YEAR ONE

LANDSCAPE of CHANGE

FINAL REPORT

LANDSCAPE of CHANGE - YEAR 1 FINAL REPORT

A collaborative project to compare historical and contemporary data in the Mount Desert Island environment to understand past and future change, and inform community response.

Launched on April 19, 2021, Landscape of Change is a collaborative project led by Mount Desert Island Historical Society with Schoodic Institute, Acadia National Park, College of the Atlantic, MDI Biological Laboratory, and A Climate to Thrive with the goal of publishing and compiling historical records on the Mount Desert Island environment, and comparing these with contemporary data to document change over time. Knowing how, and how quickly, this place is changing provides important information needed to make decisions about to respond today to ensure a livable future.

With support from private donations, Schoodic Institute is leading the citizen science and data analysis of Landscape of Change. This project is an example of how we work with the National Park Service to share information related to science in the park, share stories about science past and present, and provide opportunities for people of all ages to participate in science.

This report presents a summary of 2021 activities, the results of analysis of bird and insect diversity trends, and recommendations for continued work.

Background

Historical records are a vital resource for understanding environmental change. The Mount Desert Island Historical Society cares for an important collection of logbooks written by a group of Harvard students between 1880 and 1890. Calling themselves the Champlain Society, the students cataloged Mount Desert Island region natural history, including plants, birds, insects, marine invertebrates, fish, geology, and weather. Their work directly inspired conservation efforts that led to the formation of Acadia National Park. In 2021, Mount Desert Island Historical Society published the first three years of the Champlain Society logbooks in a special "Summers of Science and Wonder" edition of the annual journal *Chebacco,* edited by Catherine Schmitt of Schoodic Institute.

Birds, plants, and insects have a long history of attention in Acadia, from Wabanaki knowledge to the Champlain Society's surveys in the 1880s, through the work of twentieth-century naturalists and scientists. The thousands of preserved specimens and recorded observations provide a baseline for documenting the Mount Desert Island "Landscape of Change." The 2021 work consisted of:

1. compiling climate data and analyzing trends specific to Mount Desert Island;
2. expanding a campaign to engage the public in documenting biodiversity via citizen science platforms (iNaturalist and eBird);
3. digitizing historical data sets on birds and insects, including georeferenced locations;
4. comparative analysis of historical and contemporary data to understand trends in birds and pollinating insects (bees, butterflies, moths).

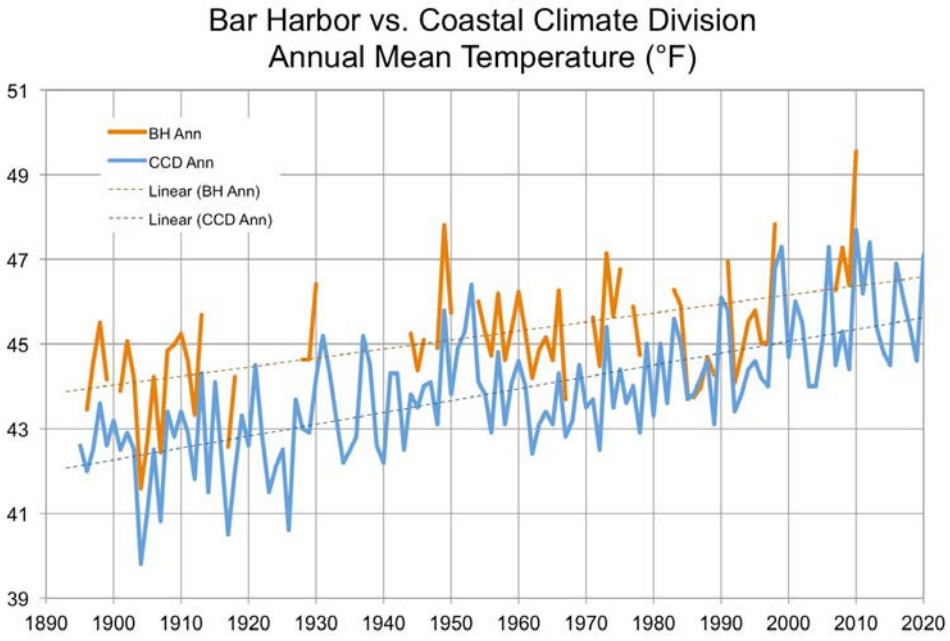
The Landscape of Change partner organizations chose to focus initially on birds and pollinating insects because of the quality of available historical data, and the heightened public interest and awareness of these animals as well as the threats posed by climate change.

CLIMATE, THEN AND NOW

Temperature

The Champlain Society Meteorological Department, led by Sam Eliot, established a weather monitoring station at Camp Pemetic on Somes Sound, and at several private residences around Mount Desert Island. The information they recorded, in camp logs as well as a Meteorological Department report, provides a glimpse of summer climate conditions in Acadia during the late nineteenth century. The National Weather Service began monitoring year-round climate conditions in Bar Harbor in 1893, however monitoring locations varied over time, resulting in an incomplete time series. The National Park Service currently monitors weather at MacFarland Hill, Cadillac Mountain, and Jordan Pond.

The available data do show that Mount Desert Island is warmer than the average for coastal Maine, but with a similar rate of warming.



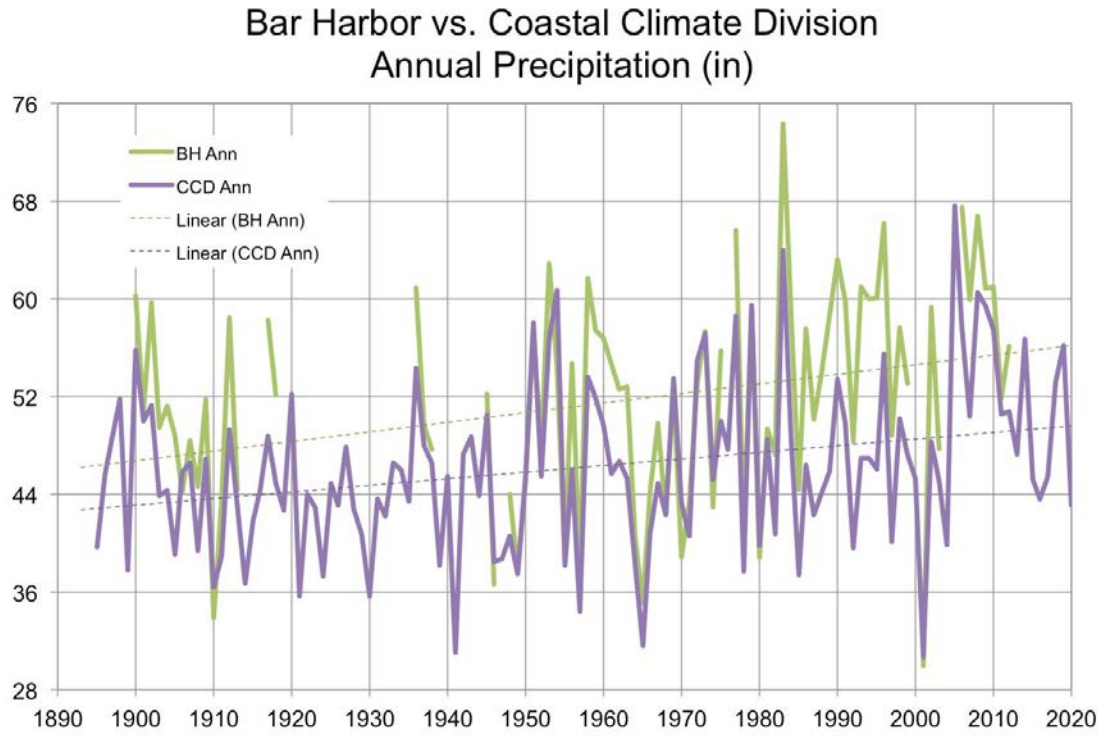
Average annual temperature for the Coastal Climate Division (blue) and Bar Harbor station (brown). The "Bar Harbor" data include the station at Bar Harbor (1893-Aug 1982) and Acadia (Sep 1982-2014) and were prepared by S. Birkel, Climate Change Institute, University of Maine.

Over the last 130 years, average annual temperatures in the coastal region have warmed by 3.4 degrees Fahrenheit (°F), with additional projected warming of 2-4 °F by 2050 and up to 10 °F projected by 2100 (Maine Climate Council 2020). Warming has been strongest during the winter: average annual minimum (coldest) temperature in the coastal region has increased from 32.1 to 36.4 degrees (Fernandez et al. 2020). The growing season or frost-free period has lengthened by two weeks. Spring arrives earlier, autumn falls later.

This report presents a summary of 2021 activities, and the results of analyses of bird and insect diversity trends. We have also identified potential areas for continued work, which are highlighted in yellow.

Precipitation

Annual precipitation has increased by six inches, with more rain, less snow, and more frequent "extreme" events (storms with two inches or more of rain within 24 hours).



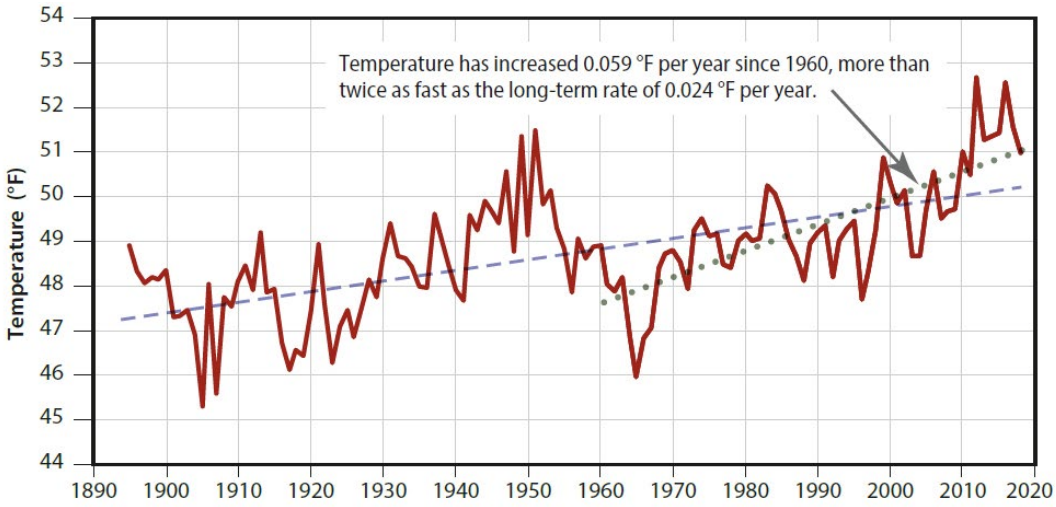
Total annual precipitation (in inches) for the Coastal Climate Division (purple) and Bar Harbor station (green). The "Bar Harbor" data includes the station at Bar Harbor (1893-Aug 1982) and Acadia (Sept 1982-2014), and were prepared by S. Birkel, Climate Change Institute, University of Maine.

Future work could research news accounts of flooding and drought, similar to a recent project evaluating changes in fog presence and density (Houston 2021). Historical evidence for changes in precipitation can be found on the landscape in the numerous culverts, bridges, roads, and other twentieth-century infrastructure that are now often overwhelmed by high water flows. Maine Department of Transportation and/or local town public works departments may have records about culvert flooding and road repairs that would indicate evidence of changes in precipitation. Trout Unlimited also has a data set of brook trout and water quality, and Downeast Salmon Federation keeps historical information on rivers in the region.

Coastal Conditions

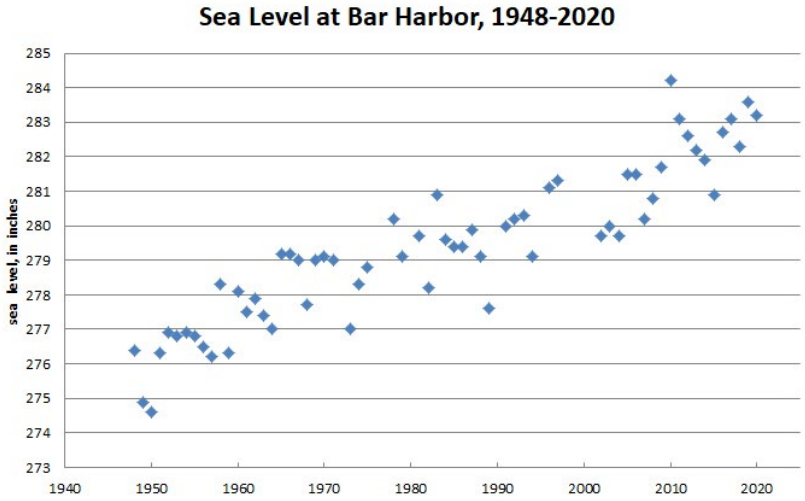
The surface water temperature of the Gulf of Maine has increased 3 °F since 1895. Again, the steepest temperature rise has occurred in recent decades, with "heat waves" occurring in some years.

Efforts are underway to compile historical data and repeat surveys of intertidal flora and fauna (Capuano 2021), with numerous possibilities for future work.



Average annual sea surface temperature, 1895–2018, averaged across the Gulf of Maine based on monthly data from the NOAA Extended Reconstructed Sea-Surface Temperature Version 5 gridded dataset (NOAA ERSST5), with linear trends for the periods 1895–2018 (dashed) and 1960–2018 (dotted). From *Maine's Climate Future 2020 Update* (Fernandez et al. 2020).

As the global ocean warms, expands, and swells with melting polar ice and glaciers, average sea level—already eight inches higher than it was in 1950—is rising at an increasing rate, now over an inch per decade. Reviews of historical photographs and maps of the shoreline, as well as records of water levels storm damage, could be used to understand changes in the coastal landscape.



Annual mean sea level measured at the Bar Harbor tide gauge, 1948-2020, from the Permanent Service for Mean Sea Level.

Previously documented changes in land - and sea-scapes of Mount Desert Island

The work of the Champlain Society Botanical Department, led by Edward Rand, has allowed scientists to document long-term changes in plant life: one of every six plant species found in the nineteenth century no longer grows on Mount Desert Island. Native plant species have declined in abundance, while non-native species have increased, causing the total number of plant species on the island to increase from 730 to 829. These changes match trends in other locations in the Northeast region, and occur across habitats (e.g., wetlands, coastal areas, grasslands and fields, wooded areas), suggesting that more large-scale factors—such as climate change, acid rain, land use changes, and nitrogen deposition—likely played important roles (Rand et al. 1894; Greene et al. 2005; McDonough MacKenzie 2019).

Bird populations, monitored by Schoodic Institute via programs such as Sea Watch, Songbird Watch, and the annual Christmas Bird Count, are shifting as Acadia's climate warms. Over the last fifty years, there has been an estimated 50% decline in the abundance of birds observed during the early winter Christmas Bird Count. Species with the greatest declines include evening grosbeak, American tree sparrow, brown-headed cowbird, white-winged scoter, and blue jay (Benz et al. in prep). Some cold-climate bird species, such as boreal chickadee, no longer breed in the park. Other species showing an increasing trend in population numbers include mallard, wild turkey, bald eagle, northern cardinal, and harlequin duck.

Citizen Science Effort

Landscape of Change has inspired expanded efforts to leverage historical data to document change. Much of the data from the past was contributed by "amateur naturalists," volunteers akin to today's "citizen scientists."

Beginning in April 2021, through a series of media campaigns and scheduled events, we invited Mount Desert Island residents and visitors to revisit historical data sets and contribute observations of birds and pollinators (butterflies, bees, moths), using iNaturalist and eBird. This project built upon Schoodic Institute's previous efforts, ongoing since 2012, to engage the public in documenting biodiversity (Benz 2022).

During the new "Season of Science and Wonder" on Mount Desert Island (April 10 – October 31, 2021), 633 people contributed 4,357 observations of 668 bird and insect species to iNaturalist. The most observed species was the tri-colored bumble bee (145 records), followed by herring gull (142), and monarch butterfly (83).

Over the same time period, 1, 206 eBird observers submitted checklists totaling 87,973 observations of 243 species. The most frequently observed species, in order, were Herring Gull (4,155), American Crow (3,788), Black-capped Chickadee (3,280), and Song Sparrow (3,060).

The public engagement campaign received assistance from University of Maine students enrolled in the Communications & Journalism 345 course and University of Southern Maine student Ryan Avery, who conducted his capstone on volunteerism in Acadia National Park for a Certificate of Advanced Study in Adult Education.

Schoodic Institute developed informational materials as aids to the citizen science effort, including tables, spreadsheets, species lists, and themed articles for World Bee Day, Moth Week, Pollinator Week, etc.

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LANDSCAPE OF CHANGE: RESULTS OF DATA ANALYSIS

Kyle Lima, Catherine Schmitt, Seth Benz, and Peter Nelson

BIRDS

Introduction

In the 1880s, a group of Harvard students known as the Champlain Society spent summers on Mount Desert Island (MDI) conducting surveys of flora and fauna, including birds. Their records, preserved by the Mount Desert Island Historical Society, present an opportunity to evaluate changes in bird populations on the island. North America has lost nearly 3 billion birds in recent times. According to Rosenberg et al. (2019), this is a loss of 25% of all birds on the continent since 1970! This shocking decline in North America's bird population is just one reason why it's so critical to study bird populations locally.

This study's objective was to compare the Champlain Society's records to the past four years of eBird and iNaturalist data for MDI. Our goals were: 1) determine how historically recorded species' relative abundance changed over the last 140 years, 2) find if new species are present on the island, and 3) consider what might have caused these changes in MDI bird populations.

Methods

Champlain Society bird records, compiled in a report by Henry Spelman, were transcribed into a digital spreadsheet. For each species, recorded dates and locations were cross-referenced with daily notes on bird collection from the Champlain Society camp logs and specimen vouchers from the Harvard Museum of Comparative Zoology, obtained via the iDigBio online database. A summary of the Champlain Society Ornithology Department can be found in Schmitt and MacDonald (2018).

The Champlain Society collected data from early July through the first week of September, 1880 – 1883. To compare these data to modern day, we used eBird and iNaturalist data from the same time frame (early July through the first week of September), and over the same number of years (4) from 2018 – 2021.

To compare how often these species were detected, we had to create a qualitative descriptor for each species, as the historical dataset did not allow for a quantitative analysis. Found in the Champlain Society's report (Spelman 1941), these designations ("common," "uncommon," etc.) are based on their own observations and experiences, and follow the convention of other national and regional bird lists of the period. For the modern dataset, we used a count of the number of times a species was reported and designated a category based on these bins: < 5 = very rare, 5 > 20 = rare, 20 > 50 = uncommon, > 50 = common. These standards are adapted from the American Birding Association (2022).

We used these relative abundances to compare modern and historical times. Due to the qualitative nature of the data, we designated species with changes of **more than one category** into the "increasing" or "decreasing" class. So, if a species was "common" in the 1880s but is now "uncommon," that would not constitute a decrease that we can be confident in. Whereas, if a species was "common" in the 1880s but is now "rare," that would qualify as a decreasing species

because we are confident that a change of that magnitude is real. For example, Cliff Swallow was a historically "common" species but now is "very rare" on MDI, and therefore is decreasing. In contrast, Sharp-shinned Hawk was "uncommon" historically and is now "common," but this difference is not enough to confidently determine if it is increasing and is therefore categorized as "no change."

Results

The Champlain Society recorded 98 species, which is less than half (47%) of the 210 species recorded in modern times according to eBird and iNaturalist. The Champlain Society categorized 60 species as common, while today there are 95. This is an increase of 35 common species over 140 years.

When we examined the changes in relative abundance of historically observed bird species (n=98) over the last 140 years, we found that 8% of these species increased in relative abundance (Table 1), 14% decreased (Table 2), and 76% exhibited no change (Figure 1). Table 1 also includes more notably increasing species that were not detected by the Champlain Society, but are now uncommon or common on MDI.

Some examples of the 8% of historical species that have increased are Black-throated Blue Warbler (Figure 2), Blue Jay (Figure 3), and Eastern Phoebe (Figure 4).

Examples of the 14% of historical species that have decreased are American Woodcock (Figure 5), Black-crowned Night-Heron (Figure 6), and Yellow-bellied Flycatcher (Figure 7).

Modern day records show 82 species not recorded by the Champlain Society, that are regularly documented by observers today (Table 3). Three of these species were introduced by humans between the 1880s and present day: House Sparrow, European Starling, and Rock Pigeon. For a complete list of relative abundance changes by species see Table 4.

Changes in Mount Desert Island bird species abundance, 1880-present

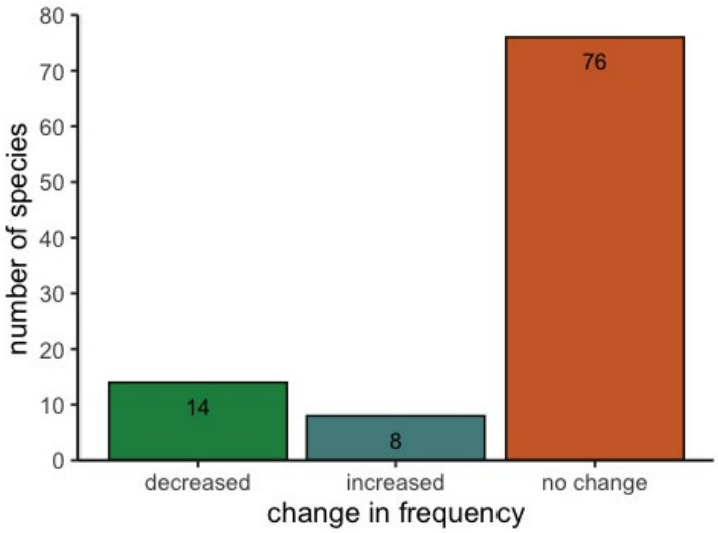

Figure 1. The 98 total number of bird species recorded by the Champlain Society in the 1880s, the number of species that have decreased (14), increased (8), and showed no change (76) in relative abundance from the 1880s to present day. Data collected on Mount Desert Island, Maine, USA, and provided by eBird and iNaturalist.

Increasing Species

Table 1. Species recorded by the Champlain Society with notable increases in relative abundance (r.a.). Also included are species with notable increases in relative abundance that were not recorded in the 1880s by the Champlain Society. There are 33 species that are now common on MDI, and 19 uncommon species that were not present historically. Data collected on Mount Desert Island, Maine, USA, and provided by eBird and iNaturalist.

Common name	Scientific name	r. a. 1880s	r. a. modern	r. a. changes
Black-throated Blue Warbler	*Setophaga caerulescens*	very rare	common	increased
Blue Jay	*Cyanocitta cristata*	rare	common	increased
Brown Creeper	*Certhia americana*	rare	common	increased
Eastern Bluebird	*Sialia sialis*	very rare	uncommon	increased
Eastern Phoebe	*Sayornis phoebe*	rare	common	increased
Red Crossbill	*Loxia curvirostra*	rare	common	increased
Red-tailed Hawk	*Buteo jamaicensis*	very rare	uncommon	increased
Solitary Sandpiper	*Tringa solitaria*	rare	common	increased
Black-bellied Plover	*Pluvialis squatarola*	not detected	uncommon	increased
Blackpoll Warbler	*Setophaga striata*	not detected	uncommon	increased
Canada Goose	*Branta canadensis*	not detected	common	increased
Cape May Warbler	*Setophaga tigrina*	not detected	uncommon	increased
Common Eider	*Somateria mollissima*	not detected	common	increased
Common Grackle	*Quiscalus quiscula*	not detected	common	increased
Common Merganser	*Mergus merganser*	not detected	common	increased
Common Raven	*Corvus corax*	not detected	common	increased
Cooper's Hawk	*Accipiter cooperii*	not detected	uncommon	increased
Double-crested Cormorant	*Nannopterum auritum*	not detected	common	increased
Eastern Towhee	*Pipilo erythrophthalmus*	not detected	common	increased
Eastern Wood-Pewee	*Contopus virens*	not detected	common	increased
European Starling	*Sturnus vulgaris*	not detected	uncommon	increased
Gray Catbird	*Dumetella carolinensis*	not detected	common	increased
Great Black-backed Gull	*Larus marinus*	not detected	common	increased
Great Cormorant	*Phalacrocorax carbo*	not detected	uncommon	increased
Great Crested Flycatcher	*Myiarchus crinitus*	not detected	uncommon	increased
Great Egret	*Ardea alba*	not detected	uncommon	increased
Green-winged Teal	*Anas crecca*	not detected	uncommon	increased
Hooded Merganser	*Lophodytes cucullatus*	not detected	common	increased
House Finch	*Haemorhous mexicanus*	not detected	common	increased
House Sparrow	*Passer domesticus*	not detected	common	increased
Laughing Gull	*Leucophaeus atricilla*	not detected	common	increased
Least Flycatcher	*Empidonax minimus*	not detected	uncommon	increased
Mallard	*Anas platyrhynchos*	not detected	common	increased
Merlin	*Falco columbarius*	not detected	common	increased

Table 1, *continued*

Common name	Scientific name	r. a. 1880s	r. a. modern	r. a. changes
Mourning Dove	*Zenaida macroura*	not detected	common	increased
Nelson's Sparrow	*Ammospiza nelsoni*	not detected	common	increased
Northern Cardinal	*Cardinalis cardinalis*	not detected	common	increased
Northern Gannet	*Morus bassanus*	not detected	common	increased
Palm Warbler	*Setophaga palmarum*	not detected	uncommon	increased
Peregrine Falcon	*Falco peregrinus*	not detected	common	increased
Pileated Woodpecker	*Dryocopus pileatus*	not detected	common	increased
Pine Warbler	*Setophaga pinus*	not detected	common	increased
Red-necked Grebe	*Podiceps grisegena*	not detected	uncommon	increased
Ring-billed Gull	*Larus delawarensis*	not detected	common	increased
Rock Pigeon	*Columba livia*	not detected	common	increased
Ruby-crowned Kinglet	*Corthylio calendula*	not detected	uncommon	increased
Semipalmated Plover	*Charadrius semipalmatus*	not detected	common	increased
Snowy Egret	*Egretta thula*	not detected	uncommon	increased
Swamp Sparrow	*Melospiza georgiana*	not detected	common	increased
Tennessee Warbler	*Leiothlypis peregrina*	not detected	uncommon	increased
Tufted Titmouse	*Baeolophus bicolor*	not detected	uncommon	increased
Turkey Vulture	*Cathartes aura*	not detected	common	increased
Veery	*Catharus fuscescens*	not detected	uncommon	increased
White-breasted Nuthatch	*Sitta carolinensis*	not detected	common	increased
White-winged Scoter	*Melanitta deglandi*	not detected	common	increased
Wild Turkey	*Meleagris gallopavo*	not detected	common	increased
Wilson's Storm-Petrel	*Oceanites oceanicus*	not detected	uncommon	increased
Wood Duck	*Aix sponsa*	not detected	common	increased
Wood Thrush	*Hylocichla mustelina*	not detected	common	increased
Yellow-bellied Sapsucker	*Sphyrapicus varius*	not detected	uncommon	increased

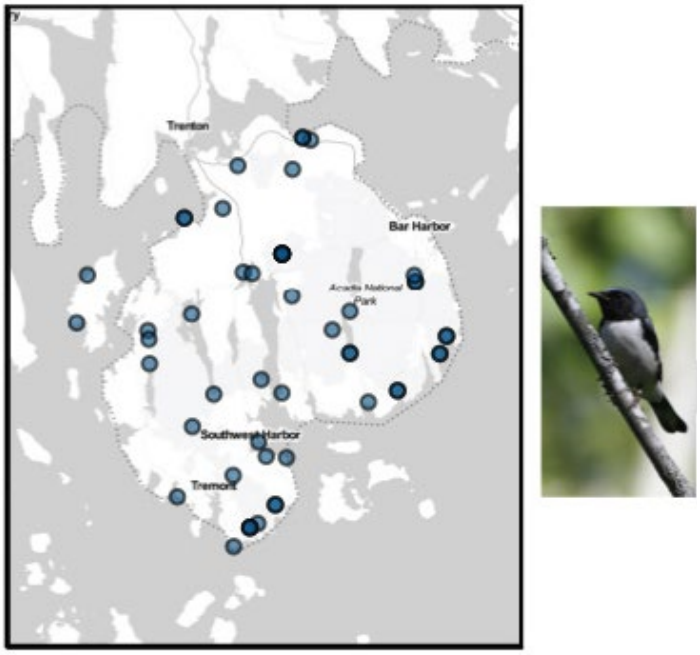

Figure 2. Black-throated Blue Warbler *(Setophaga caerulescens)* modern day distribution across MDI. Data provided by eBird and iNaturalist, 2018 - 2021. This species was "very rare" in the 1880s and is "common" today.

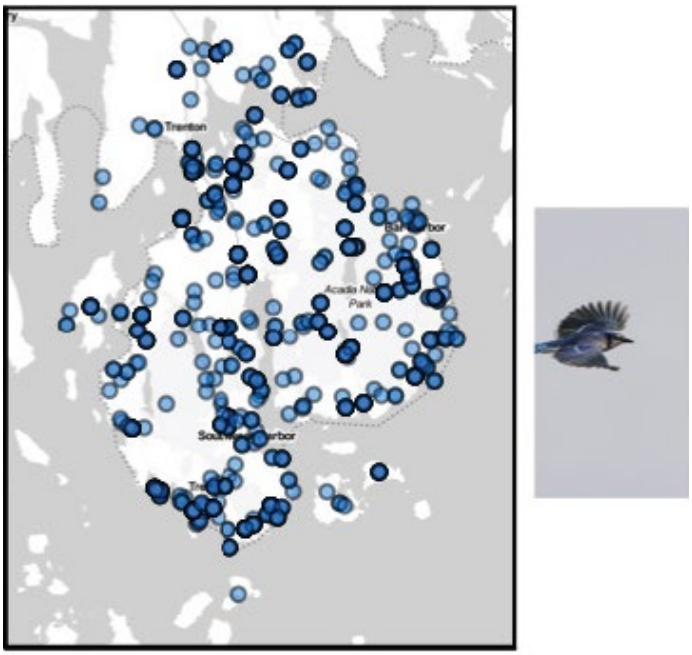

Figure 3. Blue Jay *(Cyanocitta cristata)* modern day distribution across MDI. Data provided by eBird and iNaturalist, 2018 - 2021. This species was "rare" in the 1880s and is "common" today.

eBird iNaturalist

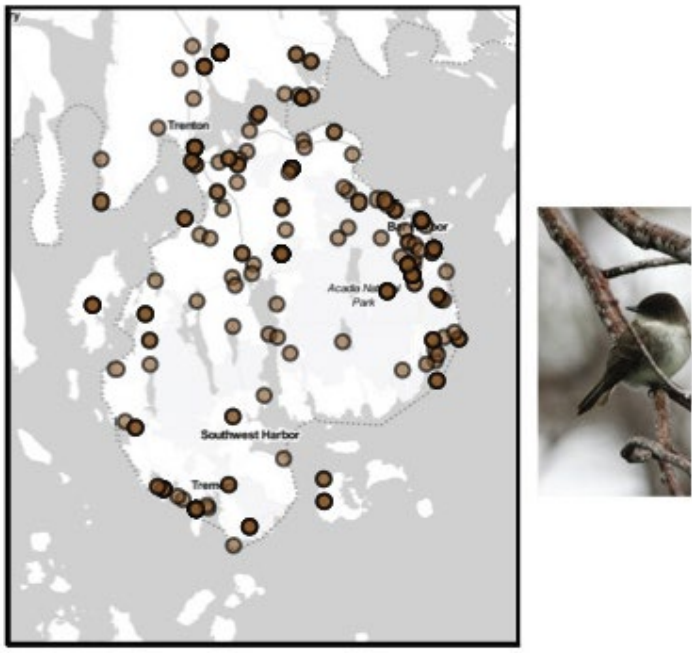

Figure 4. Eastern Phoebe *(Sayornis phoebe)* modern day distribution across MDI. Data provided by eBird and iNaturalist, 2018 - 2021. This species was "rare" in the 1880s and is "common" today.

Decreasing Species

Table 2. Species that exhibited notable decreases in relative abundance (r.a.) since the 1880s. Data collected on Mount Desert Island, Maine, USA, and provided by eBird and iNaturalist.

Common name	Scientific name	r. a. 1880s	R. a. modern	R. a. changes
American Woodcock	*Scolopax minor*	common	rare	decreased
Bank Swallow	*Riparia riparia*	common	rare	decreased
Black-billed Cuckoo	*Coccyzus erythropthalmus*	common	rare	decreased
Black-crowned Night-Heron	*Nycticorax nycticorax*	common	very rare	decreased
Black-legged Kittiwake	*Rissa tridactyla*	uncommon	very rare	decreased
Canada Warbler	*Cardellina canadensis*	common	rare	decreased
Chimney Swift	*Chaetura pelagica*	common	rare	decreased
Cliff Swallow	*Petrochelidon pyrrhonota*	common	very rare	decreased
Passenger Pigeon	*Ectopistes migratorius*	rare	extinct	decreased
Pine Siskin	*Spinus pinus*	common	rare	decreased
Ruffed Grouse	*Bonasa umbellus*	common	rare	decreased
Yellow-bellied Flycatcher	*Empidonax flaviventris*	common	rare	decreased

eBird iNaturalist

Figure 5. American Woodcock *(Scolopax minor)* modern day distribution across MDI. Data provided by eBird and iNaturalist, 2018 - 2021.

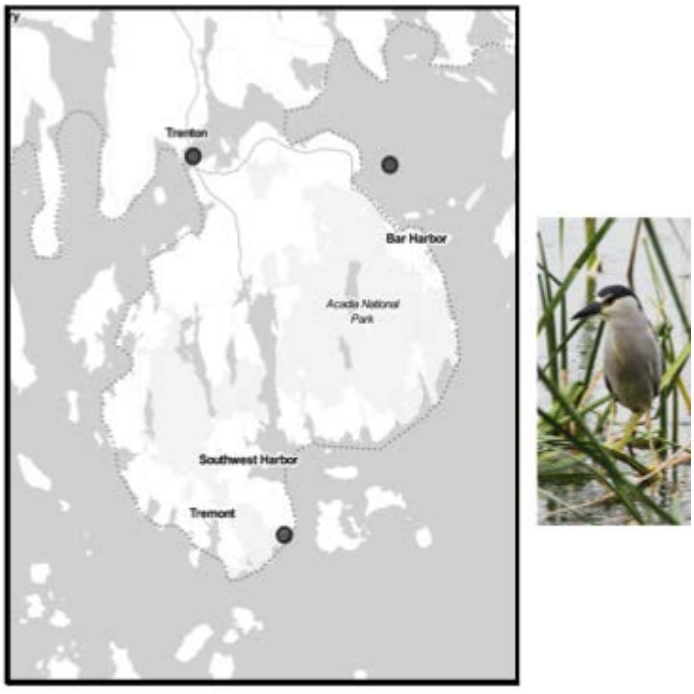

Figure 6. Black-crowned Night-Heron *(Nycticorax nycticorax)* modern day distribution across MDI. Data provided by eBird and iNaturalist, 2018 - 2021.

eBird iNaturalist

Figure 7. Yellow-bellied Flycatcher *(Empidonax flaviventris)* modern day distribution across MDI. Data provided by eBird and iNaturalist, 2018 - 2021.

Modern Species not Recorded Historically

Table 3. Species that can be seen regularly (those with the relative frequencies of rare, uncommon, and common) on MDI, but were not documented in the 1880s by the Champlain Society's efforts.

Common name	Scientific name	Relative abundance
American Kestrel	*Falco sparverius*	rare
American Oystercatcher	*Haematopus palliatus*	rare
Arctic Tern	*Sterna paradisaea*	rare
Atlantic Puffin	*Fratercula arctica*	rare
Baltimore Oriole	*Icterus galbula*	rare
Black-bellied Plover	*Pluvialis squatarola*	uncommon
Blackpoll Warbler	*Setophaga striata*	uncommon
Brown-headed Cowbird	*Molothrus ater*	rare
Canada Goose	*Branta canadensis*	common
Cape May Warbler	*Setophaga tigrina*	uncommon
Carolina Wren	*Thryothorus ludovicianus*	rare
Common Eider	*Somateria mollissima*	common
Common Grackle	*Quiscalus quiscula*	common
Common Merganser	*Mergus merganser*	common
Common Murre	*Uria aalge*	rare
Common Raven	*Corvus corax*	common
Cooper's Hawk	*Accipiter cooperii*	uncommon
Double-crested Cormorant	*Nannopterum auritum*	common
Eastern Towhee	*Pipilo erythrophthalmus*	common
Eastern Wood-Pewee	*Contopus virens*	common
European Starling	*Sturnus vulgaris*	uncommon
Field Sparrow	*Spizella pusilla*	rare
Gray Catbird	*Dumetella carolinensis*	common
Great Black-backed Gull	*Larus marinus*	common
Great Cormorant	*Phalacrocorax carbo*	uncommon
Great Crested Flycatcher	*Myiarchus crinitus*	uncommon
Great Egret	*Ardea alba*	uncommon
Great Shearwater	*Ardenna gravis*	rare
Green-winged Teal	*Anas crecca*	uncommon
Hooded Merganser	*Lophodytes cucullatus*	common
House Finch	*Haemorhous mexicanus*	common
House Sparrow	*Passer domesticus*	common
House Wren	*Troglodytes aedon*	rare
Killdeer	*Charadrius vociferus*	rare
Laughing Gull	*Leucophaeus atricilla*	common
Least Flycatcher	*Empidonax minimus*	uncommon

Table 3, *continued*

Common name	Scientific name	Relative abundance
Lesser Black-backed Gull	*Larus fuscus*	rare
Lincoln's Sparrow	*Melospiza lincolnii*	rare
Mallard	*Anas platyrhynchos*	common
Merlin	*Falco columbarius*	common
Mourning Dove	*Zenaida macroura*	common
Nelson's Sparrow	*Ammospiza nelsoni*	common
Northern Cardinal	*Cardinalis cardinalis*	common
Northern Gannet	*Morus bassanus*	common
Northern Goshawk	*Accipiter gentilis*	rare
Northern Mockingbird	*Mimus polyglottos*	rare
Olive-sided Flycatcher	*Contopus cooperi*	rare
Palm Warbler	*Setophaga palmarum*	uncommon
Peregrine Falcon	*Falco peregrinus*	common
Philadelphia Vireo	*Vireo philadelphicus*	rare
Pileated Woodpecker	*Dryocopus pileatus*	common
Pine Warbler	*Setophaga pinus*	common
Razorbill	*Alca torda*	rare
Red-breasted Merganser	*Mergus serrator*	rare
Red-necked Grebe	*Podiceps grisegena*	uncommon
Red-necked Phalarope	*Phalaropus lobatus*	rare
Red-shouldered Hawk	*Buteo lineatus*	rare
Ring-billed Gull	*Larus delawarensis*	common
Rock Pigeon	*Columba livia*	common
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	rare
Ruby-crowned Kinglet	*Corthylio calendula*	uncommon
Sanderling	*Calidris alba*	rare
Scarlet Tanager	*Piranga olivacea*	rare
Semipalmated Plover	*Charadrius semipalmatus*	common
Snowy Egret	*Egretta thula*	uncommon
Surf Scoter	*Melanitta perspicillata*	rare
Swamp Sparrow	*Melospiza georgiana*	common
Tennessee Warbler	*Leiothlypis peregrina*	uncommon
Tufted Titmouse	*Baeolophus bicolor*	uncommon
Turkey Vulture	*Cathartes aura*	common
Veery	*Catharus fuscescens*	uncommon
Warbling Vireo	*Vireo gilvus*	rare
Whimbrel	*Numenius phaeopus*	rare
White-breasted Nuthatch	*Sitta carolinensis*	common
White-rumped Sandpiper	*Calidris fuscicollis*	rare
White-winged Scoter	*Melanitta deglandi*	common

Table 3, *continued*

Common name	Scientific name	Relative abundance
Wild Turkey	*Meleagris gallopavo*	common
Wilson's Storm-Petrel	*Oceanites oceanicus*	uncommon
Wood Duck	*Aix sponsa*	common
Wood Thrush	*Hylocichla mustelina*	common
Yellow-bellied Sapsucker	*Sphyrapicus varius*	uncommon
Yellow-billed Cuckoo	*Coccyzus americanus*	rare

Total Species List Changes

Table 4. This table depicts the species recorded by the Champlain Society with their relative abundance (r.a.) status from the 1880s contrasted with today's. Data collected on Mount Desert Island, Maine, USA, and provided by eBird and iNaturalist.

Common name	Scientific name	r. a. 1880s	r. a. modern
Alder Flycatcher	*Empidonax alnorum*	common	common
American Bittern	*Botaurus lentiginosus*	rare	uncommon
American Black Duck	*Anas rubripes*	common	common
American Crow	*Corvus brachyrhynchos*	common	common
American Goldfinch	*Spinus tristis*	common	common
American Redstart	*Setophaga ruticilla*	common	common
American Robin	*Turdus migratorius*	common	common
American Woodcock	*Scolopax minor*	common	rare
Bald Eagle	*Haliaeetus leucocephalus*	common	common
Bank Swallow	*Riparia riparia*	common	rare
Barn Swallow	*Hirundo rustica*	common	common
Barred Owl	*Strix varia*	uncommon	common
Bay-breasted Warbler	*Setophaga castanea*	common	uncommon
Belted Kingfisher	*Megaceryle alcyon*	common	common
Black Guillemot	*Cepphus grylle*	common	common
Black Scoter	*Melanitta americana*	rare	uncommon
Black-and-white Warbler	*Mniotilta varia*	common	common
Black-billed Cuckoo	*Coccyzus erythropthalmus*	common	rare
Black-capped Chickadee	*Poecile atricapillus*	common	common
Black-crowned Night-Heron	*Nycticorax nycticorax*	common	very rare
Black-legged Kittiwake	*Rissa tridactyla*	uncommon	very rare
Black-throated Blue Warbler	*Setophaga caerulescens*	very rare	common
Black-throated Green Warbler	*Setophaga virens*	common	common
Blackburnian Warbler	*Setophaga fusca*	common	common
Blue Jay	*Cyanocitta cristata*	rare	common
Blue-headed Vireo	*Vireo solitarius*	common	common
Bobolink	*Dolichonyx oryzivorus*	uncommon	uncommon
Bonaparte's Gull	*Chroicocephalus philadelphia*	uncommon	common
Boreal Chickadee	*Poecile hudsonicus*	rare	very rare
Broad-winged Hawk	*Buteo platypterus*	common	common

Table 4, *continued*

Common name	Scientific name	r. a. 1880s	r. a. modern
Brown Creeper	*Certhia americana*	rare	common
Canada Warbler	*Cardellina canadensis*	common	rare
Cedar Waxwing	*Bombycilla cedrorum*	common	common
Chestnut-sided Warbler	*Setophaga pensylvanica*	common	common
Chimney Swift	*Chaetura pelagica*	common	rare
Chipping Sparrow	*Spizella passerina*	common	common
Common Loon	*Gavia immer*	uncommon	common
Common Nighthawk	*Chordeiles minor*	common	common
Common Tern	*Sterna hirundo*	common	common
Common Yellowthroat	*Geothlypis trichas*	common	common
Dark-eyed Junco	*Junco hyemalis*	common	common
Downy Woodpecker	*Dryobates pubescens*	common	common
Eastern Bluebird	*Sialia sialis*	very rare	uncommon
Eastern Kingbird	*Tyrannus tyrannus*	uncommon	rare
Eastern Phoebe	*Sayornis phoebe*	rare	common
Golden-crowned Kinglet	*Regulus satrapa*	common	common
Great Blue Heron	*Ardea herodias*	common	common
Greater Yellowlegs	*Tringa melanoleuca*	uncommon	common
Hairy Woodpecker	*Dryobates villosus*	common	common
Hermit Thrush	*Catharus guttatus*	common	common
Herring Gull	*Larus argentatus*	common	common
Indigo Bunting	*Passerina cyanea*	rare	very rare
Leach's Storm-Petrel	*Hydrobates leucorhous*	rare	rare
Least Sandpiper	*Calidris minutilla*	common	common
Lesser Yellowlegs	*Tringa flavipes*	uncommon	common
Long-tailed Duck	*Clangula hyemalis*	very rare	very rare
Magnolia Warbler	*Setophaga magnolia*	common	common
Nashville Warbler	*Leiothlypis ruficapilla*	common	uncommon
Northern Flicker	*Colaptes auratus*	common	common
Northern Harrier	*Circus hudsonius*	rare	uncommon
Northern Parula	*Setophaga americana*	common	common
Northern Waterthrush	*Parkesia noveboracensis*	rare	rare
Osprey	*Pandion haliaetus*	common	common
Ovenbird	*Seiurus aurocapilla*	common	common
Pectoral Sandpiper	*Calidris melanotos*	very rare	very rare
Pied-billed Grebe	*Podilymbus podiceps*	rare	very rare
Pine Siskin	*Spinus pinus*	common	rare
Purple Finch	*Haemorhous purpureus*	common	common
Red Crossbill	*Loxia curvirostra*	rare	common
Red-breasted Nuthatch	*Sitta canadensis*	common	common
Red-eyed Vireo	*Vireo olivaceus*	common	common
Red-tailed Hawk	*Buteo jamaicensis*	very rare	uncommon

Table 4, *continued*

Common name	Scientific name	r. a. 1880s	r. a. modern
Red-winged Blackbird	*Agelaius phoeniceus*	uncommon	common
Ring-necked Duck	*Aythya collaris*	rare	very rare
Ruby-throated Hummingbird	*Archilochus colubris*	common	common
Ruddy Turnstone	*Arenaria interpres*	uncommon	rare
Ruffed Grouse	*Bonasa umbellus*	common	rare
Savannah Sparrow	*Passerculus sandwichensis*	common	common
Semipalmated Sandpiper	*Calidris pusilla*	common	common
Sharp-shinned Hawk	*Accipiter striatus*	uncommon	common
Short-billed Dowitcher	*Limnodromus griseus*	uncommon	rare
Solitary Sandpiper	*Tringa solitaria*	rare	common
Song Sparrow	*Melospiza melodia*	common	common
Spotted Sandpiper	*Actitis macularius*	common	common
Swainson's Thrush	*Catharus ustulatus*	common	common
Tree Swallow	*Tachycineta bicolor*	common	common
Vesper Sparrow	*Pooecetes gramineus*	rare	rare
White-throated Sparrow	*Zonotrichia albicollis*	common	common
White-winged Crossbill	*Loxia leucoptera*	rare	uncommon
Wilson's Warbler	*Cardellina pusilla*	rare	rare
Winter Wren	*Troglodytes hiemalis*	common	common
Yellow Warbler	*Setophaga petechia*	common	common
Yellow-bellied Flycatcher	*Empidonax flaviventris*	common	rare
Yellow-rumped Warbler	*Setophaga coronata*	common	common
Eastern Whip-poor-will	*Antrostomus vociferus*	rare	very rare
Passenger Pigeon	*Ectopistes migratorius*	rare	extinct
Cliff Swallow	*Petrochelidon pyrrhonota*	common	very rare
Purple Martin	*Progne subis*	rare	very rare

Conclusion and Next Steps

Of the species recorded by the Champlain Society that have increased in relative abundance, most can be explained by human-caused changes to the landscape. For example, human urbanization of natural landscapes is proposed to be the main reason for Blue Jay range expansion (Smith et al. 2020). Similar reasoning can be attributed to the observed Eastern Phoebe increase. The increase in infrastructure such as bridges and buildings has been linked to the range expansion of this species (Weeks Jr. 2020). Another cause for some of these species' local increases can be associated with European colonization and settlement. Black-throated Blue Warbler was likely driven off MDI due to the extensive logging and associated changes to the forest leaving MDI with little appropriate habitat (Irland 1982). In more recent times forested ecosystems have regenerated allowing for Black-throated Blue Warbler to return to the region (Holmes et al. 2020).

The Landscape of Change partners intended to compare past and present observations by mapping them. We realized, however, that this would be an improper representation of our findings because of differences in collection and reporting methods for the historical and contemporary data. The historical dataset used in this analysis consisted of collected specimens or personal observations compiled into a species list with notes on each species including details of abundance. The historical data, in contrast to today, do not include every location where a species was found. So, if we mapped even a very common species, the historical data would only have a few points on the map, and the modern data would have numerous points. For this reason, we chose not to represent these data by mapping them, as we felt it would not properly show the trends in *abundance*. There remains opportunity to more closely examine changes in species *distribution* across Mount Desert Island, and we hope that the efforts continuing as part of Landscape of Change address this question.

Similar changes in the landscape might explain those species that have decreased in relative abundance. For example, the American Woodcock has decreased due to the transition of farmlands to forest (McAuley 2020), while the Black-crowned Night-Heron decrease has been attributed to the loss of wetland habitats (Hothem et al. 2020). Additionally, species that breed in boreal landscapes such as Pine Siskin and Yellow-bellied Flycatcher show local declines due to boreal habitats disappearing from climate warming, habitat degradation, and logging (Price et al. 2013).

We also wanted to look more closely at the species present on MDI today, but not recorded historically by the Champlain Society's efforts. These species may have ranges that expanded due to human-caused changes on the landscape, shifted north due to climate change, or changed due to other factors. This trend of climate changes and human manipulation of the landscape have had dramatic effects on the birds of MDI, but the effects are often species-specific and highly variable. Future research to explain the changes could incorporate additional data sets, such as the Audubon Christmas Bird Count and Maine Breeding Bird Atlas, as well as analyze changes in Mount Desert Island habitat types and land cover.

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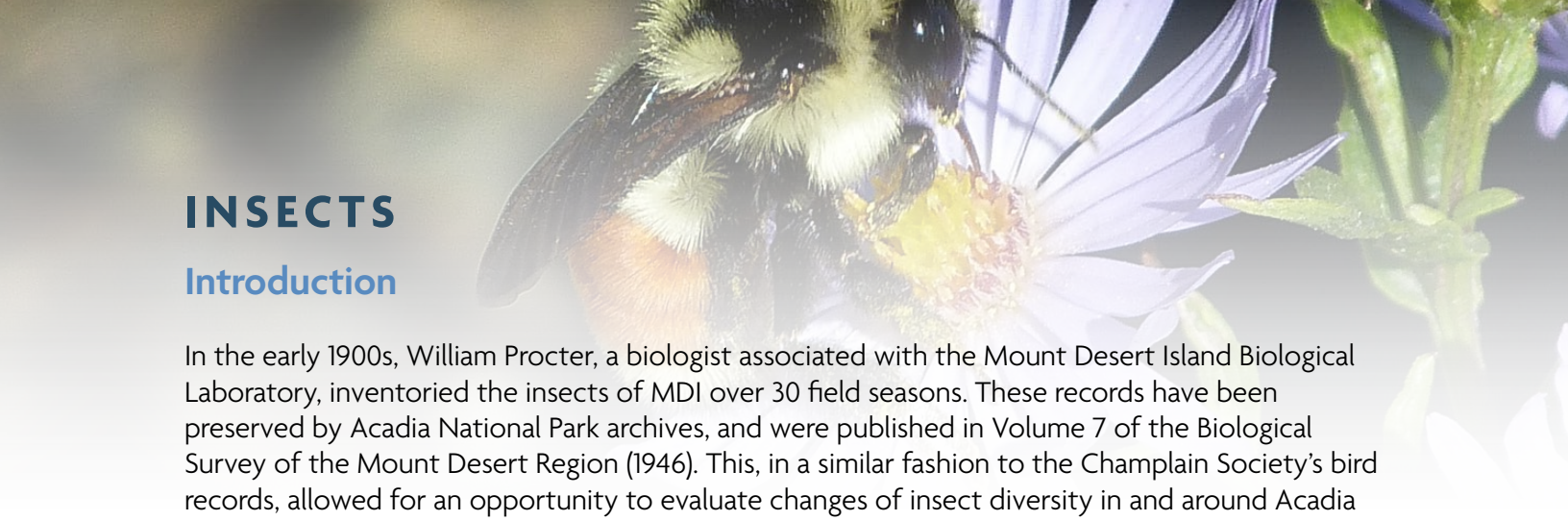

INSECTS

Introduction

In the early 1900s, William Procter, a biologist associated with the Mount Desert Island Biological Laboratory, inventoried the insects of MDI over 30 field seasons. These records have been preserved by Acadia National Park archives, and were published in Volume 7 of the Biological Survey of the Mount Desert Region (1946). This, in a similar fashion to the Champlain Society's bird records, allowed for an opportunity to evaluate changes of insect diversity in and around Acadia National Park.

We focused on two groups of insects that are generally known as pollinators: Butterflies and Moths (order Lepidoptera), and Bees (family Apidae). Pollination is a critical ecosystem service performed by animals that 75% of the world's plants rely on to reproduce (Natural Resource Council, 2007). This includes fruits, vegetables, and other plants that we rely upon for food, drugs, and oxygen (USDA 2021). However, pollinating insects are facing many threats such as parasites, pathogens, pesticides, and environmental stressors (USDA 2021).

This study's objective was to examine how the local Lepidoptera and Apidae insects have changed between the early 1900s and present day. Our goals were to determine: 1) how effective were the Landscape of Change citizen science efforts at engaging the public to survey insects on MDI, 2) what species are no longer present that were recorded 100 years ago, and 3) what species are present today that were not recorded by Procter.

Methods

Landscape of Change focuses broadly on two groups of insects that include pollinating species: family Apidae and order Lepidoptera. While the Landscape of Change citizen science project took place in 2021, a broader effort to crowdsource biodiversity data of the Downeast and Acadia Region using iNaturalist has been ongoing since 2012. We compared the number of species on MDI identified to species by the iNaturalist community 2012 - 2021, and compared this to a historical collection of insects compiled by Procter in the early 1900s (1927 - 1950 with a few earlier records). We used only iNaturalist records that were identified to species and labeled as Research Grade (iNaturalist 2022). We then compared these two data sets to examine species not recorded 100 years ago, and specific changes in threatened or endangered species.

Acadia National Park has archives of all specimens collected in and around the park from historical times to the present day. This includes specimens from more intensive scientific surveys such as the Maine Bumble Bee Atlas, studies led by U.S. Geological Survey, and professional-led bioblitzes (Chandler et al 2012, Schmitt 2020). We used this expanded dataset of bumble bees to get a better representation of insect changes in the region.

Results

Between Lepidoptera and Apidae, Procter collected 1,360 species, while the iNaturalist community over the last 10 years identified 362 species. The iNaturalist community identified 20% (n = 274) of the 1,360 species that Procter documented in the 1900s. This means there were 88 species

identified by the iNaturalist community that were not recorded by Procter's efforts, and were likely not present in the early 1900s (Table 1). For a full look at the species diversity between all families, see Figure 1.

We examined the bumble bees (Bombus spp.) to represent a group of pollinating insects. There were 10 species recorded by Procter, and 9 species recorded today on MDI. However, there are only six species in common between historical and contemporary times. Procter identified four species that are no longer present on MDI: three of which are cuckoo-bumble bees, and the other is the Rusty-patched Bumble Bee (Table 2). Additionally, three species documented recently were not collected by Procter: Brown-belted Bumble Bee, Common Eastern Bumble Bee, and Sanderson's Bumble Bee (Table 2).

Threatened and endangered species were another category we wanted to explore the status of on MDI. There were two species listed as either state or federally threatened or endangered and recorded in the dataset. Both species were found by Procter but were not observed recently. Procter collected specimens of a Maine endangered species known as the Edwards' Hairstreak *(Satyrium edwardsii)* (MDIFW 2003). Today, this species is rarely found at three sites throughout the entire state of Maine. Another species, the federally endangered Rusty-patched Bumble Bee *(Bombus affinis)*, has experienced a similar fate as the Edwards' Hairstreak. This species was collected by Procter in the early 1900s, and was once widespread across most of the eastern United States (U.S. Fish & Wildlife Service 2021). The Rusty-patched Bumble Bee has experienced large-scale range reductions and can no longer be found in most of the northeastern U.S.

Modern Species not Recorded by Procter

Table 1. This table shows the 88 species that the iNaturalist community identified over the past 10 years that were not recorded by Procter in the 1900s. Data collected on Mount Desert Island, Maine, USA, and provided by iNaturalist and the National Park Service.

Order	Super family	Family	Scientific name	Common name
Hymenoptera	Apoidea	Apidae	*Bombus griseocollis*	Brown-belted Bumble Bee
Hymenoptera	Apoidea	Apidae	*Bombus impatiens*	Common Eastern Bumble Bee
Hymenoptera	Apoidea	Apidae	*Xylocopa virginica*	Eastern Carpenter Bee
Lepidoptera	Bombycoidea	Saturniidae	*Callosamia promethea*	Promethea Silkmoth
Lepidoptera	Bombycoidea	Sphingidae	*Hemaris aethra*	Diervilla Clearwing
Lepidoptera	Bombycoidea	Sphingidae	*Manduca sexta*	Carolina Sphinx
Lepidoptera	Gelechioidea	Gelechiidae	*Arogalea cristifasciella*	White Stripe-backed Moth
Lepidoptera	Gelechioidea	Autostichidae	*Gerdana caritella*	
Lepidoptera	Gelechioidea	Gelechiidae	*Scrobipalpula manierreorum*	
Lepidoptera	Geometroidea	Geometridae	*Idaea dimidiata*	Single-dotted Wave
Lepidoptera	Geometroidea	Geometridae	*Macaria aemulataria*	Common Angle
Lepidoptera	Geometroidea	Geometridae	*Macaria pustularia*	Lesser Maple Spanworm Moth
Lepidoptera	Geometroidea	Geometridae	*Nematocampa resistaria*	Horned Spanworm Moth

Table 1, *continued*

Order	Super family	Family	Scientific name	Common name
Lepidoptera	Geometroidea	Geometridae	*Rheumaptera prunivorata*	Cherry Scallop Shell Moth
Lepidoptera	Geometroidea	Geometridae	*Xanthotype*	Crocus Geometer Moths
Lepidoptera	Hepialoidea	Hepialidae	*Sthenopis pretiosus*	Gold-spotted Ghost Moth
Lepidoptera	Noctuoidea	Noctuidae	*Acronicta fallax*	Green Marvel
Lepidoptera	Noctuoidea	Noctuidae	*Acronicta funeralis*	Funerary Dagger
Lepidoptera	Noctuoidea	Noctuidae	*Acronicta insita*	Large Gray Dagger
Lepidoptera	Noctuoidea	Noctuidae	*Acronicta oblinita*	Smeared Dagger
Lepidoptera	Noctuoidea	Erebidae	*Apantesis figurata*	Figured Tiger Moth
Lepidoptera	Noctuoidea	Erebidae	*Apantesis virgo*	Virgin Tiger Moth
Lepidoptera	Noctuoidea	Erebidae	*Arctia parthenos*	St. Lawrence Tiger Moth
Lepidoptera	Noctuoidea	Nolidae	*Baileya doubledayi*	Doubleday's Baileya Moth
Lepidoptera	Noctuoidea	Noctuidae	*Bellura obliqua*	Cattail Borer Moth
Lepidoptera	Noctuoidea	Noctuidae	*Calophasia lunula*	Toadflax Brocade Moth
Lepidoptera	Noctuoidea	Erebidae	*Chytolita morbidalis*	Morbid Owlet
Lepidoptera	Noctuoidea	Erebidae	*Cycnia tenera*	Delicate Cycnia Moth
Lepidoptera	Noctuoidea	Notodontidae	*Datana contracta*	Contracted Datana Moth
Lepidoptera	Noctuoidea	Erebidae	*Doryodes spadaria*	Dull Doryodes Moth
Lepidoptera	Noctuoidea	Noctuidae	*Elaphria alapallida*	Pale-winged Midget
Lepidoptera	Noctuoidea	Erebidae	*Euchaetes egle*	Milkweed Tussock Moth
Lepidoptera	Noctuoidea	Noctuidae	*Eudryas grata*	Beautiful Wood-nymph
Lepidoptera	Noctuoidea	Noctuidae	*Eupsilia vinulenta*	Straight-toothed Sallow
Lepidoptera	Noctuoidea	Noctuidae	*Feltia herilis*	Master's Dart
Lepidoptera	Noctuoidea	Erebidae	*Haploa clymene*	Clymene Moth
Lepidoptera	Noctuoidea	Erebidae	*Hypena manalis*	Flowing-line Snout
Lepidoptera	Noctuoidea	Noctuidae	*Lithophane baileyi*	Bailey's Pinion Moth
Lepidoptera	Noctuoidea	Erebidae	*Lophocampa caryae*	Hickory Tussock Moth
Lepidoptera	Noctuoidea	Noctuidae	*Maliattha synochitis*	Black-dotted Glyph
Lepidoptera	Noctuoidea	Erebidae	*Mycterophora inexplicata*	Pale-edged Snout Moth
Lepidoptera	Noctuoidea	Noctuidae	*Neoligia exhausta*	Exhausted Brocade
Lepidoptera	Noctuoidea	Noctuidae	*Noctua pronuba*	Large Yellow Underwing
Lepidoptera	Noctuoidea	Noctuidae	*Oligia strigilis*	Marbled Minor
Lepidoptera	Noctuoidea	Erebidae	*Panopoda rufimargo*	Red-lined Panopoda Moth
Lepidoptera	Noctuoidea	Noctuidae	*Psectraglaea carnosa*	Pink Sallow
Lepidoptera	Noctuoidea	Erebidae	*Zanclognatha laevigata*	Variable Fan-foot
Lepidoptera	Papilionoidea	Hesperiidae	*Anatrytone logan*	Delaware Skipper
Lepidoptera	Papilionoidea	Hesperiidae	*Carterocephalus mandan*	Arctic Skipper
Lepidoptera	Papilionoidea	Lycaenidae	*Celastrina lucia*	Northern Azure
Lepidoptera	Papilionoidea	Nymphalidae	*Coenonympha california*	Common Ringlet
Lepidoptera	Papilionoidea	Hesperiidae	*Epargyreus clarus*	Silver-spotted Skipper
Lepidoptera	Papilionoidea	Hesperiidae	*Erynnis juvenalis*	Juvenal's Duskywing
Lepidoptera	Papilionoidea	Lycaenidae	*Glaucopsyche lygdamus*	Silvery Blue

Table 1, *continued*

Order	Super family	Family	Scientific name	Common name
Lepidoptera	Papilionoidea	Nymphalidae	*Lethe anthedon*	Northern Pearly-eye
Lepidoptera	Papilionoidea	Nymphalidae	*Lethe appalachia*	Appalachian Brown
Lepidoptera	Papilionoidea	Nymphalidae	*Limenitis arthemis arthemis*	American White Admiral
Lepidoptera	Papilionoidea	Hesperiidae	*Lon hobomok*	Hobomok Skipper
Lepidoptera	Papilionoidea	Lycaenidae	*Lycaena phlaeas hypophlaeas*	Eastern American Copper
Lepidoptera	Papilionoidea	Nymphalidae	*Megisto cymela*	Little Wood Satyr
Lepidoptera	Papilionoidea	Nymphalidae	*Nymphalis l-album*	Compton Tortoiseshell
Lepidoptera	Papilionoidea	Papilionidae	*Papilio canadensis*	Canadian Tiger Swallowtail
Lepidoptera	Papilionoidea	Papilionidae	*Papilio polyxenes*	Black Swallowtail
Lepidoptera	Papilionoidea	Nymphalidae	*Phyciodes cocyta*	Northern Crescent
Lepidoptera	Papilionoidea	Lycaenidae	*Satyrium liparops*	Striped Hairstreak
Lepidoptera	Papilionoidea	Nymphalidae	*Speyeria cybele*	Great Spangled Fritillary
Lepidoptera	Papilionoidea	Hesperiidae	*Thymelicus lineola*	Essex Skipper
Lepidoptera	Pterophoroidea	Pterophoridae	*Geina buscki*	Buck's Plume Moth
Lepidoptera	Pyraloidea	Crambidae	*Anania hortulata*	Small Magpie
Lepidoptera	Pyraloidea	Crambidae	*Donacaula longirostrallus*	Long-beaked Donacaula Moth
Lepidoptera	Pyraloidea	Crambidae	*Eoparargyractis plevie*	
Lepidoptera	Pyraloidea	Pyralidae	*Hypsopygia olinalis*	Yellow-fringed Dolichomia Moth
Lepidoptera	Pyraloidea	Crambidae	*Microcrambus biguttellus*	Gold-striped Grass-veneer
Lepidoptera	Pyraloidea	Pyralidae	*Pococera expandens*	Striped Oak Webworm Moth
Lepidoptera	Pyraloidea	Crambidae	*Scoparia biplagialis*	Double-striped Scoparia Moth
Lepidoptera	Pyraloidea	Crambidae	*Sitochroa palealis*	Carrot Seed Moth
Lepidoptera	Sphingoidea	Sphingidae	*Sphinx poecila*	Northern Apple Sphinx
Lepidoptera	Tortricoidea	Tortricidae	*Acleris forsskaleana*	Maple Leaftier Moth
Lepidoptera	Tortricoidea	Tortricidae	*Archips dissitana*	Boldly-marked Archips Moth
Lepidoptera	Tortricoidea	Tortricidae	*Cenopis reticulatana*	Reticulated Fruitworm Moth
Lepidoptera	Tortricoidea	Tortricidae	*Eucosma ochroterminana*	Buff-tipped Eucosma Moth
Lepidoptera	Tortricoidea	Tortricidae	*Eucosma parmatana*	Aster Eucosma Moth
Lepidoptera	Tortricoidea	Tortricidae	*Gymnandrosoma punctidiscanum*	Dotted Gymnandrosoma Moth
Lepidoptera	Tortricoidea	Tortricidae	*Pelochrista derelicta*	Derelict Pelochrista Moth
Lepidoptera	Tortricoidea	Tortricidae	*Platynota exasperatana*	Exasperating Platynota Moth
Lepidoptera	Tortricoidea	Tortricidae	*Sparganothis tristriata*	Three-streaked Sparganothis Moth
Lepidoptera	Zygaenoidea	Limacodidae	*Apoda biguttata*	Shagreened Slug Moth
Lepidoptera	Zygaenoidea	Limacodidae	*Euclea delphinii*	Spiny Oak-slug Moth

Comparisons by Insect Families

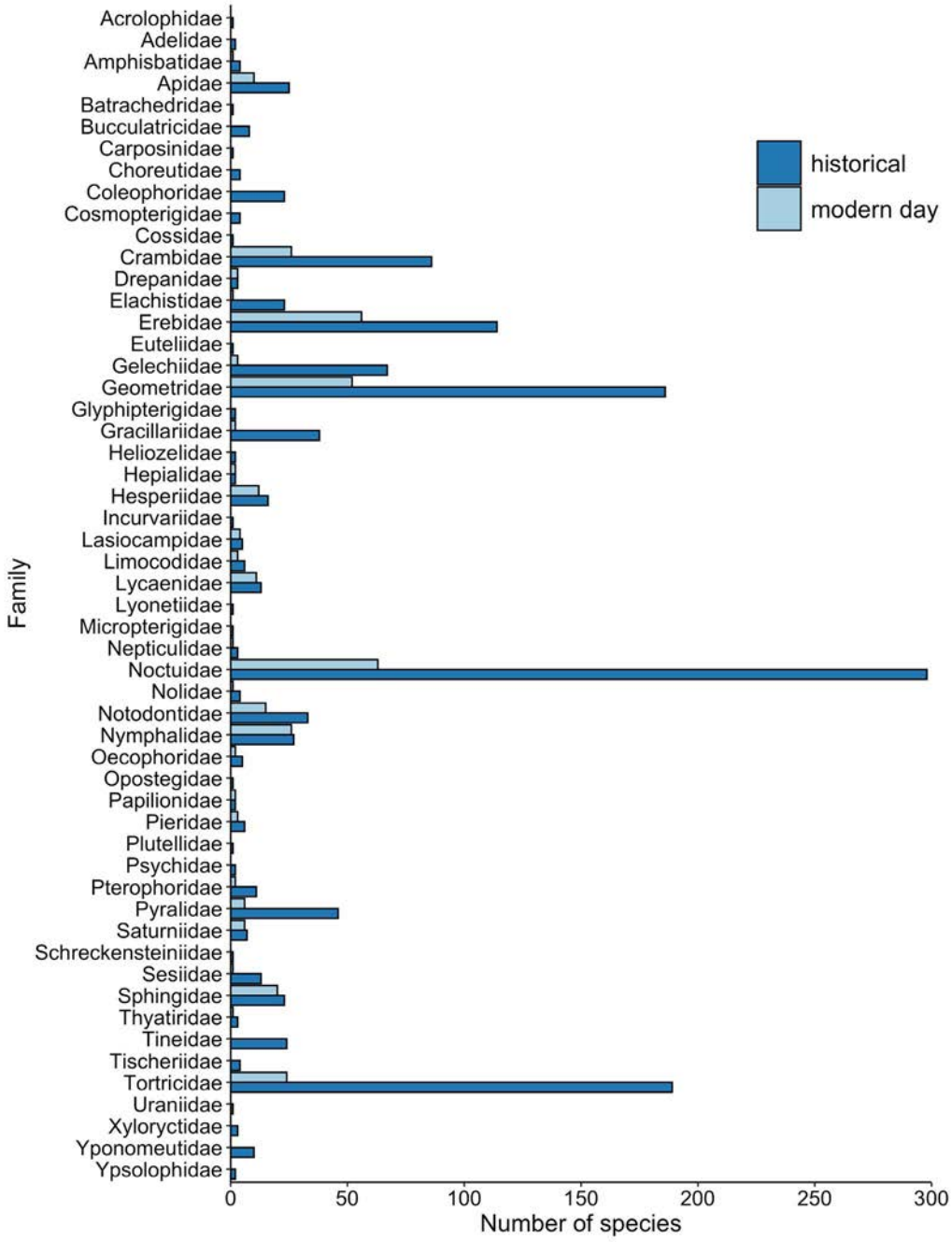

Figure 1. Comparison of the number of species by family from modern iNaturalist data and historical data collected by Procter in the 1900s. Data collected on Mount Desert Island, Maine, USA, and provided by iNaturalist and the National Park Service.

Pollinators: Bumble Bees

Table 2. This table shows just the bumble bee species that modern day sources (iNaturalist, Acadia National Park BioBlitz, and Maine Bumble Bee Atlas) and Procter identified, and when they were present on MDI. Data collected on Mount Desert Island, Maine, USA, and provided by iNaturalist and the National Park Service. Red shading indicates species no longer present; green shading indicates species "new" to MDI; yellow are those present during both sampling periods.

Common name	Scientific name	Present 1900?	Present modern?
Ashton's cuckoo bumble bee	*Bombus ashtoni*	yes	*no*
Brown-belted bumble bee	*Bombus griseocollis*	no	*yes*
Common eastern bumble bee	*Bombus impatiens*	no	*yes*
Confusing bumble bee	*Bombus perplexus*	yes	*yes*
Half-black bumble bee	*Bombus vagans*	yes	*yes*
Lemon cuckoo-bumble bee	*Bombus citrinus*	yes	*no*
Northern amber bumble bee	*Bombus borealis*	yes	*yes*
Rusty-patched bumble bee	*Bombus affinis*	yes	*no*
Sanderson's bumble bee	*Bombus sandersoni*	no	*yes*
Tri-colored bumble bee	*Bombus ternarius*	yes	*yes*
Two-spotted bumble bee	*Bombus bimaculatus*	yes	*yes*
Yellow-banded bumble bee	*Bombus terricola*	yes	*yes*
Yellowish cuckoo-bumble bee	*Bombus fervidus*	yes	*no*

Conclusions and Next Steps

The iNaturalist observers recorded dramatically fewer species than Procter, and much of this can be attributed to the difference in methods: Procter's intensive and long-term specimen collection method vs. the casual and minimally invasive photo documentation of iNaturalist. Based on this analysis, we cannot conclude that a species found by Procter but not recorded in iNaturalist is absent or decreasing. It is very likely, however, that species *not* found by Procter, but documented in iNaturalist, are new arrivals and/or have greatly increased in abundance since the early 1900s. It may be that closer examination of these species and the reasons for their range expansion might tell us something about the species we aren't finding.

The Landscape of Change partners intended to compare past and present observations by mapping them. We realized, however, that this would be an improper representation of our findings because of differences in collection and reporting methods for the historical and contemporary data. There were also differences in data collection effort. For example, the Lepidoptera bioblitzes consisted of just two weekends, compared to Procter's multi-year summer surveys across a larger area (D. Manski, personal communication).

The historical dataset used in this analysis consisted of collected specimens or personal observations compiled into a species list with notes on each species including details of abundance. Additionally, and in contrast to today, it did not include every location where a species was found. So, if we mapped even a very common species the historical data would only have a few points on the map, and the modern data would have numerous points. We chose not to represent these data by mapping them, as it would not properly show the trends in *abundance*. There remains

opportunity to more closely examine changes in species *distribution* across Mount Desert Island, and we hope that the efforts continuing as part of Landscape of Change address this question.

While iNaturalist's methods are much safer and less invasive, there are limitations as many insects can only be identified to species in the hand with equipment such as hand lenses or microscopes. That said, we would not have the modern data set for comparison without community efforts by citizen scientists. Continued careful and extensive photographic evidence collected via iNaturalist can be subsidized with intensive, scientist-led bioblitzes to get a better understanding of the insect populations of MDI.

The bumble bees are a great example of pollinators to look into due to many researchers and projects focused on this group. Of the four species that are no longer found on MDI, three are cuckoo-bumble bees, a group that invades other bumble bee colonies, kills the queen, and takes control of the workers. These species have been undergoing large-scale range reductions, and some of this can be attributed to their host species also decreasing (Colla et al. 2012). An example is the Ashton's Cuckoo-Bumble Bee. Its host, the Rusty-patched Bumble Bee, is now federally endangered because of its population loss (more on this species below). There were also three species of bumble bee that have become present on MDI since Procter was surveying the area. These three now occur here for various reasons. The Brown-belted Bumble Bee has been linked to human-developed land, increasing as planted meadows, roadsides, and urbanization have become more common (Novotny et al. 2021). Somewhat similarly, the Common Eastern Bumble Bee has shown impressive range expansion due to human introduction and commercialization of bumble bees (Palmier & Sheffield 2019). This species is also thought to be replacing species that have decreased due to landscape and climate change, such as the Rusty-patched Bumble Bee, due to its highly generalized habitat use (Palmier & Sheffield 2019). The Rusty-patched Bumble Bee has experienced large-scale range reductions, once having been present on MDI, but now not found anywhere in the state of Maine. This species requires grasslands and meadows, which have decreased in area in the Mount Desert Island region and Maine as a whole as forest cover has increased (U.S. Fish & Wildlife Service 2021).

In addition to the Rusty-patched Bumble Bee, there was one other species recorded that is currently listed as threatened or endangered. According to the MDIFW Endangered Species Program (2003), the Edward's Hairstreak has undergone a major range restriction and today has only been found at three sites in southwestern Maine. The extensive reduction in abundance of this species can largely be attributed to the loss of their native habitat, pitch pine-scrub oak barrens, which human activities have reduced to less than 50% of their historical range (MDIFW 2003).

As part of our analysis we resolved an issue with formatting of specimen dates in the Acadia National Park database, which means that Procter's collection can be incorporated into ongoing efforts by Maine Audubon in partnership with the Maine Department of Inland Fisheries and Wildlife and the Maine Entomological Society to document statewide insect population trends (Drummond 2022).

Future research could incorporate additional data sets, such as bioblitzes that were conducted from the early 2000s to 2016. The addition of these data will provide us with a more complete snapshot of what species are currently present on the island, and how we can make management recommendations to help the native insects of our region.

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Next Steps – 2022 and beyond

To understand changes and stability in island ecosystems and responses to climate change, development, conservation practices, and other factors, we have identified the need for more detailed studies in several theme areas that have both rich historical data and current scientific focus, including the birds and insects studied in 2021.

We are assembling teams of scientists, historians, students, and community volunteers to continue and expand assessments of historical and contemporary data for Mount Desert Island climate, birds, insects, marine life, and plants, beginning with birds. Using a multi-disciplinary approach, each team will:

- identify and compile data from historical resources
- summarize the strengths and gaps in contemporary data available for comparison
- develop plans for analyzing and sharing the findings of landscape change.

The first team, focused on birds and led by Seth Benz of Schoodic Institute, began work in March 2022.

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