0	2.6	5.9
Hermit Warbler	15.2	35.6	40.9

Appendix 3, continued.

Species	B1	A1B	A2
MacGillivray's Warbler	17.3	39.4	46.3
Common Yellowthroat	2.3	4.8	6.3
Wilson's Warbler	6.1	17.4	22.5
Yellow-breasted Chat	6.9	24.2	29.6
Western Tanager	6.5	23.1	30.1
Summer Tanager	5.0	5.0	5.0
Green-tailed Towhee	23.6	38.9	44.1
Spotted Towhee	1.8	11.4	17.0
California Towhee	8.4	25.9	36.8
Abert's Towhee	10.6	39.9	66.8
Rufous-crowned Sparrow	1.7	16.2	23.3
Chipping Sparrow	5.0	17.1	23.4
Brewer's Sparrow	16.5	28.9	33.6
Black-chinned Sparrow	16.3	30.5	34.3
Vesper Sparrow	14.5	29.3	34.6
Lark Sparrow	1.3	9.3	16.5
Black-throated Sparrow	12.0	21.3	26.1
Sage Sparrow	4.9	8.1	10.6
Savannah Sparrow	4.9	10.9	14.2
Grasshopper Sparrow	24.9	47.7	51.5
Fox Sparrow	2.9	9.2	12.1
Song Sparrow	2.3	12.8	18.5
Lincoln's Sparrow	1.5	4.3	7.5
White-throated Sparrow	1.4	5.9	9.2
White-crowned Sparrow	4.4	12.2	16.8
Golden-crowned Sparrow	1.5	5.7	8.4
Dark-eyed Junco	5.1	14.0	18.5
Black-headed Grosbeak	4.0	17.2	25.3
Blue Grosbeak	11.0	22.4	30.1
Lazuli Bunting	8.5	24.7	32.8
Lapland Longspur	1.5	4.0	7.3
Red-winged Blackbird	3.4	8.2	10.7
Tricolored Blackbird	3.3	13.3	21.1
Western Meadowlark	2.9	7.5	10.7
Yellow-headed Blackbird	13.4	21.0	25.4
Brewer's Blackbird	5.6	14.0	19.1
Hooded Oriole	8.4	15.1	17.5
Bullock's Oriole	4.3	14.2	22.4
Scott's Oriole	1.0	4.6	7.3
Great-tailed Grackle	76.2	86.2	89.1
Bronzed Cowbird	16.7	86.7	96.7
Brown-headed Cowbird	2.0	9.3	15.7
Gray-crowned Rosy-finch	25.8	42.3	52.1
Pine Grosbeak	31.4	48.7	53.6
Purple Finch	4.1	17.9	25.5
Cassin's Finch	7.0	15.6	17.6
House Finch	3.8	8.9	11.9
Red Crossbill	7.1	14.6	15.7
Pine Siskin	3.3	11.4	15.9
Lesser Goldfinch	3.0	9.8	14.0
Lawrence's Goldfinch	1.2	8.5	15.7
American Goldfinch	6.1	15.3	20.1
Evening Grosbeak	6.9	20.5	23.7
House Sparrow	5.2	10.1	12.1