National Park Service
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Natural Resource Stewardship and Science

Climate Change and Birds of the Acadia National Park Region

Projected Changes in Habitat Suitability for 130 Breeding Bird Species

Natural Resource Report NPS/ACAD/NRR—2014/840

ON THE COVER
View from Gorham Mountain, Acadia National Park.
NPS photo.

Climate Change and Birds of the Acadia National Park Region

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Nicholas A. Fisichelli[1], William B. Monahan[2], Matthew P. Peters[3], Stephen N. Matthews[3,4]

[1]US National Park Service
Natural Resource Science and Stewardship
Climate Change Response Program
Fort Collins, CO 80525
nicholas_fisichelli@nps.gov

[2]US National Park Service
Natural Resource Science and Stewardship
Inventory and Monitoring Division
Fort Collins, CO 80525

[3]US Forest Service
Northern Research Station
Delaware, OH 43015

[4]Ohio State University
School of Environment and Natural Resources
Columbus, OH 43210

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Abstract

Climate change is affecting species and resources across national parks. Stewarding resources for continuous change is a challenge for park managers; however, understanding projected rates and directions of change should facilitate monitoring, management, and visitor education on park lands. To support such efforts for Acadia National Park, we analyzed projected changes in bird habitat suitability for 130 North American breeding bird species (primarily terrestrial [landbird] and some freshwater species) for three future periods (2040, 2070, and 2100). We present model output from two climate scenarios, the 'least change' and 'major change' scenarios that represent plausible lower and upper bounds of future climatic conditions. Looking out to 2100, general trends in the data indicate decreasing habitat suitability under both climate scenarios for 30 species (23% of species analyzed), no change under both scenarios for 15 species (12%), increases or new habitat for 48 species (37%), and mixed results (i.e., different change classes among climate scenarios) for 37 species (28%). Projected changes in habitat suitability varied by habitat preference and migratory status. For example, extant Neotropical migrants, such as the magnolia and black-throated green warblers, generally show decreases in potential habitat and many previously rare or absent Neotropical migrants gain substantial potential habitat in the future, suggesting a possible large turnover in long-distance migrants found in the park during summer months. Similarly, extant forest birds have relatively low suitability projections, but forest is also the habitat type with the greatest number of new bird species (n = 12). Under the 'major change' climate scenario, several species previously absent or rare in the Acadia region, such as the summer tanager, worm-eating warbler, and hooded warbler, are likely to have suitable habitat gains by the end of the 21st century. Resident birds, such as the northern cardinal and white-breasted nuthatch, generally maintain or have increases in potential habitat over the next several decades. Birds, as highly mobile species able to track a shifting climate and as resources of keen interest to many park visitors, are ideal bellwethers of change within parks and useful examples for educating the public on how ongoing climate change is affecting park resources.

Acknowledgements

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Acronyms

A1FI	Greenhouse gas emissions scenario which assumes increased emissions in the coming decades (a fossil fuel intensive future; IPCC 2007)
ANOVA	Analysis of variance
B1	Greenhouse gas emissions scenario which assumes a trajectory of decreasing emissions by the mid-21st century (IPCC 2007)
BBS	Breeding Bird Survey
CO_2	Carbon dioxide
DISTRIB	Species habitat model used to project potential future suitable tree habitat (Iverson et al. 2008)
Had	Hadley CM3 global climate model
IPCC	Intergovernmental Panel on Climate Change
IV	Importance value
NFWPCAP	National Fish, Wildlife and Plants Climate Adaptation Partnership.
NPS	National Park Service
PCM	Parallel Climate Model global climate model
USGS	United States Geological Survey

Introduction

Climate change affects park resources in many ways, including alterations to ecosystem composition, structure, and function. Detecting and understanding species' range shifts and ecological community changes are vital undertakings for effective land management. Interpretations of species distribution models, projecting shifts in potential habitat suitability due to climate change, can inform forward-looking natural resource planning and management actions. Bird species and assemblages are fundamental resources at many parks, and 189 (70%) natural resource parks of the National Park Service (NPS) Inventory and Monitoring Program track bird population trends as a 'vital sign' (Fancy and Bennetts 2012). Climate change is likely to have both direct and indirect impacts on bird species within and beyond park boundaries. This report synthesizes and interprets previously published projections of changes in potential bird habitat suitability in response to climate and habitat changes in and around Acadia National Park.

The climate is changing and these changes will likely continue and intensify in the coming decades (IPCC 2007). Mean annual temperatures across the U.S. are roughly 0.8 °C (1.5 °F) higher than at the beginning of the 20th century; warming is evident in all regions of the contiguous U.S., with an especially high rate of increase in the upper Midwest and Northeast (Melillo et al. 2014). Over 80% of NPS units with significant natural resources (235 out of 289 units) are already near the extreme warm edge of their historical climates (Monahan and Fisichelli 2014). Future projected changes include a rise in mean annual temperatures in the eastern U.S. of 1.7-2.8 °C (3-5 °F) by mid-century and 2.2-4.4 °C (4-8 °F) by 2100, compared with the 1961-1990 average (Kunkel et al. 2013). Much of the eastern U.S. is likely to see an increase in winter precipitation and decrease in summer totals, though there is greater uncertainty in precipitation than temperature projections (Kunkel et al. 2013). Warming and changes in precipitation may lead to lower snow depths, earlier spring snowmelt and runoff, and an expanded growing season (Melillo et al. 2014). Climate change in conjunction with disturbances, such as wildfires, wind and ice storms, and forest insect and pathogen outbreaks, are expected to result in pulses of ecosystem change as systems self-sort and reorganize (Dale et al. 2001).

Birds are vagile and thus poised to track changes in climate. Indeed, a long record exists of birds responding to changes in climate and other human factors by adjusting their behavior, population density, and geographic range. Changes in songbird populations in the eastern U.S. over the past century relate to multiple factors, including habitat alteration in both summer and winter ranges (Robbins et al. 1989), pollution affecting reproduction (Fry 1995), brood parasitism by brown-headed cowbirds (Brittingham and Temple 1983), nest predation by increasing populations of mesocarnivores (Schmidt 2003), and habitat alteration by overabundant white-tailed deer (DeCelesta 1994) and nonnative earthworms (Loss and Blair 2011). Numerous recent studies indicate that birds are already responding to climate change by altering their behavior and shifting their distributions. Some bird species nest earlier in the year to match warming trends and earlier peak availability of key food sources, such as caterpillars (Dunn and Winkler 1999; Both and Visser 2005). Birds are also shifting their ranges north and upslope with rising temperatures (La Sorte and Thompson 2007, Tingley et al. 2009), and short-distance migrants are decreasing the distance traveled to wintering grounds (Visser et al. 2009).

Bird distribution patterns are strongly correlated with climate and habitat variables (Root 1988) and thus ongoing changes in these factors are likely to impact birds (Matthews et al. 2011). In the Acadia region, forests may undergo substantial changes in response to climate, including range contraction of boreal tree species and expansions of warm-adapted temperate species (Fisichelli et al. 2013), and such vegetation shifts are likely to impact bird populations. Species distribution models including climate and habitat change enable managers to explore potential climate change vulnerability of individual bird species and entire guilds over the coming decades (Box 1). The results presented here, specifically potential habitat suitability changes for 130 North American breeding

bird species (primarily terrestrial [landbird] and some freshwater species) in the region including Acadia National Park, are useful to focus monitoring and management efforts and to educate park visitors about ongoing changes.

Box 1. Interpreting Potential Bird Habitat Projections

The model output presented here does not forecast future abundances of individual species or the overall future bird list for the park. Rather, it is meant to inform managers of potential changes in the suitability of habitat for bird species given both baseline environmental conditions in which they were found and where those conditions may exist on the landscape in the future as the climate changes (see 'Interpreting the Output' in the Methods below for more details).

Methods

Potential bird habitat suitability projections in the Acadia region are based on bird geographic distribution models that consider climate, elevation, and modeled distributions of 39 tree species (Matthews et al. 2011). Potential habitat is modeled for the 1961-1990 baseline period, and models trained during this period are projected to three future 30 year periods ending in 2040, 2070, and 2100. For synthesis and reporting, we utilize habitat change classes and future-to-baseline habitat ratios to provide simple and easy to interpret metrics of potential changes in habitat suitability (see below for details). Potential habitat changes were also assessed in relation to bird habitat preference and migratory status (Peterjohn and Sauer 1993; Matthews et al. 2011), as species sharing these traits or characteristics may be expected to respond similarly to climate change. Habitat projections for Maine state-listed species of special concern and endangered species are also highlighted to aid in potential conservation efforts for focal species. See below for details on the modeling methods and interpretation of the data.

Climate Data

Climate change cannot be precisely predicted in part because of irreducible uncertainties regarding future greenhouse gas emissions and differences among individual climate models. We evaluated a potential range of future climatic conditions and present two scenarios that bracket a probable range of future conditions using two general

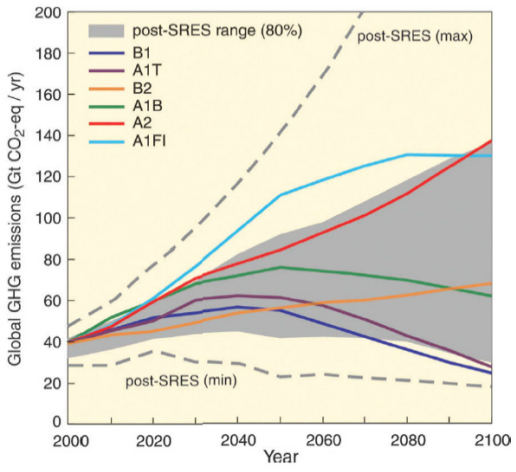


Figure 1. Global greenhouse gas emissions (in gigatons of carbon dioxide equivalent per year) under six potential scenarios (B1, A1T, B2, A1B, A2, and A1FI). The dashed lines show the full range of scenarios. The B1 and A1FI scenarios were used in the analyses in this report as lower and upper bounds, respectively, of plausible future emissions. Figure from IPCC (2007).

circulation models (Parallel Climate Model [PCM] and HadleyCM3 [Had]) and two greenhouse gas emissions scenarios (B1 and A1FI) (Figure 1, IPCC 2007).

Neither climate projection is assigned a probability here; rather the two models and emissions scenarios provide 'least change' and 'major change' bounds on the plausible range of future conditions. The PCM combined with the B1 scenario presents a 'least change' climate scenario based on strong cuts in greenhouse gas emissions and modest climatic changes (Figure 2, 3), and the Had-A1FI combination represents a 'major change' scenario under continued increasing greenhouse gas emissions and rapid warming. These two model-emissions combinations project an increase in mean annual temperature of 3-6 °C (5.4-10.8 °F) over the 21st century in the eastern U.S. and a decrease (-27%) or increase (+75%) in

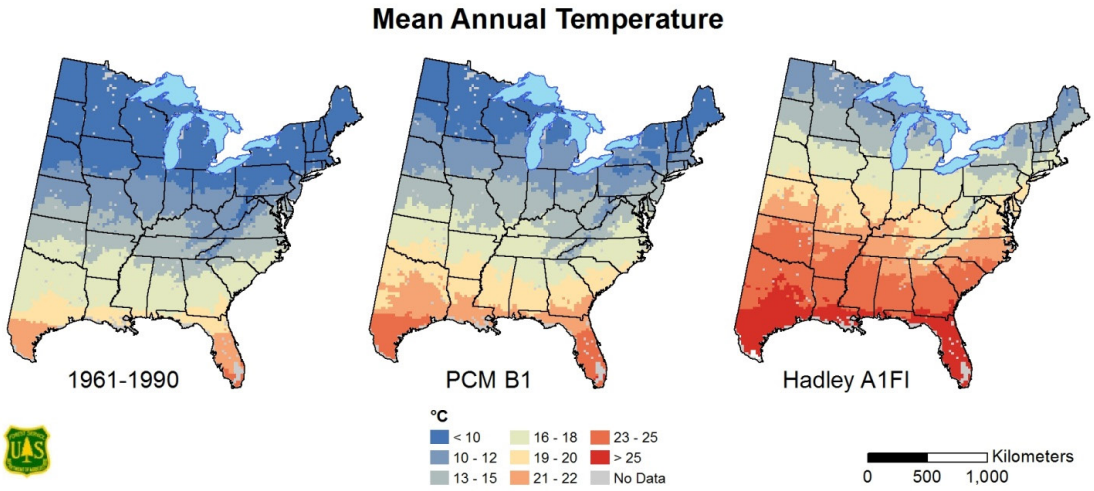


Figure 2. Baseline (1961-1990) and projected mean annual temperature for the end of the 21st century (2071-2100). The PCM B1 model represents the lowest levels of warming under a very low greenhouse gas emissions scenario. The Hadley A1FI model shows the warmest projections under the high greenhouse gas emissions scenario. Emissions scenarios are from IPCC (2007).

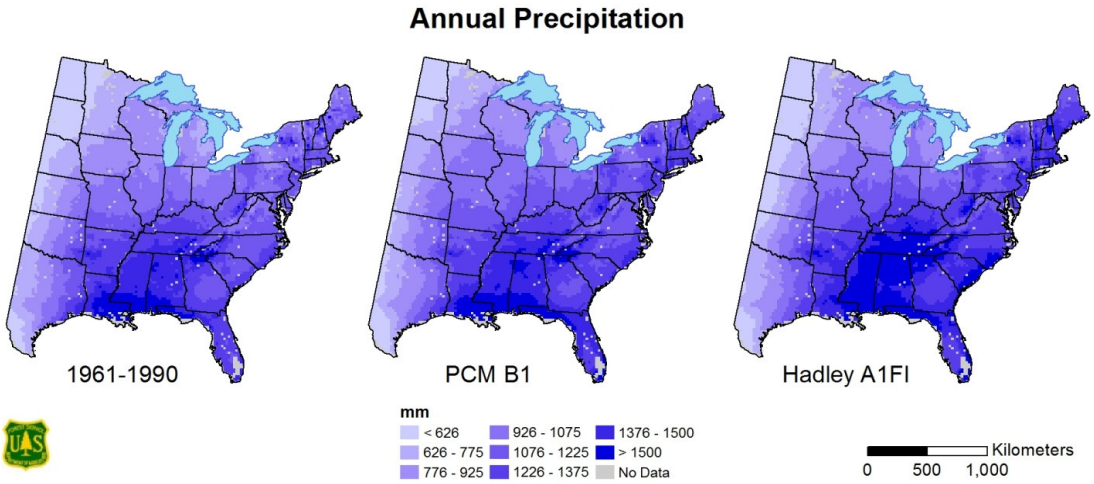


Figure 3. Baseline (1961-1990) and projected mean annual precipitation for the end of the 21st century (2071-2100). PCM B1 and Hadley A1FI represent the coolest and warmest temperature projections and indicate slight to moderate increases in annual precipitation for the eastern US. Emissions scenarios are from IPCC (2007).

precipitation, depending on geographic location and climate model (values are compared with the 1961-1990 baseline). For Acadia, mean annual temperature by 2100 rises 2.7 °C (4.9 °F) in the 'least change' scenario and 7.4 °C (13.3 °F) under 'major change' compared with the 1961-1990 baseline.

Potential Bird Habitat Modeling

Baseline (1961-1990) and future (2010-2039 [2040], 2040-2069 [2070], 2070-2099 [2100]) potential habitat for 147 breeding bird species across the eastern U.S. is based on DISTRIB tree habitat suitability models for 39 tree species (Iverson et al. 2008), seven climate variables, and four elevation variables (Matthews et al. 2011) (see Appendix 1 for a full list of predictor variables). Breeding bird habitat suitability is defined from bird incidence values (IVs), calculated as the proportion of years where a species was recorded as present on USGS Breeding Bird Survey (BBS) routes from the period 1981-1990 (Sauer et al. 2014; only routes with ≥ 7 years were included). These modeled incidence values under baseline and future time periods were summarized for a region around Acadia National Park encompassed by forty-two 20 x 20 km DISTRIB grid cells (Figure 4). Within these 42 grid cells, eight BBS route starting points were used to represent bird incidence within the habitat suitability model. Due to variations among model runs, climatic predictors, and sample sizes, it is important to consider a larger areal extent for species-specific assessments, rather than a single cell.

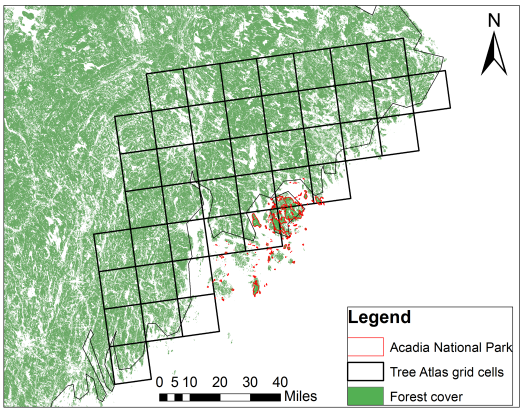


Figure 4. The area of analysis for Acadia National Park included 42 pixels (each 12 x 12 mi, 20 x 20 km) for a total area of 6048 mi² (16,800 km2).

Modeling resulted in potential baseline and/or future habitat for 130 bird species in the Acadia region. See Appendix 2 for the complete summary table reporting model reliability, IV sums, change classes, recent (1966-2011) BBS trend value, and a BBS abundance index for each species. See Appendix 3 for migratory and habitat preference classifications. For the eastern U.S. as a whole, each of the seven climate variables was included in the top three predictor variables for at least one bird species, annual precipitation was included in the top three variables for almost half of the bird species, and 57% of forest birds had tree species habitat as a top-three predictor variable (Matthews et al. 2011). Potential suitable habitat for 2100 was compared among bird habitat preference groups (forest, shrubland, grassland, wetland, and unclassified) and migratory status groups (resident, short distance, and Neotropical) via one-way ANOVA tests in R ver. 2.12.

Reading the Tables and Figures

The complete data tables are provided in Appendix 2. Actual BBS IV is the sum for cells

containing the survey route. The baseline modeled IV is the predicted IV under baseline (1961-1990) climate and habitat conditions for the region, and since the model predicts into cells not captured in the actual BBS column, values will often be larger due to more cells having modeled values. Output for the two future climate models (PCM and HadleyCM3 [Had]) and emissions scenario (B1 and A1FI) combinations provide estimates of 'least change' (PCM-B1) and 'major change' (Had-A1FI) futures. Model reliability is indicated as low, medium, or high, and was calculated from the pseudo R2 of the randomForest model, consistency among 30 bagging tree models, and a fuzzy kappa score (see Matthews et al. 2011 for further detail). Future IVs for the Acadia region are summed for each species for three future 30 year periods ending in 2040, 2070, and 2100. Thus these values indicate how the incidence of a species could be related to its suitable habitat (Appendix 2). Additionally, each species has been assigned a change class for each climate scenario based on the ratio of future-to-baseline modeled IV (see Appendix 4 for change class designations). For example, a doubling of habitat (ratio = 2) is a 'large increase' and a 50% reduction in habitat (ratio = 0.5) is a 'large decline'.

BBS trend and abundance data are provided for further information on individual bird species and as supporting information to help interpret the models (Appendix 2; Matthews et al. 2011). Trend data indicate whether the trend line of the species has increased at least 1.5% per year (+), decreased at least 1.5% per year (-), or remained within those bounds (•) during the sample period (1966-2011) for each BBS grid cell (~21x21 km). Interpolated abundance data using records from 2006-2010 were reclassified into seven 'BBS Abundance Index' categories (0-6). Both the trend and abundance data grids were intersected with the 20 km DISTRIB grid and summarized for the assessment region. A species was classified as increasing, decreasing, or having no change in the assessment region based on the proportion of trend data among all cells. Similarly, the proportion of cells in each abundance class, normalized to the total number of cells in the region, is used to indicate the recent abundance. Generally, species with an abundance index < 1 are not present among all cells in the region and fall in class 1. Index values ≥1 typically fall into classes 1-6 where the whole number indicates the class (i.e., index of 2.3 indicates that the mean abundance falls in class 2). Because some models have higher uncertainty, for example when actual BBS IVs report no suitable habitat (IV=0) and mean baseline modeled IVs are relatively low (≤ 0.1), this supporting information can confirm whether the species has been observed in recent years.

Interpreting the Output

"All models are wrong, but some are useful" – statistician George Box

Habitat suitability models are a useful tool for managers to examine potential patterns and direction of change in resources, but managers should keep several caveats and limitations in mind as they interpret these results. The model output presented here does not forecast future abundances of individual species or the overall future bird list for the park. Rather, it is meant to inform managers of potential changes in the suitability of habitat for bird species given both baseline environmental conditions in which they were found and where those conditions may exist on the landscape in the future as the climate changes. Thus, these models assume that the relationship between predictor and response variables during the baseline period hold for future periods and that that predictor variables are ecologically meaningful to birds (Matthews et al. 2011). The direction and magnitude of change in habitat suitability for suites of species should help inform managers of potential future park conditions.

Managers should use local knowledge of habitat and environmental conditions when assessing whether bird species may remain in current locations and/or colonize future suitable habitat. For example, the area of analysis here includes a large area outside of the park boundary, some of which includes fragmented habitat. Thus, a manager should consider how any differences in lands inside and outside the park may affect future response to climate change. The park may be well beyond the current range limits of some plant species which provide crucial habitat for a particular bird, and thus a dispersal distance barrier may preclude a

southern species from inhabiting the park in the near future. Furthermore, the analyses presented here are at a large landscape scale. Local topographic complexity may create refugia with cool microclimates that enable northern species to persist on the landscape longer into the future. Local examples of refugia within and south of a park can inform managers as to where species may persist for longer periods under climate change. Other factors, such as biotic interactions (e.g., interspecific competition among bird species) are not captured in this modeling effort and are assumed not to change over time and affect model outcomes.

Model output indicates potential suitable habitat for a bird species, and not where the species will necessarily occur at a particular point in time. This distinction is important because the models do not account for dispersal, demography, or other factors that influence habitat quality (e.g., disturbance). Nevertheless, the models are valuable for park managers because – by effectively controlling for the habitat, climate, and topographic variables that serve as inputs – they identify new questions and testable hypotheses on the role of non-modeled factors and possible management actions in proactively shaping future bird distributions. Habitat suitability models should be used in conjunction with other tools and data, such as observational studies, other vulnerability assessments, and scenario planning exercises, to envision the range of plausible futures for national park bird communities.

Birding in Acadia National Park. Photo by Lora Haller, NPS.

Results

Potential Bird Habitat Suitability Changes

Analyses for the Acadia region resulted in 130 breeding bird species with baseline (1990) and/or future (2040, 2070, 2100) habitat suitability. Looking out to 2100 and based on change class definitions, general trends in the data indicate decreasing habitat suitability under both climate scenarios for 30 species (23% of species), no change under both scenarios for 15 species (12%), increases or new habitat for 48 species (37%), and mixed results (i.e., different change classes among climate scenarios) for 37 species (28%; Table 1). 'New' species were very rare or absent during the baseline period and assumed to have minimal to no suitable habitat during that time.

Common trends in potential 21st century habitat suitability and uncertainty are shown in Figure 5 (see Appendices 5-14 for plots of all modeled species sorted by taxonomic guilds). The ruffed grouse and Swainson's thrush show large decreases in potential habitat suitability under both the 'least change' and 'major change' climate scenarios, and the American crow has only very minor change in habitat under both climate scenarios. Conversely, changes in habitat suitability depend greatly on climate scenario for the rose-breasted grosbeak and willow flycatcher. Potential habitat suitability decreases strongly for the rose-breasted grosbeak under the 'major change' scenario but shows only minor changes under 'least change'. Conversely, habitat increases for the willow flycatcher under 'least change' and remains relatively stable under the 'major change' scenario. Finally, the northern mockingbird has large potential increases in habitat under both futures.

Potential Changes by Habitat Preference and Migratory Status

Habitat suitability projections for the end of the 21st century showed moderate differences by bird habitat preference ($F_{4,84} = 2.12$, p-value = 0.09; Figure 6A) and significant differences by migratory status ($F_{2,86} = 3.11$, p-value = 0.05; Figure 7A) for species present during the baseline period (1961-1990). Interestingly, baseline-present forest birds have relatively low future suitability projections (Figure 6A) but forest is also the habitat type with the greatest number of absent or rare bird species ($n = 12$) with new future habitat in the region (Figure 6B). Unclassified birds, including generalist and urban species, show both relatively high habitat suitability for existing species and several previously rare/absent species ($n = 6$) with new habitat in the region. Similar to the trend for forest birds, Neotropical migrants have both the lowest projections for extant species (Figure 7A) and the highest number of species ($n = 21$) with new future suitable habitat in the region (Figure 7B). Within the Neotropical migrant group, warblers show a general decreasing trend for multiple species under both 'least change' and 'major change' scenarios by 2100 (Figure 8; see Appendix 15 for end of the century change class listings for all Neotropical migrant species).

Table 1a-e. Potential changes in habitat suitability for 130 bird species in the Acadia National Park region for the end of the 21st century. Species are grouped into decreasing, no change, increasing, new habitat, and mixed results groups based on change class designations for the 'least change' and 'major change' climate scenarios. See Appendix 2 for scientific names and Appendix 4 for change class definitions.

Table 1a

Decreases under Both Scenarios

Common Name	Least Change	Major Change
American Bittern	Large decrease	Large decrease
American Kestrel	Small decrease	Small decrease
Blackburnian Warbler	Small decrease	Large decrease
Black-throated Blue Warbler	Small decrease	Large decrease
Black-throated Green Warbler	Small decrease	Large decrease
Blue-headed Vireo	Small decrease	Large decrease
Canada Warbler	Large decrease	Large decrease
Cliff Swallow	Large decrease	Large decrease
Common Loon	Large decrease	Large decrease
Common Snipe	Large decrease	Large decrease
Dark-eyed Junco	Small decrease	Large decrease
Evening Grosbeak	Large decrease	Large decrease
Hermit Thrush	Small decrease	Large decrease
Least Flycatcher	Small decrease	Large decrease
Magnolia Warbler	Large decrease	Large decrease
Mourning Warbler	Small decrease	Small decrease
Nashville Warbler	Large decrease	Large decrease
Northern Parula	Large decrease	Small decrease
Northern Waterthrush	Large decrease	Large decrease
Purple Finch	Small decrease	Large decrease
Red-breasted Nuthatch	Small decrease	Large decrease
Ruffed Grouse	Small decrease	Large decrease
Savannah Sparrow	Small decrease	Large decrease
Spotted Sandpiper	Small decrease	Large decrease
Swainson's Thrush	Extirpated	Extirpated
Vesper Sparrow	Small decrease	Large decrease
White-throated Sparrow	Small decrease	Large decrease
Winter Wren	Large decrease	Large decrease
Yellow-bellied Sapsucker	Large decrease	Large decrease
Yellow-rumped Warbler	Small decrease	Large decrease

Table 1b

No Change under Both Scenarios

Common Name	Least Change	Major Change
American Robin	No change	No change
Barn Swallow	No change	No change
Brown-headed Cowbird	No change	No change
Common Yellowthroat	No change	No change
Eastern Meadowlark	No change	No change
European Starling	No change	No change
Great Blue Heron	No change	No change
Killdeer	No change	No change
Mallard	No change	No change
Mourning Dove	No change	No change
Rock Dove	No change	No change
Ruby-throated Hummingbird	No change	No change
Warbling Vireo	No change	No change
Whip-poor-will	No change	No change
Wood Thrush	No change	No change

Table 1c

Increases under Both Scenarios

Common Name	Least Change	Major Change
Eastern Towhee	Small increase	Small increase
Field Sparrow	Small increase	Small increase
House Sparrow	Small increase	Small increase
House Wren	Large increase	Small increase
Indigo Bunting	Small increase	Small increase
Northern Cardinal	Small increase	Small increase
Northern Mockingbird	Large increase	Large increase
Pine Warbler	Small increase	Small increase
White-breasted Nuthatch	Small increase	Small increase

Table 1d

New Suitable Habitat

Common Name	Least Change	Major Change
Acadian Flycatcher	--	New entry
Black Vulture	--	New entry
Blue Grosbeak	--	New entry
Blue-gray Gnatcatcher	New entry	New entry
Blue-winged Warbler	New entry	New entry
Canada Goose	New entry	New entry
Carolina Wren	New entry	New entry
Cattle Egret	--	New entry
Chuck-Will's Widow	--	New entry
Common Nighthawk	--	New entry
Dickcissel	--	New entry
Fish Crow	--	New entry
Grasshopper Sparrow	--	New entry
Great Egret	--	New entry
Hooded Warbler	--	New entry
Horned Lark	--	New entry
Kentucky Warbler	--	New entry
Little Blue Heron	--	New entry
Loggerhead Shrike	--	New entry
Mississippi Kite	--	New entry
Northern Bobwhite	New entry	New entry
Orchard Oriole	--	New entry
Painted Bunting	--	New entry
Prairie Warbler	New entry	New entry
Prothonotary Warbler	--	New entry
Red-bellied Woodpecker	New entry	New entry
Red-headed Woodpecker	--	New entry
Red-shouldered Hawk	--	New entry
Red-tailed Hawk	New entry	New entry
Scissor-tailed Flycatcher	--	New entry
Summer Tanager	--	New entry
Tufted Titmouse	New entry	New entry
White-eyed Vireo	--	New entry
Worm-eating Warbler	--	New entry
Yellow-billed Cuckoo	New entry	New entry
Yellow-breasted Chat	--	New entry
Yellow-crowned Night-Heron	--	New entry
Yellow-throated Vireo	New entry	New entry
Yellow-throated Warbler	--	New entry

Table 1e

Mixed Results

Common Name	Least Change	Major Change
American Crow	No change	Small decrease
American Goldfinch	No change	Small decrease
American Redstart	No change	Large decrease
Baltimore Oriole	Small increase	Small decrease
Bank Swallow	No change	Large decrease
Black-and-white Warbler	No change	Small decrease
Black-billed Cuckoo	No change	Large decrease
Black-capped Chickadee	No change	Large decrease
Blue Jay	No change	Small decrease
Bobolink	No change	Extirpated
Broad-winged Hawk	No change	Small decrease
Brown Creeper	No change	Small decrease
Brown Thrasher	No change	Small increase
Cedar Waxwing	No change	Large decrease
Chimney Swift	Small increase	No change
Chipping Sparrow	No change	Large decrease
Downy woodpecker	Small increase	No change
Eastern Kingbird	No change	Small decrease
Eastern Phoebe	No change	Small decrease
Eastern Wood-Pewee	No change	Small decrease
Gray Catbird	No change	Small decrease
Great Horned Owl	No change	Large increase
Green Heron	No change	Small increase
House Finch	Large increase	No change
Ovenbird	No change	Small decrease
Pileated Woodpecker	Small decrease	Small increase
Purple Martin	No change	Large increase
Red-eyed Vireo	No change	Small decrease
Ring-necked Pheasant	Small increase	No change
Rose-breasted Grosbeak	No change	Large decrease
Song Sparrow	No change	Large decrease
Swamp Sparrow	No change	Large decrease
Tree Swallow	No change	Large decrease
Turkey Vulture	No change	Small increase
Veery	No change	Large decrease
Willow Flycatcher	No change	Small decrease
Yellow Warbler	No change	Large decrease

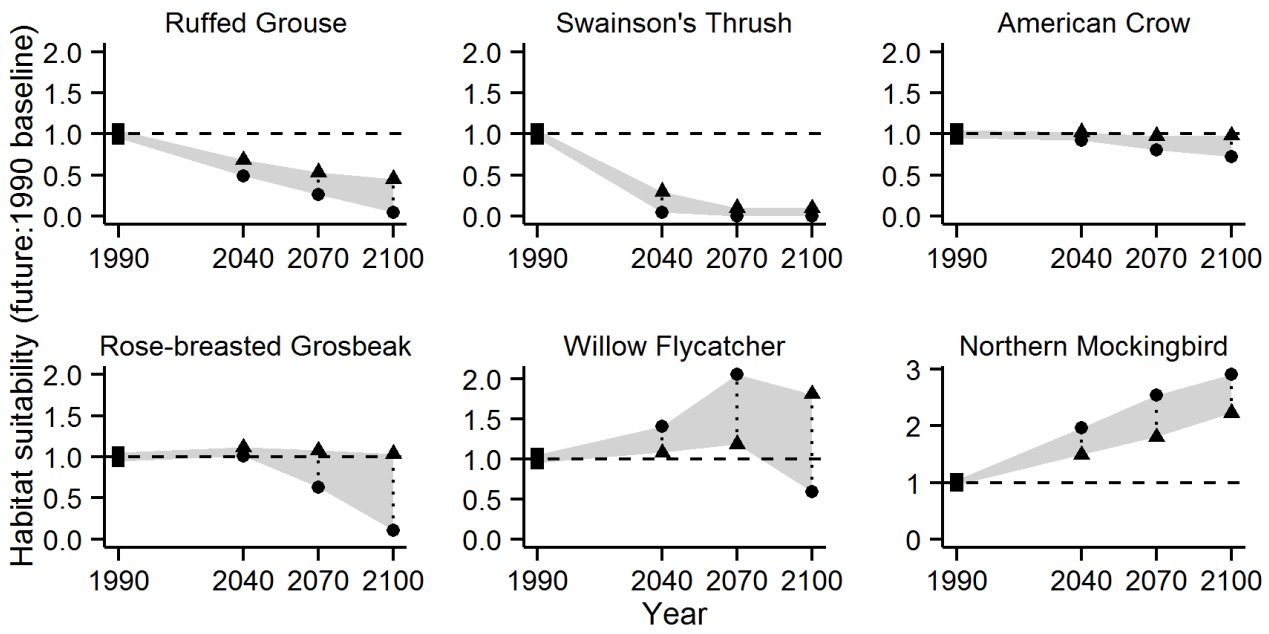


Figure 5. Projected changes in potential habitat suitability for six bird species with sufficient occurrence data during the late 20th century baseline period (1961-1990) in the Acadia region to permit modeling. Future projections (30 year periods ending in 2040, 2070, 2100) are based on 'least change' (black triangles) and 'major change' (black circles) climate scenarios and are shown as a ratio of future to late 20th century habitat suitability (e.g., y-axis value of 2.0 = doubling of suitable habitat; 0.5 = 50% reduction in habitat).

State-listed Species of Special Concern

State-listed species of special concern and endangered species exhibit the full range of changes in potential habitat. Species of special concern with sufficient occurrence data to enable baseline habitat modeling show shifts in habitat suitability from large decreases to large increases (Figure 9; additional birds of special concern include the yellow warbler, black-and-white warbler, Canada warbler, and American redstart in Figure 8). The purple martin and whip-poor-will show relatively large potential increases and the evening grosbeak and Canada warbler have large potential decreases. Species of special concern rare/absent during the baseline period and with new habitat under both climate change scenarios include the yellow-billed cuckoo, prairie warbler, and blue-winged warbler. The state-listed endangered grasshopper sparrow and species of special concern orchard oriole, loggerhead shrike, and horned lark gain new habitat under the 'major change' scenario but not under the 'least change' scenario.

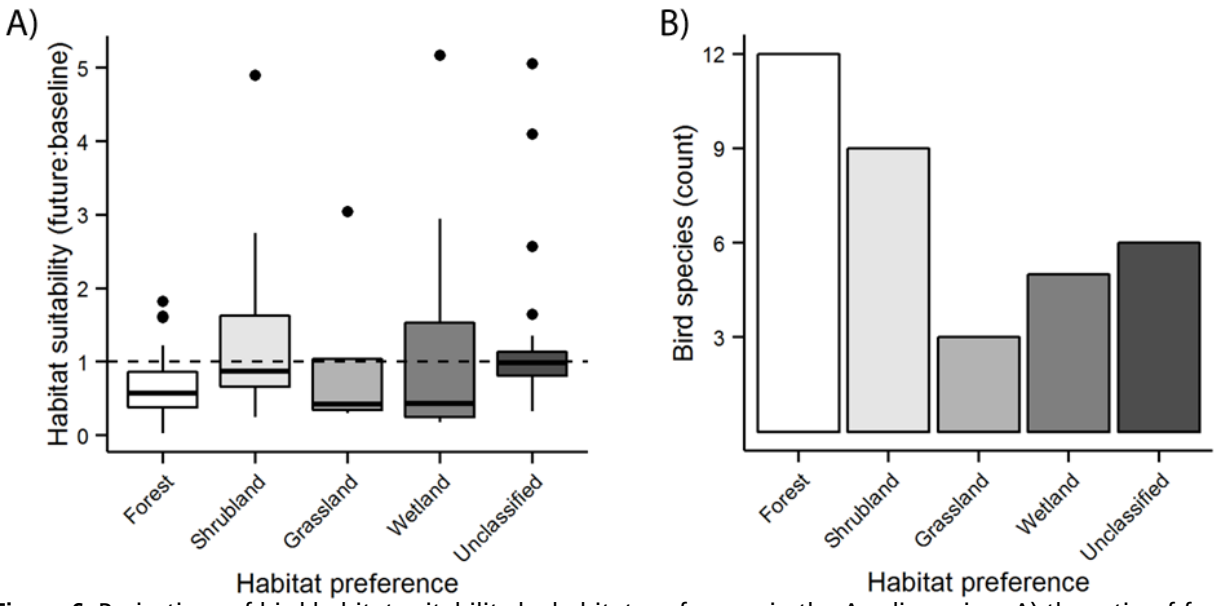


Figure 6. Projections of bird habitat suitability by habitat preference in the Acadia region. A) the ratio of future (2100) to baseline (1990) habitat for species with sufficient occurrence data during the baseline period (1961-1990) in the Acadia region to permit modeling. B) count of bird species very rare or absent from the region during the baseline period with suitable habitat in 2100 under either climate scenario.

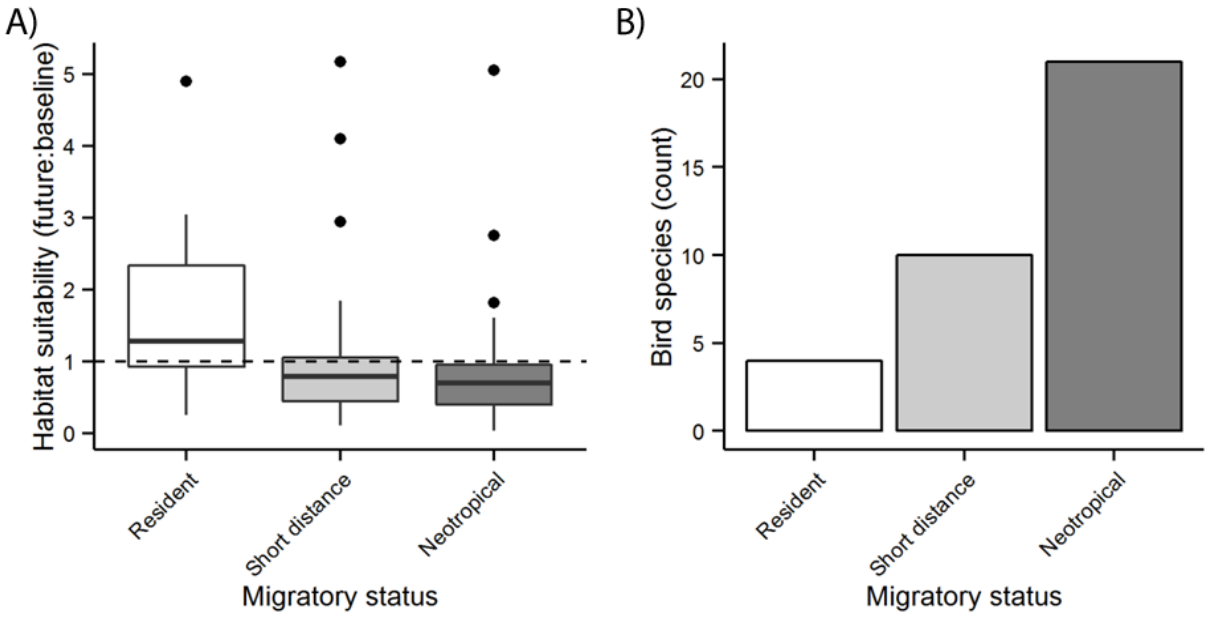


Figure 7. Projections of bird habitat suitability by migratory status in the Acadia region. A) the ratio of future (2100) to baseline (1990) habitat for species with sufficient occurrence data during the baseline period (1961-1990) in the Acadia region to permit modeling. B) count of bird species very rare or absent from the region during the baseline period with suitable habitat in 2100 under either climate scenario.

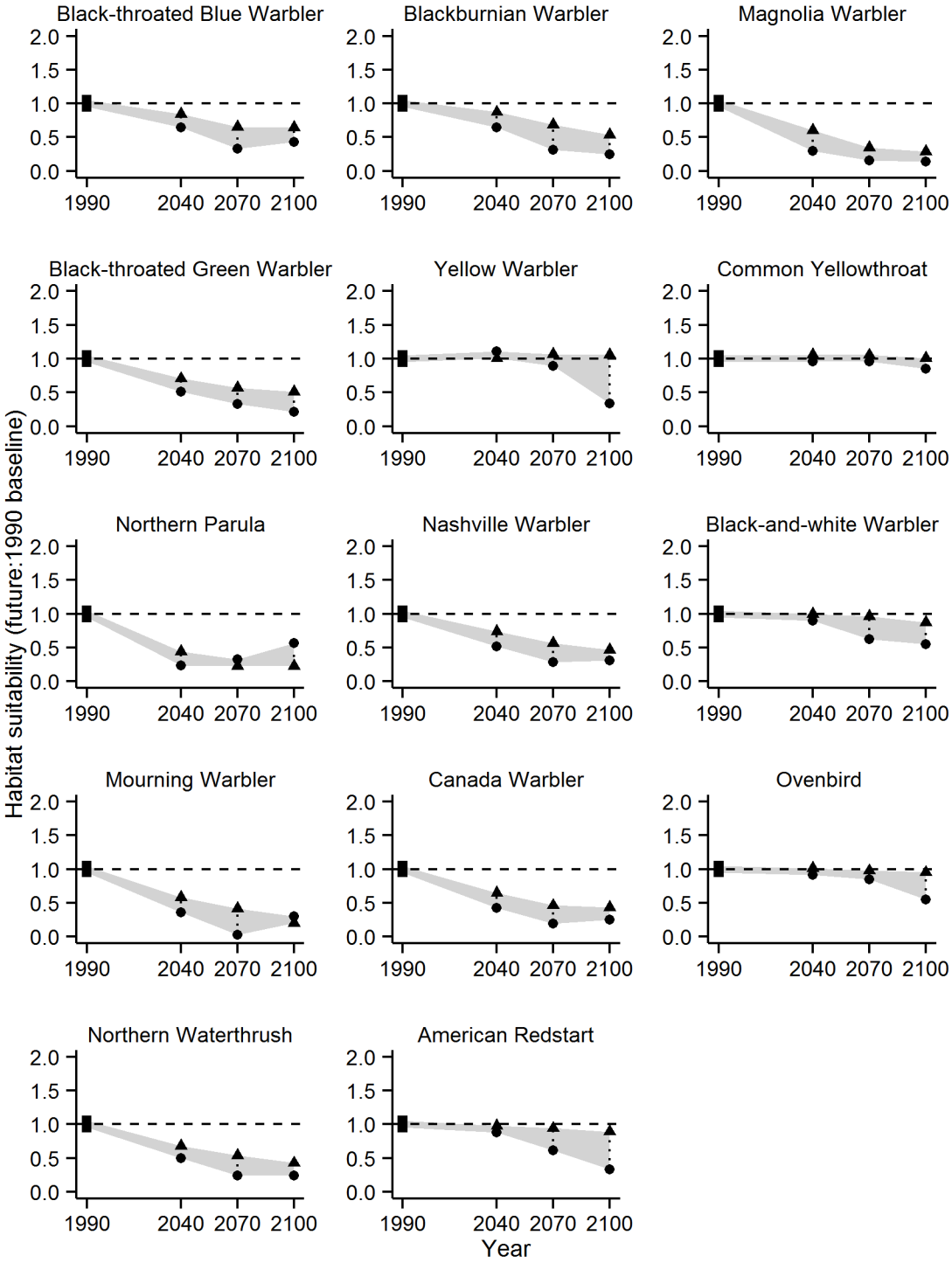


Figure 8. Projected changes in potential habitat suitability for Neotropical migrant warblers with sufficient occurrence data during the late 20th century baseline period (1961-1990) in the Acadia region to permit modeling. Future projections (30 year periods ending in 2040, 2070, 2100) are based on 'least change' (black triangles) and 'major change' (black circles) climate scenarios and are shown as a ratio of future to late 20th century habitat suitability (e.g., y-axis value of 2.0 = doubling of suitable habitat; 0.5 = 50% reduction in habitat).

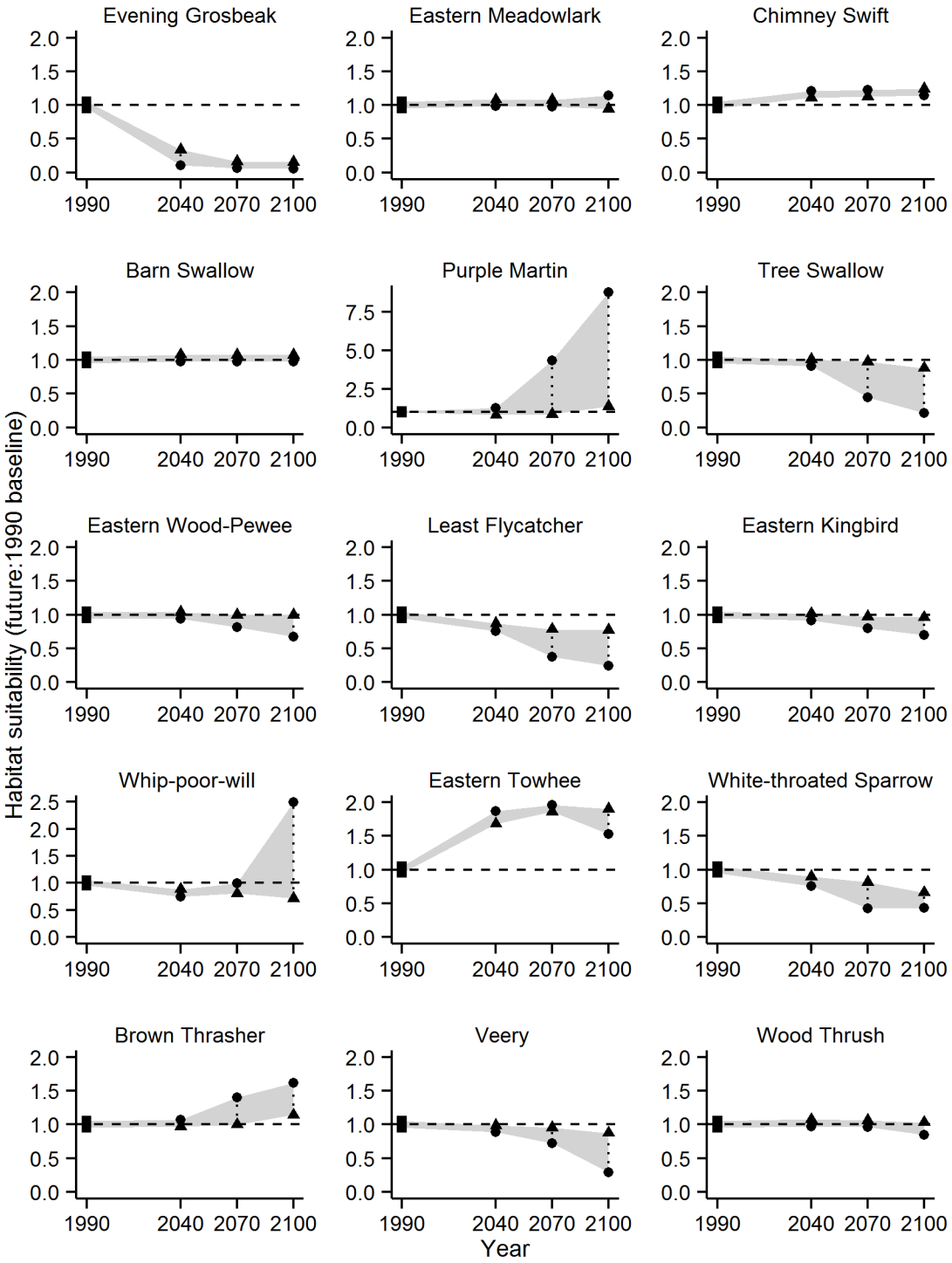


Figure 9. Projected changes in potential habitat suitability for Maine state-listed species of special concern with sufficient occurrence data during the late 20th century baseline period (1961-1990) in the Acadia region to permit modeling. Future projections (30 year periods ending in 2040, 2070, 2100) are based on 'least change' (black triangles) and 'major change' (black circles) climate scenarios and are shown as a ratio of future to late 20th century habitat suitability (e.g., y-axis value of 2.0 = doubling of suitable habitat; 0.5 = 50% reduction in habitat).

Discussion

The results presented here suggest a diversity of breeding bird responses to changing climatic and habitat conditions in the Acadia region. Acadia National Park is already near the extreme warm edge of its historical climate envelope (Monahan and Fisichelli 2014) and conditions are projected to continue warming across this century (Kunkel et al. 2013). Mean centers of bird habitat in the eastern U.S. are projected to move north-northeast 98-203 km by 2100 (Matthews et al. 2011).

Many bird species are vagile and thus expected to be able to physically track a shifting climate across the landscape; however, many indirect climate-related factors are likely to influence bird distributions and population densities and the strengths of these factors are likely to change over time (Matthews et al. 2011). Short-term potential impacts include mismatches in phenology of birds and their food. Over the longer term, mismatches between climate and habitat types (i.e., time lags due to rates of habitat change not keeping pace with climate change) and possible changes in interspecific competition may affect birds. Based on responses to past changes in climate, the risk of extinction is likely relatively low for birds compared with more dispersal-limited species (Sandel et al. 2011); however, changes in bird assemblages within fixed areas such as parks may be relatively rapid compared with other taxa. Thus, park bird assemblages may be bellwethers of change and useful examples for educating the public on ongoing climate change effects to park resources (see Box 2). NPS managers are tasked with stewarding resources for continuous change (NPS AB 2012) and potential habitat suitability models are one tool to understand and anticipate near- and long-term changes.

Climate change will likely alter where, when, and which bird species park visitors encounter. Photo by Jim Schmidt.

Box 2. Education and Understanding Through Birds

Bird watching is a common and highly valued activity for many park visitors. Park bird species and assemblages may be bellwethers of change and useful examples for educating the public on ongoing climate change effects to park resources. The following key points can help visitors understand ongoing change and impacts in Acadia:

- Acadia National Park has seen a significant warming trend over the past century and is at the extreme warm edge of its historical temperature distribution.
- The climate is highly likely to continue warming across the northeast region over the coming decades.
- Birds across the globe are responding to climate change by modifying their phenology, behavior, and home ranges.
- The assemblage of bird species in Acadia will change with a changing climate. Some species will move out of the park and other species will move in. This may include changes in the suite of Neotropical migrants summering in the park and resident birds which remain in the park year round.
- It is difficult to attribute observed changes in a single species to climate change; however, consistent changes across multiple species that correlate with directional climate change lend stronger support to climate as a driving factor.
- Ongoing citizen science efforts are vital to help the park detect and understand climate related changes to resources.

Responses by Migratory Status and Habitat Preference

Habitat suitability projections varied across species, though trends were evident for migratory groups. Most resident bird species present during the baseline period are likely to maintain suitable breeding habitat and a small number of new colonizers may expand into the region during this century. Ranges of resident birds are often limited by winter temperatures (Root 1988) and continued warming may increase overwinter survival of these species. Projections for present and new colonizing Neotropical migrants suggest a large potential turnover in this assemblage of species in the Acadia region (Appendix 15). There are multiple additional threats to long-distance migrants, such as winter habitat loss due to climate change, habitat fragmentation and loss of important migratory stopover sites, and exposure to extreme weather events (Hedenström et al. 2007, Lemoine et al. 2007, Weber et al. 1999), which need to be assessed in addition to the model results provided here. For example the number of long-distance migrant birds and other species able colonize newly available habitat in the Acadia region may depend in part on the availability and quality of overwintering habitat in the tropics.

In addition to migratory behavior, other factors such as habitat requirements will influence the ability of birds to respond to climate change. The rate and magnitude of vegetation change will be an important factor for many bird species. In the Acadia region, cold-adapted boreal tree species, including fir, spruce, aspen, and paper birch, are projected to have strong decreases in suitable habitat in the future, whereas most temperate species currently present retain suitable habitat (Fisichelli et al. 2013). Under the warmest scenario (same 'major change' as used in this report), several oak, hickory, and pine species common in the southeast and

Numerous Neotropical migrants, such as the yellow-rumped warbler, are projected to see large decreases in habitat suitability over the 21st century due to climate change. Photo by Jim Schmidt.

Some species, such as the black-capped chickadee, have very minor changes in habitat suitability under the 'least change' climate scenario but large projected decreases under the warmest scenario. NPS photo.

south central U.S. are likely to have suitable habitat in the Acadia region by the end of the 21st century. Some of these tree species may fail to keep pace with rapid 21st century climate change (Iverson et al. 2004); thus, although Acadia may become climatically suitable for a bird species, the vegetation type may limit actual habitat suitability.

Climate change will also interact with other stressors not explicitly included in the models presented here. Nonnative tree pests (most of which are not reflected in the tree habitat models) may accelerate the decline of existing habitats and/or slow the expansion of other species better adapted to warmer conditions. For example, the balsam woolly adelgid may accelerate decline of balsam fir (*Abies balsamea*), while arrival of the Asian long-horned beetle could slow expansion of temperate hardwood species (Fisichelli et al. 2014). Species with specific habitat requirements, including type and size of core areas, may be more sensitive to these climate-mediated changes in habitat than generalist species. The results presented here are at a relatively coarse spatial scale and the presence and size of local climate refugia with suitable habitat will be an important factor enabling some specialist species to persist, perhaps such as the Swainson's thrush. Conversely, birds with 'unclassified' habitat preference, such as the American robin and House finch, may not be strongly impacted by changes in one specific habitat type. Habitat models only included tree species and it is assumed that shifts in forest types are generally consistent with other habitat types (Matthews et al. 2011), though additional modeling of specific habitat types may improve our understanding of potential changes.

Although these analyses include a large number of species (n = 130), many other bird species also occupy the park and surrounding landscape. Modeled species with similar behaviors, habitat requirements, and migration patterns can provide general indications of likely responses of other species. Additional information, such as distance to southern range edge or lower elevation limits in mountainous areas can also give general indications of sensitivity to climate change (Conroy et al. 2011).

Phenology and Competition

Phenological responses of bird species to ongoing climate change are important near-term indicators of change for bird communities. Notably, phenological responses have already been detected in numerous studies and, in Europe, species failing to show phenological responses to climate change are already declining in abundance (Møller et al. 2008). Results presented here show short-distance migrants with changes in breeding habitat suitability intermediate to those of resident and Neotropical migrants. This short-distance migrant group may be able to adapt more rapidly to a shifting climate than long-distance Neotropical migrants as the location of wintering grounds and migratory behavior may be more strongly controlled by temperature for short-distance migrants whereas Neotropical migrant behavior appears to be more genetically controlled (Møller et al. 2004, Lemoine et al. 2007). Also, long-distance migratory birds using habitats with more seasonal peaks in food availability, such as caterpillar eating birds in forests, may see larger population declines due to mismatches in phenology than birds using habitats with more consistently available food, such as within marshes (Visser et al. 2006, Both et al. 2010).

The modeling employed here assumes that past species interactions will be similar to future interactions. This necessary assumption may not hold for all species and should be monitored for detection of shifting trends and novel interactions. Colonizers may be unable to establish in newly suitable habitat due to competition with existing species or, conversely, existing species may decline more rapidly due to invasion and competition with colonizers (Yackulic et al. 2014). For example, the wood thrush expanded in Maine during the mid-20th century and this socially dominant species reduced the types

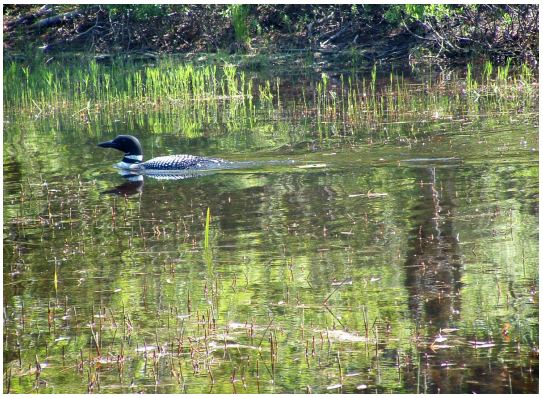
and area of nesting habitat utilized by the hermit thrush and veery (Morse 1971).

Detecting Change

Monitoring data collected within the park and from across the broader region can provide early indications of on-the-ground changes. For example, tracking shifts in phenology (e.g., spring arrival, nesting time, and fall departure) over decades can yield valuable information on which species are already adapting to a changing climate. Over shorter time scales, tracking of interannual climate variability by bird species may provide evidence for which species potentially have higher adaptive capacity to long-term climate change (Møller et al. 2008). Changes in nesting success, population densities, lifespan, and habitat selection (e.g., shifts to higher elevations or latitudes) may also indicate climate-mediated trends. Focused monitoring conducted along elevational gradients and over longer time periods within a season, such as during migration and nesting periods, can also facilitate detection of responses to climate.

Because the baseline modeling period was 1961-1990, the first habitat suitability projection period is 2010-2039 [2040], and BBS trend data were available for this report from 1966-2011, initial rough comparisons between field data and model data can be made (see Table 2 for select species where recent BBS trends agree and disagree with projections, see Appendix 2 for results for all species). Such comparisons are useful for developing hypotheses of the causes and mechanisms of change, which are further testable using data collected from additional or ongoing field monitoring. Agreement and disagreement among actual trends and model projections may be due to multiple climatic and non-climatic factors. Recent rates of climate change may not be large enough to fully elicit the projected responses due to the climate average across 2010-2039. For example, the climate may not have changed sufficiently yet to allow species such as the house sparrow and eastern towhee to gain potential habitat. For some species, factors other than climate may have played a larger role in population trends over the past few decades. Conservation efforts for the common loon, including reduction of contaminants in lakes and acid rain, likely have allowed this species to increase its numbers (Evers 2004). Model projections suggest that future climatic and related factors, such as disease outbreaks, could impact this recent increasing population trend for the loon. Finally, some recent population increases could be due to a combination of climate and non-climate factors, such as habitat alteration and warmer temperatures facilitating Canada goose year-round survival on breeding grounds (Monzón et al. 2011).

Habitat suitability of the Acadia region is projected to increase across all climate scenarios for several bird species, such as the northern cardinal. Photo by Jim Schmidt



Common loon on Echo Lake in Acadia National Park. Although this species has shown recent population gains due to international conservation efforts, a changing climate may reduce suitable habitat in the Acadia region. NPS photo.

Climate Change Adaptation

Climate change adaptation actions will be shaped by local priorities, scientific information, and NPS policies. Managers cannot change global atmospheric CO_2 levels but they can focus on other actions to influence the performance of bird species found within their jurisdiction (Conroy et al. 2011). National parks are located within a matrix of other federal, state, tribal, and private lands and maintaining regional avian diversity will require collaboration with managers from neighboring jurisdictions. The most appropriate climate adaptation strategies depend on management objectives and goals, though many common approaches exist that managers can focus on today, both within and across jurisdictional boundaries. These include reducing existing non-climate stress-

Table 2. Select species with recent trends in population numbers (BBS change 1966-2011) that agree or disagree with modeled habitat suitability changes (between baseline [1961-1990] and 2040 [2010-2039]). BBS trend data indicate whether the trend line of the species has increased at least 1.5% per year (+), decreased at least 1.5% per year (-), or remained within those bounds (•) during the sample period (1966-2011). BBS changes of 1.5% per year roughly correlate with future to baseline habitat ratios < 0.5 for decreasing trends and > 2.0 for increasing trends. See Appendix 2 for data on all species.

	Future (2040): baseline habitat ratio			
Common Name	**'Least change'**	**'Major change'**	**BBS trend**	**Comparison**
Cliff Swallow	0.65	0.35	-	agree
Dark-eyed Junco	0.59	0.35	-	
Nashville Warbler	0.74	0.52	-	
Eastern Towhee	1.68	1.87	-	disagree
House Sparrow	1.31	1.41	-	
Canada Goose	3.98	6.97	+	agree
Northern Cardinal	2.95	4.19	+	
White-breasted Nuthatch	1.53	1.87	+	
Blue-headed Vireo	0.75	0.61	+	disagree
Common Loon	0.60	0.30	+	
Northern Parula	0.44	0.23	+	
American Goldfinch	1.01	0.99	•	agree
American Robin	1.00	1.00	•	
Black-capped Chickadee	1.03	1.01	•	
Song Sparrow	1.00	1.01	•	

Responses to a changing climate will vary widely across bird species, some will expand into the Acadia region, others will retreat north, and yet others such as the great blue heron may retain much suitable habitat across the coming century under most climate scenarios. NPS photo.

ors (e.g., nonnative species and pollution), enhancing landscape connectivity, and restoring ecological processes such as fire and hydrologic regimes (NFWPCAP 2012). Furthermore, cross-jurisdictional collaborations may facilitate implementation of a larger suite of management actions than would be feasible or even permitted solely within the park boundary. For example, silviculture treatments on forest lands outside of the park boundary may increase overall regional habitat for species dependent on early-successional habitat (DeGraaf et al. 1993).

This report provides information on species which may lose habitat, retain baseline habitat, or gain new climatically suitable habitat. Conservation priorities, such as for state listed species of special concern, can be informed by these habitat suitability projections. At risk species with potentially decreasing future habitat may require refined goals and management actions. Topographically complex parks such as Acadia may hold climate refugia for some bird species projected to lose significant habitat. Management actions could be focused on these refugial locations to maintain or improve habitat; for example, prescribed fire in forests, fire or mowing in grasslands, and nonnative plant control could improve the habitat quality of climate refugia. Other species of conservation concern may have future increases in potential habitat due to climate-related changes and thus continued reductions of non-climate stressors may enable persistence until populations can expand and increase their numbers. As birds shift their phenologies, management actions will also have to shift to earlier or later time periods to remain effective. Management could also be shifted to higher elevations or latitude in order to remain within climatically suitable areas (Conroy et al. 2011).

Conclusions

The bird species of the Acadia region, their abundance, and habitat use are continuously changing due to multiple factors. Past greenhouse gas emissions, the residence time of these gases in the atmosphere, and our current emissions trajectory suggest that climate change will be substantial (Wigley 2005, Peters et al. 2013), and thus both ecological processes and species assemblages will continue to change. The model projections presented here can aid natural resource managers in anticipating and detecting specific changes and for interpretive staff to educate visitors on past and future changes. Bird species are fundamental resources and a major draw for visitors at many parks. Birds can provide tangible evidence of climate-related changes already occurring on the landscape and the habitat suitability projections can help visitors understand the potential direction and magnitude of change over the coming decades.

Ongoing climate change is likely to result in new and expanded future suitable habitat in the Acadia region for many species, such as the prothonotary warbler. Photo by Jim Schmidt.

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Appendix 1. Predictor variables used in modeling potential bird habitat suitability (see Iverson et al. 2008 and Matthews et al. 2011 for further details).

Tree species habitat suitability	Climate variables	Elevation variables (measured within each 20 x 20 km grid cell
Abies balsamea	Mean annual temperature	minumum elevation
Acer pensylvanicum	Mean July temperature	maximum elevation
Acer rubrum	Mean January temperature	mean elevation
Acer saccharum	Total precipitation	range (max - min elevation)
Betula alleghaniensis	Seasonality (difference between mean July and January temperature)	
Betula lenta	Mean May to September temperature	
Betula papyrifera	Total May to September precipitation	
Carya texana		
Celtis occidentalis		
Cornus florida		
Fagus grandifolia		
Fraxinus americana		
Fraxinus nigra		
Larix laricina		
Liquidambar styraciflua		
Liriodendron tuliperfia		
Nyssa sylvatica		
Picea mariana		
Picea rubens		
Pinus banksiana		
Pinus echinata		
Pinus elliottii		
Pinus rigida		
Pinus strobus		
Pinus taeda		
Pinus virginiana		
Populus tremuloide		
Prunus serotina		
Quercus alba		
Quercus laurifolia		
Quercus nigra		
Quercus prinus		
Quercus rubra		
Quercus stellata		
Quercus virginiana		
Taxodium distichum var. nutans		
Thuja occidentalis		
Tsuga canadensis		
Ulmus americana		

Appendix 2. Climate change bird atlas habitat suitability output for 130 bird species in the region including Acadia National Park

Potential habitat suitability is defined from bird incidence values (IVs), calculated as the proportion of years where a species was recorded as present on USGS Breeding Bird Survey (BBS) routes from the period 1981-1990 (see Methods for details). Habitat suitability is shown for four periods: baseline (1961-1990), 2040 (2010-2039), 2070 (2040-2069), and 2100 (2070-2099) and two climate model-emissions trajectory projections, the PCM B1 and Had A1FI, which represent the 'least change' and 'major change' scenarios, respectively. Species are sorted by common name. BBS trend and abundance data are provided for further information on individual bird species and as supporting information to help interpret the models (see Methods for further details).

		Baseline Habitat			Future Habitat									
					2040		2070		2100					
Scientific Name	Common Name	Actual	Current	Model Reliability	PCM B1	Had A1FI	PCM B1	Had A1FI	PCM B1	Had A1FI	Change Class PCM B1	Change Class Had A1FI	BBS Trend	BBS Abundance Index
Empidonax virescens	Acadian Flycatcher	**0**	0	Low	0	0	0	5	1	10	--	New entry		0.00
Botaurus lentiginosus	American Bittern	**1**	9	Low	4	3	3	2	2	1	Large decrease	Large decrease	+	1.02
Corvus brachyrhynchos	American Crow	**5**	25	Low	24	24	24	20	24	18	No change	Small decrease	•	4.13
Carduelis tristis	American Goldfinch	**5**	28	High	28	27	28	26	28	16	No change	Small decrease	•	3.44
Falco sparverius	American Kestrel	**3**	13	Low	11	9	9	9	9	9	Small decrease	Small decrease	-	0.56
Setophaga ruticilla	American Redstart	**5**	27	Medium	26	24	26	17	24	9	No change	Large decrease	-	2.19
Turdus migratorius	American Robin	**5**	29	High	29	29	29	29	29	27	No change	No change	•	4.08
Icterus galbula	Baltimore Oriole	**3**	20	High	26	27	27	26	27	14	Small increase	Small decrease	•	1.19
Riparia riparia	Bank Swallow	**3**	13	Low	14	13	13	6	12	3	No change	Large decrease	-	1.06
Hirundo rustica	Barn Swallow	**5**	28	Medium	29	28	29	28	29	28	No change	No change	-	1.88
Coragyps atratus	Black Vulture	**0**	0	Medium	0	0	0	0	0	3	--	New entry		0.00
Mniotilta varia	Black-and-white Warbler	**5**	27	Medium	27	24	26	17	23	15	No change	Small decrease	-	2.50
Coccyzus erythropthalmus	Black-billed Cuckoo	**2**	9	High	9	10	9	8	10	2	No change	Large decrease	-	0.92
Dendroica fusca	Blackburnian Warbler	**2**	9	Medium	8	6	6	3	5	2	Small decrease	Large decrease	-	1.08
Poecile atricapillus	Black-capped Chickadee	**5**	28	High	29	28	29	19	28	4	No change	Large decrease	•	3.37

Scientific Name	Common Name	Baseline Habitat		Model Reliability	Future Habitat						Change Class PCM B1	Change Class Had A1FI	BBS Trend	BBS Abundance Index
					2040		2070		2100					
		Actual	Current		PCM B1	Had A1FI	PCM B1	Had A1FI	PCM B1	Had A1FI				
Dendroica caerulescens	Black-throated Blue Warbler	**1**	7	High	6	5	5	2	5	3	Small decrease	Large decrease	+	1.19
Dendroica virens	Black-throated Green Warbler	**5**	22	Medium	15	11	12	7	11	5	Small decrease	Large decrease	•	3.13
Guiraca caerulea	Blue Grosbeak	**0**	0	High	0	0	0	5	0	20	--	New entry		0.00
Cyanocitta cristata	Blue Jay	**5**	24	Low	24	24	24	20	24	18	No change	Small decrease	•	3.02
Polioptila caerulea	Blue-gray Gnatcatcher	**0**	0	Medium	1	3	2	9	5	17	New entry	New entry	+	0.00
Vireo solitarius	Blue-headed Vireo	**3**	17	Medium	12	10	11	6	8	4	Small decrease	Large decrease	+	2.40
Vermivora pinus	Blue-winged Warbler	**0**	1	Medium	3	6	4	10	7	4	New entry	New entry		0.00
Dolichonyx oryzivorus	Bobolink	**5**	27	High	27	25	26	6	22	1	No change	Extirpated	•	2.75
Buteo platypterus	Broad-winged Hawk	**1**	6	Low	5	5	5	5	5	4	No change	Small decrease	+	1.00
Certhia americana	Brown Creeper	**0**	4	Medium	5	5	5	4	5	2	No change	Small decrease	+	0.92
Toxostoma rufum	Brown Thrasher	**2**	13	Medium	13	14	13	19	15	22	No change	Small increase	-	0.81
Molothrus ater	Brown-headed Cowbird	**5**	26	Low	27	27	27	26	27	27	No change	No change	-	1.13
Coccyzus erythropthalmus	Black-billed Cuckoo	**2**	9	High	9	10	9	8	10	2	No change	Large decrease	-	0.92
Dendroica fusca	Blackburnian Warbler	**2**	9	Medium	8	6	6	3	5	2	Small decrease	Large decrease	-	1.08
Poecile atricapillus	Black-capped Chickadee	**5**	28	High	29	28	29	19	28	4	No change	Large decrease	•	3.37
Branta canadensis	Canada Goose	**0**	1	Low	2	4	3	7	5	3	New entry	New entry	+	1.73
Wilsonia canadensis	Canada Warbler	**4**	18	Medium	12	8	8	3	8	5	Large decrease	Large decrease		1.02
Thryothorus ludovicianus	Carolina Wren	**0**	0	High	0	1	0	15	3	21	New entry	New entry	+	0.02
Bubulcus ibis	Cattle Egret	**0**	0	High	0	0	0	0	0	9	--	New entry		0.00
Bombycilla cedrorum	Cedar Waxwing	**5**	27	High	27	24	26	15	25	6	No change	Large decrease	-	3.23
Chaetura pelagica	Chimney Swift	**4**	21	Medium	24	24	24	25	25	25	Small increase	No change	-	1.06
Spizella passerina	Chipping Sparrow	**5**	29	High	29	29	29	28	29	14	No change	Large decrease	•	3.19

Scientific Name	Common Name	Baseline Habitat		Model Reliability	Future Habitat						Change Class PCM B1	Change Class Had A1FI	BBS Trend	BBS Abundance Index
					2040		2070		2100					
		Actual	Current		PCM B1	Had A1FI	PCM B1	Had A1FI	PCM B1	Had A1FI				
Caprimulgus carolinenis	Chuck-Will's Widow	**0**	0	High	0	0	0	0	0	11	--	New entry		0.00
Petrochelidon pyrrhonota	Cliff Swallow	**5**	19	Medium	13	7	7	2	6	7	Large decrease	Large decrease	-	1.42
Gavia immer	Common Loon	**1**	5	Medium	3	2	2	0	2	1	Large decrease	Large decrease	+	0.90
Chordeiles minor	Common Nighthawk	**0**	0	Medium	0	0	0	0	0	6	--	New entry	-	0.00
Gallinago gallinago	Common Snipe	**1**	12	Medium	6	2	3	0	2	2	Large decrease	Large decrease	-	1.00
Geothlypis trichas	Common Yellowthroat	**5**	29	High	29	29	29	29	29	25	No change	No change	-	3.98
Junco hyemalis	Dark-eyed Junco	**0**	5	Medium	3	2	2	1	1	0	Small decrease	Large decrease	-	1.27
Spiza americana	Dickcissel	**0**	0	High	0	0	0	3	0	13	--	New entry		0.00
Picoides pubescens	Downy woodpecker	**3**	18	Low	20	21	21	24	23	22	Small increase	No change	+	1.21
Tyrannus tyrannus	Eastern Kingbird	**5**	24	Low	24	23	23	19	23	17	No change	Small decrease	-	1.13
Sturnella magna	Eastern Meadowlark	**4**	21	Medium	22	21	21	21	19	24	No change	No change	-	0.44
Sayornis phoebe	Eastern Phoebe	**4**	22	Low	23	23	23	17	22	15	No change	Small decrease	•	2.65
Pipilo erythrophthalmus	Eastern Towhee	**2**	14	Medium	23	26	26	27	26	21	Small increase	Small increase	-	0.23
Contopus virens	Eastern Wood-Pewee	**4**	23	Low	23	22	23	19	23	15	No change	Small decrease	-	1.69
Sturnus vulgaris	European Starling	**5**	27	Low	29	29	29	29	29	26	No change	No change	-	3.48
Coccothraustes vespertinus	Evening Grosbeak	**1**	7	Medium	2	1	1	1	1	1	Large decrease	Large decrease	+	0.87
Spizella pusilla	Field Sparrow	**1**	9	High	14	16	15	20	17	18	Small increase	Small increase	+	0.44
Corvus ossifragus	Fish Crow	**0**	0	Low	0	0	0	3	1	7	--	New entry		0.00
Ammodramus savannarum	Grasshopper Sparrow	**0**	0	Medium	0	1	0	6	1	8	--	New entry		0.00
Dumetella carolinensis	Gray Catbird	**5**	27	High	29	29	29	28	29	15	No change	Small decrease	-	2.44
Ardea herodias	Great Blue Heron	**2**	11	Low	12	12	12	9	11	12	No change	No change	-	1.02
Ardea alba	Great Egret	**0**	0	Medium	0	0	0	0	0	5	--	New entry		0.00

Scientific Name	Common Name	Baseline Habitat		Model Reliability	Future Habitat						Change Class PCM B1	Change Class Had A1FI	BBS Trend	BBS Abundance Index
					2040		2070		2100					
		Actual	Current		PCM B1	Had A1FI	PCM B1	Had A1FI	PCM B1	Had A1FI				
Bubo virginianus	Great Horned Owl	**0**	0	Low	0	0	0	2	0	4	No change	Large increase	•	0.00
Butorides virescens	Green Heron	**0**	2	Low	4	6	5	9	6	19	No change	Small increase	-	0.00
Catharus guttatus	Hermit Thrush	**3**	18	High	15	12	13	7	10	5	Small decrease	Large decrease	+	3.17
Wilsonia citrina	Hooded Warbler	**0**	0	Medium	0	0	0	3	1	3	--	New entry		0.00
Eremophila alpestris	Horned Lark	**0**	0	High	0	1	0	6	2	10	--	New entry		0.00
Carpodacus mexicanus	House Finch	**1**	10	High	18	23	21	24	25	10	Large increase	No change	•	0.96
Passer domesticus	House Sparrow	**3**	19	Low	25	27	27	27	26	26	Small increase	Small increase	-	1.44
Troglodytes aedon	House Wren	**0**	6	High	21	27	27	24	26	9	Large increase	Small increase	+	0.87
Passerina cyanea	Indigo Bunting	**2**	15	High	19	20	20	23	22	25	Small increase	Small increase	+	1.02
Oporornis formosus	Kentucky Warbler	**0**	0	Medium	0	0	0	6	1	14	--	New entry		0.00
Charadrius vociferus	Killdeer	**4**	21	Medium	20	19	19	19	17	23	No change	No change	-	0.73
Empidonax minimus	Least Flycatcher	**4**	23	Medium	20	17	18	9	18	6	Small decrease	Large decrease	-	1.67
Egretta caerulea	Little Blue Heron	**0**	0	Medium	0	0	0	0	0	8	--	New entry		0.00
Lanius ludovicianus	Loggerhead Shrike	**0**	0	High	0	0	0	0	0	14	--	New entry		0.00
Dendroica magnolia	Magnolia Warbler	**4**	18	High	11	5	6	3	5	2	Large decrease	Large decrease	•	2.00
Anas platyrhynchos	Mallard	**0**	3	Medium	6	7	7	9	9	7	No change	No change	+	0.94
Ictinia mississippiensis	Mississippi Kite	**0**	0	Medium	0	0	0	0	0	4	--	New entry		0.00
Zenaida macroura	Mourning Dove	**5**	26	Medium	28	29	29	29	29	28	No change	No change	+	3.46
Oporornis philadelphia	Mourning Warbler	**0**	5	Medium	3	2	2	0	1	1	Small decrease	Small decrease	-	0.27
Vermivora ruficapilla	Nashville Warbler	**5**	23	High	17	12	13	6	11	7	Large decrease	Large decrease	-	2.27
Colinus virginianus	Northern Bobwhite	**0**	0	High	1	3	2	16	4	27	New entry	New entry		0.00
Cardinalis cardinalis	Northern Cardinal	**0**	4	High	12	17	16	22	19	22	Small increase	Small increase	+	1.40
Mimus polyglottos	Northern Mockingbird	**1**	9	High	14	18	17	24	21	27	Large increase	Large increase	•	0.27

Scientific Name	Common Name	Baseline Habitat		Model Reliability	Future Habitat						Change Class PCM B1	Change Class Had A1FI	BBS Trend	BBS Abundance Index
					2040		2070		2100					
		Actual	Current		PCM B1	Had A1FI	PCM B1	Had A1FI	PCM B1	Had A1FI				
Parula americana	Northern Parula	**4**	17	Low	8	4	5	5	4	10	Large decrease	Small decrease	+	2.83
Seiurus noveboracensis	Northern Waterthrush	**3**	15	Medium	10	8	8	4	6	4	Large decrease	Large decrease	-	1.02
Icterus spurius	Orchard Oriole	**0**	0	High	0	1	0	11	2	22	--	New entry		0.00
Seiurus aurocapillus	Ovenbird	**5**	29	High	28	27	28	24	27	16	No change	Small decrease	•	3.98
Passerina ciris	Painted Bunting	**0**	0	High	0	0	0	0	0	4	--	New entry		0.00
Dryocopuc pileatus	Pileated Woodpecker	**2**	11	Medium	7	6	6	6	5	13	Small decrease	Small increase	+	1.06
Dendroica pinus	Pine Warbler	**0**	7	High	10	10	11	7	9	9	Small increase	Small increase	+	1.35
Dendroica discolor	Prairie Warbler	**0**	2	Medium	4	7	6	12	9	9	New entry	New entry	+	0.12
Protonotaria citrea	Prothonotary Warbler	**0**	0	Medium	0	0	0	7	1	12	--	New entry		0.00
Carpodacus purpureus	Purple Finch	**4**	24	High	22	19	20	9	17	8	Small decrease	Large decrease	•	2.02
Progne subis	Purple Martin	**0**	2	Medium	2	3	2	10	3	21	No change	Large increase	-	0.00
Melanerpes carolinus	Red-bellied Woodpecker	**0**	0	High	1	5	3	18	6	26	New entry	New entry		0.00
Sitta canadensis	Red-breasted Nuthatch	**2**	15	High	14	12	13	7	10	5	Small decrease	Large decrease	+	1.77
Vireo olivaceus	Red-eyed Vireo	**5**	29	High	29	28	29	26	28	23	No change	Small decrease	+	4.12
Melanerpes erythrocephalus	Red-headed Woodpecker	**0**	0	High	0	1	0	5	1	13	--	New entry		0.00
Buteo lineatus	Red-shouldered Hawk	**0**	1	Medium	1	0	0	2	1	8	--	New entry		0.00
Buteo jamaicensis	Red-tailed Hawk	**0**	0	Low	2	4	2	7	4	7	New entry	New entry		0.00
Phasianus colchicus	Ring-necked Pheasant	**0**	1	High	3	6	4	9	7	2	Small increase	No change	+	0.13
Columba livia	Rock Dove	**3**	16	Low	18	18	18	18	18	18	No change	No change	-	1.85
Pheucticus ludovicianus	Rose-breasted Grosbeak	**4**	24	High	26	26	26	16	25	3	No change	Large decrease		1.65
Archilochus colubris	Ruby-throated Hummingbird	**1**	4	Low	4	4	4	6	4	12	No change	No change	+	1.00
Bonasa umbellus	Ruffed Grouse	**0**	4	Low	2	2	2	1	2	0	Small decrease	Large decrease	+	0.19

Scientific Name	Common Name	Baseline Habitat		Model Reliability	Future Habitat						Change Class PCM B1	Change Class Had A1FI	BBS Trend	BBS Abundance Index
					2040		2070		2100					
		Actual	Current		PCM B1	Had A1FI	PCM B1	Had A1FI	PCM B1	Had A1FI				
Passerculus sandwichensis	Savannah Sparrow	**5**	20	High	16	14	14	4	11	1	Small decrease	Large decrease	•	1.96
Tyrannus forficatus	Scissor-tailed Flycatcher	**0**	0	Low	0	0	0	0	0	4	--	New entry		0.00
Melospiza melodia	Song Sparrow	**5**	29	High	29	29	29	28	29	14	No change	Large decrease	•	3.54
Actitis macularia	Spotted Sandpiper	**1**	4	Low	3	3	3	2	2	0	Small decrease	Large decrease	•	0.04
Piranga rubra	Summer Tanager	**0**	0	High	0	0	0	4	0	17	--	New entry		0.00
Catharus ustulatus	Swainson's Thrush	**1**	6	Medium	2	0	0	0	0	0	Extirpated	Extirpated	•	0.85
Melospiza georgiana	Swamp Sparrow	**2**	13	Medium	13	13	13	7	13	1	No change	Large decrease	+	1.08
Tachycineta bicolor	Tree Swallow	**5**	28	High	28	26	28	13	25	6	No change	Large decrease	-	2.75
Baeolophus bicolor	Tufted Titmouse	**0**	2	High	6	12	10	26	19	26	New entry	New entry	+	1.35
Cathartes aura	Turkey Vulture	**0**	2	Medium	2	3	2	8	4	10	No change	Small increase	+	0.79
Catharus fuscescens	Veery	**5**	27	High	27	24	26	20	24	8	No change	Large decrease	-	2.62
Pooecetes gramineus	Vesper Sparrow	**1**	6	Medium	5	5	4	5	4	1	Small decrease	Large decrease	-	1.10
Vireo gilvus	Warbling Vireo	**3**	16	Medium	18	19	18	15	19	13	No change	No change	+	1.13
Caprimulgus vociferus	Whip-poor-will	**1**	5	Low	4	3	4	5	3	12	No change	No change	-	0.31
Sitta carolinensis	White-breasted Nuthatch	**1**	11	Medium	18	21	20	20	22	15	Small increase	Small increase	+	1.48
Vireo griseus	White-eyed Vireo	**0**	0	High	0	0	0	9	2	19	--	New entry		0.00
Zonotrichia albicollis	White-throated Sparrow	**5**	28	High	25	21	23	12	18	12	Small decrease	Large decrease	-	3.13
Empidonax traillii	Willow Flycatcher	**1**	4	Low	4	5	5	8	7	2	No change	Small decrease	+	0.48
Troglodytes troglodytes	Winter Wren	**4**	18	High	11	6	7	4	6	4	Large decrease	Large decrease	•	2.02
Hylocichla mustelina	Wood Thrush	**5**	28	High	28	28	28	27	28	23	No change	No change	-	1.29
Helmitheros vermivorus	Worm-eating Warbler	**0**	0	Low	0	0	0	4	1	4	--	New entry		0.00
Dendroica petechia	Yellow Warbler	**5**	27	High	28	28	28	24	28	9	No change	Large decrease	-	2.33
Sphyrapicus varius	Yellow-bellied Sapsucker	**3**	18	High	13	9	10	5	8	5	Large decrease	Large decrease	•	2.12

Scientific Name	Common Name	Baseline Habitat		Model Reliability	Future Habitat						Change Class PCM B1	Change Class Had A1FI	BBS Trend	BBS Abundance Index
					2040		2070		2100					
		Actual	Current		PCM B1	Had A1FI	PCM B1	Had A1FI	PCM B1	Had A1FI				
Coccyzus americanus	Yellow-billed Cuckoo	**0**	0	High	3	4	3	16	6	27	New entry	New entry	-	0.00
Icteria virens	Yellow-breasted Chat	**0**	0	High	0	0	0	9	2	23	--	New entry		0.00
Nyctanassa violacea	Yellow-crowned Night-Heron	**0**	0	Low	0	0	0	0	0	5	--	New entry		0.00
Dendroica coronata	Yellow-rumped Warbler	**4**	19	High	18	16	17	9	12	6	Small decrease	Large decrease		2.19
Vireo flavifrons	Yellow-throated Vireo	**0**	1	Low	5	9	7	14	12	14	New entry	New entry	+	0.00
Dendroica dominica	Yellow-throated Warbler	**0**	0	Low	0	0	0	3	1	6	--	New entry		0.00

Appendix 3. Habitat preference and migratory status for modeled bird species of the Acadia region. Classifications based on data from Peterjohn and Sauer (1993) and Matthews et al. (2011).

Common Name	Scientific Name	Habitat preference	Migratory status
Acadian Flycatcher	*Empidonax virescens*	Forest	Neotropical
American Bittern	*Botaurus lentiginosus*	Wetland	
American Crow	*Corvus brachyrhynchos*	Unclassified	Short distance
American Goldfinch	*Carduelis tristis*	Shrubland	Short distance
American Kestrel	*Falco sparverius*	Unclassified	Short distance
American Redstart	*Setophaga ruticilla*	Forest	Neotropical
American Robin	*Turdus migratorius*	Unclassified	Short distance
Baltimore Oriole	*Icterus galbula*	Unclassified	Neotropical
Bank Swallow	*Riparia riparia*	Unclassified	Neotropical
Barn Swallow	*Hirundo rustica*	Unclassified	Neotropical
Black Vulture	*Coragyps atratus*	Unclassified	Resident
Black-and-white Warbler	*Mniotilta varia*	Forest	Neotropical
Black-billed Cuckoo	*Coccyzus erythropthalmus*	Forest	Neotropical
Blackburnian Warbler	*Dendroica fusca*	Forest	Neotropical
Black-capped Chickadee	*Poecile atricapillus*	Forest	Resident
Black-throated Blue Warbler	*Dendroica caerulescens*	Forest	Neotropical
Black-throated Green Warbler	*Dendroica virens*	Forest	Neotropical
Blue Grosbeak	*Guiraca caerulea*	Shrubland	Neotropical
Blue Jay	*Cyanocitta cristata*	Unclassified	Short distance
Blue-gray Gnatcatcher	*Polioptila caerulea*	Forest	Neotropical
Blue-headed Vireo	*Vireo solitarius*	Forest	Neotropical
Blue-winged Warbler	*Vermivora pinus*	Shrubland	Neotropical
Bobolink	*Dolichonyx oryzivorus*	Grassland	Neotropical
Broad-winged Hawk	*Buteo platypterus*	Forest	Neotropical
Brown Creeper	*Certhia americana*	Forest	Short distance
Brown Thrasher	*Toxostoma rufum*	Shrubland	Short distance
Brown-headed Cowbird	*Molothrus ater*	Unclassified	Short distance
Canada Goose	*Branta canadensis*	Wetland	
Canada Warbler	*Wilsonia canadensis*	Forest	Neotropical
Carolina Wren	*Thryothorus ludovicianus*	Shrubland	Resident
Cattle Egret	*Bubulcus ibis*	Wetland	
Cedar Waxwing	*Bombycilla cedrorum*	Unclassified	Short distance
Chimney Swift	*Chaetura pelagica*	Unclassified	Neotropical
Chipping Sparrow	*Spizella passerina*	Unclassified	Neotropical
Chuck-Will's Widow	*Caprimulgus carolinenis*	Forest	Neotropical
Cliff Swallow	*Petrochelidon pyrrhonota*	Unclassified	Neotropical
Common Loon	*Gavia immer*	Wetland	
Common Nighthawk	*Chordeiles minor*	Unclassified	Neotropical
Common Snipe	*Gallinago gallinago*	Wetland	
Common Yellowthroat	*Geothlypis trichas*	Shrubland	Neotropical
Dark-eyed Junco	*Junco hyemalis*	Forest	Short distance
Dickcissel	*Spiza americana*	Grassland	Neotropical
Downy woodpecker	*Picoides pubescens*	Forest	Resident
Eastern Kingbird	*Tyrannus tyrannus*	Unclassified	Neotropical
Eastern Meadowlark	*Sturnella magna*	Grassland	Short distance

Common Name	Scientific Name	Habitat preference	Migratory status
Eastern Phoebe	*Sayornis phoebe*	Unclassified	Short distance
Eastern Towhee	*Pipilo erythrophthalmus*	Shrubland	Short distance
Eastern Wood-Pewee	*Contopus virens*	Forest	Neotropical
European Starling	*Sturnus vulgaris*	Unclassified	Short distance
Evening Grosbeak	*Coccothraustes vespertinus*	Forest	Short distance
Field Sparrow	*Spizella pusilla*	Shrubland	Short distance
Fish Crow	*Corvus ossifragus*	Unclassified	Short distance
Grasshopper Sparrow	*Ammodramus savannarum*	Grassland	Neotropical
Gray Catbird	*Dumetella carolinensis*	Shrubland	Neotropical
Great Blue Heron	*Ardea herodias*	Wetland	
Great Egret	*Ardea alba*	Wetland	
Great Horned Owl	*Bubo virginianus*	Unclassified	Resident
Green Heron	*Butorides virescens*	Wetland	
Hermit Thrush	*Catharus guttatus*	Forest	Short distance
Hooded Warbler	*Wilsonia citrina*	Forest	Neotropical
Horned Lark	*Eremophila alpestris*	Grassland	Short distance
House Finch	*Carpodacus mexicanus*	Unclassified	Short distance
House Sparrow	*Passer domesticus*	Unclassified	Resident
House Wren	*Troglodytes aedon*	Shrubland	Neotropical
Indigo Bunting	*Passerina cyanea*	Shrubland	Neotropical
Kentucky Warbler	*Oporornis formosus*	Forest	Neotropical
Killdeer	*Charadrius vociferus*	Unclassified	Short distance
Least Flycatcher	*Empidonax minimus*	Forest	Neotropical
Little Blue Heron	*Egretta caerulea*	Wetland	
Loggerhead Shrike	*Lanius ludovicianus*	Unclassified	Short distance
Magnolia Warbler	*Dendroica magnolia*	Forest	Neotropical
Mallard	*Anas platyrhynchos*	Wetland	
Mississippi Kite	*Ictinia mississippiensis*	Unclassified	Neotropical
Mourning Dove	*Zenaida macroura*	Unclassified	Short distance
Mourning Warbler	*Oporornis philadelphia*	Shrubland	Neotropical
Nashville Warbler	*Vermivora ruficapilla*	Shrubland	Neotropical
Northern Bobwhite	*Colinus virginianus*	Shrubland	Resident
Northern Cardinal	*Cardinalis cardinalis*	Shrubland	Resident
Northern Mockingbird	*Mimus polyglottos*	Unclassified	Resident
Northern Parula	*Parula americana*	Forest	Neotropical
Northern Waterthrush	*Seiurus noveboracensis*	Forest	Neotropical
Orchard Oriole	*Icterus spurius*	Unclassified	Neotropical
Ovenbird	*Seiurus aurocapillus*	Forest	Neotropical
Painted Bunting	*Passerina ciris*	Shrubland	Neotropical
Pileated Woodpecker	*Dryocopuc pileatus*	Forest	Resident
Pine Warbler	*Dendroica pinus*	Forest	Short distance
Prairie Warbler	*Dendroica discolor*	Shrubland	Neotropical
Prothonotary Warbler	*Protonotaria citrea*	Shrubland	Neotropical
Purple Finch	*Carpodacus purpureus*	Shrubland	Short distance
Purple Martin	*Progne subis*	Unclassified	Neotropical
Red-bellied Woodpecker	*Melanerpes carolinus*	Forest	Resident
Red-breasted Nuthatch	*Sitta canadensis*	Forest	Short distance
Red-eyed Vireo	*Vireo olivaceus*	Forest	Neotropical
Red-headed Woodpecker	*Melanerpes erythrocephalus*	Unclassified	Short distance
Red-shouldered Hawk	*Buteo lineatus*	Forest	Short distance

Common Name	Scientific Name	Habitat preference	Migratory status
Red-tailed Hawk	*Buteo jamaicensis*	Unclassified	Short distance
Ring-necked Pheasant	*Phasianus colchicus*	Grassland	Resident
Rock Dove	*Columba livia*	Unclassified	Resident
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	Forest	Neotropical
Ruby-throated Hummingbird	*Archilochus colubris*	Forest	Neotropical
Ruffed Grouse	*Bonasa umbellus*	Forest	Resident
Savannah Sparrow	*Passerculus sandwichensis*	Grassland	Short distance
Scissor-tailed Flycatcher	*Tyrannus forficatus*	Unclassified	Neotropical
Song Sparrow	*Melospiza melodia*	Shrubland	Short distance
Spotted Sandpiper	*Actitis macularia*	Wetland	
Summer Tanager	*Piranga rubra*	Forest	Neotropical
Swainson's Thrush	*Catharus ustulatus*	Forest	Neotropical
Swamp Sparrow	*Melospiza georgiana*	wetland	Short distance
Tree Swallow	*Tachycineta bicolor*	Unclassified	Short distance
Tufted Titmouse	*Baeolophus bicolor*	Forest	Resident
Turkey Vulture	*Cathartes aura*	Unclassified	Short distance
Veery	*Catharus fuscescens*	Forest	Neotropical
Vesper Sparrow	*Pooecetes gramineus*	Grassland	Short distance
Warbling Vireo	*Vireo gilvus*	Forest	Neotropical
Whip-poor-will	*Caprimulgus vociferus*	Forest	Neotropical
White-breasted Nuthatch	*Sitta carolinensis*	Forest	Resident
White-eyed Vireo	*Vireo griseus*	Shrubland	Neotropical
White-throated Sparrow	*Zonotrichia albicollis*	Shrubland	Short distance
Willow Flycatcher	*Empidonax traillii*	Shrubland	Neotropical
Winter Wren	*Troglodytes troglodytes*	Forest	Short distance
Wood Thrush	*Hylocichla mustelina*	Forest	Neotropical
Worm-eating Warbler	*Helmitheros vermivorus*	Forest	Neotropical
Yellow Warbler	*Dendroica petechia*	Shrubland	Neotropical
Yellow-bellied Sapsucker	*Sphyrapicus varius*	Forest	Short distance
Yellow-billed Cuckoo	*Coccyzus americanus*	Forest	Neotropical
Yellow-breasted Chat	*Icteria virens*	Shrubland	Neotropical
Yellow-crowned Night-Heron	*Nyctanassa violacea*	Wetland	
Yellow-rumped Warbler	*Dendroica coronata*	Forest	Short distance
Yellow-throated Vireo	*Vireo flavifrons*	Forest	Neotropical
Yellow-throated Warbler	*Dendroica dominica*	Forest	Neotropical

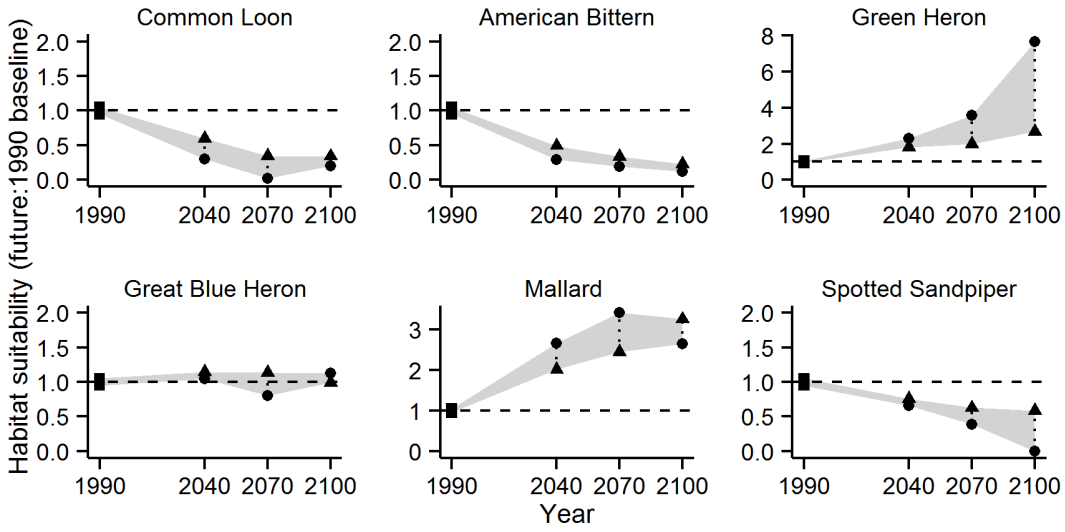
Appendix 4. Change class rules for common (IV > 5) and rare (IV ≤ 5) species. 'IV' is the incidence value (see Methods)

Future:Baseline modeled IV	Change Class
Common species	
<0.05	extirpated
0.05 to <0.5	large decrease
0.5 to 0.8	small decrease
>0.8 to <1.2	no change
1.2 to 2.0	small increase
>2	large increase
Rare species	
<0.2	large decrease
0.2 to <0.6	small decrease
0.6 to <4	no change
4 to 8	small increase
>8	large increase

Because the BBS data are rather sparse compared to the Forest Inventory and Analysis (FIA) data used to model tree species (fewer than 1200 BBS routes vs. ~100,000 FIA plots in the eastern US), modifications were made to the rules defining species' change classes. Modifications included: (1) if BBS Actual IV equals 0 and the Baseline mean IV for the region is ≤ 3, the habitat is considered at most marginally suitable for the species and the rules for new migrant species are applied; and (2) the threshold for classifying a species as a new migrant is 3, in that if both PCM low and Hadley high have a summed future:baseline ratio ≥ 3 the species is classed as a new migrant under both climate scenarios. If the ratio is only ≥ 3 under the Hadley high (or PCM low) scenario, then the species is new under high (or low). Otherwise, when the summed ratio is ≤ 3 for both scenarios, the habitat is considered not suitable for the species and removed from the analysis.

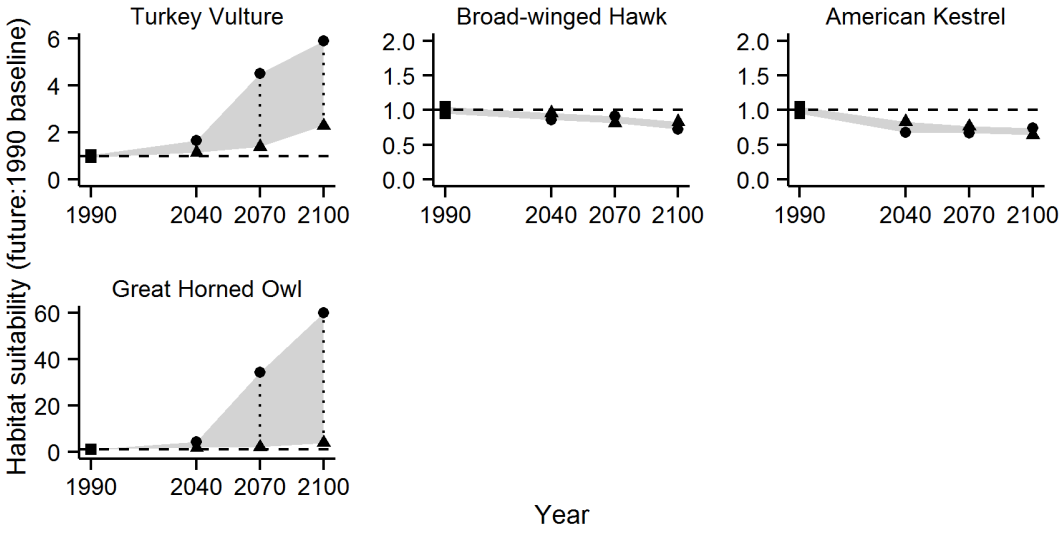
Appendix 5. Projected changes in potential habitat suitability for water, wading, and shore birds with sufficient occurrence data during the late 20th century baseline period (1961-1990) in the Acadia region to permit modeling

Future projections (30 year periods ending in 2040, 2070, 2100) are based on 'least change' (black triangles) and 'major change' (black circles) climate scenarios and are shown as a ratio of future to late 20th century habitat suitability (e.g., y-axis value of 2.0 = doubling of suitable habitat; 0.5 = 50% reduction in habitat).



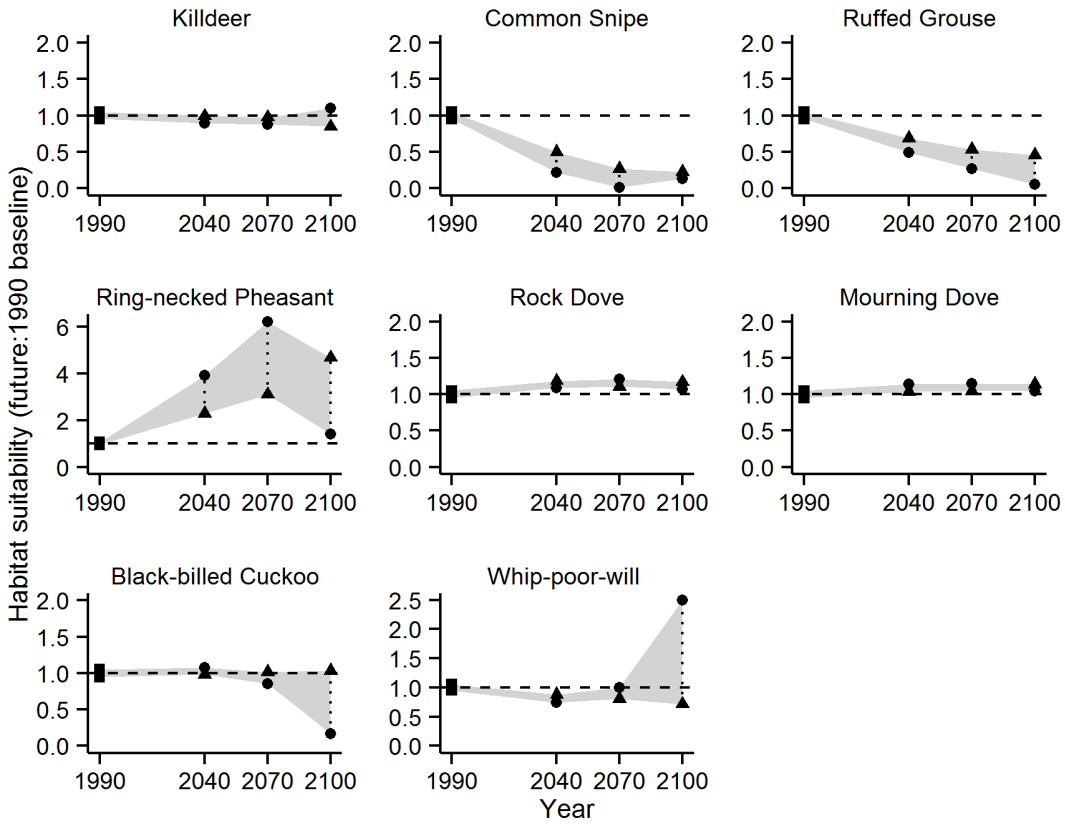
Appendix 6. Projected changes in potential habitat suitability for vulture, bird of prey and owl species with sufficient occurrence data during the late 20th century baseline period (1961-1990) in the Acadia region to permit modeling

Future projections (30 year periods ending in 2040, 2070, 2100) are based on 'least change' (black triangles) and 'major change' (black circles) climate scenarios and are shown as a ratio of future to late 20th century habitat suitability (e.g., y-axis value of 2.0 = doubling of suitable habitat; 0.5 = 50% reduction in habitat).



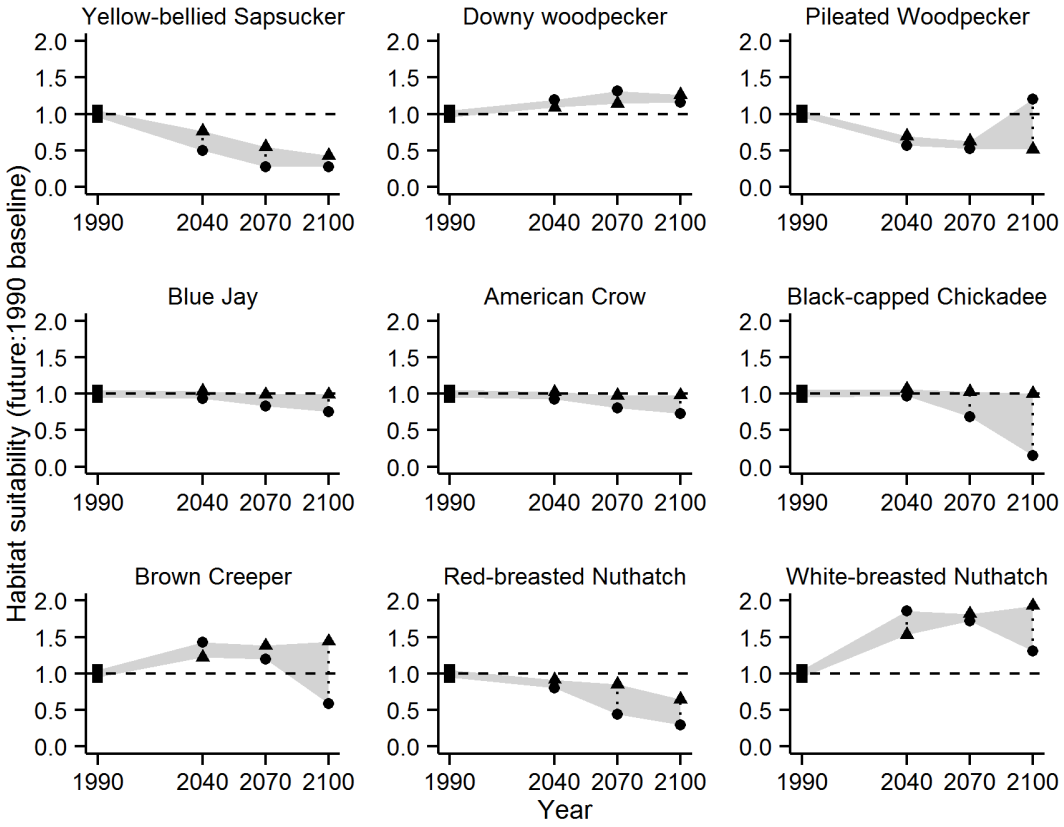
Appendix 7. Projected changes in potential habitat suitability for killdeer, grouse, pheasant, dove, and similar species with sufficient occurrence data during the late 20th century baseline period (1961-1990) in the Acadia region to permit modeling

Future projections (30 year periods ending in 2040, 2070, 2100) are based on 'least change' (black triangles) and 'major change' (black circles) climate scenarios and are shown as a ratio of future to late 20th century habitat suitability (e.g., y-axis value of 2.0 = doubling of suitable habitat; 0.5 = 50% reduction in habitat).



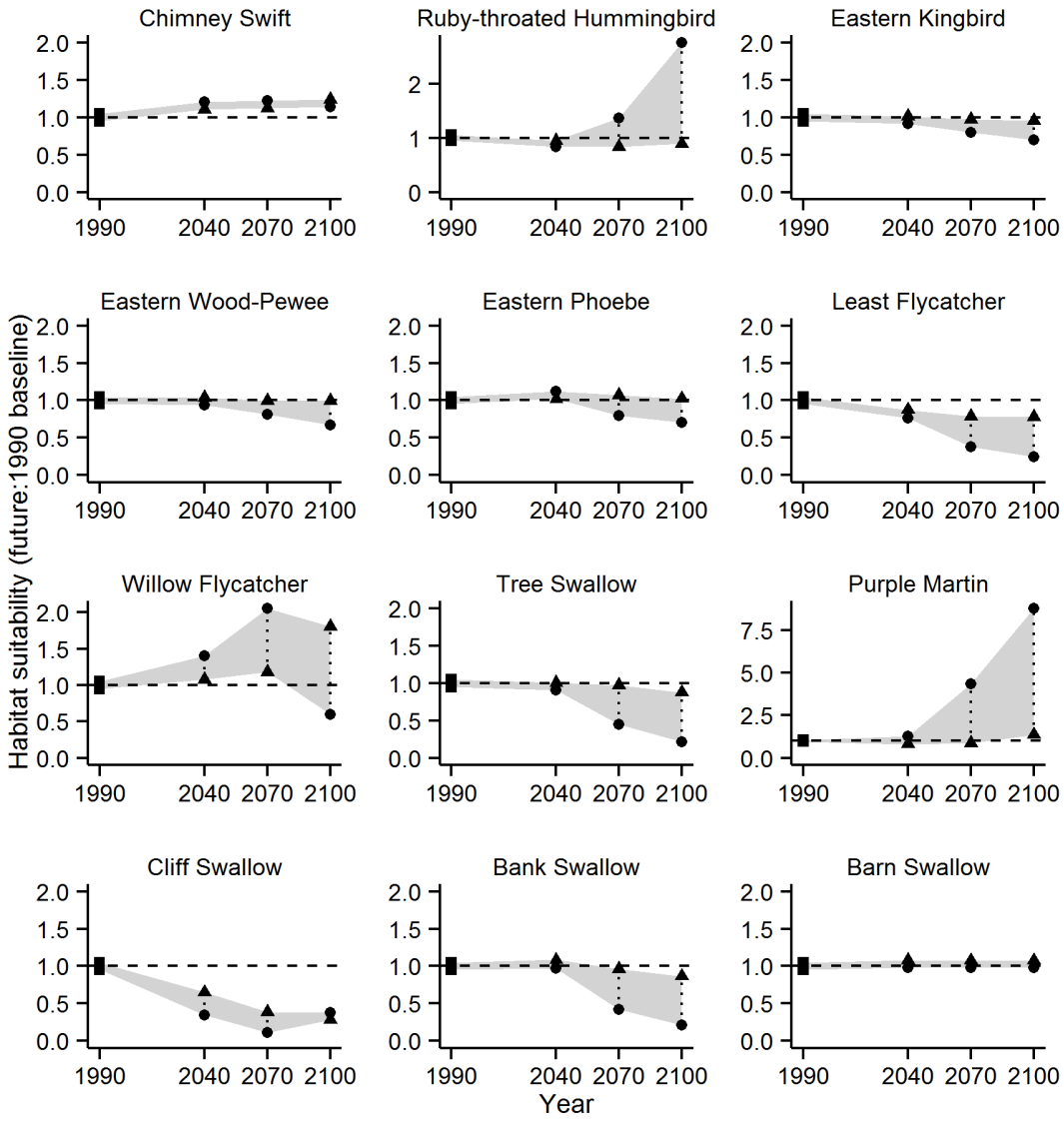
Appendix 8. Projected changes in potential habitat suitability for woodpecker, jay, crow, chickadee, and nuthatch species with sufficient occurrence data during the late 20th century baseline period (1961-1990) in the Acadia region to permit modeling

Future projections (30 year periods ending in 2040, 2070, 2100) are based on 'least change' (black triangles) and 'major change' (black circles) climate scenarios and are shown as a ratio of future to late 20th century habitat suitability (e.g., y-axis value of 2.0 = doubling of suitable habitat; 0.5 = 50% reduction in habitat).



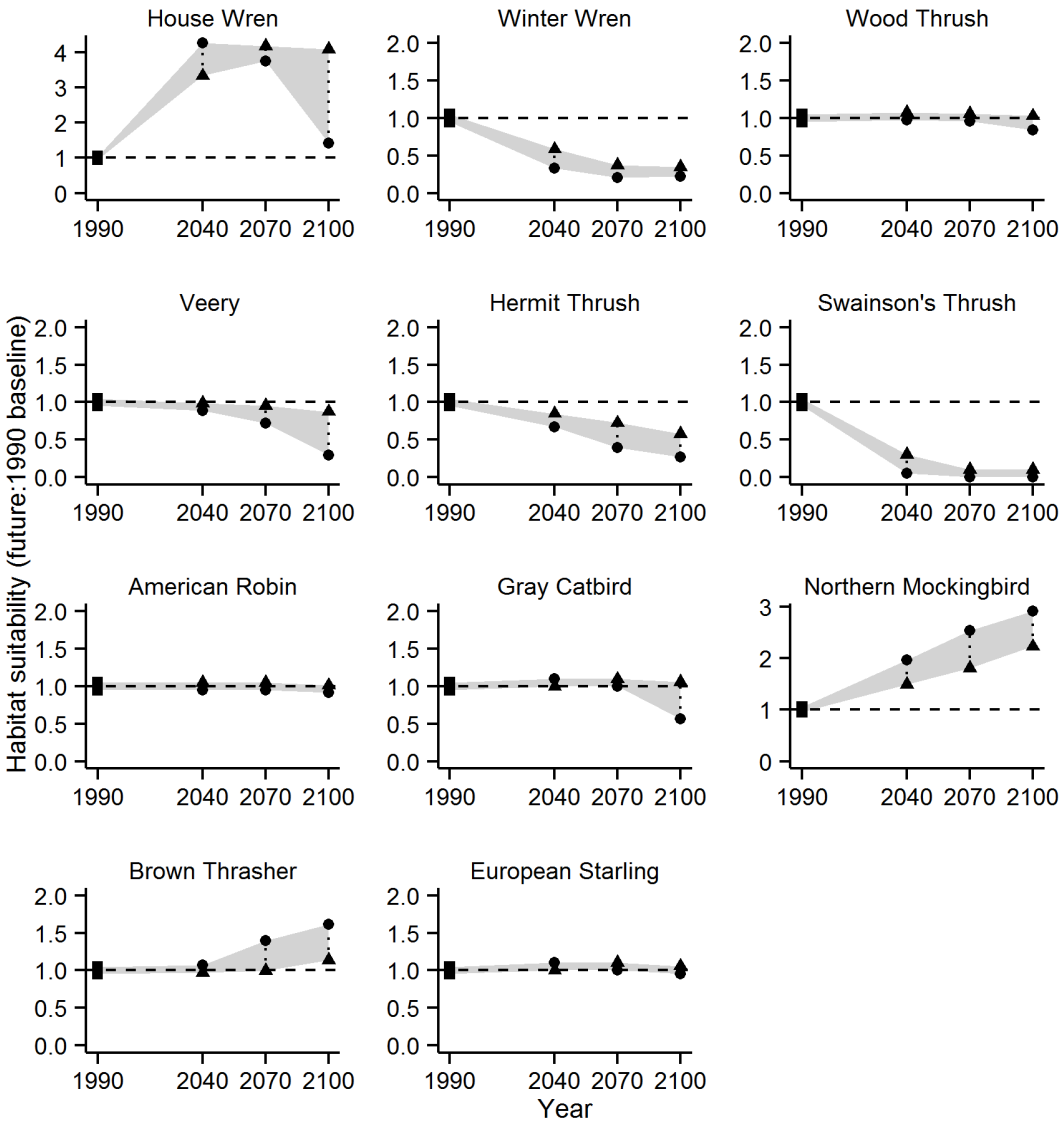
Appendix 9. Projected changes in potential habitat suitability for swift, hummingbird, flycatcher, swallow and similar species with sufficient occurrence data during the late 20th century baseline period (1961-1990) in the Acadia region to permit modeling

Future projections (30 year periods ending in 2040, 2070, 2100) are based on 'least change' (black triangles) and 'major change' (black circles) climate scenarios and are shown as a ratio of future to late 20th century habitat suitability (e.g., y-axis value of 2.0 = doubling of suitable habitat; 0.5 = 50% reduction in habitat).



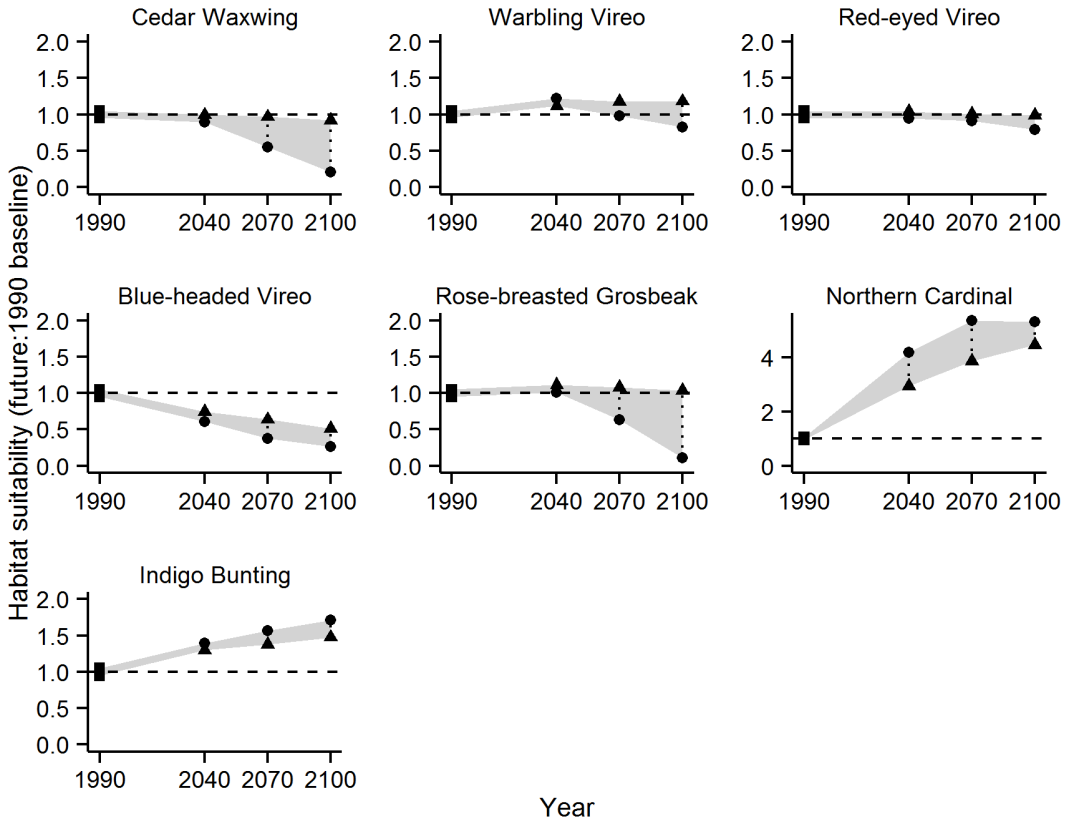
Appendix 10. Projected changes in potential habitat suitability for wren, thrush, and similar species with sufficient occurrence data during the late 20th century baseline period (1961-1990) in the Acadia region to permit modeling

Future projections (30 year periods ending in 2040, 2070, 2100) are based on 'least change' (black triangles) and 'major change' (black circles) climate scenarios and are shown as a ratio of future to late 20th century habitat suitability (e.g., y-axis value of 2.0 = doubling of suitable habitat; 0.5 = 50% reduction in habitat).



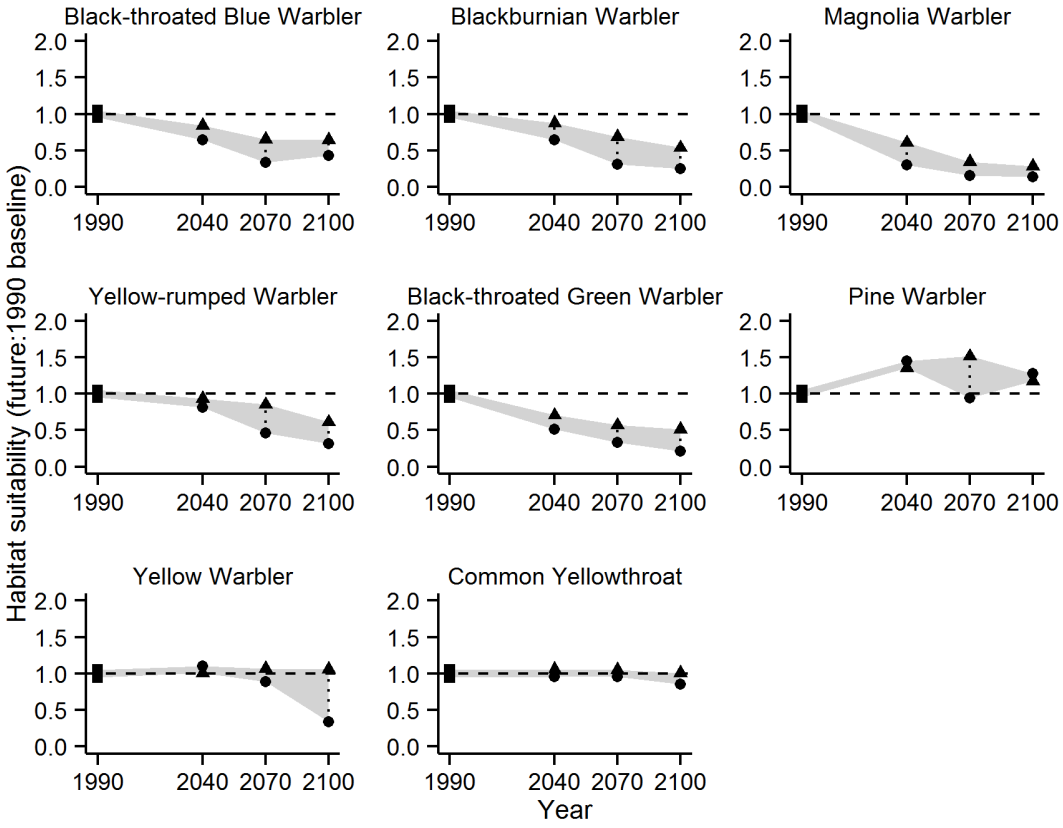
Appendix 11. Projected changes in potential habitat suitability for waxwing, vireo, cardinal, and similar species with sufficient occurrence data during the late 20th century baseline period (1961-1990) in the Acadia region to permit modeling

Future projections (30 year periods ending in 2040, 2070, 2100) are based on 'least change' (black triangles) and 'major change' (black circles) climate scenarios and are shown as a ratio of future to late 20th century habitat suitability (e.g., y-axis value of 2.0 = doubling of suitable habitat; 0.5 = 50% reduction in habitat).



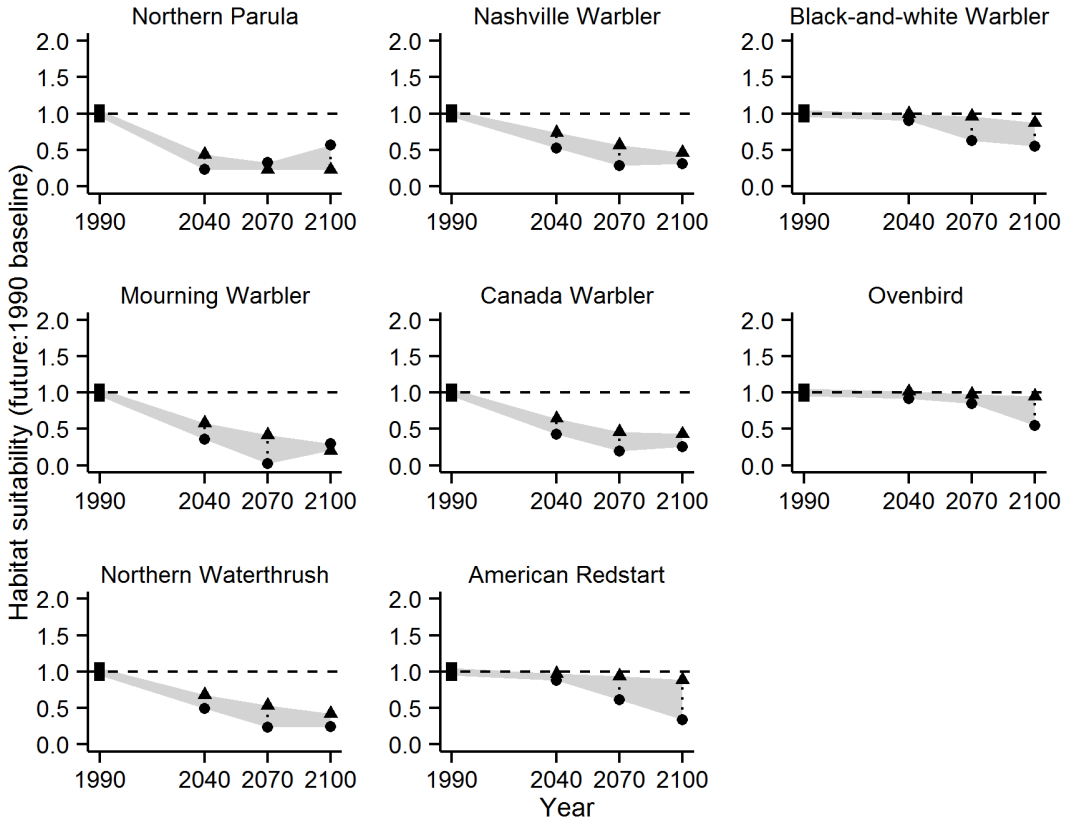
Appendix 12a. Projected changes in potential habitat suitability for warbler species with sufficient occurrence data during the late 20th century baseline period (1961-1990) in the Acadia region to permit modeling

Future projections (30 year periods ending in 2040, 2070, 2100) are based on 'least change' (black triangles) and 'major change' (black circles) climate scenarios and are shown as a ratio of future to late 20th century habitat suitability (e.g., y-axis value of 2.0 = doubling of suitable habitat; 0.5 = 50% reduction in habitat).



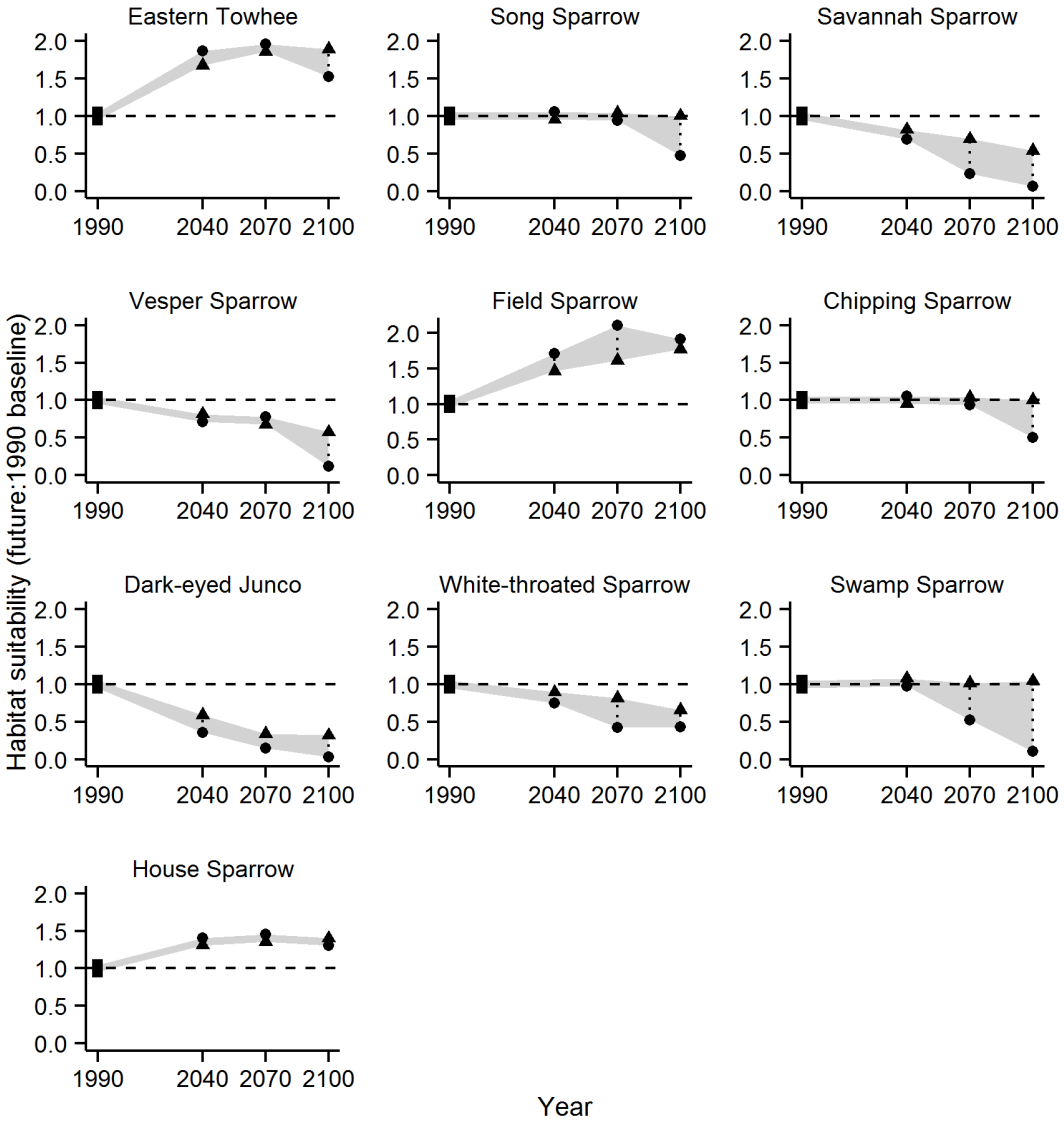
Appendix 12b. Projected changes in potential habitat suitability for warbler species with sufficient occurrence data during the late 20th century baseline period (1961-1990) in the Acadia region to permit modeling

Future projections (30 year periods ending in 2040, 2070, 2100) are based on 'least change' (black triangles) and 'major change' (black circles) climate scenarios and are shown as a ratio of future to late 20th century habitat suitability (e.g., y-axis value of 2.0 = doubling of suitable habitat; 0.5 = 50% reduction in habitat).



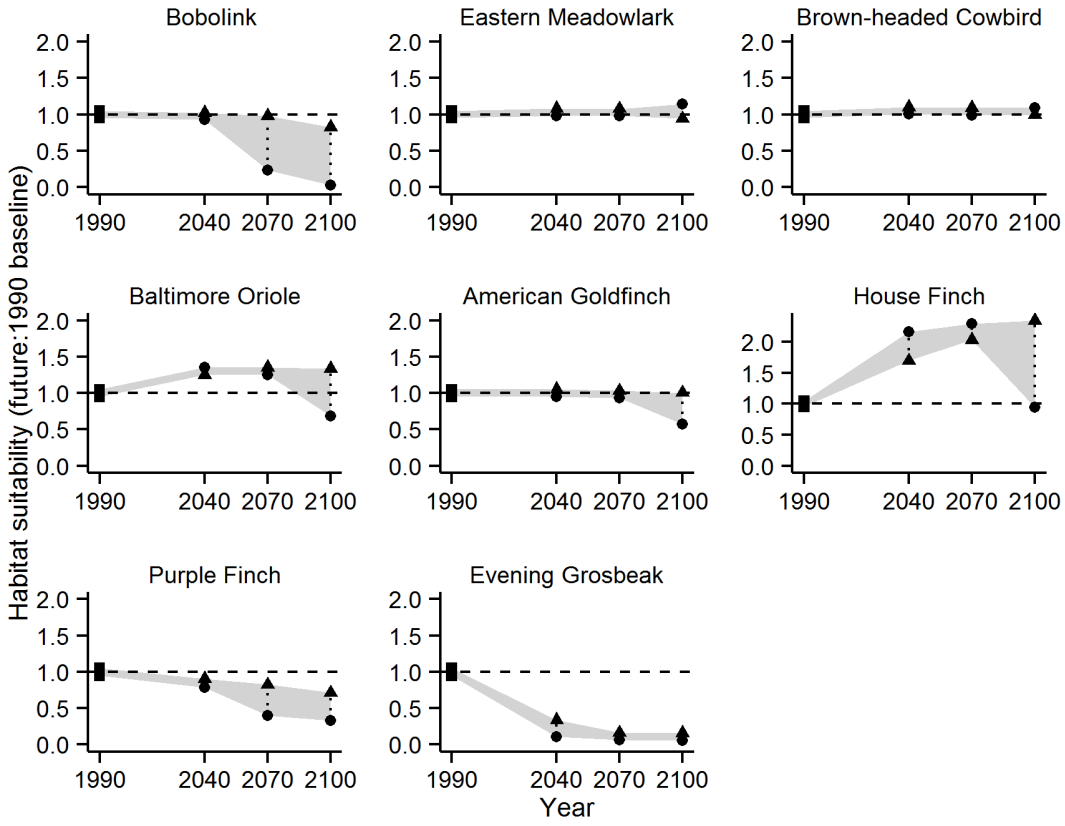
Appendix 13. Projected changes in potential habitat suitability for sparrow and similar species with sufficient occurrence data during the late 20th century baseline period (1961-1990) in the Acadia region to permit modeling

Future projections (30 year periods ending in 2040, 2070, 2100) are based on 'least change' (black triangles) and 'major change' (black circles) climate scenarios and are shown as a ratio of future to late 20th century habitat suitability (e.g., y-axis value of 2.0 = doubling of suitable habitat; 0.5 = 50% reduction in habitat)



Appendix 14. Projected changes in potential habitat suitability for bobolink, meadowlark, blackbird, oriole, finch, and similar species with sufficient occurrence data during the late 20th century baseline period (1961-1990) in the Acadia region to permit modeling

Future projections (30 year periods ending in 2040, 2070, 2100) are based on 'least change' (black triangles) and 'major change' (black circles) climate scenarios and are shown as a ratio of future to late 20th century habitat suitability (e.g., y-axis value of 2.0 = doubling of suitable habitat; 0.5 = 50% reduction in habitat).



Appendix 15a-c. Potential changes in habitat suitability for Neotropical migrant bird species (n=63) in the Acadia National Park region for the end of the 21st century.

Species are grouped into three columns: potential losers (15a.), potential persisters (15b.), and potential winners (15c.). See Appendix 2 for scientific names and Appendix 4 for change class definitions.

Appendix 15a.

Potential 'losers'

Decreases under Both Scenarios

Common Name	Least Change	Major Change
Blackburnian Warbler	Small decrease	Large decrease
Black-throated Blue Warbler	Small decrease	Large decrease
Black-throated Green Warbler	Small decrease	Large decrease
Blue-headed Vireo	Small decrease	Large decrease
Canada Warbler	Large decrease	Large decrease
Cliff Swallow	Large decrease	Large decrease
Least Flycatcher	Small decrease	Large decrease
Magnolia Warbler	Large decrease	Large decrease
Mourning Warbler	Small decrease	Small decrease
Nashville Warbler	Large decrease	Large decrease
Northern Parula	Large decrease	Small decrease
Northern Waterthrush	Large decrease	Large decrease
Swainson's Thrush	Extirpated	Extirpated

No Change to Decreases

Common Name	Least Change	Major Change
American Redstart	No change	Large decrease
Bank Swallow	No change	Large decrease
Black-and-white Warbler	No change	Small decrease
Black-billed Cuckoo	No change	Large decrease
Bobolink	No change	Extirpated
Broad-winged Hawk	No change	Small decrease
Chipping Sparrow	No change	Large decrease
Eastern Kingbird	No change	Small decrease
Eastern Wood-Pewee	No change	Small decrease

Appendix 15b.

Potential 'persisters'

No Change under Both Scenarios

Common Name	Least Change	Major Change
Barn Swallow	No change	No change
Common Yellowthroat	No change	No change
Ruby-throated Hummingbird	No change	No change
Warbling Vireo	No change	No change
Whip-poor-will	No change	No change
Wood Thrush	No change	No change

Mixed Results

Common Name	Least Change	Major Change
Baltimore Oriole	Small increase	Small decrease

Appendix 15c.

Potential 'winners'

No Change to Increases

Common Name	Least Change	Major Change
Chimney Swift	Small increase	No change
Purple Martin	No change	Large increase

Increases under Both Scenarios

Common Name	Least Change	Major Change
House Wren	Large increase	Small increase
Indigo Bunting	Small increase	Small increase

New Suitable Habitat

Common Name	Least Change	Major Change
Acadian Flycatcher	--	New entry
Blue Grosbeak	--	New entry
Blue-gray Gnatcatcher	New entry	New entry
Blue-winged Warbler	New entry	New entry
Chuck-Will's Widow	--	New entry
Common Nighthawk	--	New entry
Dickcissel	--	New entry
Grasshopper Sparrow	--	New entry
Hooded Warbler	--	New entry
Kentucky Warbler	--	New entry
Mississippi Kite	--	New entry
Orchard Oriole	--	New entry
Painted Bunting	--	New entry
Prairie Warbler	New entry	New entry
Prothonotary Warbler	--	New entry
Scissor-tailed Flycatcher	--	New entry
Summer Tanager	--	New entry
White-eyed Vireo	--	New entry
Worm-eating Warbler	--	New entry

Appendix 15. continued

Appendix 15a. continued

Potential 'losers'		
No Change to Decreases		
Common Name	**Least Change**	**Major Change**
Gray Catbird	No change	Small decrease
Ovenbird	No change	Small decrease
Red-eyed Vireo	No change	Small decrease
Rose-breasted Grosbeak	No change	Large decrease
Veery	No change	Large decrease
Willow Flycatcher	No change	Small decrease
Yellow Warbler	No change	Large decrease

Appendix 15c. continued

Potential 'winners'		
vv		
Common Name	**Least Change**	**Major Change**
Yellow-billed Cuckoo	New entry	New entry
Yellow-breasted Chat	--	New entry
Yellow-throated Vireo	New entry	New entry
Yellow-throated Warbler	--	New entry

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Natural Resource Stewardship and Science
1201 Oak Ridge Drive, Suite 150
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