Acadia National Park Winter Birds: 51 Years of Change Along the Coast of Maine

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Abstract - There is a long history of recording bird observation in Acadia National Park, ME. These studies and resulting long-term data sets provide evidence of changes happening within and around the park, as well as an opportunity to compare local dynamics with trends detected in regional to continental-scale studies. Over 51 years (1971–2021), community volunteers in and around Acadia National Park engaged in annual Christmas bird counts (CBC), collecting valuable information to assess winter bird-population dynamics and species trends. We analyzed the cumulative data from 2 CBC circles that encompass Acadia and the surrounding lands and waters to generate a combined summary of early winter population-trend estimates for 162 species. We found a 43% reduction in the total number of birds over the 51-year study, with 42 species exhibiting declines, and 33 species showing increasing abundance. The annual number of species observed has declined by over 7%; however, the cumulative species in the full dataset continues to increase as newly observed species are added in most years. Our study complements many other studies from Acadia documenting ongoing changes in the physical environment and coastal biota. Conservation and management actions take place at the local level (e.g., Acadia National Park), and local resource data and trends are critical to synthesize and share for effective decision making.

Introduction

Nature is dynamic, and species are constantly responding to environmental and biotic shifts. Climate change and other change stressors, such as invasive species, pollution, and habitat fragmentation, have coherent fingerprints at global scales. These changes are now also readily apparent at local scales, including within protected areas such as national parks. Acadia National Park, ME, and surrounding lands and waters are experiencing ongoing and rapid change. The park is already at the extreme warm and wet edge of historical conditions, mean annual temperature has risen 1.9 °C since 1895, winter minimum temperatures are warming faster than any other season, sea level is rising 2.8 mm/yr since 1990, and the Gulf of Maine sea-surface temperature has risen 1.6 °C since 1895 (Fernandez et al. 2020, Monahan and Fisichelli 2014). Understanding how species are responding in this era of rapid change is a major focus of conservation biology. Detecting and understanding change often requires long-term data.

Recent studies have documented major continental declines in North American avifauna, though these trends vary among species, habitats, and seasons. Overall, there was a massive net loss of ~3 billion birds (29% of North America's avian

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population) between 1970 and 2017 (Rosenburg et al. 2019), and these trends varied across species. Many, including introduced species, shorebirds, landbirds, and waterbirds, are decreasing, while waterfowl are increasing. Warblers, sparrows, and blackbirds are decreasing, and ducks, geese, turkey, and grouse are increasing (Rosenburg et al. 2019). Winter bird populations in North America, based on Christmas bird count (CBC) data, are overall faring better than neotropical migrants, with two-thirds of 551 species showing increasing population trends (Soykan et al. 2016). These regional to continental assessments may differ from local trends, and thus mask critical information needed at the spatial scale of most habitat-management actions. However, local datasets are often limited in the number of years and species observed.

There is a long history of attention to birds in Acadia National Park, from Wabanaki knowledge to the Champlain Society's surveys in the 1880s, through the work of 21st-century naturalists and scientists (Schmitt 2016). These studies and long-term data sets provide evidence of changes happening within and around the park. Based on a study revisiting historical natural history forays, 1 in 6 plant species have disappeared over the past 120 years from the area that is now Acadia National Park (MacKenzie et al. 2019). Intertidal invertebrate species, including mussels, barnacles, and periwinkle, have declined in recent decades in the region (La Sorte et al. 2017, Petraitis and Dudgeon 2020). Changes in birds are less well known.

In 1933, Acadia National Park initiated the Mount Desert Island CBC, joining an annual continental CBC movement that began in North America in 1900. Frank Chapman, of Audubon, established the CBC to replace the "side hunt" traditionally held each year on Christmas Day, where armed participants wandered the countryside shooting at every bird and small animal they saw. Today, the CBC is an ongoing effort to document early winter bird assemblages and has become one of the world's longest-running citizen science projects, engaging volunteers to count most every bird within a designated area (LeBaron 1999). To encompass more of the Acadia region, the Schoodic Point CBC was formed in 1956. The combined counts provide a way to assess changes in abundance of the park's winter bird populations. Here, we present 51 years of consistent CBC observations in and around Acadia National Park, ME, to assess the assemblage of bird species and whether populations are declining, increasing, or have remained relatively steady over the past half century.

Methods

Study area description

The data used in this study are from the Schoodic Point (MESP) and Mount Desert Island (MEMD) circles of the CBC, located in Hancock County, ME (Fig. 1). The center of the MESP circle is in the town of Gouldsboro, ME (44°25'40.1"N 68°06'27.4"W), and the center of the MEMD circle is in Mt. Desert, ME (44°20'09.7"N 68°18'41.9"W). Both circles have been sampled on a consistent annual basis from 1971 to 2021, apart from 2001 for MEMD. The observations for each circle happen on a single date during the CBC count date period (14 December–5 January). This citizen science effort has been led by 3 co-compilers over the 51-year history (W. Townsend: 31 years for MEMD and 49 years for MESP; M. Good: 26 years for MEMD; S. Benz: 6 years for MESP).

The 2 CBC circles encompass ~ 857 km^2 of coastal Maine, with Acadia National Park comprising >16% of the circles, while protected areas in total comprise >27% (46% of the land mass within the study area). The study area is largely ocean (41%) and forest (40%), with the forested areas categorized as coniferous (65%), mixed (30%), and deciduous (5%) (data from Dewitz and USGS 2021). The next most abundant land-cover types in the study area are wetlands (9%) and developed lands (6%), with 38% of developed land categorized as low intensity (e.g., rural single-family homes on a plot of land), and 4% as high intensity (e.g., apartment complexes, industrial or commercial areas).

Christmas bird count

The CBC has standard protocols (Butcher et al. 1990). Volunteers follow specified routes through designated 24.1-km diameter circles, counting every bird they see within a 24-hour period. Each circle is subdivided into 8- to 10-team count routes or territories. Each team records the total number of each species detected during the active count effort while attempting to keep observations independent so that the total

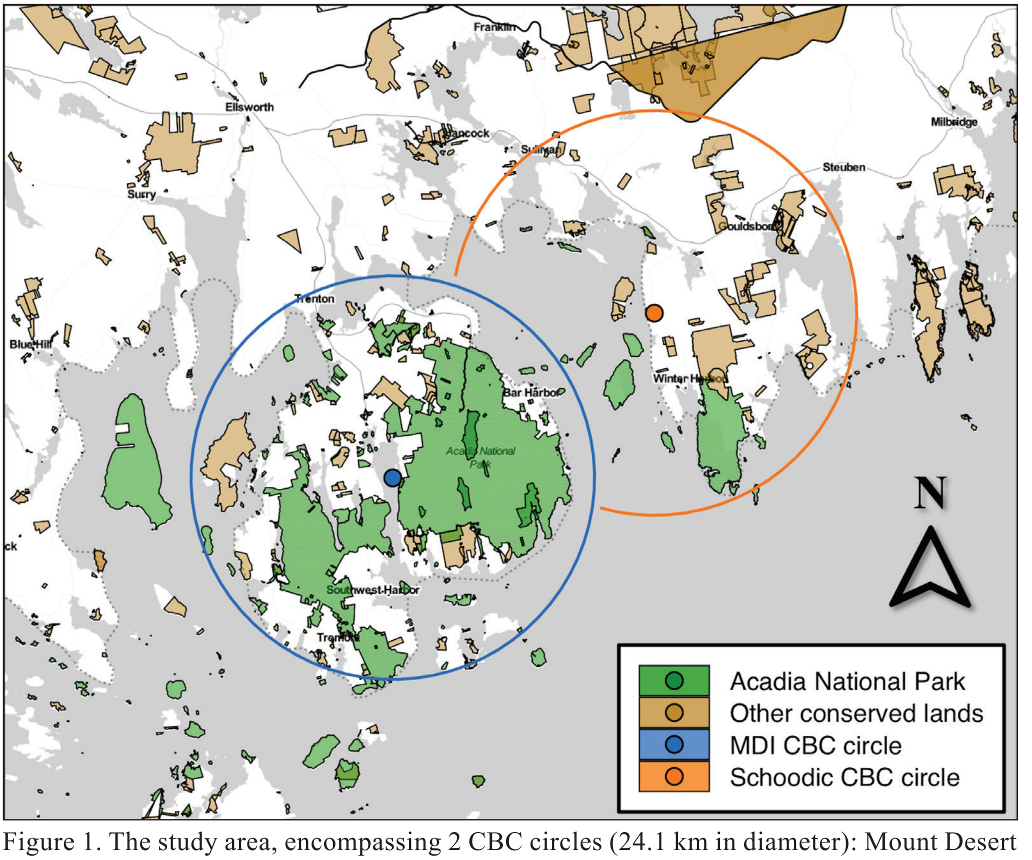

Figure 1. The study area, encompassing 2 CBC circles (24.1 km in diameter): Mount Desert Island (MEMD) and Schoodic Point (MESP), Hancock County, ME.

number is an accurate representation of the detected species population. For example, if retracing a route, only species that the party has not seen or a larger number of a species than has been previously seen can be added. Travel along each route is primarily by car and on foot. Observations of seabirds are made from shore.

The compilers also record the number of participants, and various weather-condition data for the count day. Each species count is summed across all team observations for the count day to produce the total circle count. Party hours are the sum of all teams' effort hours where they were actively searching for birds during the count day. This value represents that year's count effort, and therefore every species detected that year has the same party-hour value. The count/party-hour metric is calculated by taking the species total count and dividing by the number of party hours to create a standardized value for comparing across years.

The data used in this study are publicly accessible and provided by the National Audubon Society (National Audubon Society 2021). The CBC data exports are grouped by species, and include the common name, total count, number of party hours, and count/party-hour.

Analytical methods

To analyze these data from 2 adjacent CBC circles, we averaged the variables between the circles by species and year. This approach accounted for possible overlap between the 2 counts recording the same individuals in the same count period (i.e., year), as the exact count day differed between the 2 circles. To examine trends in the data over time, we first tested for normality with a Shapiro–Wilks test. We used a non-parametric alternative, because our data did not meet the assumptions of normality. We assessed trends in observer participation (participants/year and party-hours/year), bird abundance (total count), standardized bird abundance (count/party-hour), and species richness by year using Spearman rank correlations (r_s), which are appropriate for non-normally distributed data, do not require assumptions of a linear relationship (Sokal and Rohlf 2011), and followed the standard of $\alpha < 0.05$ for supported effects. We also present 95% confidence bands.

Additionally, we ran Spearman rank correlations for each species with records from at least 10 years to determine species-specific temporal trends. Ten years was used as a conservative threshold to protect against spurious trends from short-term and sparse data. Means used to describe the data are presented with their standard deviation (SD). We conducted all statistical analyses in R v.4.1.2 (R Core Team 2021). For presenting the data in scatter plots, we depict the line of best fit using the Loess method and a span of 1.5 using the 'ggplot2' package ver. 3.3.5 (Wickham 2016). For other data visualizations we used Stamen map tiles (http://maps.stamen.com) and 'ggmap' (Kahle and Wickham 2013). All names of birds from this study align with Clements et al. (2021).

Results

CBC effort

A total of 4684 party hours were accrued by an average of 19 (SD = 8.1) annual observers for each count. The number of citizen science participants showed a nonsignificant negative correlation with time ($r(49) = -0.25$, $P = 0.075$; Fig. 2a). The number of party hours also decreased over time, and in this case a significant negative correlation with time was supported ($r(49) = -0.28$, $P = 0.044$; Fig. 2b). Both trends are largely influenced by the especially high levels of effort in the early years of the counts (especially 1975–1987). From 1990 to 2021, the average number of participants increased slightly ($r(30) = 0.56$, $P < 0.001$). However, average party hours have been fairly consistent since 1990, showing no correlation with time ($r(30) = 0.14$, $P = 0.449$).

Population trends

The total count of individual birds recorded during 51 years of the CBC was over 380,000 (annual mean = 7452, SD = 2596). The total count of individual birds observed per party hour (mean = 172, SD = 82) was negatively correlated with time ($r(49) = -0.37$, $P = 0.007$; Fig. 3). Most of the decline occurred over recent decades, ultimately resulting in a 43% decline between the first and the last decades ($t(9) = 8.69$, $P = 0.001$).

Species changes

The total number of species observed per year varied from 52 to 84 (mean = 71, SD = 6.1; for the complete list of species observed, see Table S1 in Supplemental File 1, available online at https://www.eaglehill.us/NENAonline/suppl-files/n29-4-N1990-Lima-s1, and for BioOne subscribers, at https://www.doi.org/10.1656/N1990.s1). The number of species per party hour varied between 0.93 and 2.73 and did not show a correlation with time over the full study period ($r(49) = -0.19$, $P = 0.189$; Fig. 4a; for species-level data, see Table S2 in Supplemental File 1). However, the annual number of species declined 7.6% (from 75.2 to 69.5 species) between the first (1971–1980) and last (2012–2021) decades of the study. Meanwhile, the cumulative number of species observed in this study continued

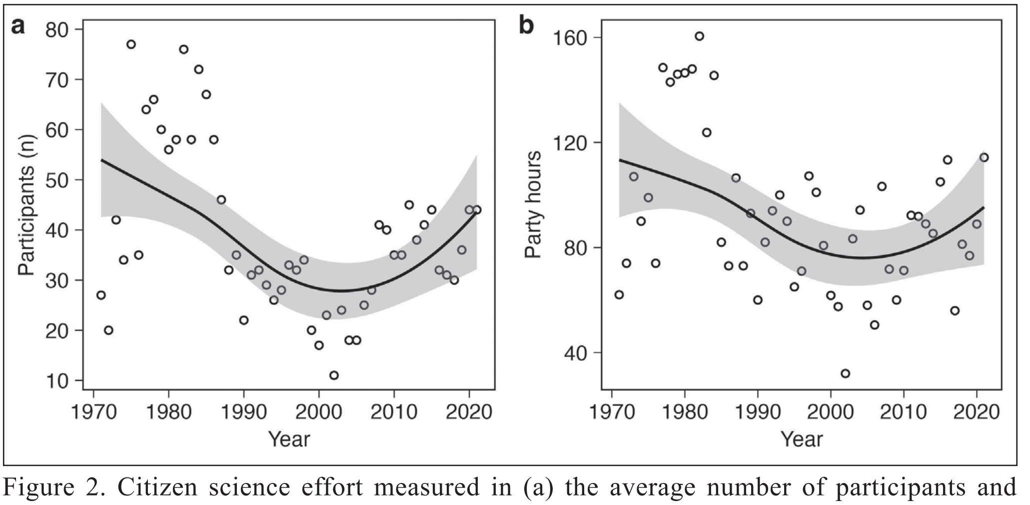

Figure 2. Citizen science effort measured in (a) the average number of participants and (b) the average number of party hours. The trend (black line) and 95% confidence bands (gray shading) are shown (see text for summary statistics).

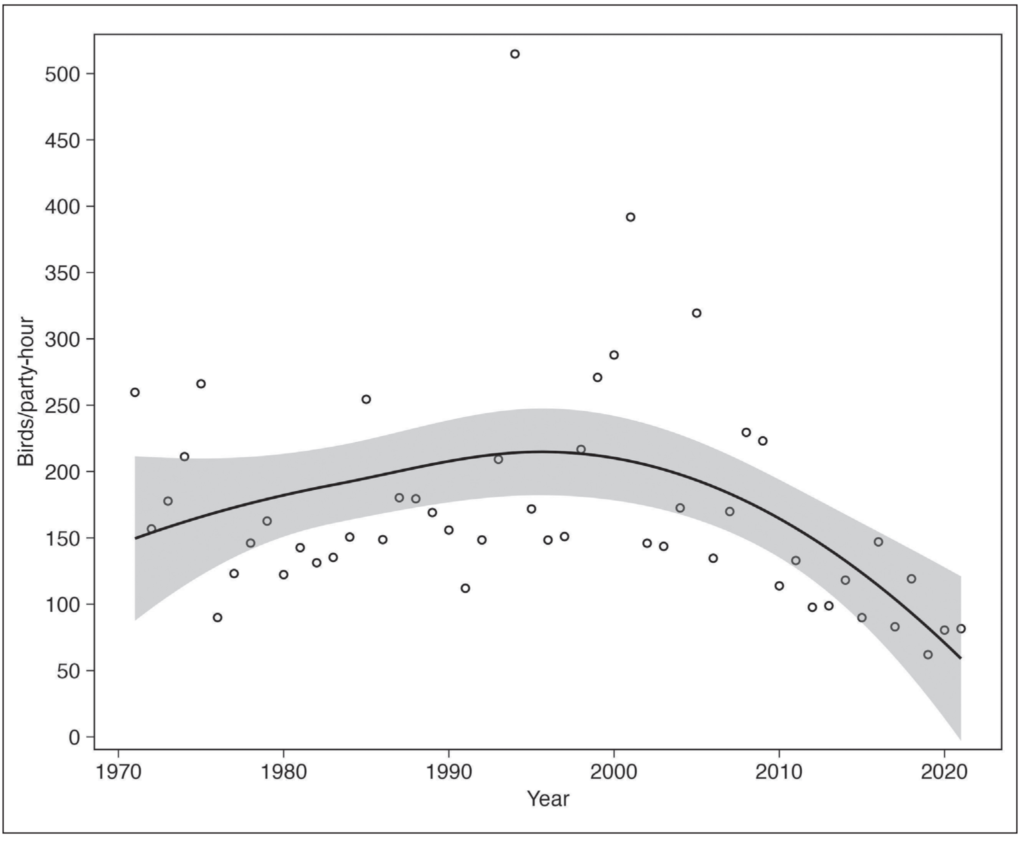

Figure 3. Relationship between the total count per party-hour and year. The trend (black line) and 95% confidence bands (gray shading) are shown (see text for summary statistics).

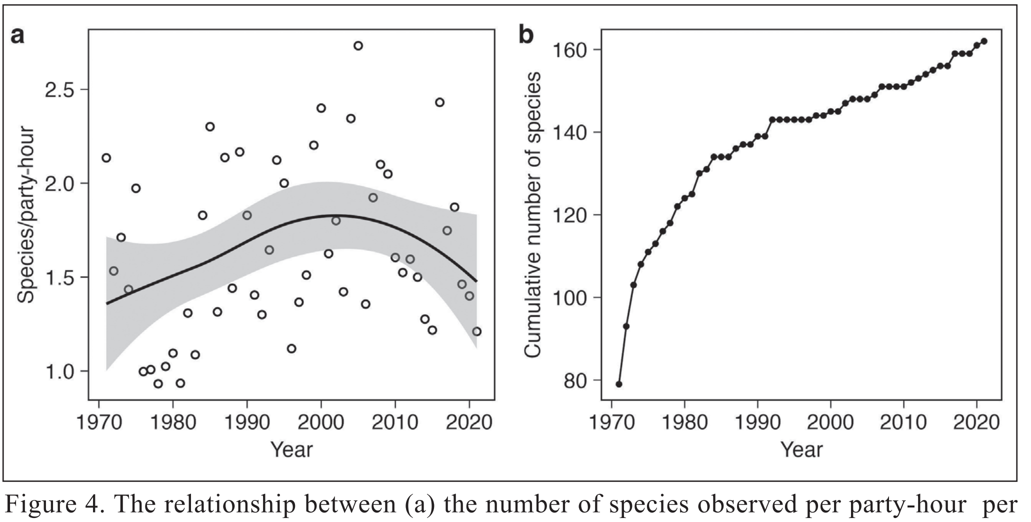

Figure 4. The relationship between (a) the number of species observed per party-hour per year and (b) the cumulative number of species observed over the entire study period. The trend (black line) and 95% confidence bands (gray shading) are shown (see text for summary statistics).

to increase, reaching 162 total species by 2021 (Fig. 4b). There were 22 new species added to the total species observed list between 1992 and 2021, of which 16 were added between 2002 and 2021, and 10 of those were added between 2012 and 2021. These new species have not fully replaced those no longer observed, hence the decreasing trend in annual species over the most recent 2 decades. There were 42 species observed in the first 41 years that have not been observed in the past 10 years. The number of rare species (those that occurred <10 years in the study period) detected each year did not correlate with time ($r(49) = -0.24$, $P = 0.0854$; see Fig. S1 in Supplemental File 1). The most abundant species in the dataset include *Somateria mollissima* L. (Common Eider), *Larus argentatus* Pontoppidan (Herring Gull), *Anas rubripes* Brewster (American Black Duck), *Clangula hyemalis* L. (Long-tailed Duck), and *Melanitta deglandi* Bonaparte (White-winged Scoter), respectively (see Table S3 in Supplemental File 1 for full list). The high number of birds in 1994 and 2001 were due to large abundances of Common Eider and Herring Gull in both years.

Individual species showed a variety of abundance patterns over time. Of the 162 species, 46% (75 species) showed a supported trend (positive or negative) from a Spearman rank correlation test between abundance (count/party hour) and year (example species shown in Fig. 5, see Table S4 in Supplemental File 1 for all species-level results). Of these species, more decreased in abundance than increased: 56% ($n = 42$) exhibited negative correlations, and 44% ($n = 33$) showed positive correlations.

Based on migration status (57 resident, and 105 non-resident migratory species), higher percentages of resident species showed no change (38.6%; $n = 22$) and increasing abundances (36.8%; $n = 21$) compared with the species that only overwinter in the area (27.6% no change, $n = 29$; 11.4% increase, $n = 12$) (Fig. 6). Similar percentages of species showed decreases by migration status, 26.7% ($n = 28$) for nonresident, and 24.6% ($n = 14$) for resident species.

We did not find consistent trends among related species. Abundance changes varied among species within and across families (Table 1). For example, the most common family, Anatidae (28 species), showed similar numbers of species that decreased ($n = 7$), increased ($n = 7$), had no detectable trend ($n = 8$), and had insufficient observations to model ($n = 6$). Similarly, Fringillidae ($n = 9$), Laridae ($n = 9$), and Picidae ($n = 9$) all had species in each change class. Passerellidae ($n = 13$) and Icteridae ($n = 6$) showed no increasing species, and Accipitridae ($n = 9$) showed no decreasing species.

Discussion

This 51-year data set shows a dynamic assemblage of winter birds and changing environmental conditions in and around Acadia National Park, ME. The overall trend of a strong decline in total birds and especially the low numbers in recent years generally matches with larger studies across North America and is of great conservation concern (Rosenburg et al. 2019). However, individual species trends vary greatly, with several species exhibiting increasing numbers, and other species

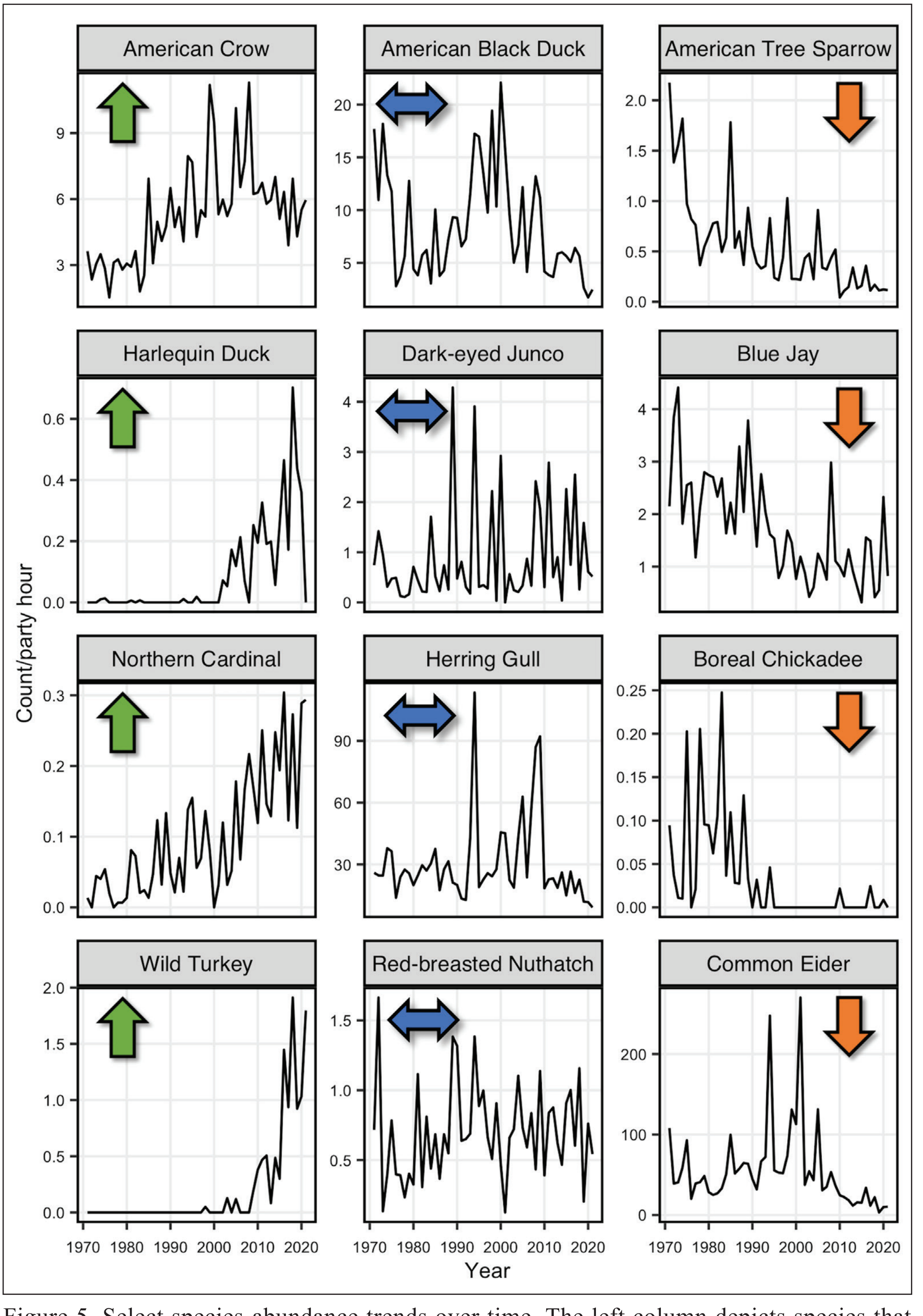

Figure 5. Select species-abundance trends over time. The left column depicts species that have shown statistically supported increases during the study period, the middle column shows species with no detectable trend, and the right column shows decreasing species.

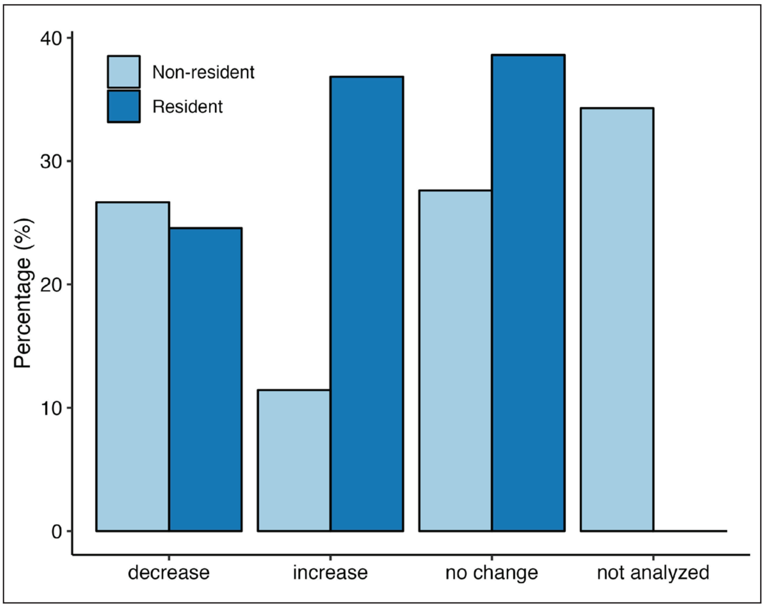

Figure 6. Percentages of the 162 bird species by migration status (57 resident and 105 non-resident migratory species) in trend classes. Trend classes are based on Spearman rank correlations of bird count/party-hour and year. Nonresident species overwinter in the study area but migrate to other areas for the breeding season. "Not analyzed" are species with <10 years of observations.

Table 1. Number of species and percent of species in each family for the 4 different change categories. "Other families" includes all the species from families with <3 species detected during the 51-year study. "% not analyzed" are rare species recorded in <10 years.

Family	Number of species	% decrease	% increase	% no change	% not analyzed
Other	30	13	20	27	40
Anatidae (ducks, geese, and waterfowl)	28	25	21	18	36
Passerellidae (new world sparrows)	13	15	0	31	54
Accipitridae (hawks, eagles, and kites)	9	0	33	44	22
Fringillidae (finches, euphonias, and allies)	9	11	33	56	0
Laridae (gulls, terns, and skimmers)	9	11	11	56	22
Picidae (woodpeckers)	9	22	22	0	56
Icteridae (troupials and allies)	6	83	0	0	17
Parulidae (new world warblers)	6	0	0	17	83
Strigidae (owls)	6	0	17	17	67
Alcidae (auks, murres, and puffins)	5	20	40	0	40
Turdidae (thrushes and allies)	5	0	0	20	80
Corvidae (crows, jays, and magpies)	4	75	25	0	0
Phasianidae (pheasants, grouse, and allies)	4	50	25	0	25
Scolopacidae (sandpipers and allies)	4	25	0	0	75
Falconidae (falcons and caracaras)	3	0	0	0	100
Gaviidae (loons)	3	0	67	0	33
Mimidae (mockingbirds and thrashers)	3	33	0	0	67
Paridae (tits, chickadees, and titmice)	3	67	33	0	0
Podicipedidae (grebes)	3	33	33	0	33

shifting their ranges and being detected for the first time in recent years, exemplifying the complexity of change at a management-relevant scale (i.e., a national park). The most recent decade of data, 2012–2021, shows the lowest overall totals and lowest numbers for many individual species, including some that do not show a statistically significant trend over the entire study period, such as Herring Gull and American Black Duck (Fig. 5). Birds are indicators of environmental change (Morrison 1986), and the trends documented here suggest that global changes are having significant impacts on bird populations and more broadly on the health of the coastal ecosystems including Acadia National Park. The varied population trends at the species level also indicate that approaches to climate-change adaptation will similarly have varied effects and not be "one-size-fits-all" solutions.

The overall decline in total birds around Acadia National Park is driven by sharp declines in the most abundant species, including Common Eider, Long-tailed Duck, and White-winged Scoter. Similar species trends are reported in coastal areas all along the Gulf of Maine (Vickery et al. 2020). Impacts on coastal seabirds beyond the broader environmental effects of warming waters, ocean acidification, sea-level rise, and fisheries management may be exacerbated by declines of sea urchins, kelp, marine worms, and mussels (Vickery et al. 2020). However, not all seabirds are showing this decline. Two coastal waterfowl species—*Histrionicus histrionicus* L. (Harlequin Duck) and *Lophodytes cucullatus* L. (Hooded Merganser)—showed increasing numbers and are species with preferential winter foraging locations in shallow intertidal locations, the former found along rocky ledges, and the latter near the mouths of tidal rivers or streams (Mittelhauser 2008, Vickery et al. 2020).

The results here for resident species, namely more species with increasing or no detectable abundance trend, align with continental analyses for winter bird populations (Rosenberg et al. 2019, Soykan et al. 2016). These studies suggest reasons for winter increase include higher overwinter survival, and population rebounds for species of conservation concern (e.g., *Haliaeetus leucocephalus* L. (Bald Eagle); Link and Sauer 2007, Marzluff 2001). There is mixed support for these explanations locally. The conservation success stories of the Bald Eagle and *Falco peregrinus* Tunstall (Peregrine Falcon) are reflected in the local data with increasing trends over the past 51 years. *Meleagris gallopavo* L. (Wild Turkey) were first observed in 2003 and every year since 2010, indicating the success of management actions at the state level to reintroduce and increase the population of this important game bird. Introduced bird species have been present throughout the 51-year record and are mostly showing declines in total numbers. This trend is largely driven by *Sturnus vulgaris* L. (European Starling) and *Passer domesticus* L. (House Sparrow) and is similar to the trend at the continental level (Rosenburg et al. 2019). *Haemorhous mexicanus* P.L. Statius Müller (House Finch) was first observed in the late 1980s and since has increased in abundance, though it is observed sporadically. Although House Finch and *Columba livia* J.F. Gmelin (Rock Pigeon) showed a positive correlation with time, this data did not change the negative correlation of all introduced species (European Starling, House Sparrow, House Finch, and Rock Pigeon).

Although total numbers of birds may not reflect winter warming, several recently arriving species are likely responding to changing conditions. This northward expansion of resident species is evident across the continent (Rushing et al. 2020) and locally includes *Cardinalis cardinalis* L. (Northern Cardinal), *Baeolophus bicolor* L. (Tufted Titmouse), *Melanerpes carolinus* L. (Red-bellied Woodpecker), and Hooded Merganser. These recent arrivals are generally at low population densities and thus have not made up for the losses of common species. Declines of some northern species, including *Poecile hudsonicus* J.R. Forster (Boreal Chickadee) and *Perisoreus canadensis* L. (Canada Jay), may reflect a contracting southern range margin (Rodenhouse et al. 2009, Rushing et al. 2020).

The need for expanded and consistent long-term monitoring is evident even in places such as national parks that have relatively robust monitoring compared to the landscape as a whole. Recent biodiversity blitzes on the Schoodic Peninsula have documented hundreds of insect species previously unknown from Acadia National Park (Chandler et al. 2012). This recent snapshot shows the richness of biodiversity that has not been tracked previously and thus the magnitude of past changes that are simply unknown. Maintaining long-term studies is a major challenge, but the value of these data is tremendous, especially given ongoing environmental changes and bird responses. Shifts in bird species presence as well as abundance are a reflection of other physical and biological changes and themselves have cascading effects (Morrison 1986) that may not be easily detectable in time for management intervention without consistent monitoring.

The annual CBC effort is one of the longest running annual monitoring efforts in and around Acadia National Park. The changes found in this study show the reach of global changes and the fact that protecting areas, such as national parks, is only a first step in conservation and management during rapid environmental change. Future studies are needed to uncover the relationships between environmental change and bird population change. Robust modeling based on CBC data require a larger (regional) spatial extent and many more circles (Dunn et al. 2005), such as across national parks in the eastern US. Within Acadia, more frequent monitoring within and across seasons can help expand on the understanding gained from this long-term but only 1-day-per-year study.

Nature is dynamic and ever changing, and birds are a key bellwether; however, to understand the change that is occurring, long-term monitoring is essential. Parks, like Acadia, have extensive research and monitoring, and thus are key locations to detect global change impacts as well as for developing and applying adaptive approaches to facilitate species adjustments to changing conditions. Most conservation and management actions take place at the local level (e.g., private property and local parks), and local resource data and trends are critical to synthesize and share for effective decision making.

Acknowledgments

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