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DRAFT
Supplemental Climate Information for Kouchibouguac National Park

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Contents

Preface

This is a supplement to the “Let’s Talks about Climate Change: Atlantic Region” (Parker, 2017) report and is intended to support climate change discussions at Kouchibouguac National Park.

Future climate projections are modelled with several different greenhouse gas concentration trajectories called **Representative Concentration Pathways (RCP)** (Vuuren *et al.*, 2011). RCPs describe possible climate futures and are named after respective radiative forcing values in the year 2100 relative to pre-industrial values (i.e., +2.6, +4.5 and +8.5 watts/m^2). **RCP 2.6** assumes we take action and greenhouse gas emissions peak in 2010-2020 and decline thereafter. **RCP 4.5** assumes emissions peak around 2040 and then decline. **RCP 8.5** assumes we take no action and emissions continue to rise “status quo” throughout the 21st century. We are currently tracking RCP 8.5.

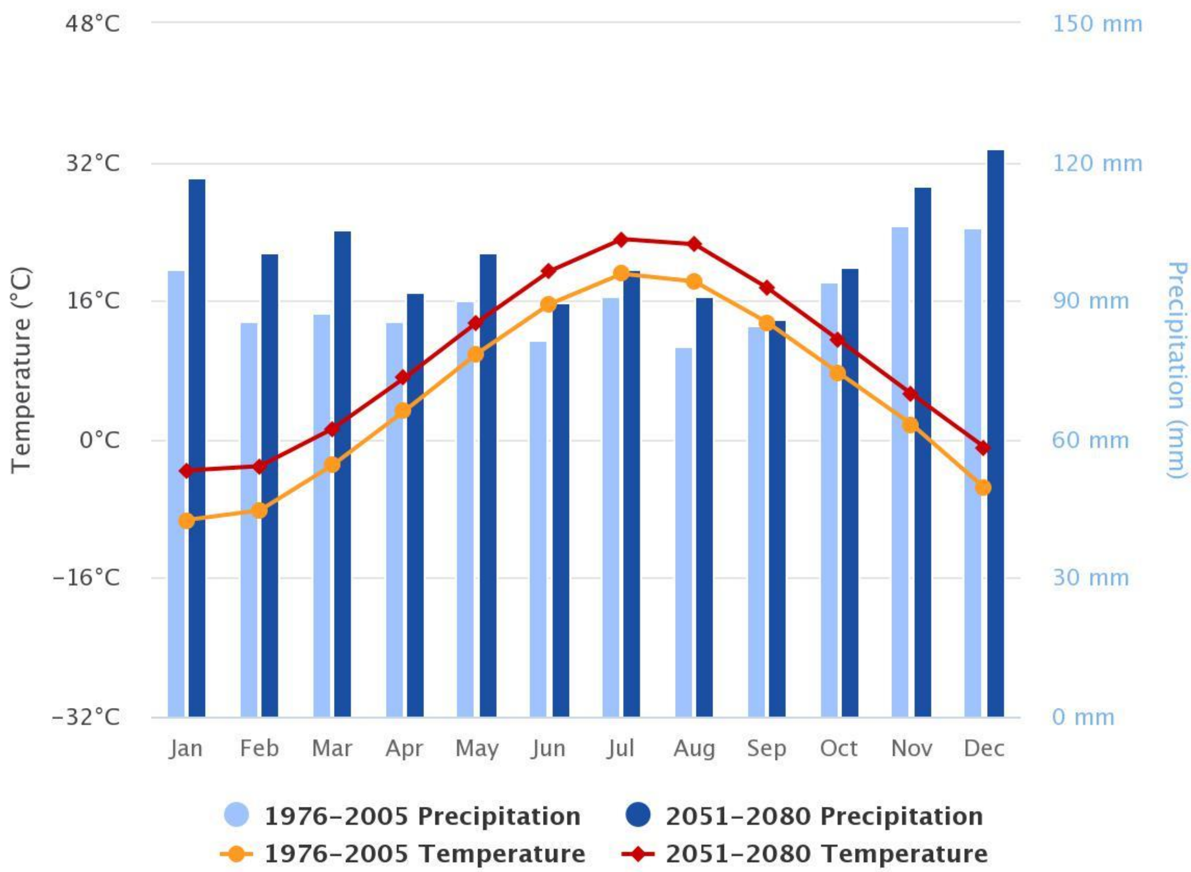
This is a site focussed document and to understand the larger climate change context please consult Canada’s changing climate assessment reports (e.g., Bush and Lemmen, 2019; Warren and Lemmen, 2014) and the Intergovernmental Panel on Climate Change assessment reports (e.g., IPCC, 2014). With respect to adaptation options, review Gross *et al.* (2016), Parker *et al.* (2018), or Rockman *et al.* (2016).

<u>Disclaimer</u>

Views, statements, findings and conclusions are solely those of the authors and do not necessarily reflect the views and policies of Parks Canada. Although the authors have made every effort to ensure that the information is accurate, complete and correct, neither Parks Canada nor the authors can guarantee its integrity. Readers are encouraged to verify with original sources.

Summary Climograph

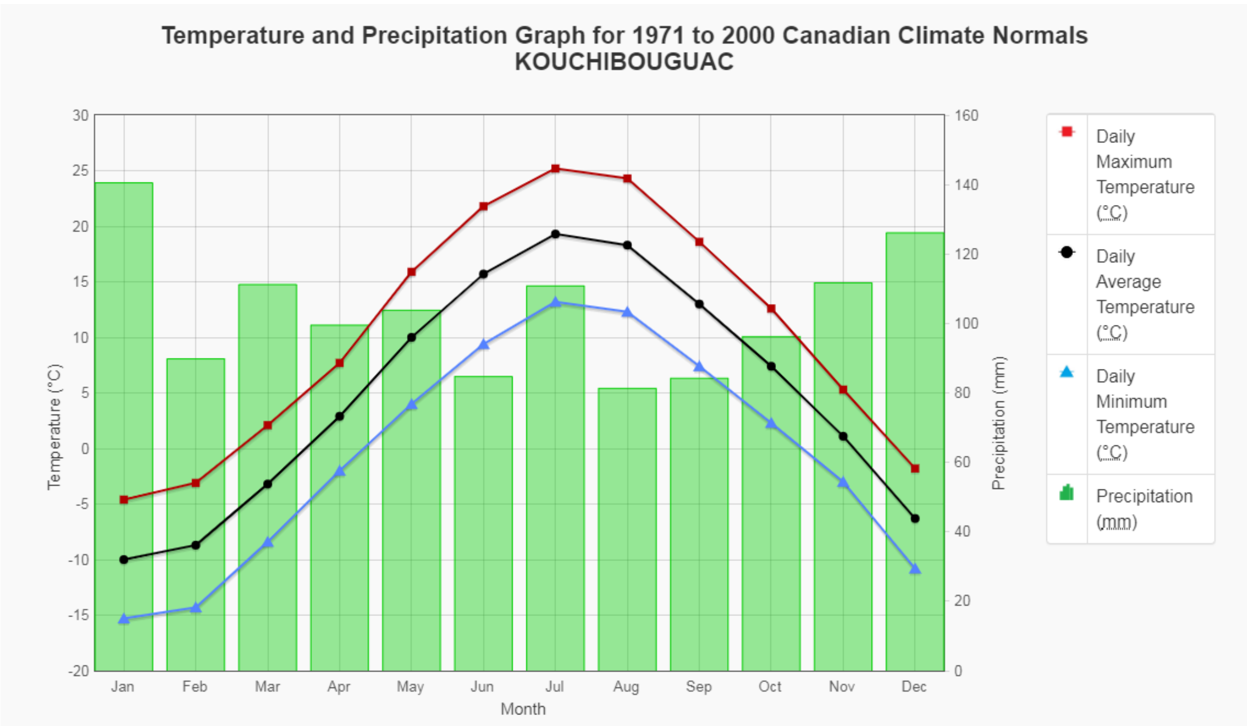
The climograph below illustrates average temperature and precipitation for both the baseline (1976-2005) and future (2051-2080) periods. In general, future temperatures are projected to be warmer and wetter for all months.



Climograph for the Moncton Region. Modelled monthly mean temperature and total precipitation for the 1976-2005 baseline and 2051-2080 future projection (RCP 8.5). Figure source: Climate Atlas of Canada (https://climateatlas.ca/).

1. Historic Climate

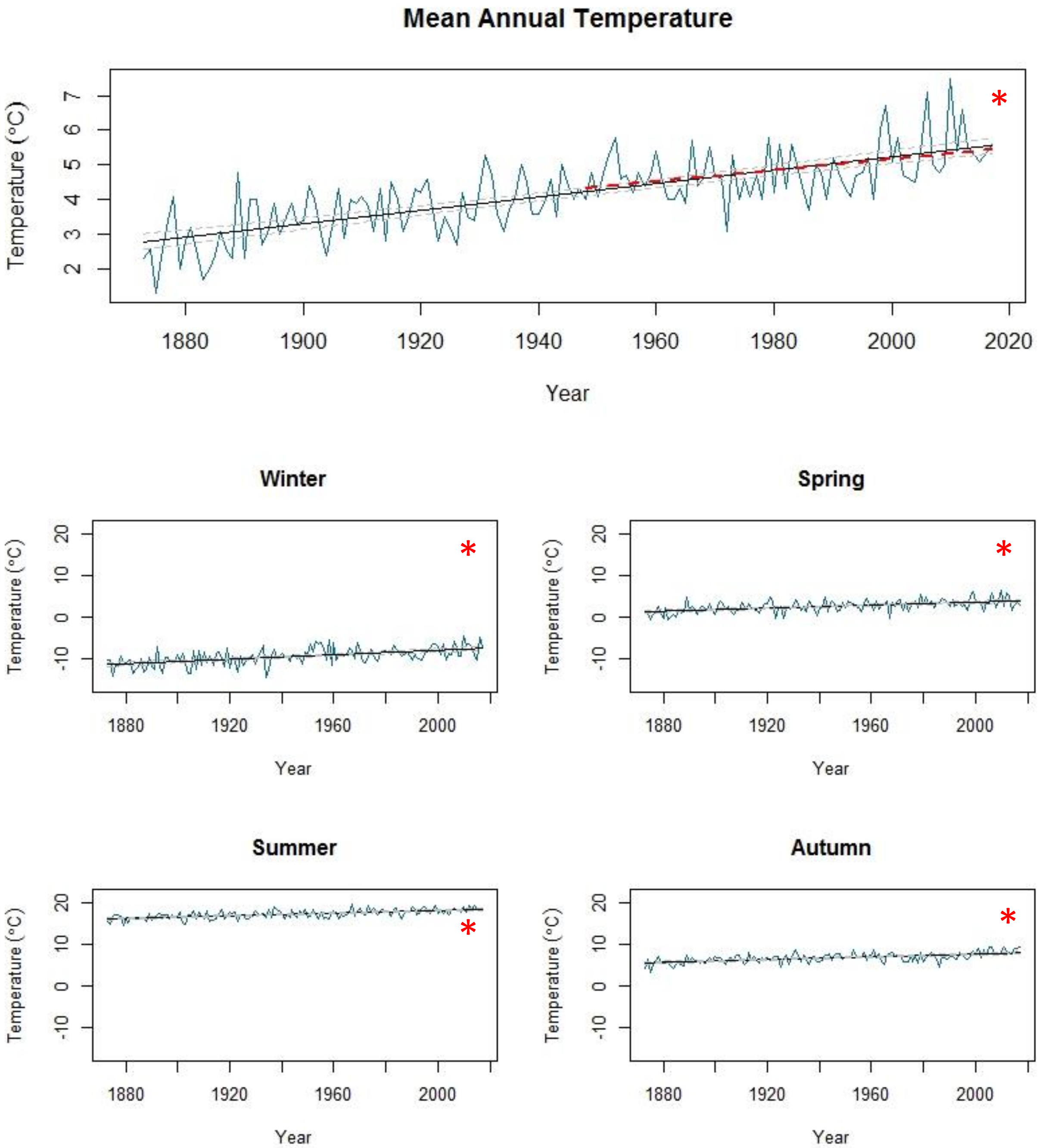
Climate normals (1971-2000) for the Kouchibouguac meteorological station (ID 8102325; 46°46'N, 65°00'W; 35.1m above sea level (asl); http://climate.weather.gc.ca/climate_normals/) report daily average temperatures from -10.0°C in January to 19.3°C in July, with an annual average of 5.0°C. January is reported as the wettest month and September the driest with an average of 140.5mm and 84.2mm of precipitation respectively and an annual total precipitation of 1239.9mm. Climate normals are also available for Rexton (ID 8104400; 46°40'N, 64°52'W; 4.6m asl). Of interest, using a 1961-1990 baseline the average daily temperature for this station is 4.9°C and total annual precipitation is 1102.6mm, while using a 1981-2010 baseline the average daily temperature increases to 5.6°C and total annual precipitation remains somewhat stable at 1103.9mm.



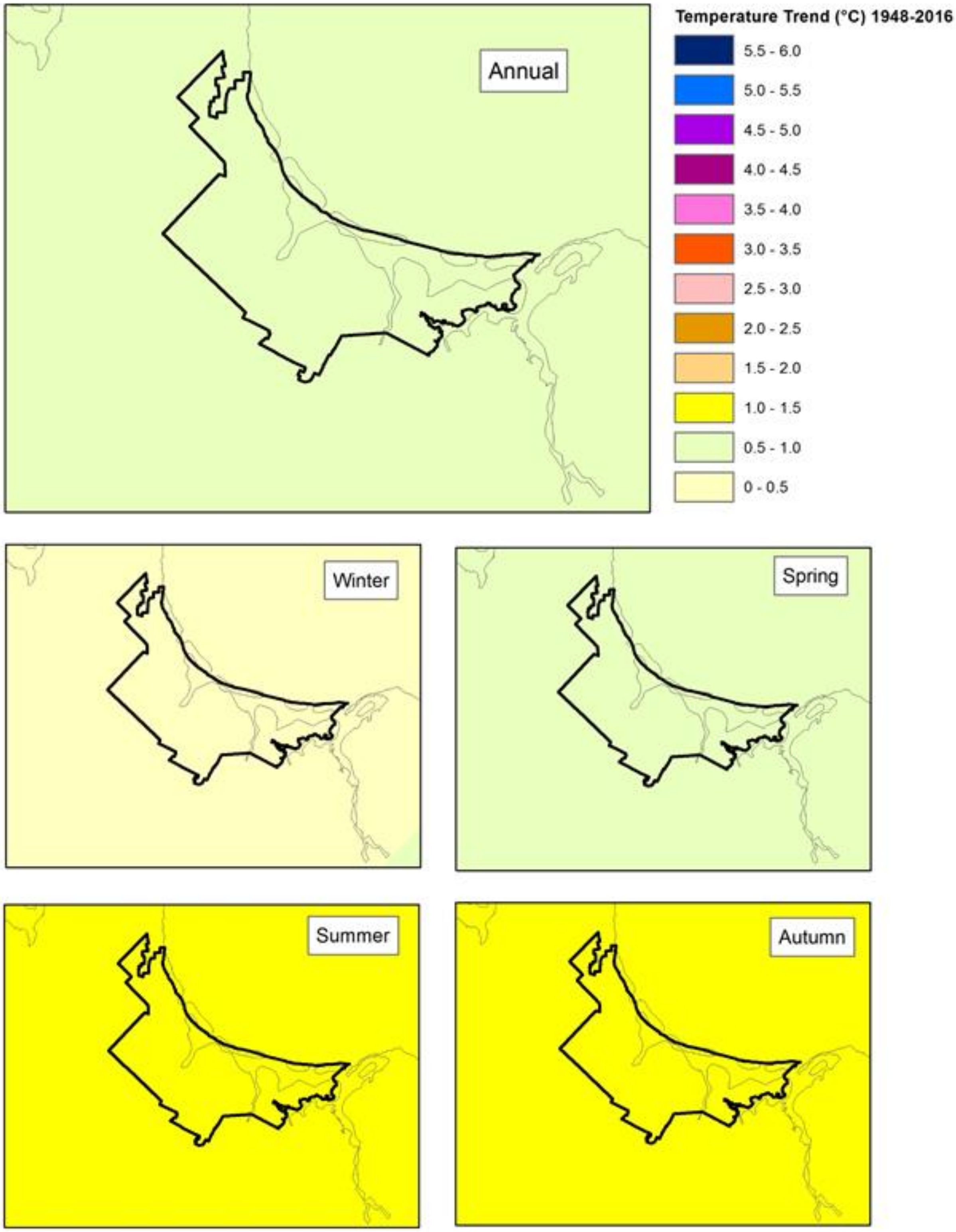
Climate normals (1971-2000) for Kouchibouguac (Station ID 8102325). Figure source: Environment and Climate Change Canada, http://climate.weather.gc.ca/climate_normals/.

1.1 Temperature

Chatham Miramichi (8100989) is the closest meteorological station with long-term temperature data (ECCC, 2017). Trends from 1873 to 2017 determined using a generalized linear model (R Core Team, 2017) including 95% confidence intervals. "*" = statistically significant trend ($P<0.05$). Red trend line in Annual plot for 1948 to 2017 period.



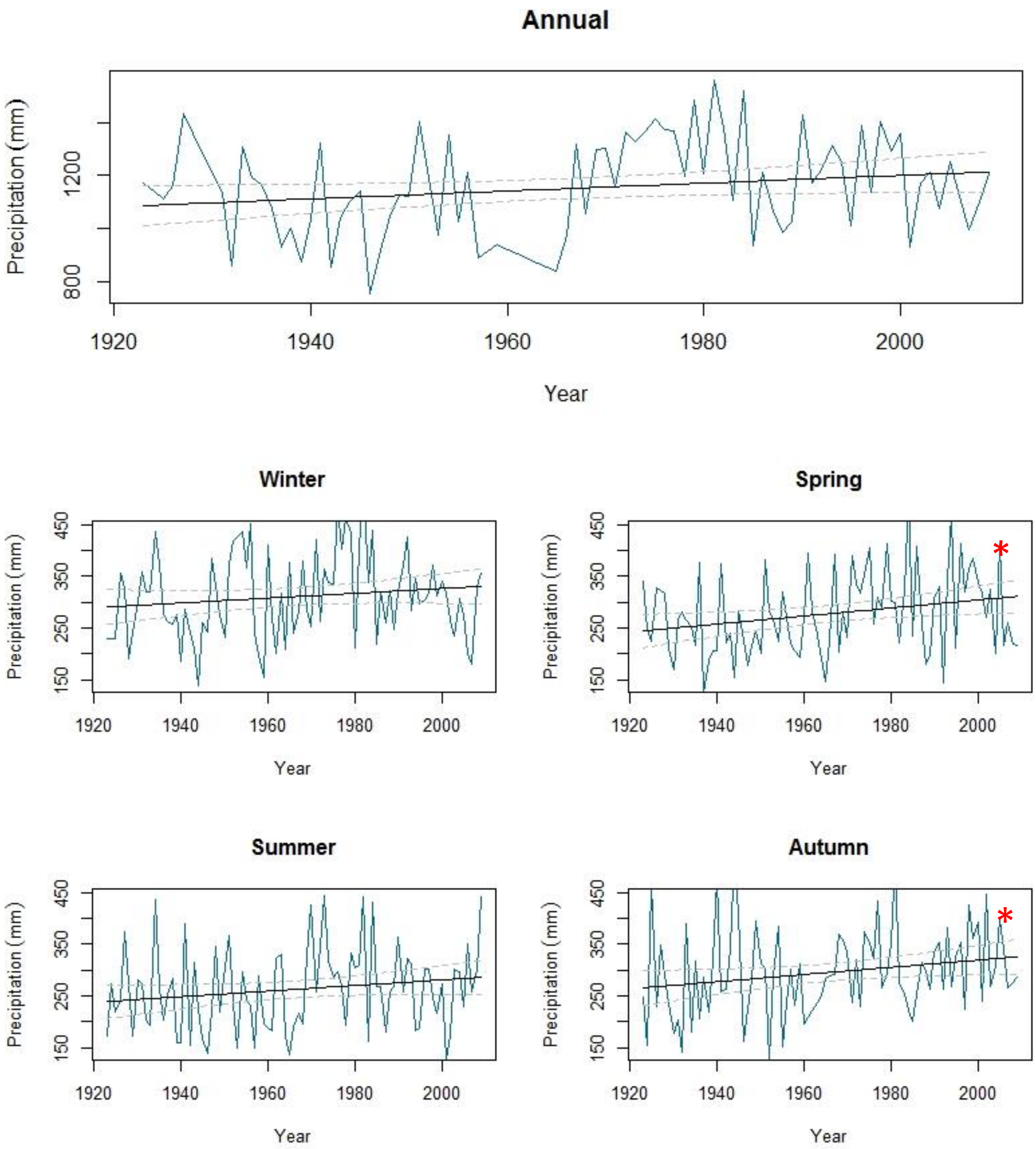
Chatham Miramichi mean annual and seasonal temperature. A statistically significant ($P<0.05$) increase observed in mean annual and seasonal temperatures. Mean annual temperature has increased by 2.8°C between 1873 and 2017. Of all the seasons, winter (Dec, Jan, Feb) temperature has increased the greatest, 3.9°C.



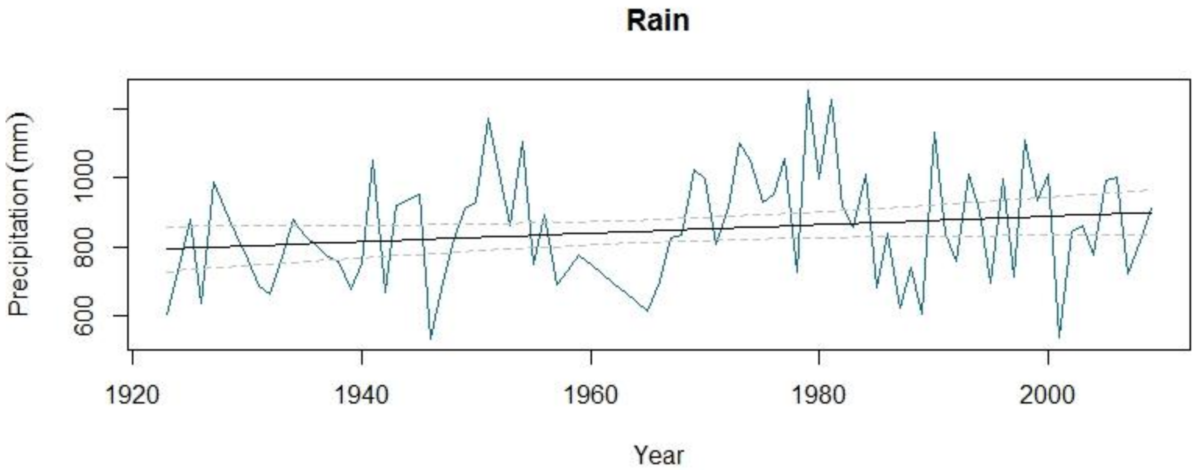
Change in mean annual and seasonal temperatures (˚C) for Kouchibouguac from 1948 to 2016. Canadian gridded data (CANGRD): https://climate-change.canada.ca/climate-data/#/historical-gridded-data.

1.2 Precipitation

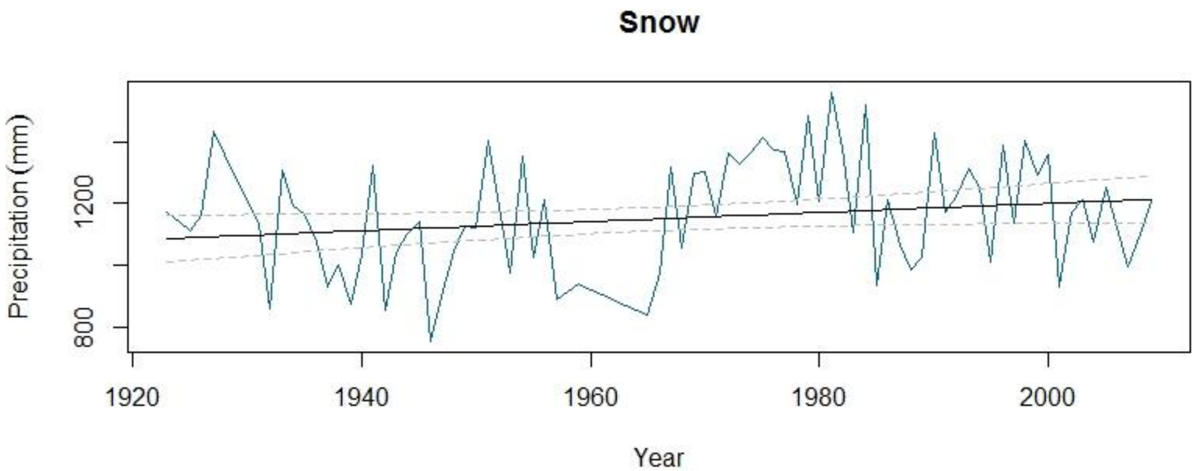
Rexton (810440) is the closest meteorological station with long-term precipitation data (ECCC, 2017). Trends from 1923 to 2009 determined using a generalized linear model (R Core Team, 2017) including 95% confidence intervals. "*" = statistically significant trend ($P<0.05$).



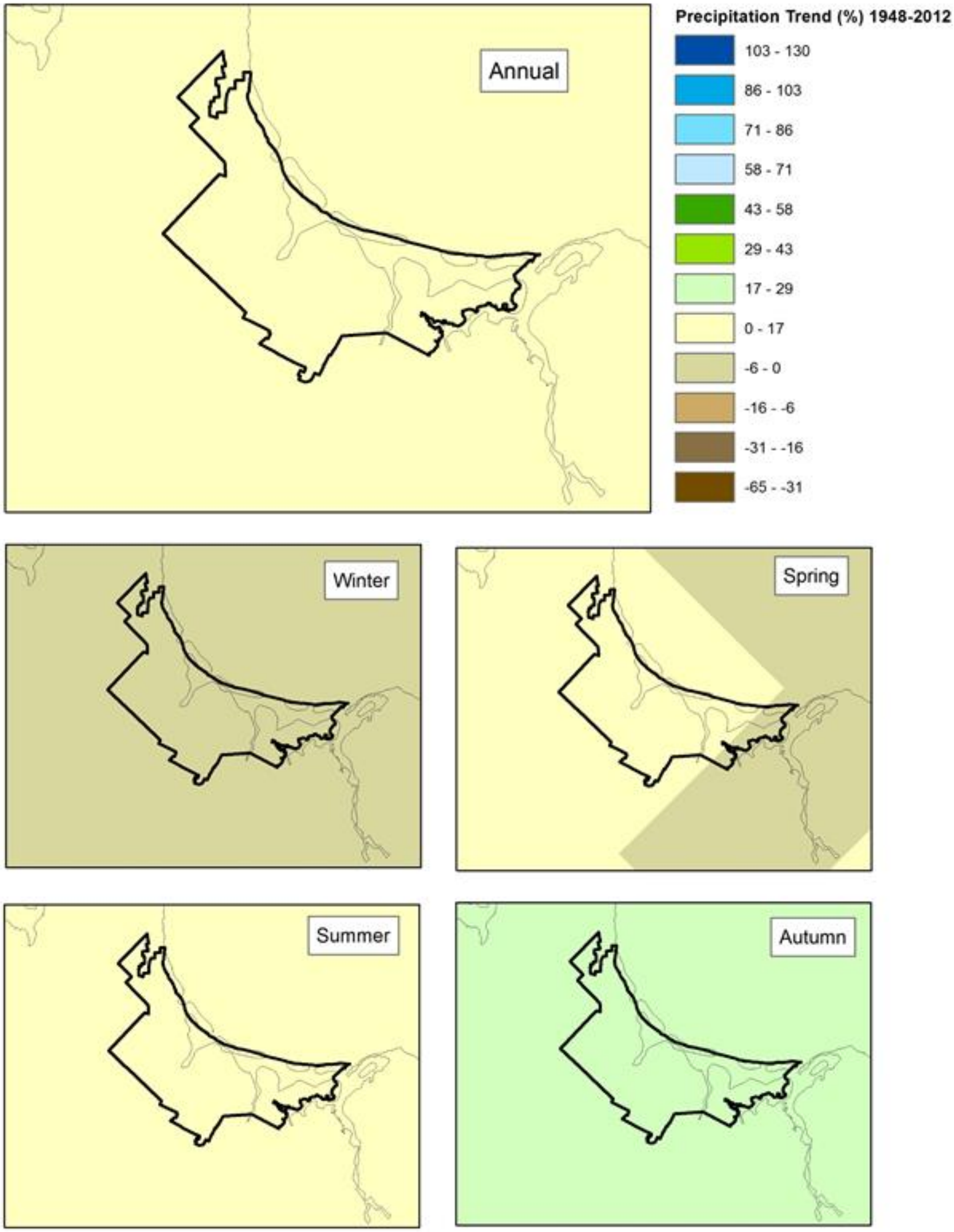
Rexton total annual and seasonal precipitation. While total annual and seasonal precipitation have all shown slight increasing trend, only Spring (Mar, Apr, May) and Autumn (Sep, Oct, Nov) demonstrated a statistically significant increase ($P<0.05$) from 1923 to 2009, +51mm (20%) and +45mm (16%) respectively.



Rexton annual rain did not demonstrate a statistically significant (P<0.05) trend between 1923 and 2009.



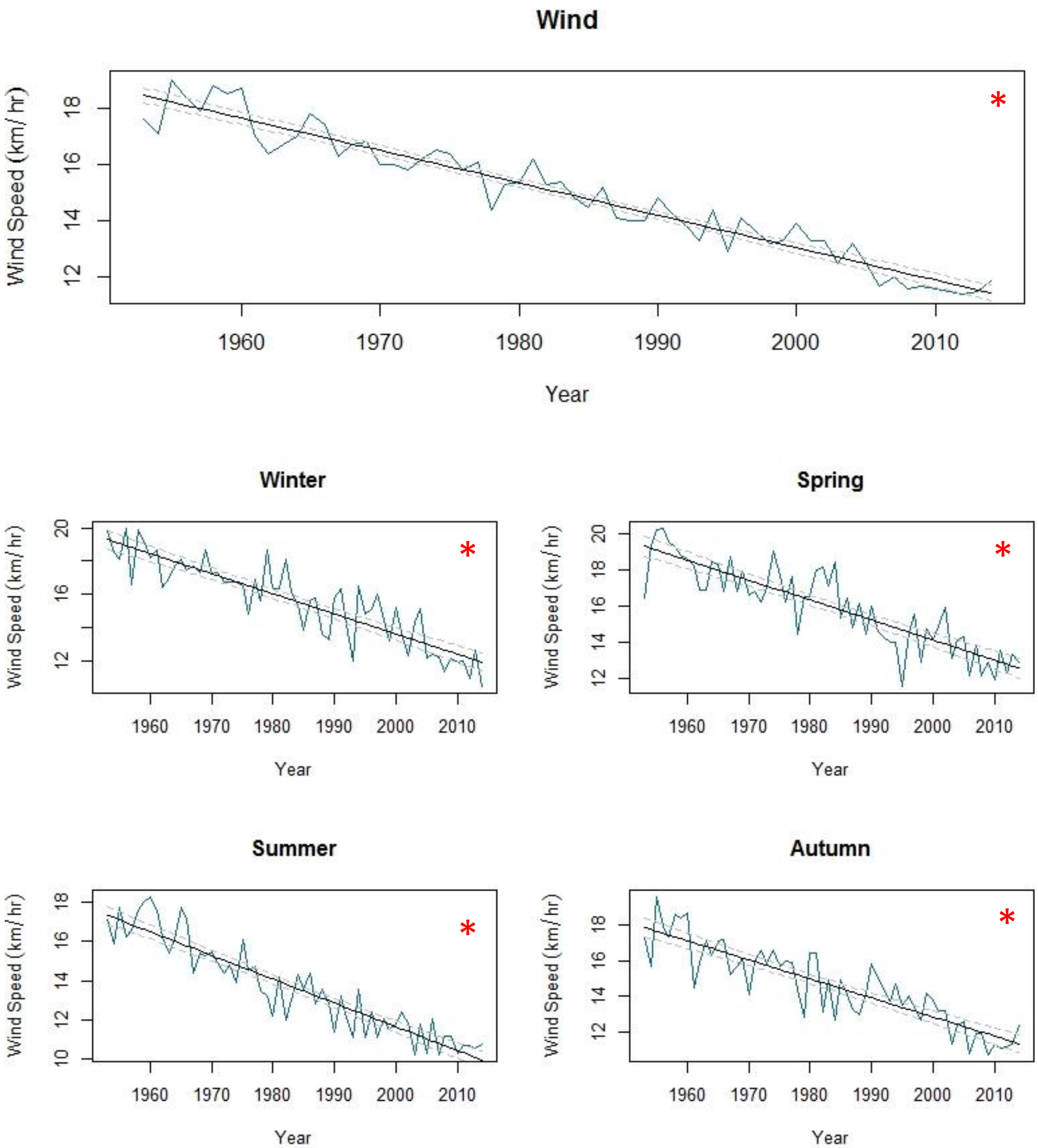
Rexton total annual snow did not demonstrate a statistically significant (P<0.05) trend between 1923 and 2009.



Percent change in total annual and seasonal precipitation for Kouchibouguac from 1948 to 2012. Canadian gridded data (CANGRD): https://climate-change.canada.ca/climate-data/#/historical-gridded-data.

1.3 Surface Wind Speed

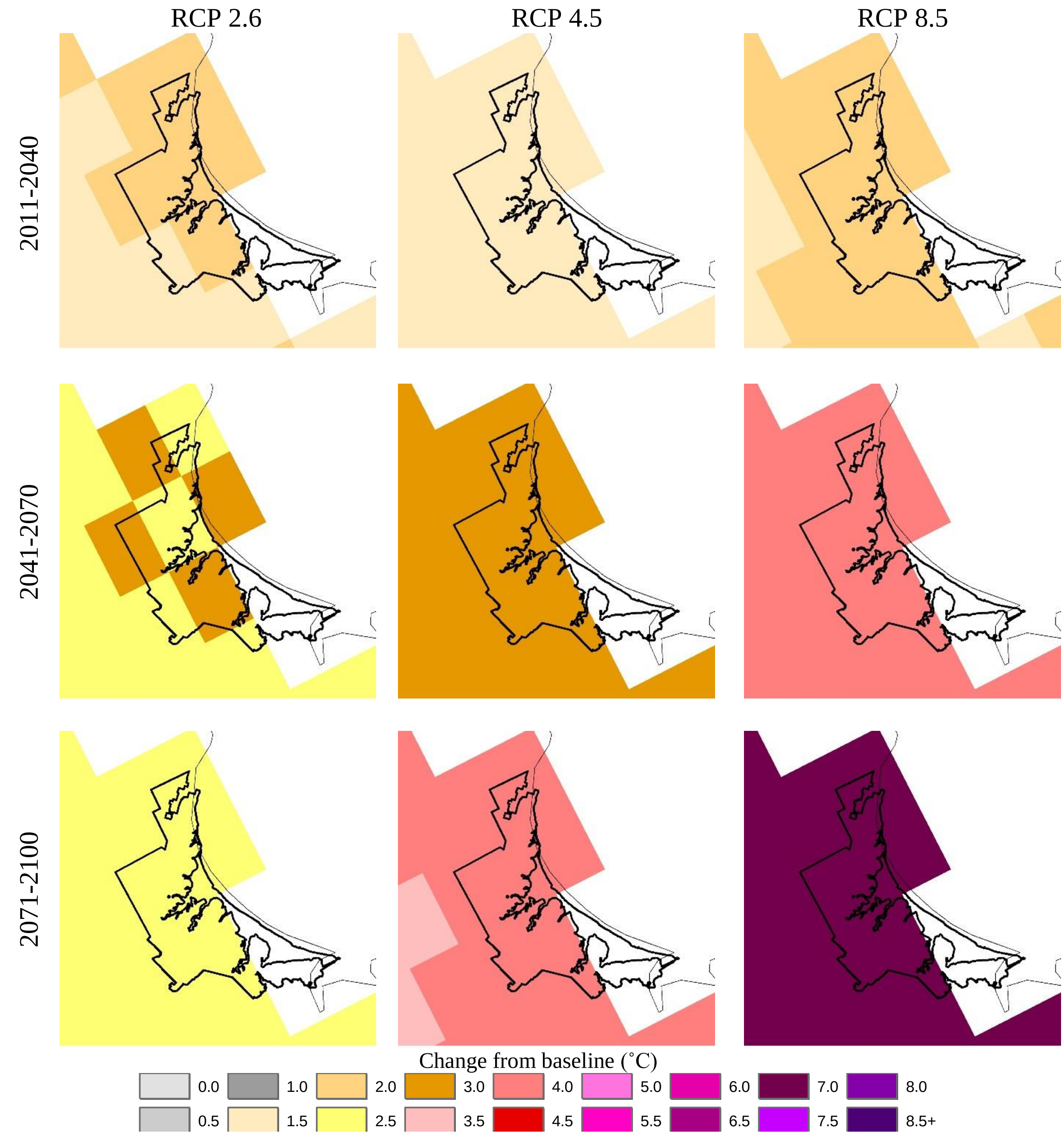
Miramichi (8101000) is the closest meteorological station with long-term wind data (ECCC, 2017). Trends from 1953 to 2014 determined using a generalized linear model (R Core Team, 2017) including 95% confidence intervals. "*" = statistically significant trend (P<0.05).



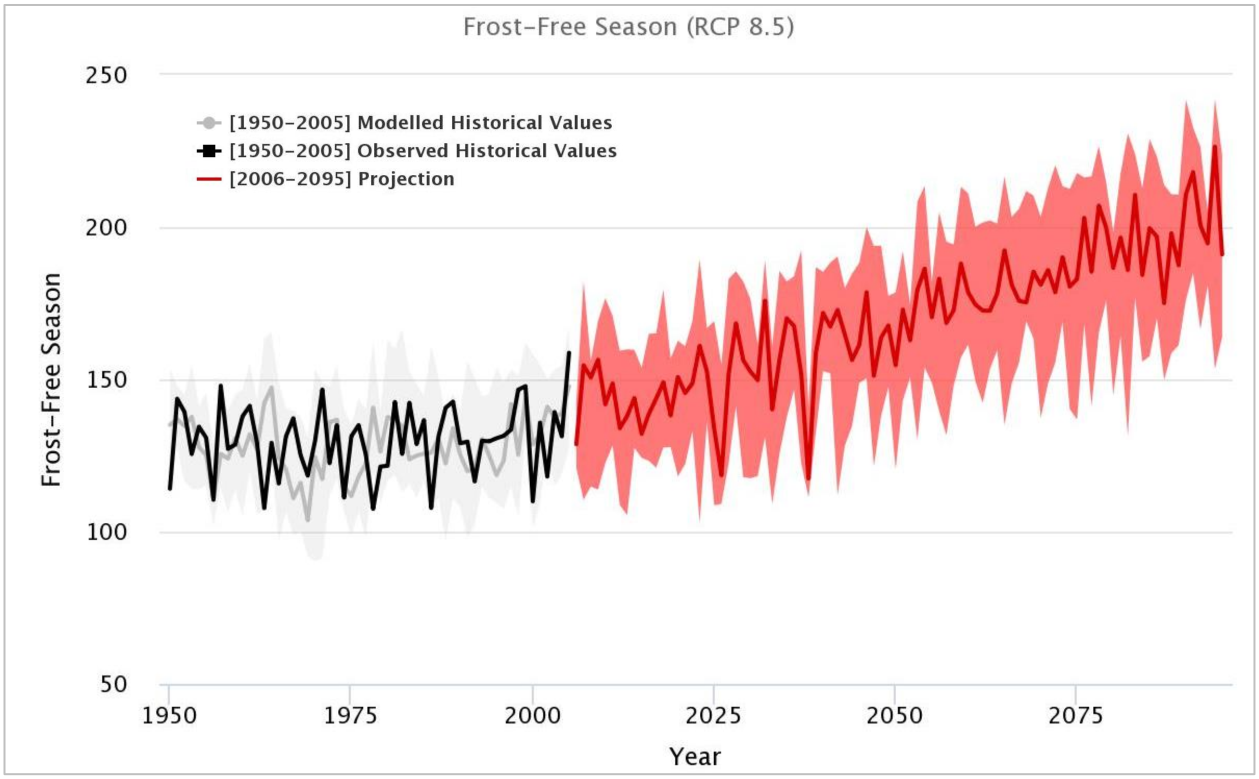
Miramichi mean annual and seasonal wind speeds. Mean annual and seasonal wind speeds all demonstrated a statistically significant decrease (P<0.05) between 1953 and 2014. Mean annual wind speeds have decreased by 7 km/hr (-38%).

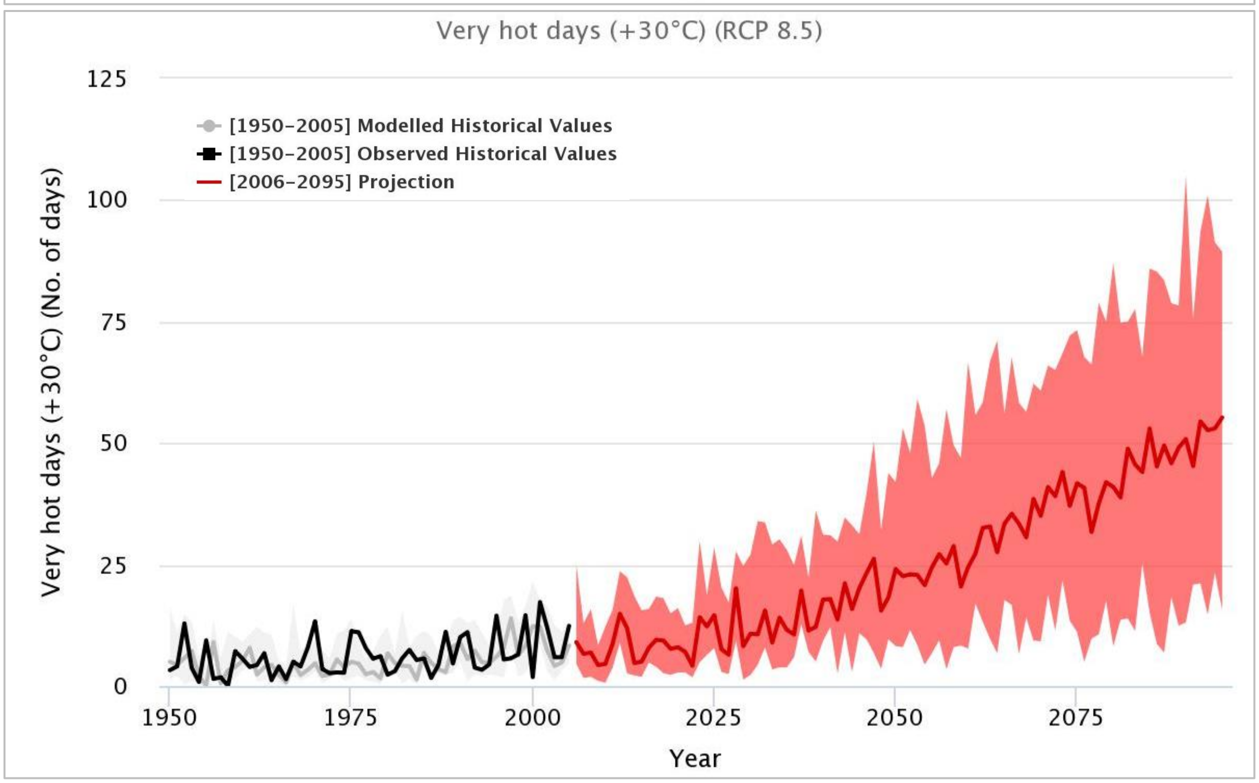
2. Projected Climate Trends

2.1 Temperature



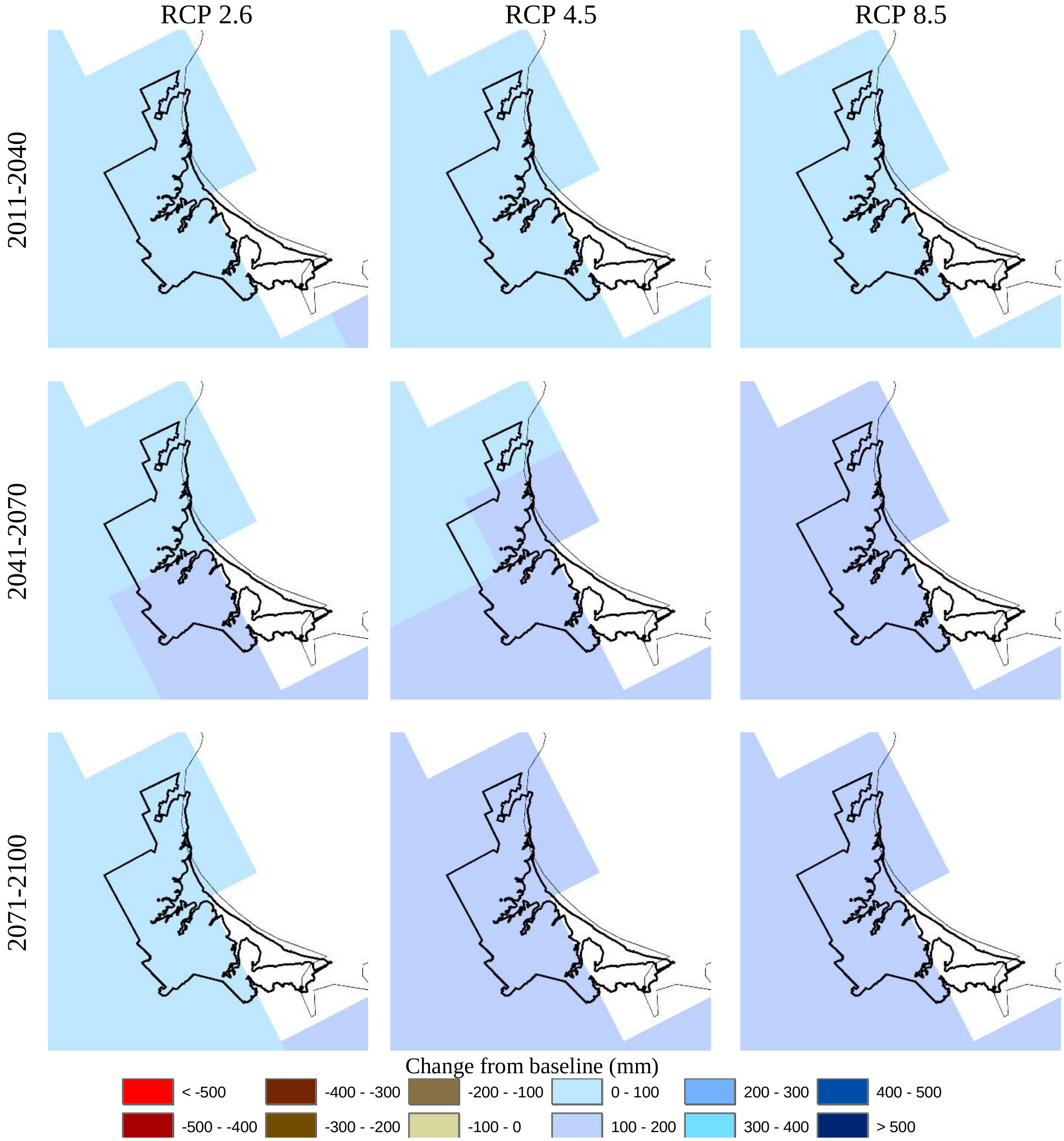
Projected mean annual temperature increase for Kouchibouguac National Park from a 1980-2010 baseline. Composite projection of CanESM2, CESM1CAM5, HADGEM2ES and MIROCESM. Data source: Natural Resources Canada, Canadian Forest Service, http://cfs.nrcan.gc.ca/projects/3 (Price *et al.*, 2011). Mean annual temperature increase could exceed 7°C by end of century.



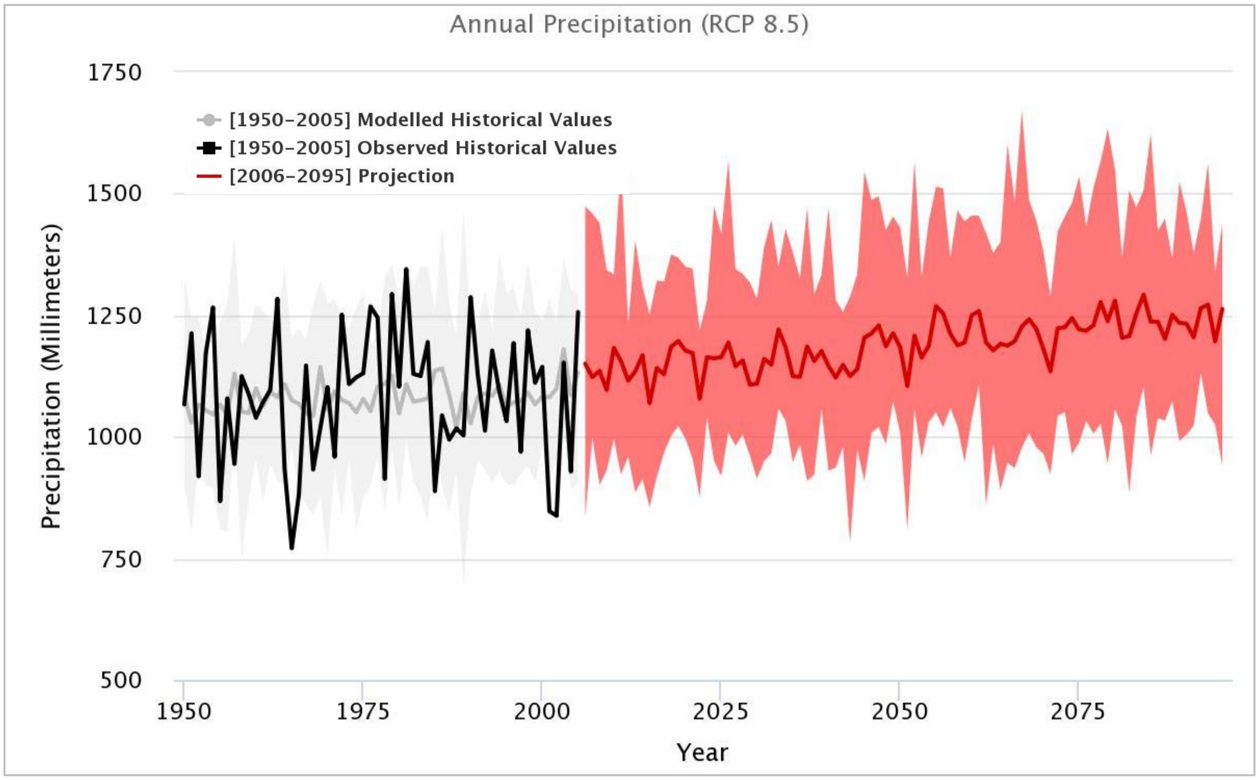


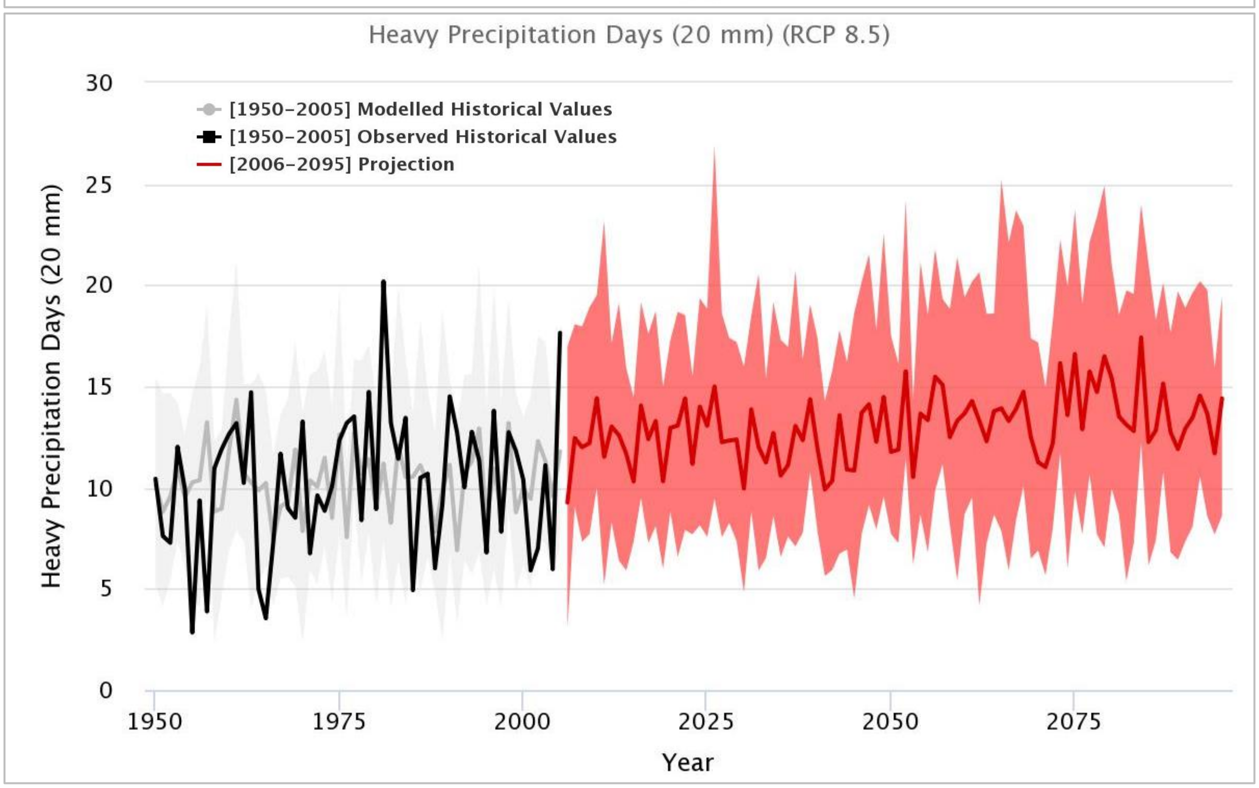
The frost-free season (days) for the Moncton region is projected to increase from a mean of 130.1 days from the 1976-2005 baseline to 181.7 days (+51.6 days) by 2051-2080 (https://climateatlas.ca/). Frost-free season approximates the length of growing season (i.e., no freezing temperatures to kill or damage plants). **The number of very hot days (+30˚C) for the Moncton region** is projected to increase from a mean of 6 days/year from the 1976-2005 baseline to 32.1 days/year by 2051-2080 (https://climateatlas.ca/).

2.2 Precipitation



Projected total annual precipitation change for Kouchibouguac National Park from a 1980-2010 baseline. Composite projection of four spatially interpolated downscaled Global Circulation Models: CanESM2, CESM1CAM5, HADGEM2ES and MIROCESM. Data source Natural Resources Canada, Canadian Forest Service, http://cfs.nrcan.gc.ca/projects/3 (Price *et al.*, 2011). Total annual precipitation could increase by over 165 mm by end of century.





Total annual precipitation for the Moncton region is projected to increase from an average of 1089mm to 1213mm by 2051-2080 (https://climateatlas.ca/). See Appendix 1 for model variability. **The number of heavy precipitation days (>20mm) for the Moncton region** is projected to increase slightly from a mean of 10.3 days for the 1976-2005 baseline to only 13.8 (+3.5 days) by 2051-2080 (https://climateatlas.ca/).

Rainfall Intensity, Duration and Frequency (IDF)

These rainfall IDF values are calculated with IDF_CC Tool 3.0 (http://www.idf-cc-uwo.ca/) using Generalized Extreme Values (Simonovic *et al.*, 2017).

Baseline total precipitation amounts (mm) for Kouchibouguac.

T (years)	2	5	10	20	25	50	100
5 min	5.54	7.78	9.33	10.93	11.40	13.02	14.71
10 min	8.61	13.05	16.36	19.90	21.00	24.83	28.98
15 min	10.60	15.97	20.02	24.40	25.77	30.55	35.78
30 min	14.72	21.03	25.29	29.57	30.80	35.02	39.36
1 h	18.58	25.92	31.24	36.85	38.56	44.44	50.72
2 h	24.70	33.37	39.69	46.34	48.37	55.37	62.82
6 h	41.28	51.20	56.84	61.95	63.15	67.37	71.27
12 h	48.89	62.02	70.33	78.28	80.43	87.67	94.65
24 h	58.40	72.42	79.96	86.51	87.89	92.83	97.06

Projected (2050-2100) precipitation (mm) for Kouchibouguac using an ensemble of models and **RCP 4.5**.

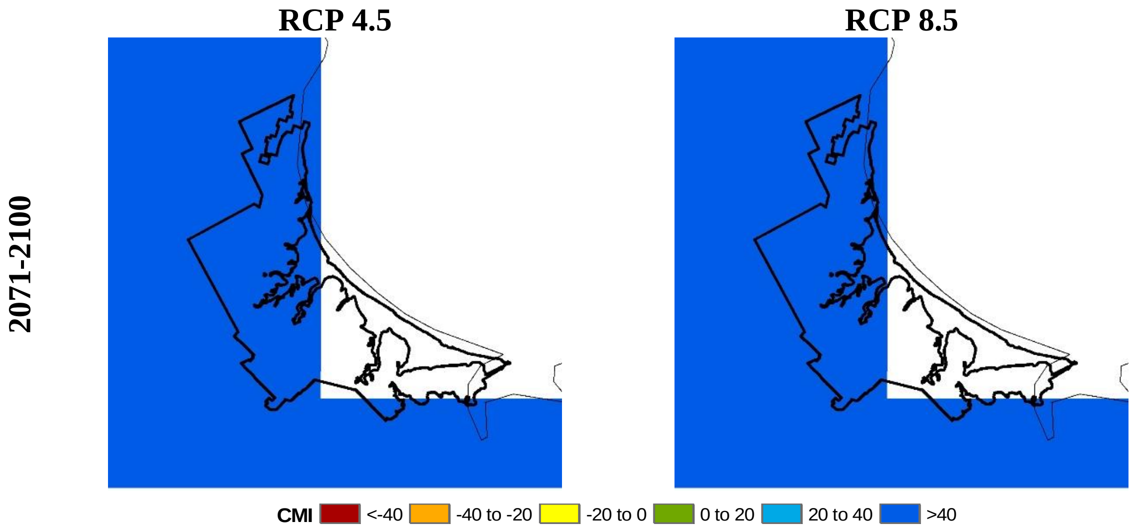
T (years)	2	5	10	20	25	50	100
5 min	6.78	9.56	11.47	13.95	14.85	17.20	19.14
10 min	10.54	16.05	20.09	25.40	27.34	32.80	37.72
15 min	12.98	19.64	24.60	31.14	33.55	40.36	46.57
30 min	18.01	25.85	31.07	37.73	40.10	46.27	51.23
1 h	22.74	31.87	38.38	47.02	50.20	58.71	66.01
2 h	30.24	41.03	48.75	59.13	62.98	73.15	81.77
6 h	50.53	62.94	69.82	79.06	82.21	89.01	92.76
12 h	59.85	76.25	86.40	99.88	104.72	115.82	123.20
24 h	71.48	89.03	98.23	110.40	114.43	122.63	126.34

Projected (2050-2100) precipitation (mm) for Kouchibouguac using an ensemble of models and **RCP 8.5**.

T (years)	2	5	10	20	25	50	100
5 min	7.48	10.63	12.67	14.53	15.10	17.13	19.28
10 min	11.63	17.85	22.20	26.45	27.81	32.66	37.99
15 min	14.32	21.84	27.18	32.44	34.13	40.18	46.90
30 min	19.89	28.76	34.33	39.30	40.79	46.07	51.59
1 h	25.10	35.44	42.41	48.98	51.06	58.46	66.48
2 h	33.38	45.63	53.87	61.59	64.06	72.84	82.35
6 h	55.78	70.01	77.15	82.35	83.62	88.63	93.42
12 h	66.06	84.81	95.47	104.04	106.52	115.33	124.07
24 h	78.90	99.03	108.54	115.00	116.39	122.11	127.23

Kouchibouguac (Lat: 46.86395 º, Lon: -64.96868 º) IDF observations and projections. Observe that today's "one in 100 year" rainfall event (i.e., 50.72 mm/hr) is projected to be closer to a "one in 25 year" event by 2050-2100 and the future "one in 100 year" rainfall event is projected to increase in intensity (i.e., 66.01 – 66.48 mm/hr).

Climate Moisture Index



Climate Moisture Index (CMI) is calculated as the difference between annual precipitation and potential evapotranspiration – the potential loss of water vapour from a landscape covered by vegetation (http://www.nrcan.gc.ca/forests/climate-change/forest-change/17772). The positive CMI value indicates wet or moist conditions (a negative value would have indicated dry conditions).

2.3 Wind

The Coupled Model Intercomparison Project Phase 5 (CMIP5) model projects a slight and continued decrease (-1.6%) in annual surface wind speeds by 2081-2100 for the region (see: https://climatedata.ca/). However, Cheng *et al.* (2014) project that the frequency of wind gust events will increase slightly for the region.

3. Climate Change Impacts

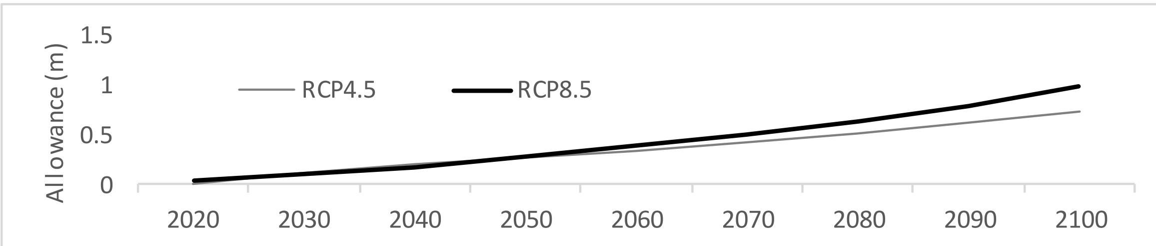
3.1 Coastal Sensitivity

Environment Canada's report "Impacts of Sea-Level Rise and Climate Change on the Coastal Zone of Southeastern New Brunswick" (Environment Canada, 2006) stands as key source of data and information for the park's coast.

Relative Sea Level Rise

Relative sea level in the region is increasing due to the combined effect of sea level rise (~1.6 mm/yr) and land subsidence (~1.6 mm/yr). For example, between 1900 and 2016 sea level at Halifax increased by 3.28 ± 0.19 mm/yr (+38 cm) (http://www.psmsl.org/products/trends/).

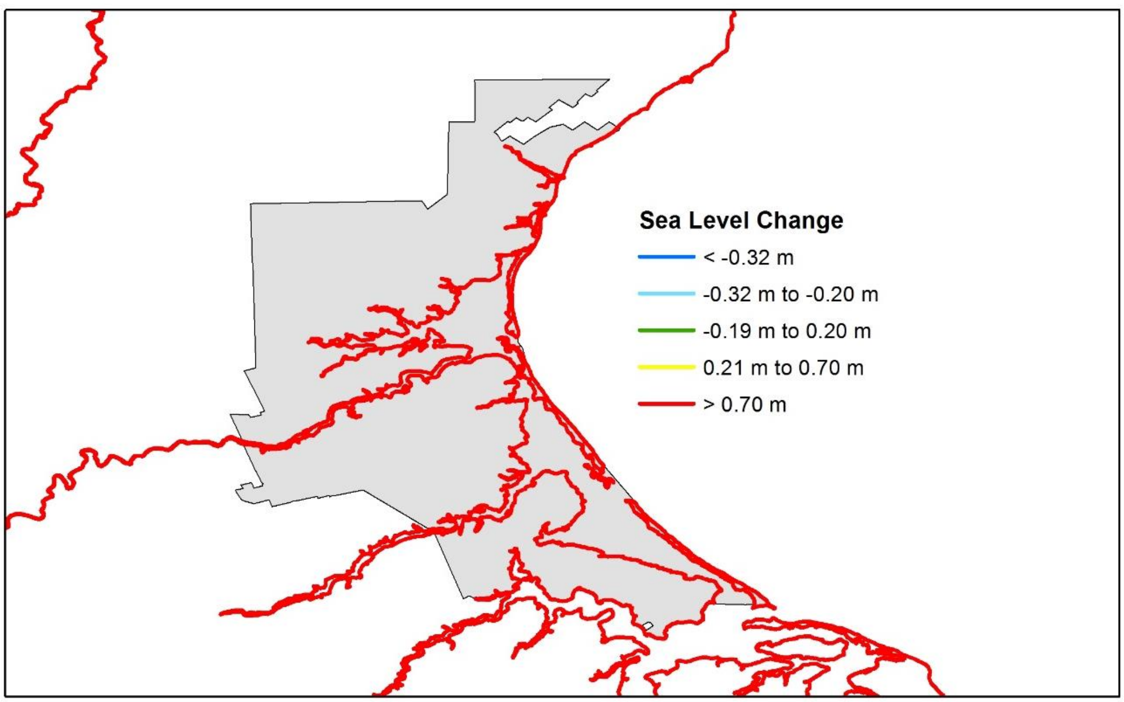
Vertical allowance for Yarmouth were acquired from the Canadian Extreme Water Level Adaptation Tool (CAN-EWLAT, http://www.bio.gc.ca/science/data-donnees/index-en.php). The vertical allowances are "recommended changes in the elevation of coastal infrastructure required to maintain the current level of flooding risk in a future scenario of sea level rise". These estimates are based on a future projection of regional sea level rise using the RCP 4.5 and RCP 8.5 scenarios and the historical water level records, including both tides and storm surge. The historical records do not incorporate predicted changes in storm tides.



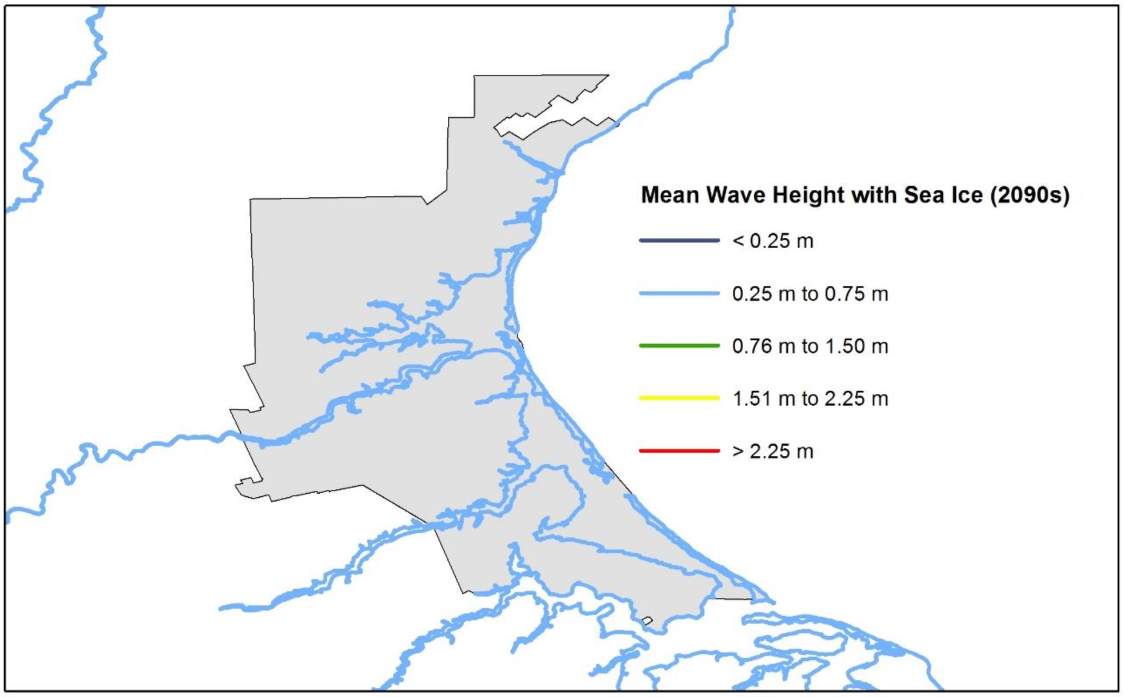
Loggiecroft, NB projected vertical allowance of 73 to 99 cm by 2100 (CAN-EWLAT).

CanCoast Data

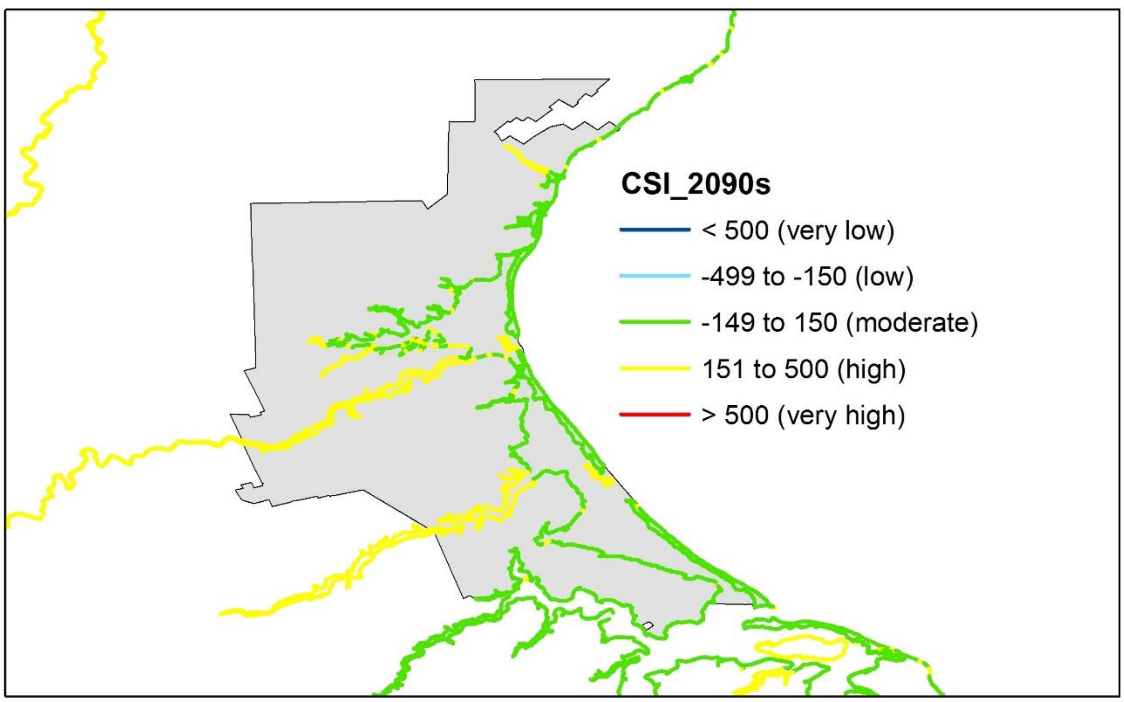
Manson *et al.* (2019) provide baseline and generalised sensitivity maps of Canada's marine coasts in early and late 21st century climates. The CanCoast dataset includes: sea-level change; wave-height and mean sea level; coastal materials; tidal range; backshore slope; and coastal sensitivity.



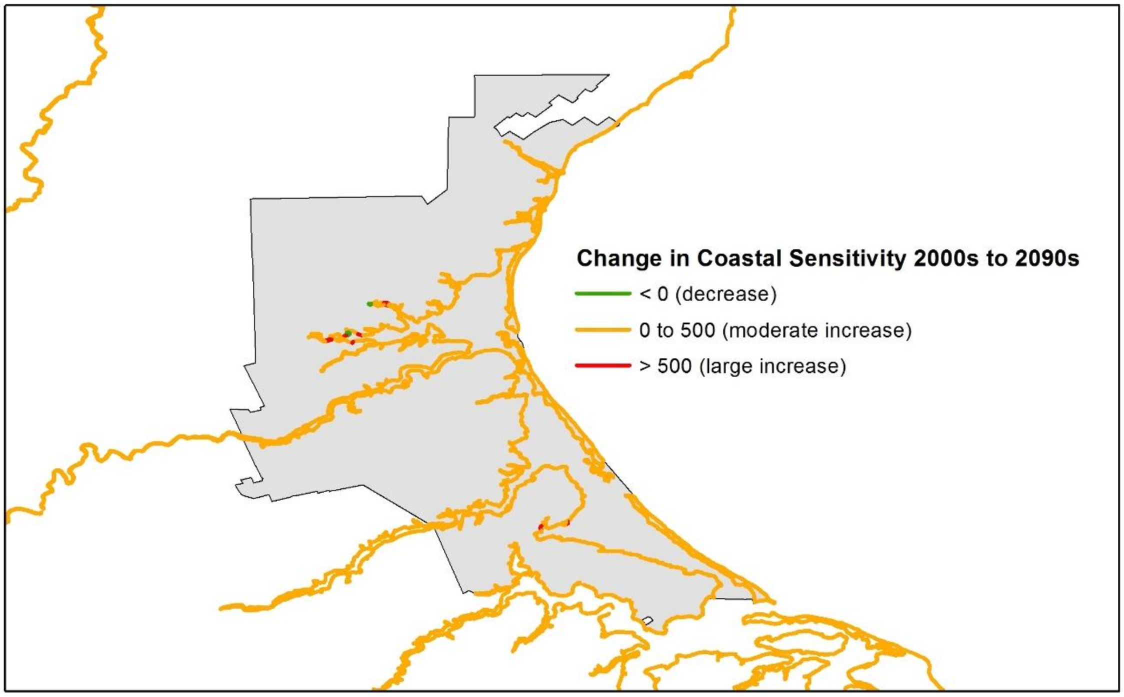
Projected relative sea-level rise between 2006 and 2099 for Kouchibouguac NP, an average of 0.89 m is projected (Manson *et al.*, 2019).



Projected significant wave heights including sea ice effects in 2090-2099 for Kouchibouguac NP (Manson *et al.*, 2019).

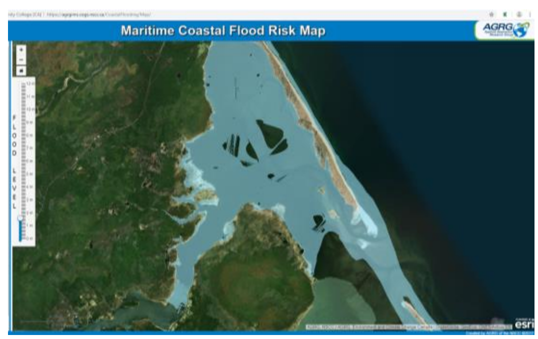


Coastal Sensitivity Index (CSI) values for Kouchibouguac NP in the 2090s (Manson *et al.*, 2019).



Predicted change in coastal sensitivity from 2000s to 2090s for Kouchibouguac NP (Manson *et al.*, 2019).

LiDAR digital elevation models and flood risk mapping was completed for Kouchibouguac NP in 2004 by the Applied Geomatics Research Group (AGRG) of the Centre of Geographic Sciences (COGS), Nova Scotia Community College (NSCC). GIS files are available from the park or can be viewed on-line using the Maritime Coastal Flood Risk Map (https://agrgims.cogs.nscc.ca/CoastalFlooding/Map/). The online tool enables users to visualize different sea level scenarios.



3.2 Species and Ecosystems

In general, the effects of climate change on biodiversity include: shifts in species distribution; changes in phenology; decoupling of interactions (plant-pollinator); reductions in population size; species extinction and extirpation; habitat loss; increased disease and spread of invasive species; competitive exclusion; and, change to ecosystem services (Nantel *et al.*, 2014; Nituch and Bowman, 2013). Some more specific regional effects include:

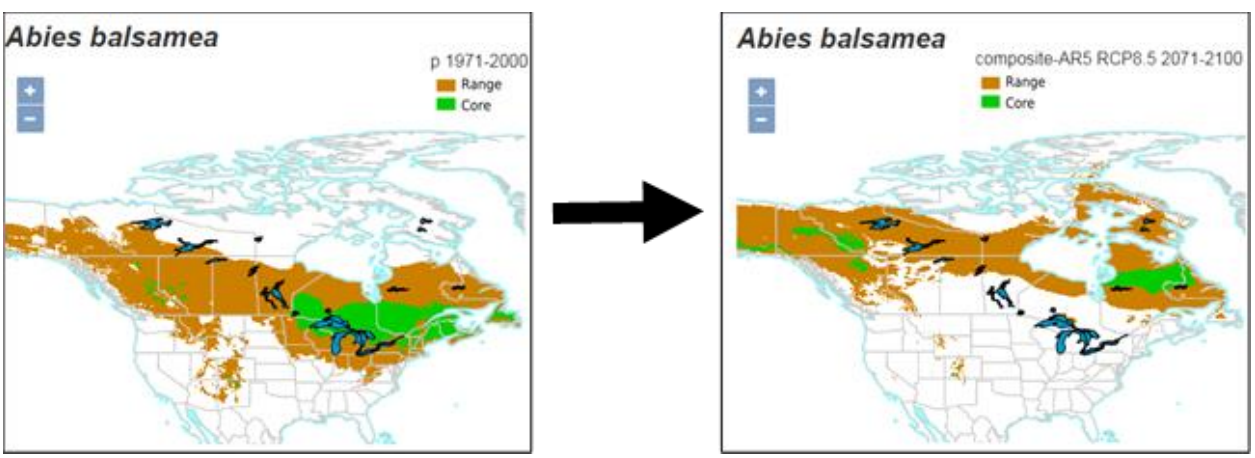
- Vasseur and Tremblay (2014) examined the potential challenges facing coastal ecosystems in Kouchibouguac and the communities that relies on them. Furthermore, they discuss possible adaptation solutions, including restoration, monitoring and translocation.

- Tremblay *et al.* (2006) report on the impacts of storm surge to Piping Plover nesting success. While, Bourque *et al.* (2015) report an increase in suitable habitat for Piping Plovers in years following coastal storm events.
- Chmura *et al.* (2016) reviewed potential changes to greenhouse gas fluxes in the salt marshes of Kouchibouguac. In addition, Kirwan *et al*. (2014) suggest that elevated atmospheric CO_2 and warmer temperatures will accelerate carbon accumulation in marshes.
- Craik *et al.* (2015) reviewed the potential threat of sea level rise and increases in storm surges on waterbird nests on barrier islands.
- Torio and Chmura (2013) report on the potential "coastal squeeze" in the park area.

Plant Hardiness

Plant Hardiness is associated with probabilities of plant survival in relation to average, broad scale climatic conditions. As the climate changes, habitat suitability for plant species also changes (McKenney *et al.*, 2001; McKenney *et al.*, 2014; McKenney *et al.*, 2011).

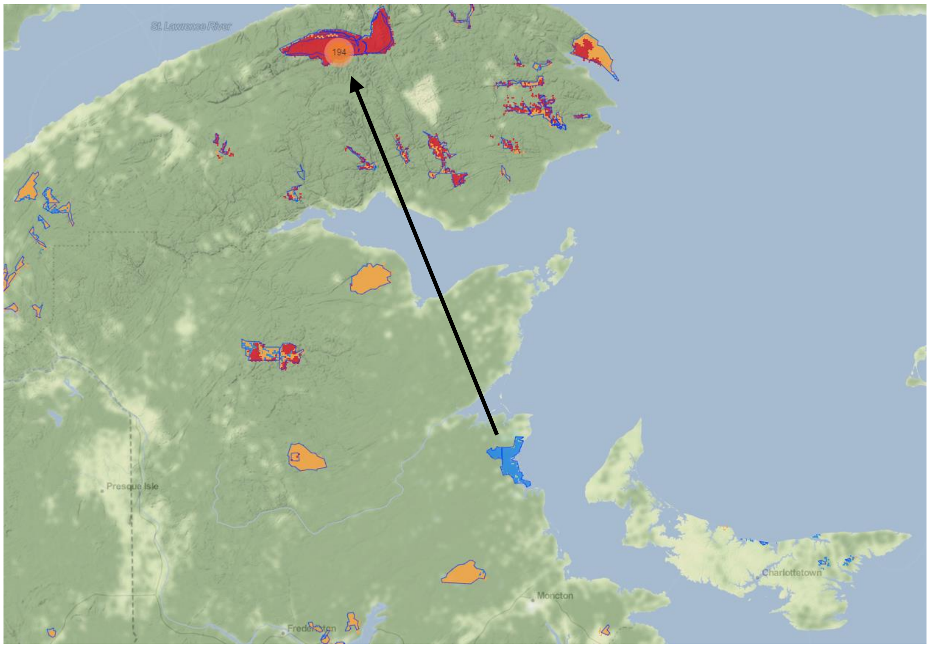
Table below summarizes species climatic distribution based on the Current and ANUCLIM Composite-AR5, RCP8.5 maps and models in the Plant Hardiness of Canada database (http://planthardiness.gc.ca/). Some species may be identified as being within their current climatic range, but may not actually be present in the area. While some of the species reviewed were worsening, no species was projected to be extirpated.



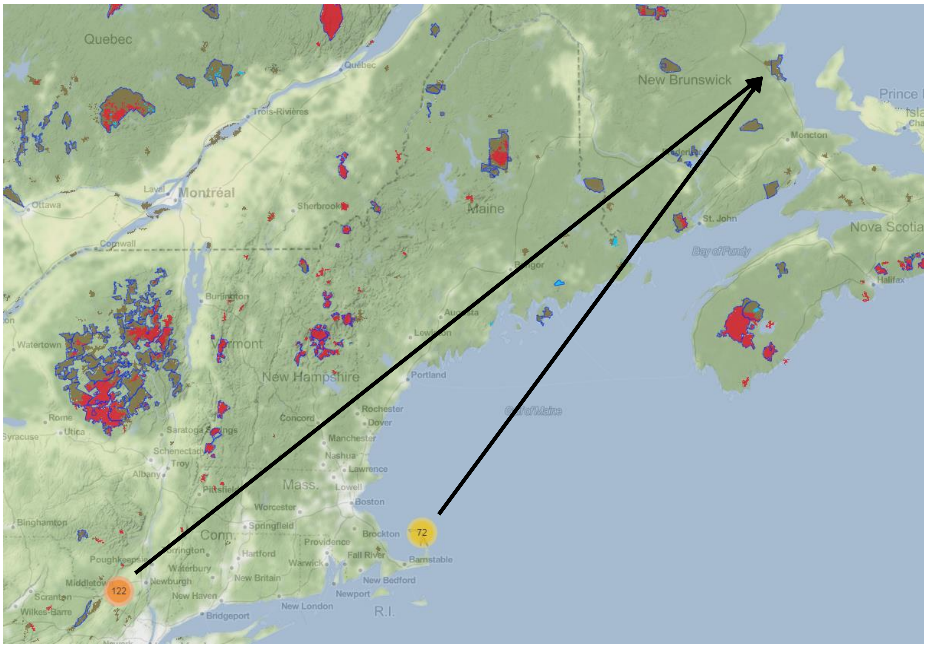
Common Name	Scientific Name	Current Range	2041-2070 Range	Trend by 2070	2071-2100 Range	Trend by 2100
American Beech	Fagus grandifolia	Core	Core	Stable	Range	Decreasing
American Willow	Salix discolor	Core	Range	Decreasing	Absent	Extirpated
Balsam Fir	Abies balsamea	Core	Absent	Extirpated	Absent	Extirpated
Balsam Poplar	Populus balsamifera	Core	Range	Decreasing	Range	Stable
Bebb's Willow	Salix bebbiana	Core	Range	Decreasing	Absent	Extirpated
Bigtooth Aspen	Populus grandidentata	Core	Range	Decreasing	Absent	Extirpated
Black spruce	Picea mariana	Core	Absent	Extirpated	Absent	Extirpated
Box Elder	Acer negundo	Core	Core	Stable	Core	Stable
Canadian Yew	Taxus canadensis	Core	Range	Decreasing	Absent	Extirpated
Eastern Hemlock	Tsuga canadensis	Core	Range	Decreasing	Range	Decreasing
Eastern White Pine	Pinus strobus	Core	Range	Decreasing	Absent	Extirpated
Gray Birch	Betula populifolia	Core	Range	Decreasing	Absent	Extirpated
Horse-chestnut	Aesculus hippocastanum	Core	Absent	Extirpated	Absent	Extirpated
Jack Pine	Pinus banksiana	Core	Range	Decreasing	Absent	Extirpated
Northern White Cedar	Thuja occidentalis	Core	Range	Decreasing	Absent	Extirpated
Pacific Willow	Salix lucida	Core	Range	Decreasing	Absent	Extirpated
Paper Birch	Betula papyrifera	Core	Range	Decreasing	Absent	Extirpated
Red Maple	Acer rubrum	Core	Core	Stable	Core	Stable
Red Pine	Pinus resinosa	Core	Range	Decreasing	Absent	Extirpated
Red Spruce	Picea rubens	Core	Range	Decreasing	Absent	Extirpated
Striped Maple	Acer pensylvanicum	Core	Range	Decreasing	Range	Decreasing
Sugar Maple	Acer saccharum	Core	Core	Stable	Range	Decreasing
Tamarack	Larix laricina	Core	Absent	Extirpated	Absent	Extirpated
Trembling Aspen	Populus tremuloides	Core	Range	Decreasing	Absent	Extirpated
White Spruce	Picea glauca	Core	Absent	Extirpated	Absent	Extirpated
White Willow	Salix alba	Range	Range	Stable	Range	Decreasing
Yellow Birch	Betula alleghaniensis	Core	Range	Decreasing	Absent	Extirpated

Climate Velocity

AdaptWest (https://adaptwest.databasin.org/) provides integrative tools that can inform conservation planning, including the following analysis on climate velocity.

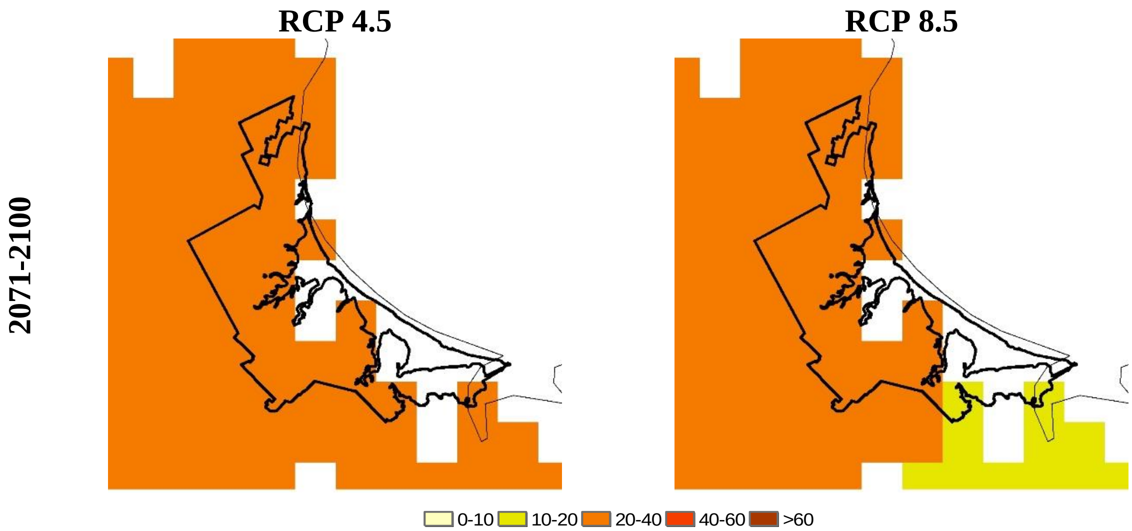


Outgoing cell destination map shows the predicted future locations for all cells (1 km pixels) currently within Kouchibouguac NP. Locations are clustered together and the number of cells is represented as the number in the cluster and by the color of the cluster. AdaptWest Climate Displacement Tool, https://adaptwest.databasin.org/pages/climate-displacement-protected-areas.



Incoming cell destination map shows the current locations for all cells expected to occupy Kouchibouguac NP in the future. Locations are clustered together and the number of cells is represented as the number in the cluster and by the color of the cluster. AdaptWest Climate Displacement Tool, https://adaptwest.databasin.org/pages/climate-displacement-protected-areas.

3.3 Wildfire



Projected increase in wildfire season for Kouchibouguac National Park. Increased length in days from baseline (1981-2010) under RCP 4.5 and RCP 8.5 scenarios. Data source: Natural Resources Canada, http://cfs.nrcan.gc.ca/fc-data-catalogue. For some area the wildfire season could increase by as much as 25 days.

- The frequency, seasonality, extent and severity of wildfires is closely tied to climatic conditions (e.g., Westerling *et al.*, 2006).
- Wildfire season length and frequency of extreme fire weather are expected to increase (e.g., affected by warmer springs and summers, less summer moisture and reduced snowpack) (Jain *et al.*, 2017; Kirchmeier-Young *et al.*, 2019; Kirchmeier-Young *et al.*, 2017; Wang *et al.*, 2017; Wang *et al.*, 2015). Mori and Johnson (2013) project that the probability of large-scale fires in this region will increase with time.
- Flannigan *et al*. (2016) demonstrate that seasonal precipitation must increase 15% to offset every 1˚C rise in temperature. Although variable, a quick scan of the data for Kouchibouguac NP suggests that precipitation may not offset temperature.
- Temperature has a positive correlation with lightening (e.g., Price and Rind, 1994; Woolford *et al.*, 2014).
- Wotton *et al.* (2017) project a future (for 2030 and 2090) increase in the number of days where crown fires are likely to occur, as well as an increase in the number of days when fire intensities (e.g., head fire intensity above 10,000 kW/m) could exceed the capabilities of suppression resources (i.e., doubling in some end of century scenarios).

3.4 Visitor Experience

- Climate change is an important theme in Parks Canada's visitor communication and interpretation efforts. Furthermore, "natural solutions", highlighting the effectiveness of ecosystem-based approaches to adaptation and mitigation, are often used to frame and present Parks Canada's response to climate change (for more information on the concept, see: Bridges *et al.*, 2018; CPC, 2013; NAWPA, 2012).

- The Visitor Experience Branch (contact: Sophie Larouche-Guilbert) is currently compiling a catalogue of climate change adaptation options for visitor experience (see: http://intranet2/our-work/visitor-experience/changements-climatiques/).
- In terms of human health, there may be heat related concerns during extreme temperature events, as well there may be concerns due to increases in disease risks. For example, Lyme disease (bacterial disease transmitted by an infected tick) which was formerly restricted to localized areas by temperature and relative humidity, is expected to expand by mid-century (Eisen *et al.*, 2016; Ogden *et al.*, 2006). Some mosquito-borne diseases also show a connection to climate change, including West Nile virus (note: besides humans it can infect over 140 species including horses, crows, ravens, etc…) (Chen *et al.*, 2013; Kulkarni *et al.*, 2015).
- A longer and more intense fire season will affect visitor safety and experience (e.g., possible area closures, no campfires, or evacuations).
- The US National Park Service National Climate Change Interpretation and Education Strategy (US NPS, 2016) and climate change communication toolkit (https://www.nps.gov/subjects/climatechange/toolkit.htm) contains information that may be of interest to park interpreters.

3.5 Assets and Infrastructure

The impacts to Canada's assets and infrastructure from climate change are well documented (e.g., Boyle *et al.*, 2013; Canada, 2017; Palko and Lemmen, 2017; Warren and Lemmen, 2014) and are explicitly mentioned as a concern in Parks Canada's Departmental Plan (Parks Canada, 2017). In light of the information in this report, expected concerns could include:

- Flooding from intense rainfall events could overwhelm surface drainage capacity and septic beds, and damage buildings, bridges, trails and roadways.
- Freezing rain or hail damage to buildings and power/communication lines.
- Longer wildfire seasons and more intense fires could increase impacts to infrastructure.
- Longer seasonal use of trails and roads by visitors. There may be less frost damage to roads in milder winters.
- Increased temperatures could lead to premature weathering. Similarly, increased spring rains could lead to premature weathering and deterioration (e.g., building foundations, corrosion, and mold).
- The energy demands for cooling buildings will increase.
- The Public Infrastructure Engineering Vulnerability Committee (PIEVC) has undertaken various climate change engineering vulnerability assessments in Canada (PIEVC, 2008). As a regional example, the City of Miramichi completed an assessment of the King George Highway, Route 117 which experiences flooding in extreme precipitation events (Riley Environment Ltd., 2013).

An assessment of greenhouse gas (GHG) emissions was not in the scope of this report. However, federally the government is committing to reducing GHG emissions by 80% below 2005 levels by 2050 (https://www.canada.ca/en/treasury-board-secretariat/services/innovation/greening-government/strategy.html). Also see Parks Canada's 2015 Master Plan to reduce GHG emissions (Parks Canada, 2015).

3.6 Cultural Resources

- Increased damage or loss of cultural resources is possible during and post- flood, wildfire and other disturbance events (Morgan *et al.*, 2016).
- Efforts to FireSmart (e.g., replace wood shake roofing) may influence the character or cultural integrity of a facility (Morgan *et al.*, 2016).
- There is a potential for increased deterioration of facilities and collections (e.g., non-mechanically ventilated interiors, HVACs) from increased temperature, humidity, and precipitation, e.g., increased mold, rot and fungal decay; increased corrosion, etc… (Brimblecombe, 2014; Brimblecombe and Brimblecombe, 2016; Horowitz *et al.*, 2016; Morgan *et al.*, 2016).
- Socio-economic impacts through lose or damage to cultural resources may occur.
- Longer growing seasons and warmer conditions may lead to increased presence and abundance of invasive plant species and pests (Morgan *et al.*, 2016)
- Micro-climates which allow historic gardens to flourish may be affected (e.g., Percy *et al.*, 2015).

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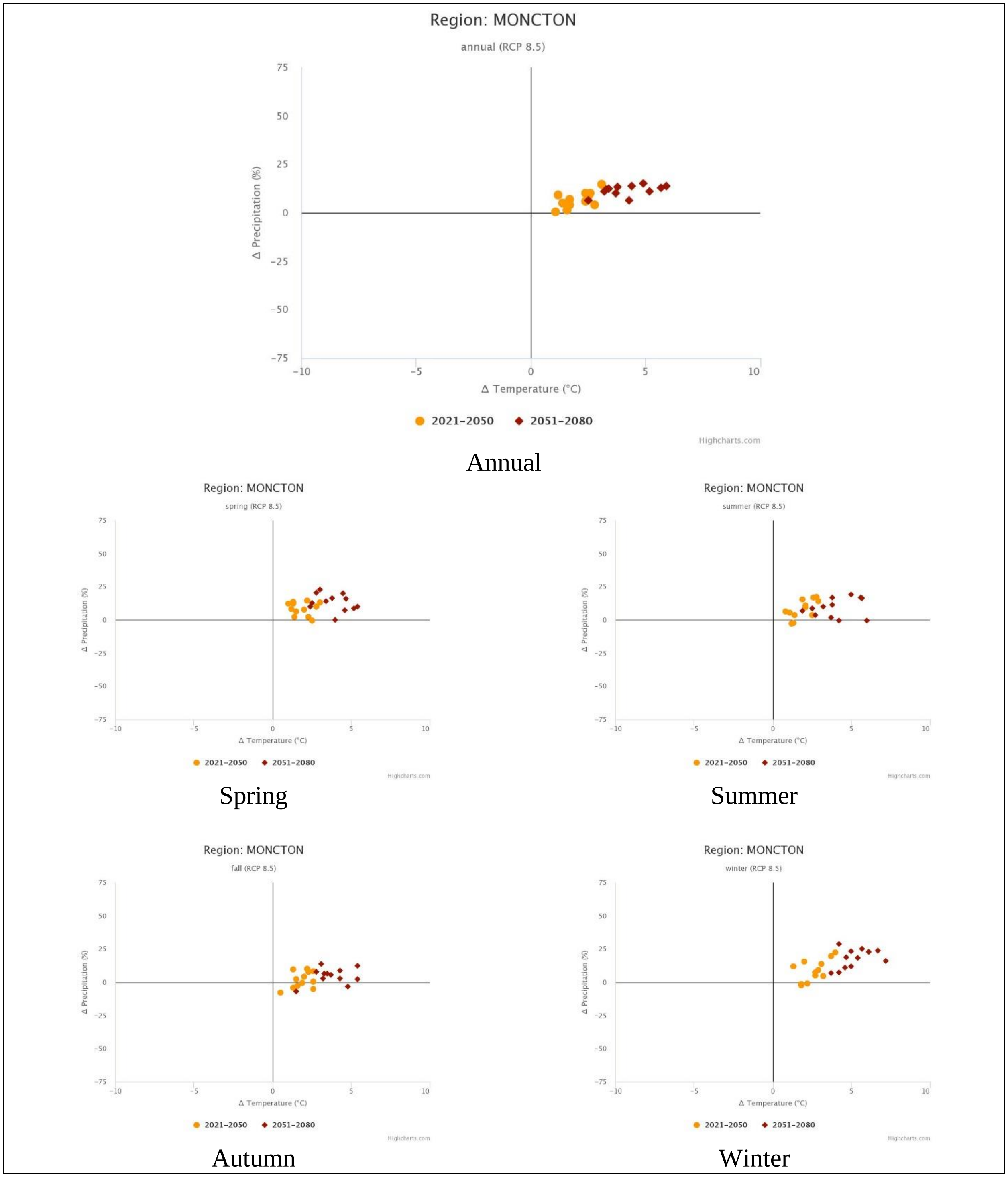
Appendix 1. Temperature and Precipitation Scatterplots



Climate models for the Region of Moncton. Each point represents a single model-simulated temperature/precipitation response to the **RCP 8.5** scenario. Statistically downscaled data (Bias Corrected Spatial Disaggregation; BCSD) derived from 12 CMIP5 global climate models (https://climateatlas.ca/; PCIC, 2014). All models project warmer conditions and most project an increase in total precipitation.

Appendix 2. Birds and Climate Change

Parks Canada, National Audubon Society, and Bird Studies Canada assessed the effects of climate change on bird species in Canada's national parks (Parker *et al.*, 2019). The following table provides a summary for Kouchibouguac National Park. Climate suitability projections by 2050 under the high-emissions pathway (RCP 8.5). "Potential colonization" indicates that climate is projected to become suitable for the species, whereas "potential extirpation" indicates that climate is suitable today but projected to become unsuitable. Omitted species were either not modeled due to data deficiency or were absent from the observation datasets. Species are listed by taxonomic order, denoted by alternating background shading.

- Species not found or found only occasionally, and not projected to colonize by 2050
x Species not modeled in this season
^ Species that are highly climate sensitive

Common Name	Summer Trend	Winter Trend
Brant	-	Potential colonization
Canada/Cackling Goose	x	Improving
Mute Swan	-	Potential colonization
Wood Duck	x	Potential colonization
Gadwall	-	Potential colonization
American Wigeon	Potential extirpation^	Potential colonization
American Black Duck	x	Improving
Mallard	Stable^	Improving
Northern Shoveler	-	Potential colonization
Green-winged Teal	-	Potential colonization
Canvasback	-	Potential colonization
Ring-necked Duck	-	Potential colonization
Greater Scaup	-	Improving^
Lesser Scaup	-	Potential colonization
Common Eider	-	Stable
Surf Scoter	-	Improving
White-winged Scoter	-	Improving
Black Scoter	-	Potential colonization
Long-tailed Duck	-	Improving
Bufflehead	-	Improving
Common Goldeneye	-	Improving
Barrow's Goldeneye	-	Potential extirpation^
Hooded Merganser	-	Potential colonization^
Common Merganser	x	Stable
Red-breasted Merganser	Stable	Improving^
Ruddy Duck	-	Potential colonization
Northern Bobwhite	Potential colonization	-
Ring-necked Pheasant	Improving	Improving
Ruffed Grouse	x	Potential extirpation
Spruce Grouse	x	Potential extirpation

Common Name	Summer Trend	Winter Trend
Red-throated Loon	-	Potential colonization
Common Loon	Potential extirpation	Stable^
Pied-billed Grebe	x	Improving
Horned Grebe	-	Potential colonization
Northern Gannet	-	Potential colonization^
Double-crested Cormorant	x	Improving
Great Cormorant	-	Potential colonization
American Bittern	Potential extirpation	-
Great Blue Heron	Improving	Improving
Great Egret	Potential colonization	-
Green Heron	Potential colonization	-
Black-crowned Night-Heron	-	Potential colonization
Turkey Vulture	x	Potential colonization
Northern Harrier	Worsening^	Improving
Sharp-shinned Hawk	x	Improving
Cooper's Hawk	x	Potential colonization
Northern Goshawk	x	Worsening
Bald Eagle	x	Improving
Red-shouldered Hawk	Improving	-
Red-tailed Hawk	Improving	Improving
Rough-legged Hawk	-	Stable
American Coot	-	Potential colonization
Killdeer	Improving	-
Solitary Sandpiper	Stable	-
Greater Yellowlegs	Stable	-
Willet	Stable^	-
Lesser Yellowlegs	Potential extirpation^	-
Sanderling	-	Potential colonization
Purple Sandpiper	-	Potential colonization
Wilson's Snipe	-	Potential colonization
Bonaparte's Gull	-	Potential colonization
Ring-billed Gull	-	Improving
Herring Gull	Stable	Improving^
Thayer's Gull	-	Potential colonization
Great Black-backed Gull	x	Improving
Black Tern	Potential extirpation	-
Rock Pigeon	Improving	Improving
Mourning Dove	Improving	Stable
Yellow-billed Cuckoo	Potential colonization	-
Black-billed Cuckoo	Stable	-
Eastern Screech-Owl	-	Potential colonization
Great Horned Owl	x	Improving
Snowy Owl	-	Stable
Barred Owl	x	Stable
Chimney Swift	Potential colonization	-
Ruby-throated Hummingbird	Stable	-
Belted Kingfisher	Worsening	Potential colonization
Red-headed Woodpecker	Potential colonization	Potential colonization

Common Name	Summer Trend	Winter Trend
Red-bellied Woodpecker	Potential colonization	Potential colonization
Yellow-bellied Sapsucker	Potential extirpation	Potential colonization
Downy Woodpecker	Improving	Worsening
Hairy Woodpecker	Potential extirpation	Worsening
Black-backed Woodpecker	x	Potential extirpation
Northern Flicker	Stable	Improving
Pileated Woodpecker	Potential extirpation	Potential extirpation
American Kestrel	x	Improving
Merlin	x	Potential colonization^
Peregrine Falcon	x	Potential colonization
Olive-sided Flycatcher	Potential extirpation	-
Eastern Wood-Pewee	Improving	-
Yellow-bellied Flycatcher	Potential extirpation	-
Acadian Flycatcher	Potential colonization	-
Alder Flycatcher	Potential extirpation	-
Willow Flycatcher	Potential colonization	-
Least Flycatcher	Potential extirpation	-
Northern Shrike	-	Worsening
Yellow-throated Vireo	Potential colonization	-
Philadelphia Vireo	Potential extirpation	-
Red-eyed Vireo	Worsening	-
Blue Jay	Improving	Stable
American Crow	Worsening	Improving

Common Name	Summer Trend	Winter Trend
Fish Crow	-	Potential colonization
Common Raven	Potential extirpation	Potential extirpation
Horned Lark	-	Improving
Northern Rough-winged Swallow	Potential colonization	-
Purple Martin	Potential colonization	-
Tree Swallow	Worsening	-
Barn Swallow	Improving	-
Black-capped Chickadee	Worsening	Worsening
Boreal Chickadee	Potential extirpation^	Potential extirpation
Tufted Titmouse	Potential colonization	-
Red-breasted Nuthatch	Potential extirpation	Worsening
White-breasted Nuthatch	Improving	Improving
Brown Creeper	Potential extirpation^	Improving
House Wren	Potential colonization	-
Winter/Pacific Wren	-	Potential colonization
Sedge Wren	Potential colonization	-
Carolina Wren	-	Potential colonization
Golden-crowned Kinglet	Potential extirpation	Stable
Ruby-crowned Kinglet	Potential extirpation	Improving
Eastern Bluebird	Potential colonization	-
Veery	Potential extirpation	-
Swainson's Thrush	Potential extirpation	-

Common Name	Summer Trend	Winter Trend
Hermit Thrush	Potential extirpation	Potential colonization
Wood Thrush	Improving	-
American Robin	Improving	Improving
Gray Catbird	Improving	Potential colonization
Northern Mockingbird	Potential colonization	-
European Starling	Improving	Improving
Bohemian Waxwing	-	Potential extirpation
Cedar Waxwing	Worsening	Improving
Snow Bunting	-	Worsening
Ovenbird	Potential extirpation	-
Worm-eating Warbler	Potential colonization	-
Northern Waterthrush	Potential extirpation	-
Blue-winged Warbler	Potential colonization	-
Black-and-white Warbler	Potential extirpation	-
Tennessee Warbler	Potential extirpation	-
Nashville Warbler	Potential extirpation	-
Common Yellowthroat	Worsening	-
Hooded Warbler	Potential colonization	-
American Redstart	Potential extirpation	-
Cape May Warbler	Potential extirpation	-
Northern Parula	Potential extirpation	-
Magnolia Warbler	Potential extirpation	-
Bay-breasted Warbler	Potential extirpation	-

Common Name	Summer Trend	Winter Trend
Blackburnian Warbler	Potential extirpation	-
Yellow Warbler	Stable	-
Chestnut-sided Warbler	Potential extirpation	-
Palm Warbler	Potential extirpation	-
Yellow-rumped Warbler	Potential extirpation	Potential colonization
Prairie Warbler	Potential colonization	-
Black-throated Green Warbler	Potential extirpation	-
Canada Warbler	Potential extirpation	-
Eastern Towhee	Potential colonization	-
American Tree Sparrow	-	Improving
Chipping Sparrow	Stable	Improving
Field Sparrow	Potential colonization	Potential colonization
Savannah Sparrow	Stable	-
Grasshopper Sparrow	Potential colonization	-
Fox Sparrow	-	Potential colonization
Song Sparrow	Stable	Improving
Lincoln's Sparrow	Potential extirpation	-
Swamp Sparrow	Worsening	Potential colonization
White-throated Sparrow	Potential extirpation	Improving
Dark-eyed Junco	x	Improving
Northern Cardinal	Potential colonization	Improving
Indigo Bunting	Potential colonization	-
Dickcissel	Potential colonization	-

Common Name	Summer Trend	Winter Trend
Red-winged Blackbird	Improving	Improving
Rusty Blackbird	Stable	Potential colonization
Common Grackle	Improving	Stable
Brown-headed Cowbird	Improving	Improving
Orchard Oriole	Potential colonization	-
Pine Grosbeak	Stable^	Potential extirpation
House Finch	Potential colonization	Potential colonization

Common Name	Summer Trend	Winter Trend
Purple Finch	Potential extirpation	Stable
Red Crossbill	Potential extirpation^	x
White-winged Crossbill	Potential extirpation	Worsening
Common Redpoll	-	Stable
Pine Siskin	Potential extirpation	Stable
American Goldfinch	Stable	Improving
Evening Grosbeak	Potential extirpation	Potential extirpation
House Sparrow	x	Improving