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Supplemental Climate Information for Georgian Bay Islands National Park

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Contents

Preface

This is a supplement to the "Let's Talks about Climate Change: Great Lakes Region" (Parker, 2017) report and is intended to support climate change discussions at Georgian Bay Islands National Park.

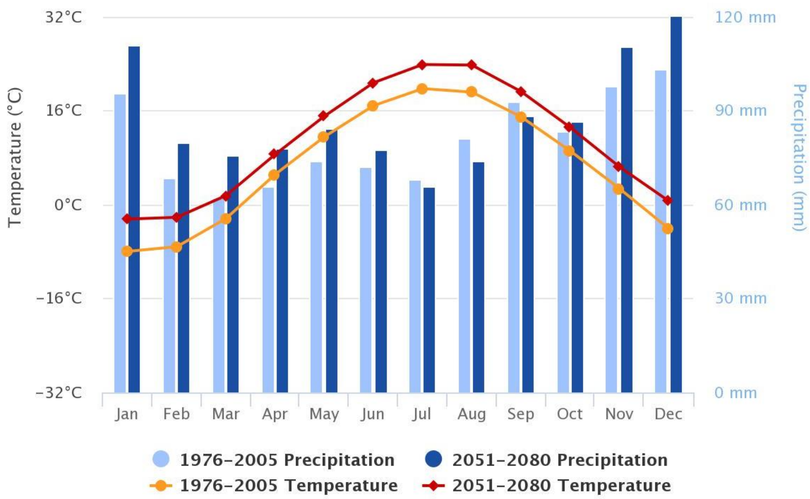
Future climate projections are modelled with several different greenhouse gas concentration trajectories called **Representative Concentration Pathways (RCP)** (Vuuren *et al.*, 2011). They describe possible climate futures and are named after respective radiative forcing values in the year 2100 relative 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 and mitigation options, please review Gross *et al.* (2016), Parker *et al.* (2018) or Rockman *et al.* (2016).

<u>Disclaimer</u>

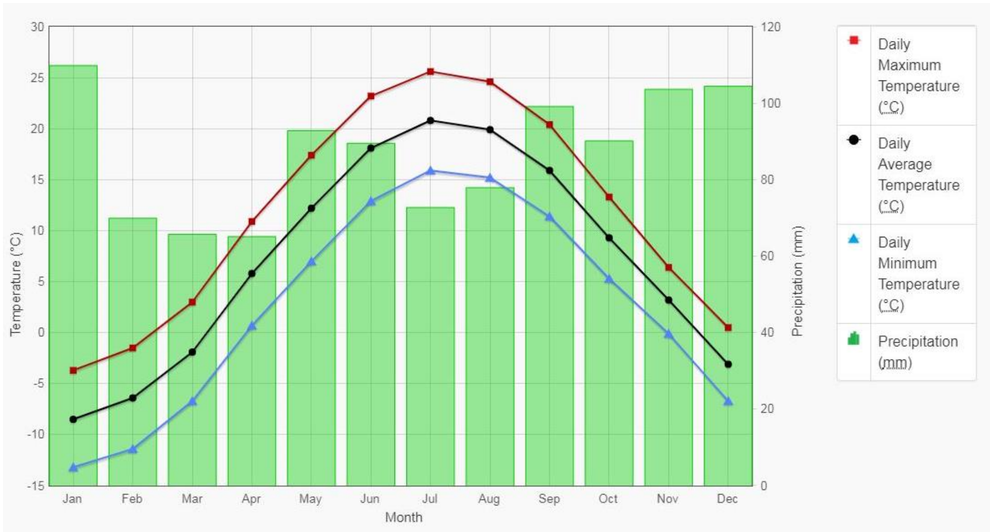
Views, statements, findings and conclusions are solely those of the author and do not necessarily reflect the views and policies of Parks Canada. Although the author has made every effort to ensure that the information is accurate, complete and correct, neither Parks Canada nor the author can guarantee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

Summary Climograph



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

1. Historic Climate

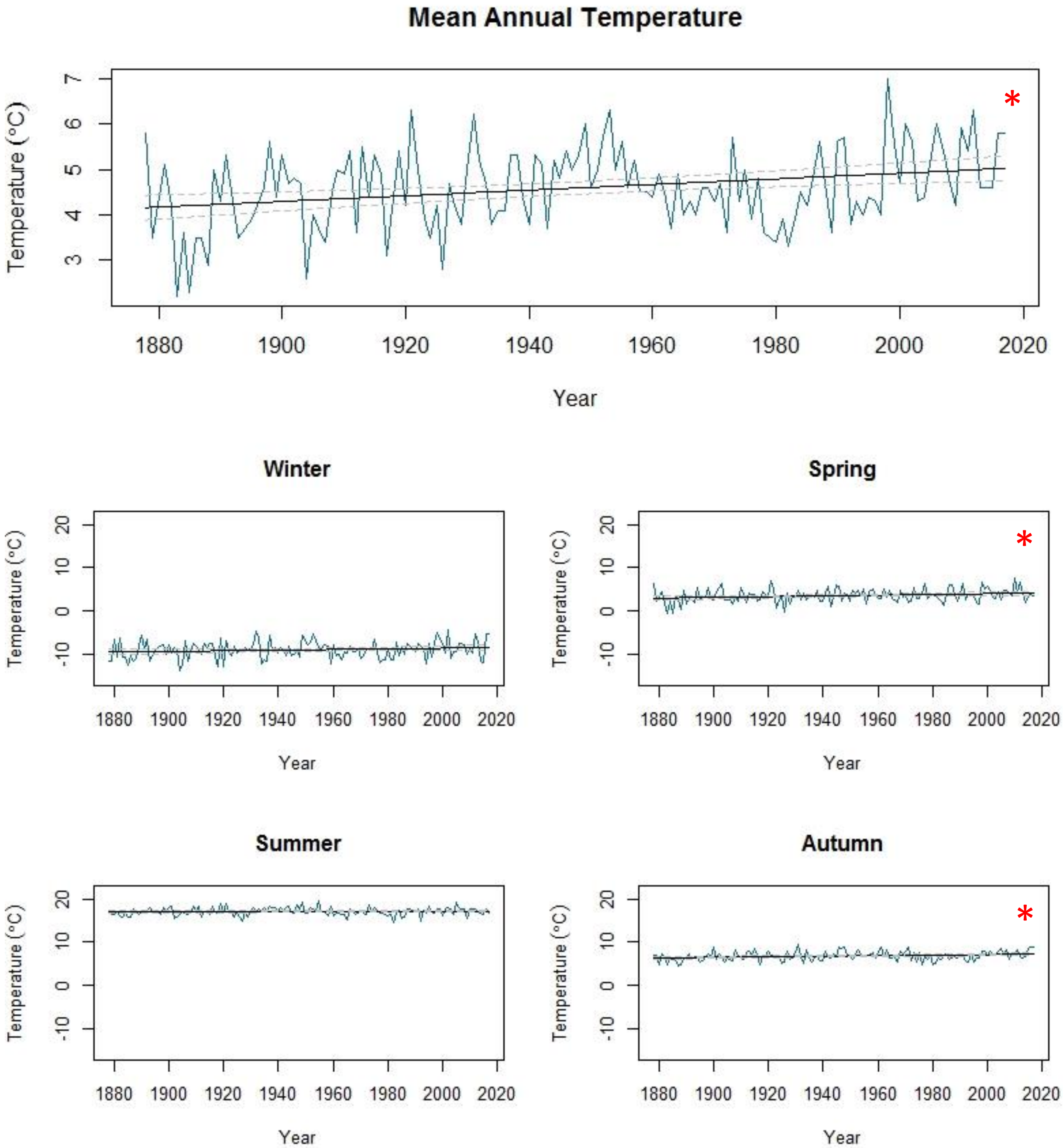


Climate "normals" (1981-2010) for Midland. Figure source: Environment and Climate Change Canada (http://climate.weather.gc.ca/climate_normals/).

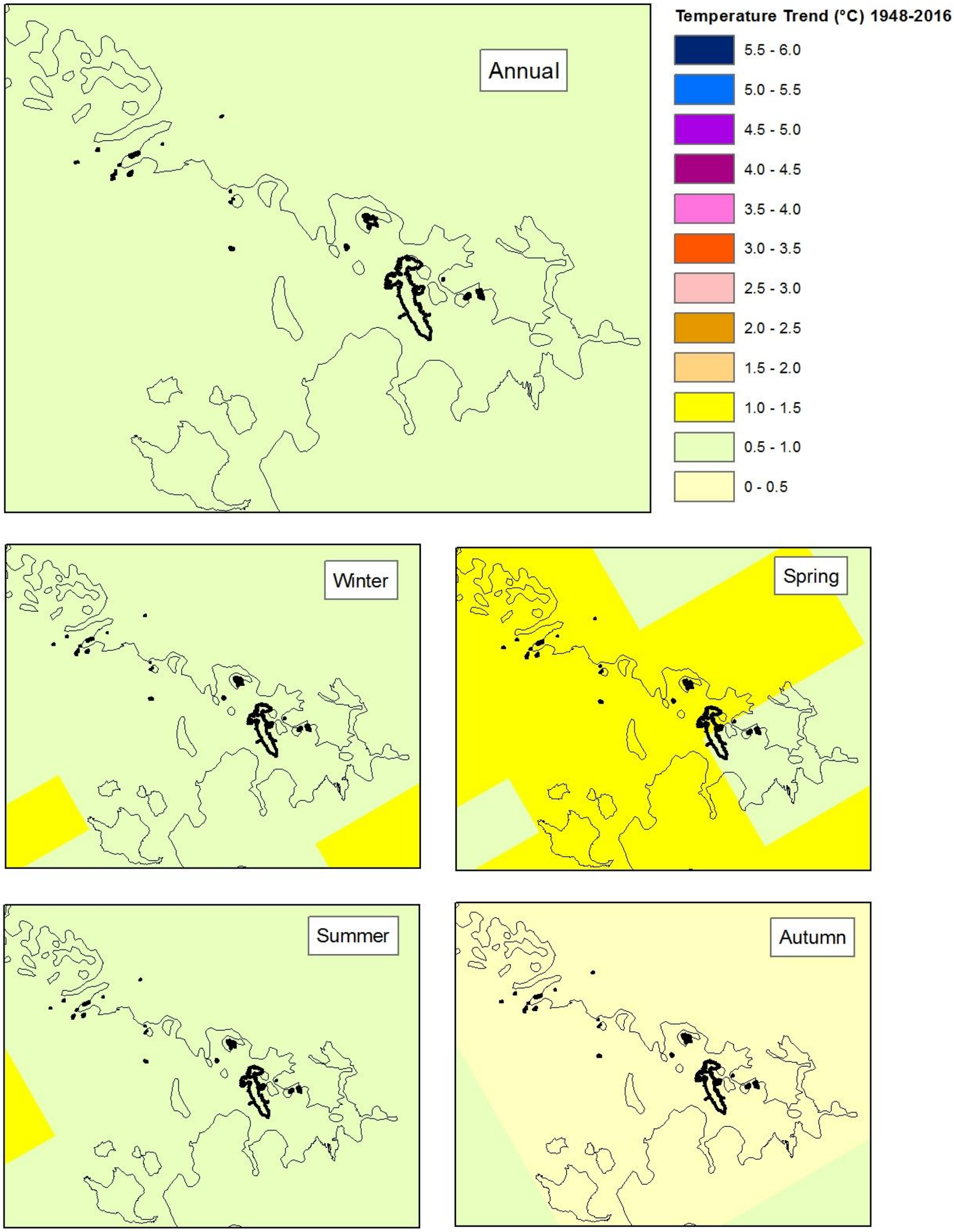
Campbell (1979) provides a detailed description of the climate of Georgian Bay Islands National Park circa 1979.

1.1 Temperature

Beatrice (6110607) is the closest meteorological station with long term temperature data (ECCC, 2017). Trends from 1878 to 2017 determined using a generalized linear model (R Core Team, 2017) including 95% confidence intervals. “*” = statistically significant trend (P<0.05).



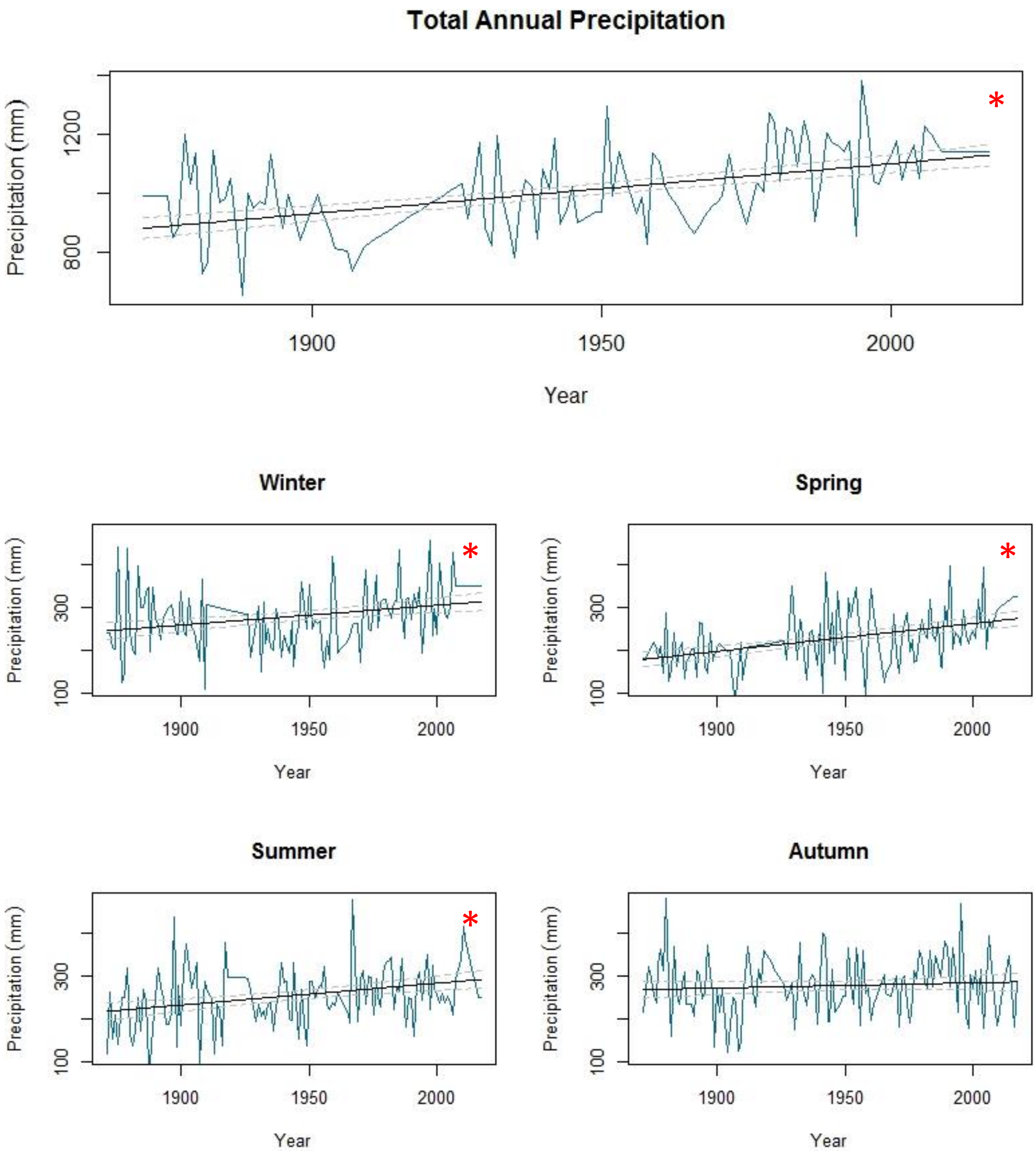
Beatrice mean annual and seasonal temperature. A statistically significant (P<0.05) increase observed in mean annual, spring (Mar, Apr. May) and autumn (Sep, Oct, Nov) temperatures. Mean annual temperature has increased by 0.9 °C since 1878. Spring temperature has increased the greatest, 1.2°C since 1878.



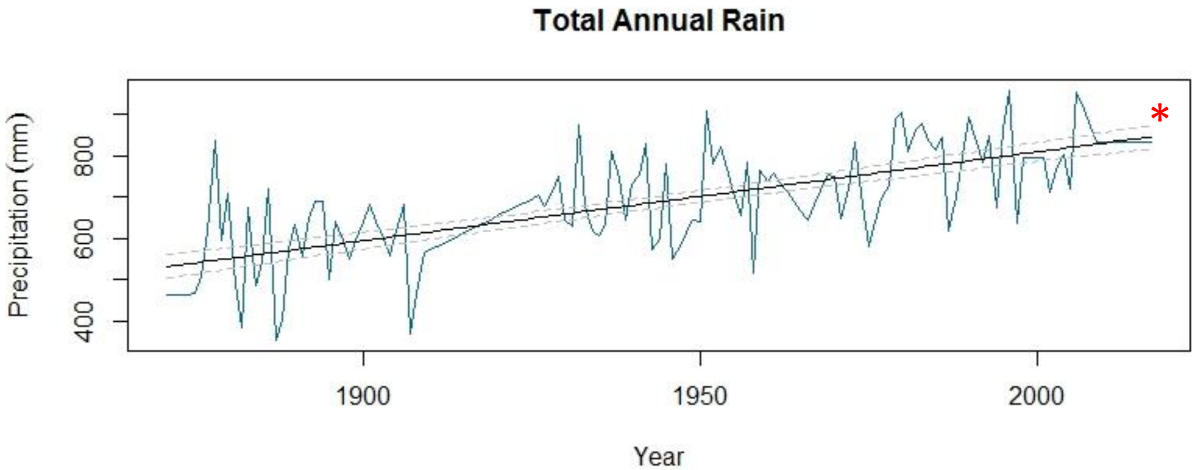
Mean annual and seasonal temperature trends (˚C) for Georgian Bay Islands NP for 1948-2016. Based on Canadian gridded data (CANGRD) it represents the change in temperature over the period of record (1950-2016). Data source: https://climate-change.canada.ca/climate-data/#/historical-gridded-data.

1.2 Precipitation

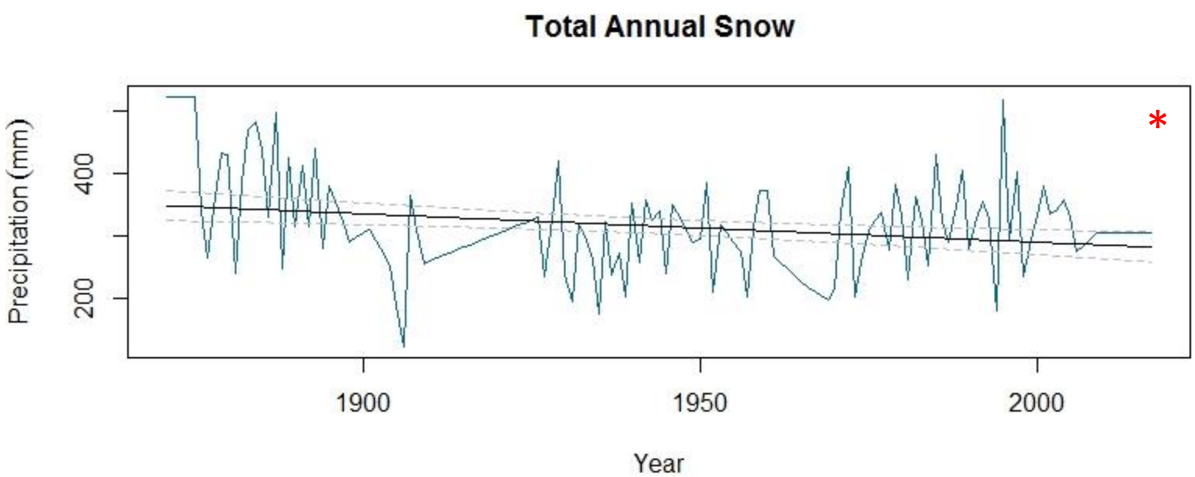
Orillia (6115811) is the closest meteorological station with long term precipitation data (ECCC, 2017). Trends from 1871 to 2017 determined using a generalized linear model (R Core Team, 2017) including 95% confidence intervals. "*" = statistically significant trend ($P<0.05$).



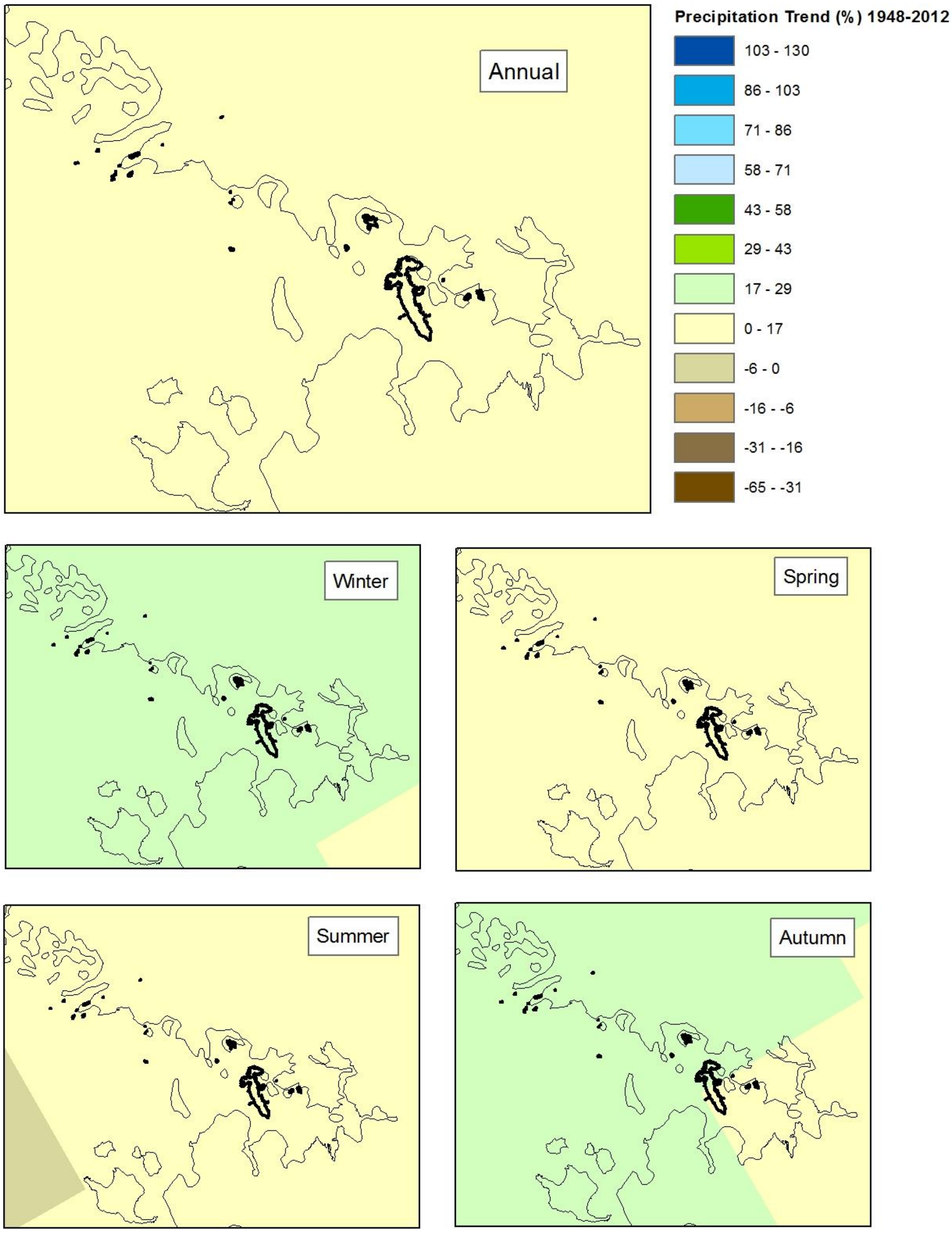
Orillia total annual and seasonal precipitation. Total annual precipitation demonstrated a statistically significant increase ($P<0.05$), 245 mm (+28%) since 1871. All seasons except autumn demonstrated a statistically significant ($P<0.05$) increase, the greatest being observed for spring (Mar, Apr, May), 95 mm (+54%).



Orillia total annual rain demonstrated a statistically significant (P<0.05) increase since 1871, 312 mm (+59%).



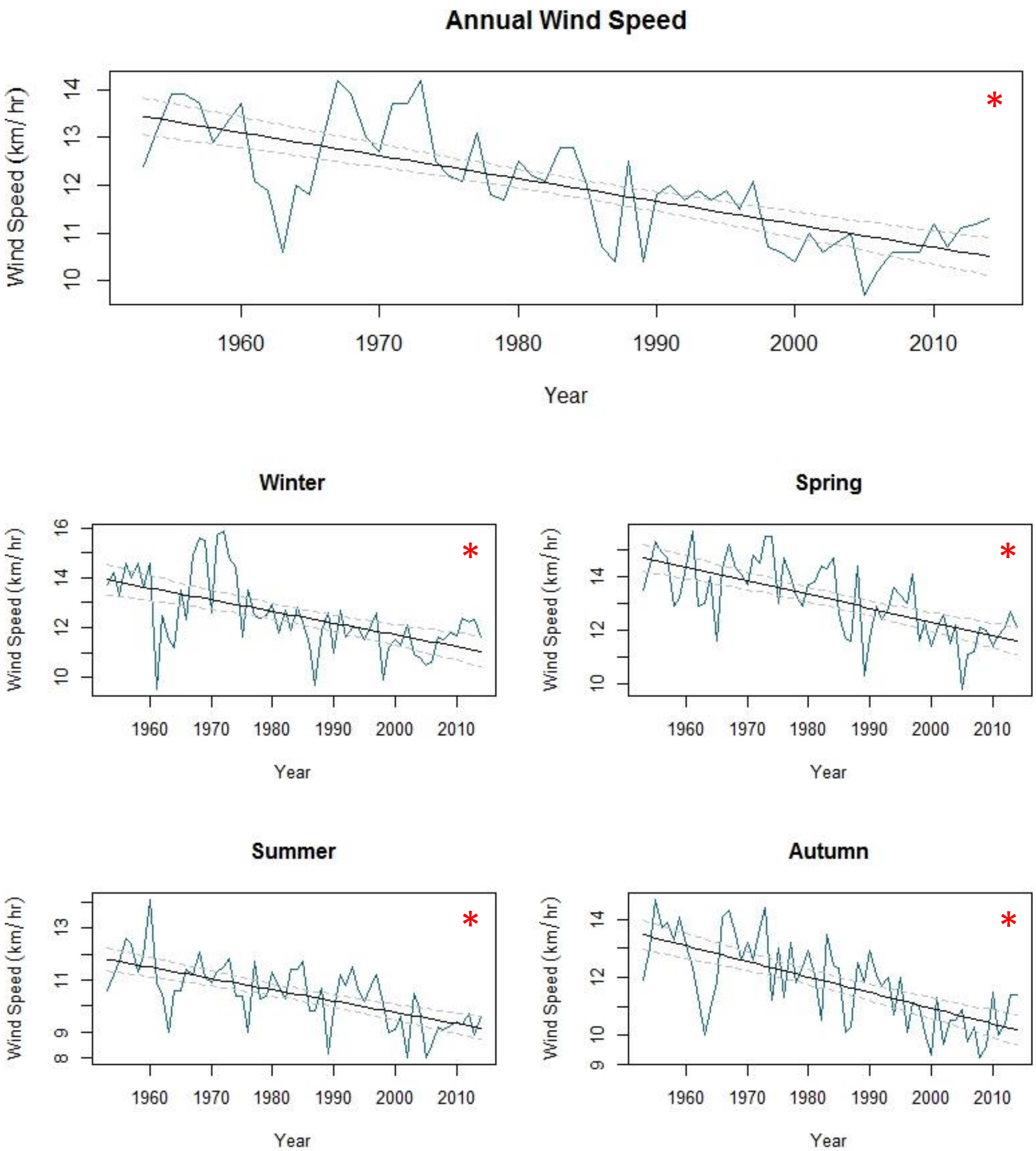
Orillia total annual snow demonstrated a statistically significant (P<0.05) decrease since 1871, -66 mm (-19%).



Total annual and seasonal precipitation trends (%) for Georgian Bay Islands NP for 1948-2012. Based on Canadian gridded data (CANGRD) the relative trends reflect the percent change in total precipitation over the period of record (1948-2012). Data source: https://climate-change.canada.ca/climate-data/#/historical-gridded-data.

1.3 Surface Wind Speed

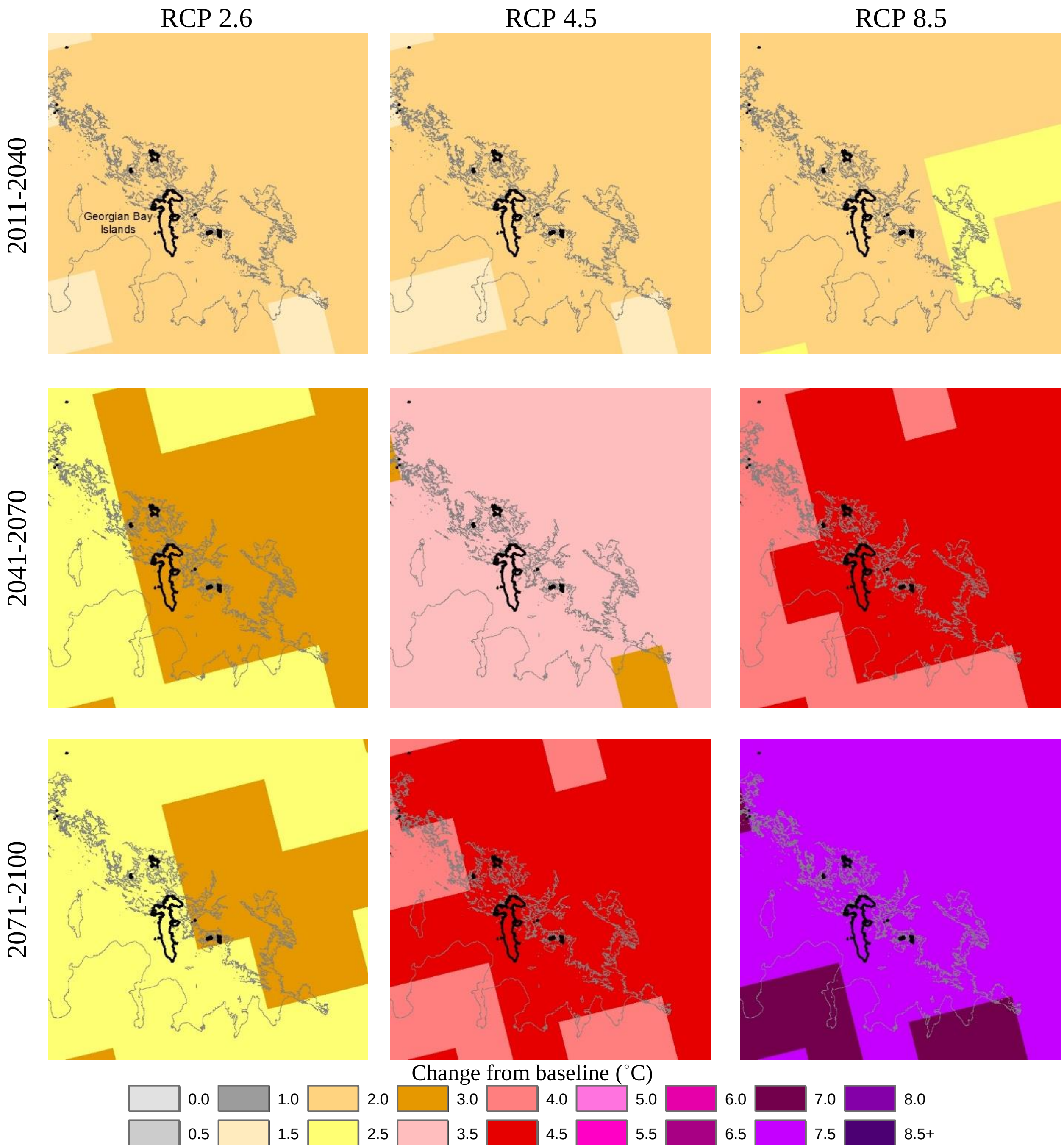
Muskoka (6115525) is the closest meteorological station with long term wind data (ECCC, 2017). Trends from 1953 to 2014 determined using a generalized linear model (R Core Team, 2017) including 95% confidence intervals. "*" = statistically significant trend (P<0.05).



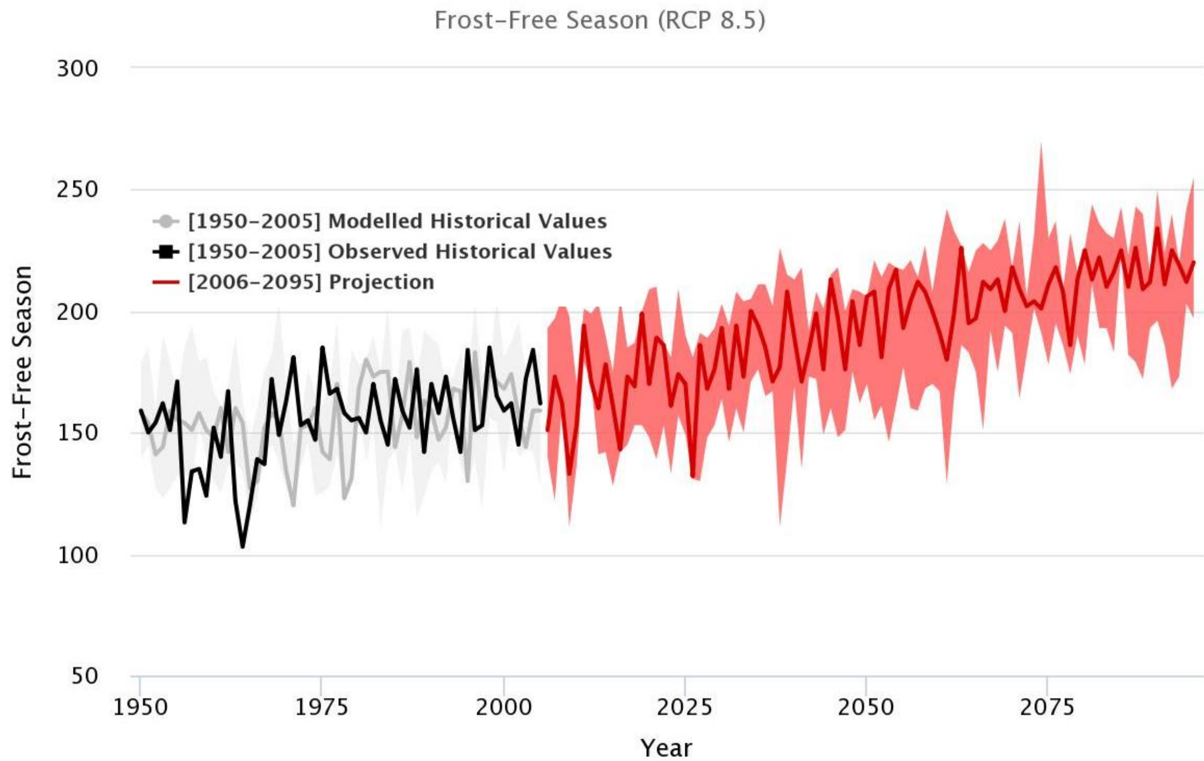
Muskoka mean annual and seasonal wind speeds. Mean annual wind speeds have demonstrated a statistically significant (P<0.05) decrease, -2.9 km/hr (-22%) from 1953 to 2014. All seasons demonstrated a statistically significant (P<0.05) decrease, the greatest being observed for autumn (Sep, Oct, Nov), -3.2 km/hr (-24%) from 1953 to 2014.

2. Projected Climate Trends

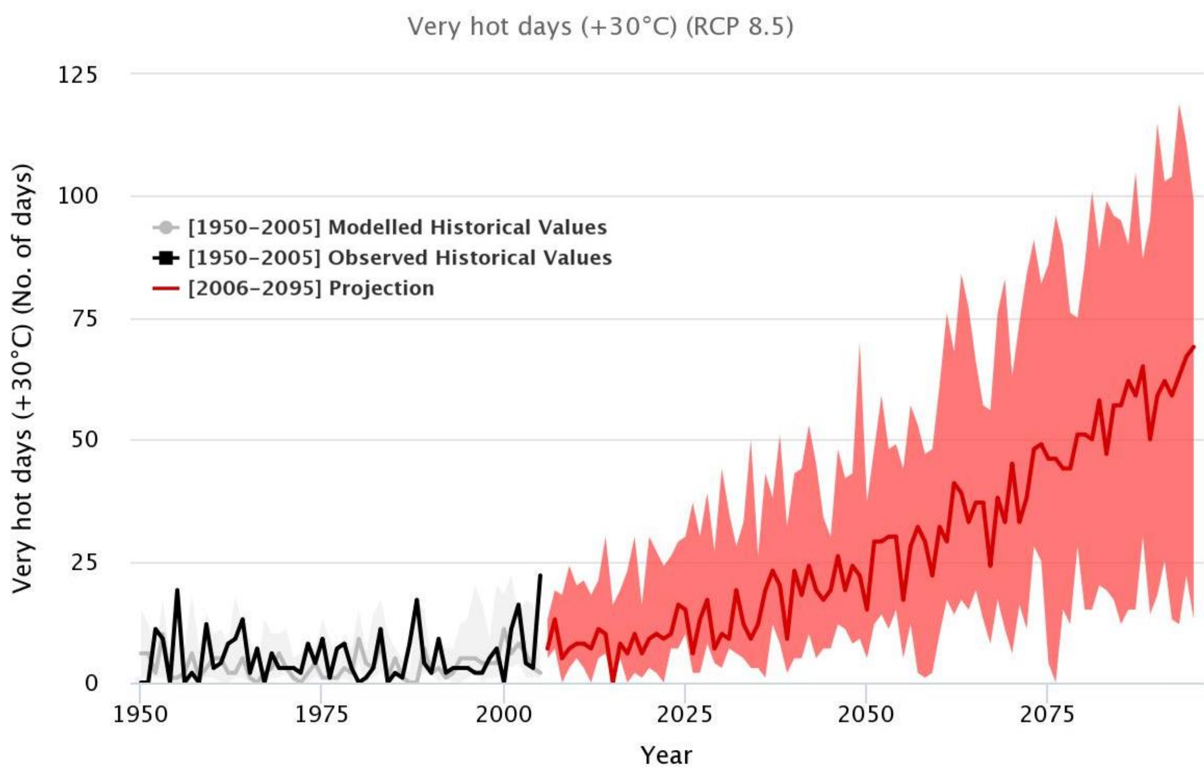
2.1 Temperature



Projected mean annual temperature increase for Georgian Bay Islands NP 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). Depending on the RCP scenario, mean annual temperatures are projected to increase 2.5 to 7.5 °C by 2071-2100.

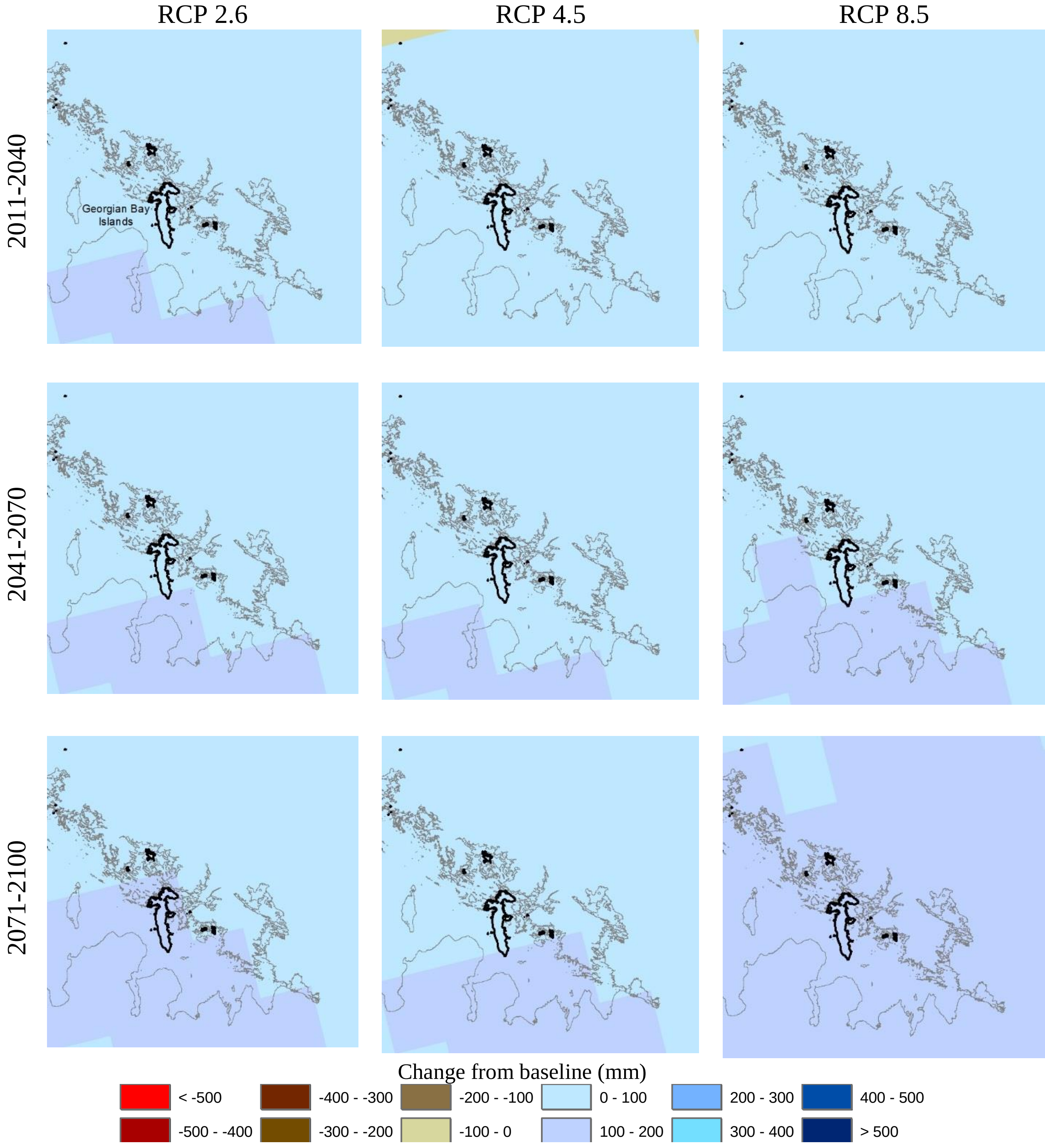


The frost-free season (days) for Midland region is projected to increase by 45.3 days from the 1976-2005 baseline by 2051-2080 (https://climateatlas.ca/). Frost-free season approximates the length of growing season (i.e., no freezing temperatures to kill or damage plants).



Very hot days (+30˚C) for Midland region are projected to increase from 3.9 days/year from the 1976-2005 baseline to 36.1 days/year by 2051-2080 (https://climateatlas.ca/).

2.2 Precipitation



Projected total annual precipitation change for Georgian Bay Islands 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). Depending on the RCP scenario, total annual precipitation is projected to increase 104 to 133 mm by 2071-2100.

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 Beausoleil Island from 1977-2007.

T (years)	2	5	10	25	50	100
5 min	8.85	11.48	13.02	14.75	15.90	16.94
10 min	11.95	16.53	19.87	24.46	28.17	32.12
15 min	14.87	20.69	24.99	31.02	35.95	41.27
30 min	19.76	28.93	36.16	46.87	56.13	66.60
1 h	23.88	35.19	44.72	59.72	73.47	89.81
2 h	28.44	41.44	51.91	67.72	81.64	97.64
6 h	42.40	58.40	68.60	81.06	90.01	98.65
12 h	49.01	69.82	83.80	101.72	115.18	128.70
24 h	50.83	72.13	87.57	108.76	125.79	143.88

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

T (years)	2	5	10	25	50	100
5 min	11.33	16.21	19.14	24.05	27.62	30.68
10 min	15.32	23.36	28.90	39.40	47.70	55.32
15 min	19.07	29.24	36.33	49.87	60.60	70.83
30 min	25.37	40.84	52.32	74.65	92.13	112.93
1 h	30.69	49.69	64.46	93.77	117.16	148.10
2 h	36.52	58.54	75.04	107.43	132.88	164.67
6 h	54.33	82.36	100.45	131.85	154.63	176.68
12 h	62.81	98.41	122.36	164.91	197.18	228.70
24 h	65.19	101.82	127.36	175.17	213.20	249.48

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

T (years)	2	5	10	25	50	100
5 min	12.17	17.36	20.71	25.10	28.46	31.37
10 min	16.73	24.95	31.31	40.94	48.73	55.35
15 min	20.86	31.21	39.35	51.81	61.84	70.55
30 min	27.93	43.60	56.70	77.60	94.37	110.31
1 h	34.04	52.93	69.71	97.74	120.20	142.72
2 h	40.30	62.42	81.25	111.75	136.14	159.64
6 h	58.60	88.37	108.91	137.24	160.53	179.81
12 h	68.02	105.58	132.78	171.62	204.45	230.93
24 h	71.16	108.89	138.09	182.15	218.00	249.04

Beausoleil Island IDF observations and projections. Observe that today's "one in 100 year" rainfall event (i.e., 89.91 mm/hr) is projected to be closer to a "one in 25 or 50 year" event by 2050-2100 and the future "one in 100 year" rainfall event is projected to increase in intensity (i.e., 142.72 – 148.10 mm/hr). In addition, the Climate Atlas of Canada (https://climateatlas.ca/) projects that the number of heavy precipitation days (>20mm) will increase from the 1976-2005 baseline of 6.1 days to 7.8 days by 2051-2080.

Other projected precipitation trends

- Wang *et al.* (2017) project that total annual precipitation will increase by 7.5%, 10.1% and 5.9% in the 2030s, 2050s and 2080s respectively relative to the 1961-1990 baseline.
- Precipitation patterns are expected to change, including more falling as rain than snow, an increase in the amount of spring time precipitation and an increase in the intensity of precipitation events (e.g., Cheng *et al.*, 2012; Deng *et al.*, 2016; Wang *et al.*, 2015).
- Cold air flowing over warmer open water (reduced ice cover) enhances lake evaporation, resulting in greater lake-effect precipitation. Local air temperatures will determine if the precipitation falls as snow or rain (Kunkel *et al.*, 2009; Notaro *et al.*, 2015b; Notaro *et al.*, 2014).
- Summer drought conditions are projected to increase due to decreased summer rain and increased temperature and evapotranspiration (Bonsal *et al.*, 2011).

2.3 Wind

Wind is an important variable in ecosystem dynamics as it influences evaporation, water currents, ice cover, erosion, thermoclines, etc. It is difficult to model and results from a few studies suggest that wind speeds will become more variable and that extreme events will have higher wind speeds (e.g., Cheng *et al.*, 2014; McDermid *et al.*, 2015).

3. Climate Change Impacts

3.1 Water Temperature and Levels

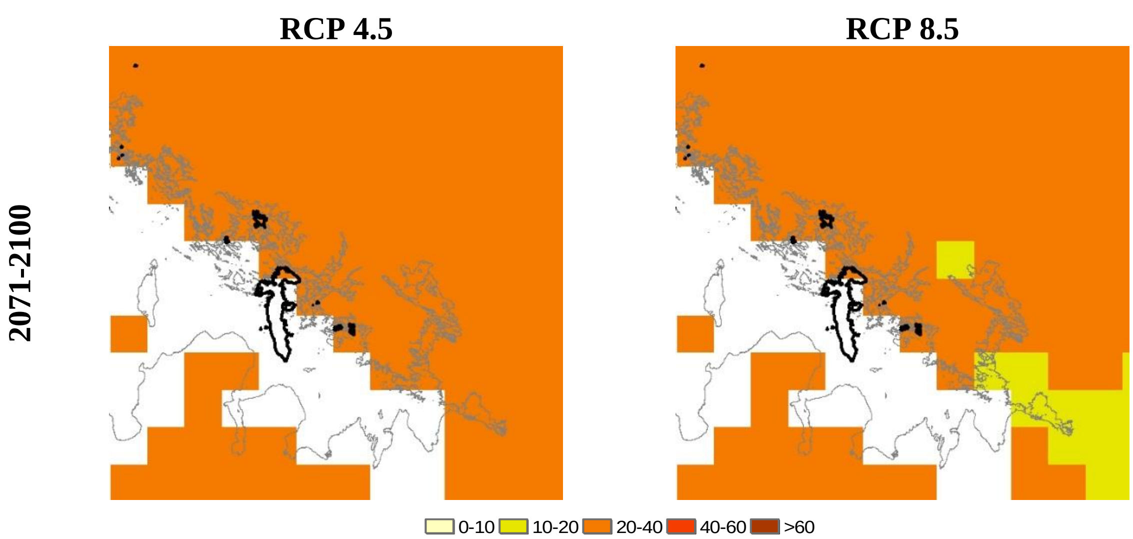
- Lake summer surface water temperature for Georgian Bay has increased by 0.07˚C/year from 1994 to 2013 (Mason *et al.*, 2016).
- Surface water temperatures for Lake Huron are projected to increase 2.6-3.9°C by 2071-2100 relative to a 1971-2000 baseline (Trumpickas *et al.*, 2009).
- An earlier onset and longer period of thermal stratification in Lake Huron is expected (Zhong *et al.*, 2016). For instance, the number of days with a surface water temperature greater than 4°C is projected to increase by 45-62 days by 2071-2100 relative to a 1971-2000 baseline (Dove-Thompson *et al.*, 2011; Trumpickas *et al.*, 2008).
- Wang *et al.* (2012) report that the spatial extent of ice coverage on Lake Huron has declined by 62% from 1973 to 2010. Mason *et al.* (2016) also report that a significant decline in ice cover duration of -0.67 days/year has occurred for Lake Huron.
- Ice cover is projected to continue to decline (e.g., by half, see figure 8 in Notaro *et al.*, 2015b).
- Hydrographic Station Data (lake level) is available for Collingwood (02ED012) from 1906 to present and for Midland (02ED033) from 2011 to present (http://collaboration.cmc.ec.gc.ca/cmc/hydrometrics/www/ or http://tides.gc.ca). Although no analysis was undertaken for this report, the data does highlight the

variability in lake levels across times scales from hours to decades, with a recorded minimum/maximum difference in levels of 2.4 m.

- Lake precipitation, basin runoff and lake evaporation are the primary drivers of water levels (IJC, 2009).
- Many of the earlier studies predicted lower lake levels due to climate change (e.g., Croley, 1990). More recent studies suggest that future lake levels will fluctuate within the historical range of variability but with a lower mean level (e.g., -14 to -25 cm from current) (IJC, 2012; Lofgren and Rouhana, 2016; MacKay and Seglenieks, 2013; Music *et al.*, 2015) and one study suggests that lake levels will be higher (+42 cm from current) (Notaro *et al.*, 2015a).
- Treasure Bay, Beausoleil Island is one of 25 study sites in a Great Lakes coastal wetland resilience study currently being led by Environment and Climate Change Canada. One outcomes of the study (2017-2021) will be a detailed hydrological model with future projections of lake levels for the bay (contact Greg Mayne, ECCC).
- Phosphorus loading into lake is expected to be higher in spring due to increased precipitation and runoff from agricultural fields (Collingsworth *et al.*, 2017).

3.2 Wildfire

Due to positive trends in drying and escalation of potential fire severity and intensity, a moderate increase in wildfire risk is projected for this area (Whitman *et al.*, 2015).



Projected increase in wildfire season for Cape Breton Island. Increased length in days from baseline (1981-2010) under RCP 4.5 and RCP 8.5 scenarios. Depending on the RCP scenario, an increase of 20 to 25 days is projected by 2071-2100. Data source: Natural Resources Canada, http://cfs.nrcan.gc.ca/fc-data-catalogue.

- Lightening has a positive correlation with temperature, increasing risk of wildfire ignitions (e.g., Veraverbeke *et al.*, 2017; Woolford *et al.*, 2014).

- Flannigan *et al*. (2016) demonstrate that seasonal precipitation must increase 15% to offset every 1˚C rise in temperature. Wotton *et al.* (2005) project drier forest floor conditions and predict a province-wide increase in the number of wildfires.
- More severe fire weather (heat and drought) may create conditions (i.e., intensity >10,000 kW/m) where fire suppression is no longer feasible or effective (Colombo, 2008; Podur and Wotton, 2010; Wotton *et al.*, 2017).
- Provincially, Fire Weather Index and Fire Severity values are projected to increase (Lemieux *et al.*, 2007; Podur and Wotton, 2010; Wotton *et al.*, 2017; Wotton *et al.*, 2005).

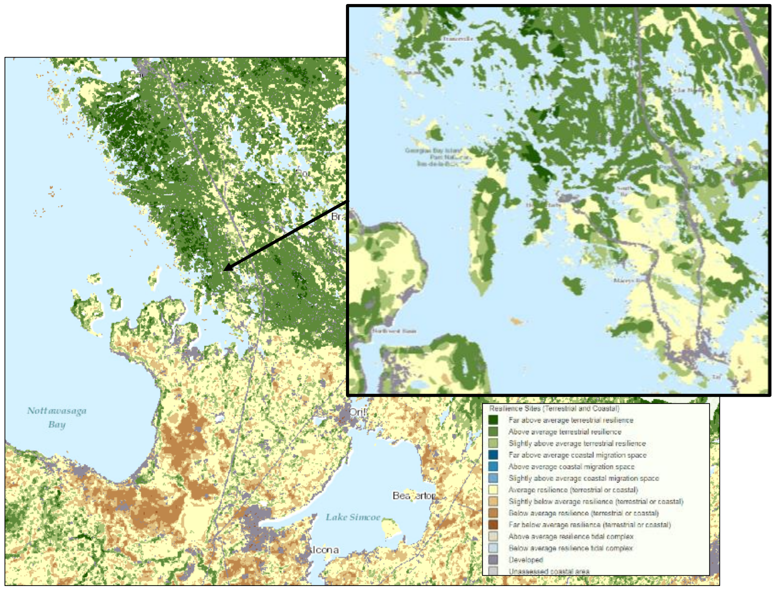
3.3 Biodiversity

Biodiversity is the variety of genes, species and ecosystems and is essential to our social, economic and ecological well-being. 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).

- 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. Natural Resources Canada maintains a database that includes future projections of plant hardiness (http://www.planthardiness.gc.ca/). See Appendix 3.
- Brinker *et al*. (2018) assessed the relative vulnerability of 280 species in Ontario. Some park species such as Puttyroot (*Aplectrum hyemale*) and Spotted Turtle (*Clemmys guttata*) were determined to have moderate vulnerablity while others such as Common Five-lined Skink (*Plestiodon fasciatus*) were determined to have low vulnerability. Consult the report for more species and details.
- Climate change could create conditions which are more favourable for invasive species, (e.g., Mainka and Howard, 2010; Walther *et al.*, 2009). For instance, beech are already sensitive to climate change (e.g., flooding/drought events) and are now facing high rates of mortality from invasive beech bark disease (Stephanson and Ribarik Coe, 2017). The invasive emerald ash borer doubled its rate of infestation in Toronto during a recent hot summer, further devastating trees already stressed by warm and dry conditions (DeSantis *et al.*, 2013). There is strong association between warmer temperatures and invasive gypsy moth distribution (potential threat to hardwood forests) (Regniere *et al.*, 2009).
- Earlier peaks in insect populations and plant biomass have been observed and may mismatch with migrant bird hatchling growth and development (e.g., asynchrony between wood warbler and eastern spruce budworm) (Knudsen *et al.*, 2011; Nituch and Bowman, 2013).
- Community level effects from climate change to terrestrial biodiversity in Ontario, including a summary of effects to 181 terrestrial vertebrate species, is discussed by Nituch and Bowman (2013). Documented effects include population expansion for 68 species (e.g., wood frog, gray treefrog, American woodcock, northern rough-winged swallow, little brown bat, meadow vole, opossum), population contraction for 11 species

(e.g., painted turtle, black-capped chickadee, alder flycatcher, northern flying squirrel) and equivocal for the other 102 species assessed.

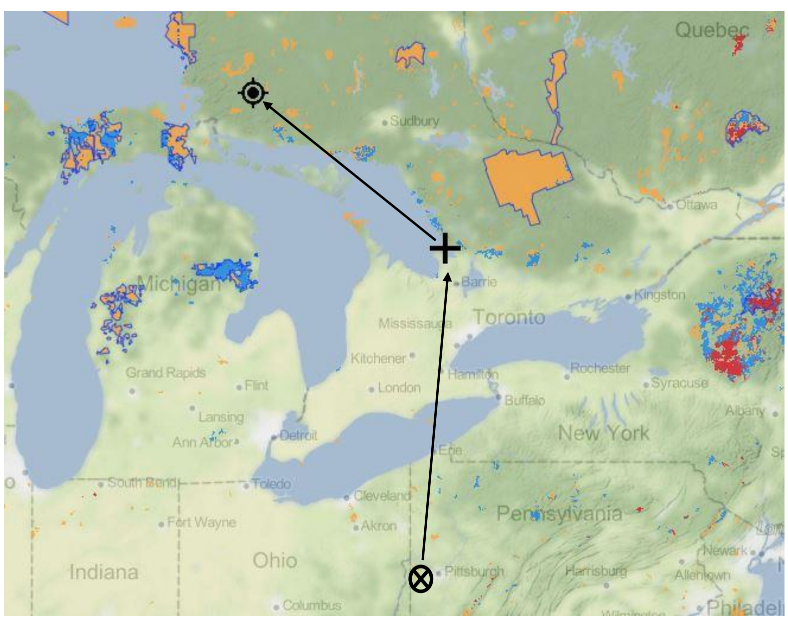
- An eastern massasauga rattlesnake vulnerability assessment predicts that the Georgian Bay Island regional population will experience high persistence and is stable/least decline in the face of climate change (Pomara *et al.*, 2014). In addition to land cover (habitat) change, winter drought and summer flooding (i.e., extreme fluctuations in water table, especially near hibernacula) were strongly associated with population declines throughout its range.
- Utilizing the National Audubon Society birds and climate change data (e.g., http://climate.audubon.org/; Wu *et al.*, 2018) a preliminary assessment for Georgian Bay Islands, suggests a potential turnover for the park species between the present and 2050 could reach 37% in summer residents and 46% in winter residents.
- A recent shift to smaller diatom species in the Great lakes (Bramburger *et al.*, 2017), including the waters near Georgian Bay Islands (Sivarajah *et al.*, 2018) may be attributed to warming waters.
- Prolonged periods of low lake levels with minimal fluctuations is shown to reduce coastal wetland area and species diversity (Fracz and Chow-Fraser, 2013; Langer *et al.*, 2018; Midwood and Chow-Fraser, 2012; Mortsch *et al.*, 2006).
- In Ontario, fish distribution has been observed to move northward at a rate of 12-17 km/decade. Cold-water fishes (e.g., brook trout, lake trout, lake whitefish) are seeking refuge further north and in deeper waters, while cool- and warm-water fishes (e.g., walleye, smallmouth bass) are moving into vacated habitats and warmer waters (Alofs *et al.*, 2014; Chu, 2015; Dove-Thompson *et al.*, 2011). While species fish richness is projected to increase, functional diversity is expected to decline (Biswas *et al.*, 2017).
- As a response to warmer waters, 27 species of fish, including non-native species, may move northward into Ontario (Mandrak, 1989).
- Phenological mismatches including changes in the timing of larval fish emergence and zooplankton production are possible and in need of further study (Collingsworth *et al.*, 2017).
- Ice cover can protect incubating eggs (e.g., lake trout, lake whitefish) by ameliorating wave action on shallow spawning shoals (Brown *et al.*, 1993).



The Nature Conservancy's Resilient Land Mapping Tool (Anderson *et al.*, 2016; http://maps.tnc.org/resilientland/). Highlights those areas with sufficient variability and microclimate options to enable species and ecosystems to persist in the face of climate change.

Climate Velocity

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



Origin and destination of the future climate type for Georgian Bay Islands (2080's, RCP 8.5) determined using AdaptWest Climate Displacement Tool, https://adaptwest.databasin.org/pages/climate-displacement-protected-areas. **Forward climate velocity**, the rate at which an organism in the current landscape has to migrate to maintain constant climate conditions is estimate at **4.5 km/yr**. **Backward climate velocity**, the rate of migration for an organism from equivalent climate conditions to colonize this climate habitat is estimated as **6.1 km/yr.**

3.4 Visitor Experience and Operations

Visitor Experience

Visitation Patterns

Although visitation patterns are monitored during the operational season, assessing and predicting the influence of climate change on total visitation or park specific activities has not been explicitly studied. However, it is expected that visitation will increase due to an earlier spring and warmer summer and autumn conditions. Naturally, knowledge from other studies may help to inform management actions in this regard, for example:

- Visitation is projected to increase in Ontario's provincial parks by the 2020s (11–27%) due to a warmer climate, and this increase may be even higher (23-41%) when combined with demographic changes (Jones and Scott, 2006b).
- Maximum and minimum temperature were determined to be most influential climate variable for predicting visitation in 15 national parks (these parks accounted for 86% of Parks Canada's visitation at the time) (Jones and Scott, 2006a).
- At Pinery Provincial Park critical temperature thresholds for visitation were revealed as being less than 11˚C and above 29˚C during the shoulder season and above 33˚C during the peak season. Modelled projections resulted in a 3.1% increase in annual visitation for every degree of warming (+1 to +5), despite increases in precipitation. Shoulder season visitation, particularly the autumn, is expected to increase (Hewer *et al.*, 2016; Hewer *et al.*, 2015; Hewer *et al.*, 2017a; 2017b).
- The US National Park Service examined visitation response across their network and found that it generally increased as mean monthly temperatures increased, but decreased strongly as temperatures exceeded 25˚C. Future climate/visitation projections suggest that there is a complex and cascading effect and a need to develop park and neighbouring community adaptation strategies (Fisichelli *et al.*, 2015).

Recreational Opportunities

- Hewer and Gough (2018) reviewed 30 years of climate change impacts on outdoor recreation in Canada, including increased risks to cold-weather activities and opportunities for warm weather activities.
- Beaches / swimming areas may face closures due to poor recreational water quality from warmer waters and increased nutrient and bacteria loads (e.g., stormwater runoff). Harmful algal blooms and filamentous algae growth will increase under such conditions as well (Barton *et al.*, 2013; Reavie *et al.*, 2014).
- Low water levels may affect vessel access and navigational safety (Shlozberg *et al.*, 2014).
- Decreased snowpack will negatively impact winter recreational activities such as snowshoeing, skiing, ice fishing, ice travel and snowmobiling.
- A longer and more intense fire season will affect visitor safety and experience (e.g., area closures, no campfires).

Human Health

- Lyme disease (tick carrying the borrelia pathogen), which was formerly restricted to localized areas by temperature and relative humidity, is expected to expand to the entire

Great Lakes region by mid-century (Eisen *et al.*, 2016; Ogden *et al.*, 2006). Other pathogens associated with black legged ticks include arboviruses (encephalitis), Anaplasma, Ehrlichia, Babesia, Rickettsia and Bartonella (Nelder *et al.*, 2016). Lyme disease and arbovisruses are reportable in Ontario. Companion animals are also at risk to Lyme and other tick-borne diseases (e.g., Public Health Ontario, 2017).

- Increasing incidences of West Nile Virus (mosquito vector) have been linked to climate change, including the temperature for mosquito development (14-35˚C) and the extrinsic incubation period (Chen *et al.*, 2013; Soverow *et al.*, 2009).
- The literature suggests that climate change will increase the northward expansion of mosquito's and associated pathogens (Wudel and Shadabi, 2016). The range of *Aedes albopictus* which is a vector for Zika virus, Dengue virus, Yellow fever and other diseases, is projected to expand into parts of Ontario by 2041-2070 (Ogden *et al.*, 2014).
- Changing weather and increased temperature can affect the rate of photochemical smog formation (e.g., ozone).
- Extreme weather events are the top risk globally in terms of likelihood and the second highest risk in terms of impact (after weapons of mass destruction) (World Economic Forum, 2018). Intense rainfall, lightning storms, hail, extreme winds and wildfire events are all potential hazards whose risks are projected to increase (e.g., Brimelow *et al.*, 2017; Cheng *et al.*, 2012; IPCC, 2012). Besides a potential role in emergency preparedness and response, protected areas are increasingly being recognized as a "natural solution" in terms of disaster risk reduction (e.g., flood control, protection from storm surge, etc…) (e.g., Dudley *et al.*, 2015; Lo, 2016; Murti and Buyck, 2014).

Interpretation and Communication
Climate change is a theme in Parks Canada's communication and interpretation programs (e.g., https://www.pc.gc.ca/en/nature/science/climat-climate). By engaging and inspiring the public, Parks Canada is able to build support for its mandate and adaptation actions. A place for "natural solutions" is a concept used to frame and present Parks Canada's response to climate change mitigation and adaptation, as it highlights the importance and effectiveness of ecosystem-based approaches (e.g., CPC, 2013; NAWPA, 2012)

"The changing climate surrounds us, compelling us to tell the story" (US NPS). Of related interest, is the US National Park Service climate change interpretation and education strategy (US NPS, 2016) and climate change interpreter training (http://idp.eppley.org/training/specialist/interpreting-climate-change). Parks Canada staff have found this training to be very helpful.

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). Although an assessment of vulnerabilities and risks to infrastructure has not been completed at Georgian Bay Islands, in light of the information in this report, expected concerns could include:

- Localized flooding from intense rainfall and winter rain events.
- Freezing rain or hail damage to buildings and power/communication lines.
- Longer wildfire season and more intense burns.
- Increased lake storm intensity and less ice cover increases risk of coastal flooding and erosion
- Longer seasonal use of trails.
- 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).
- Summer drought increases water demands and may exceed system capacity.
- The energy demands for cooling buildings will increase.

An assessment of greenhouse gas (GHG) emissions was not in the scope of this report. However, it is important to observe that throughout the document different RCP scenarios were presented and if we meet (and celebrate) RCP 2.6 or continue to track (and mourn) RCP 8.5, depends entirely on our actions to address and reduce GHG emissions today. 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).

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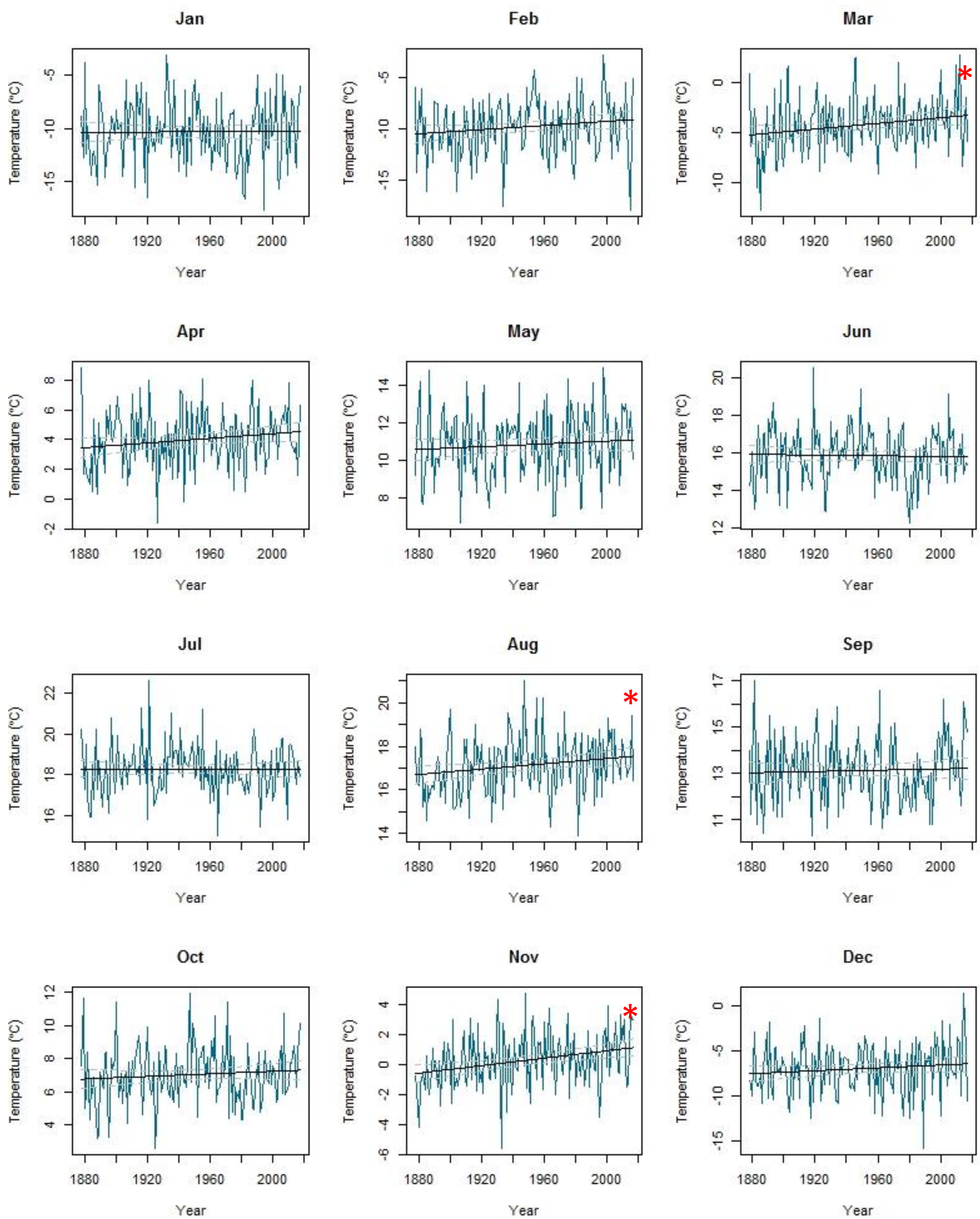
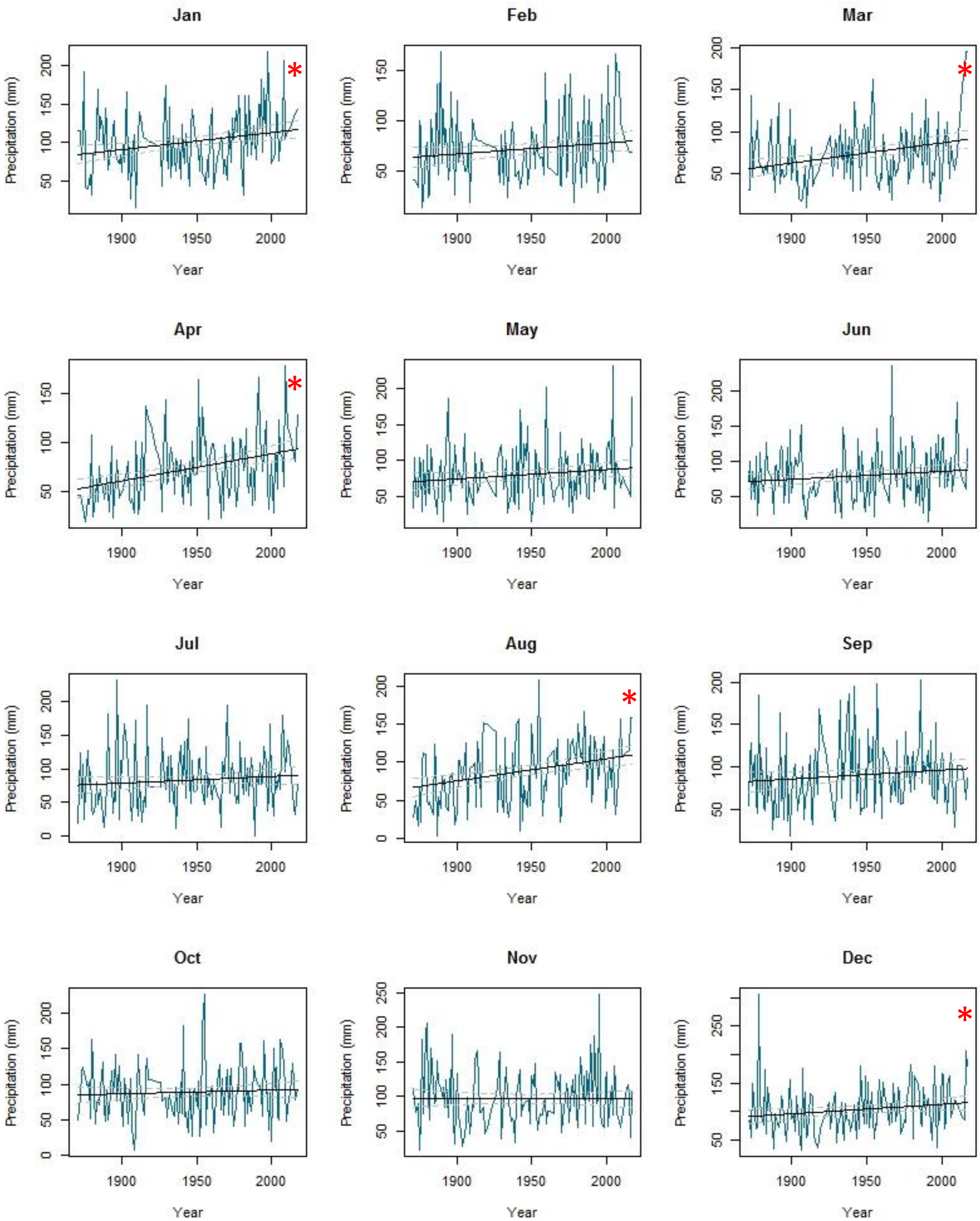
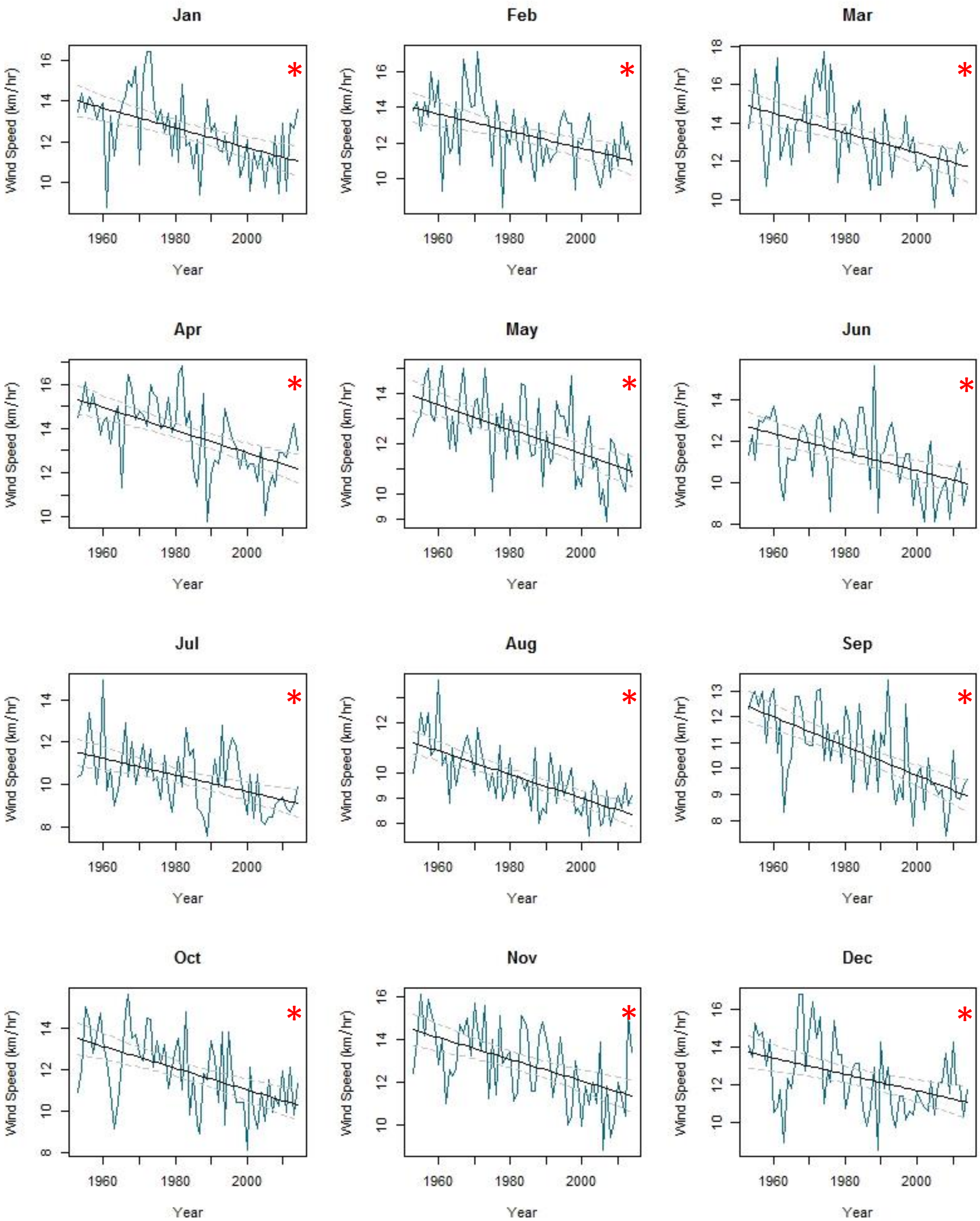
Appendix 1. Additional Climate Trends



Beatrice mean monthly temperature. While all months have increased, only Mar, Aug and Nov demonstrated a statistically significant (P<0.05) increase.

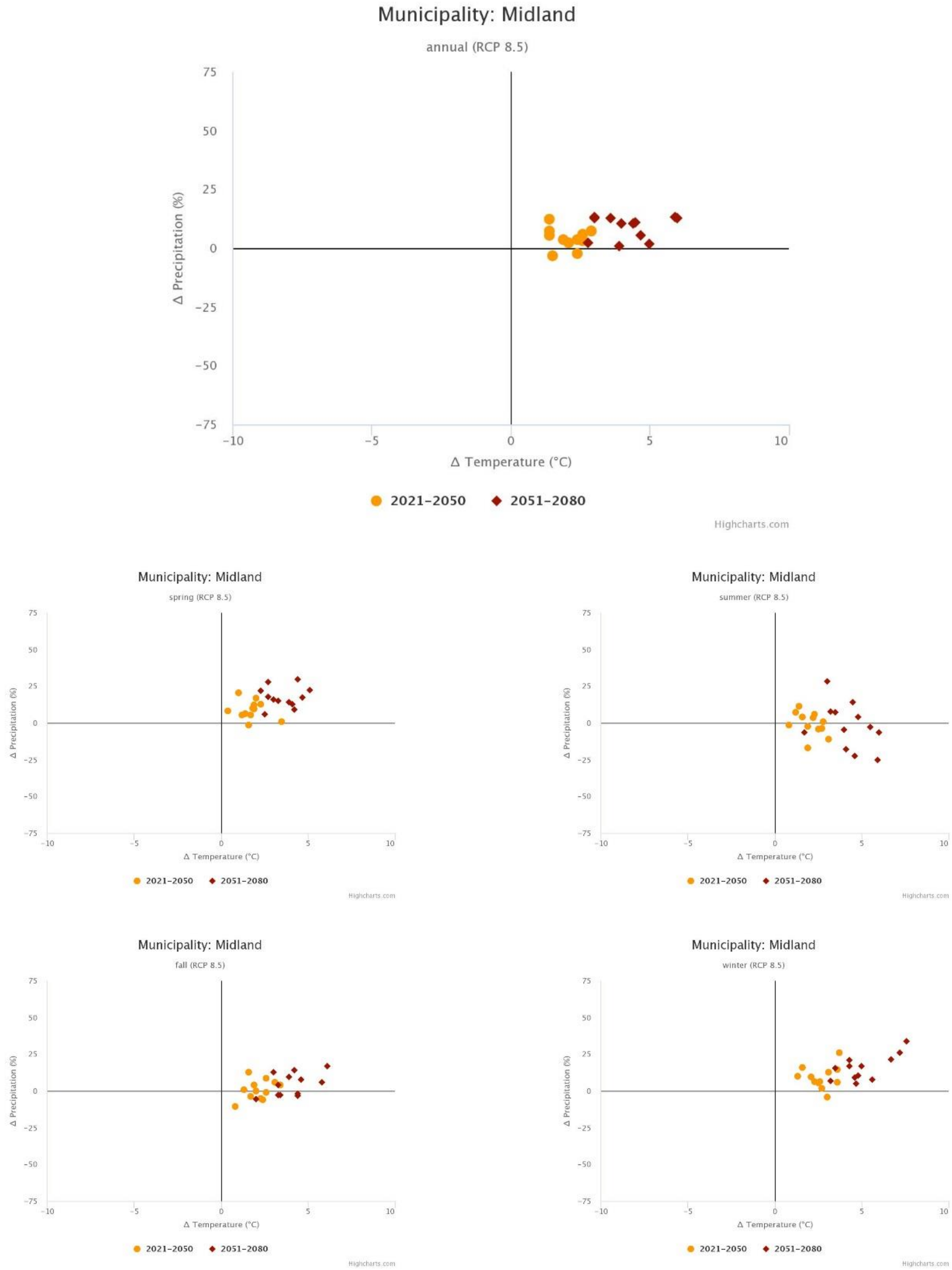


Orillia total monthly precipitation. Jan, Mar, Apr, Aug and Dec all demonstrated a statistically significant increase (P<0.05) since 1871.



Muskoka mean monthly wind speeds. All mean monthly wind speeds have demonstrated a statistically significant (P<0.05) decrease since 1953.

Appendix 2. Temperature and Precipitation Scatterplots

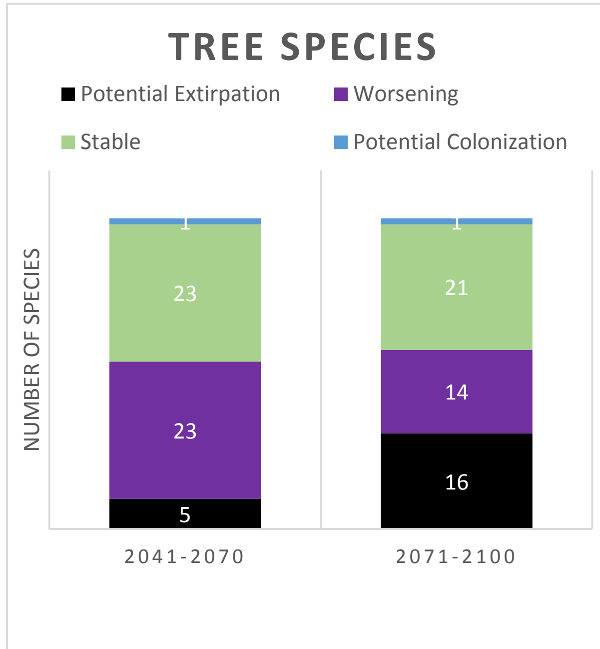


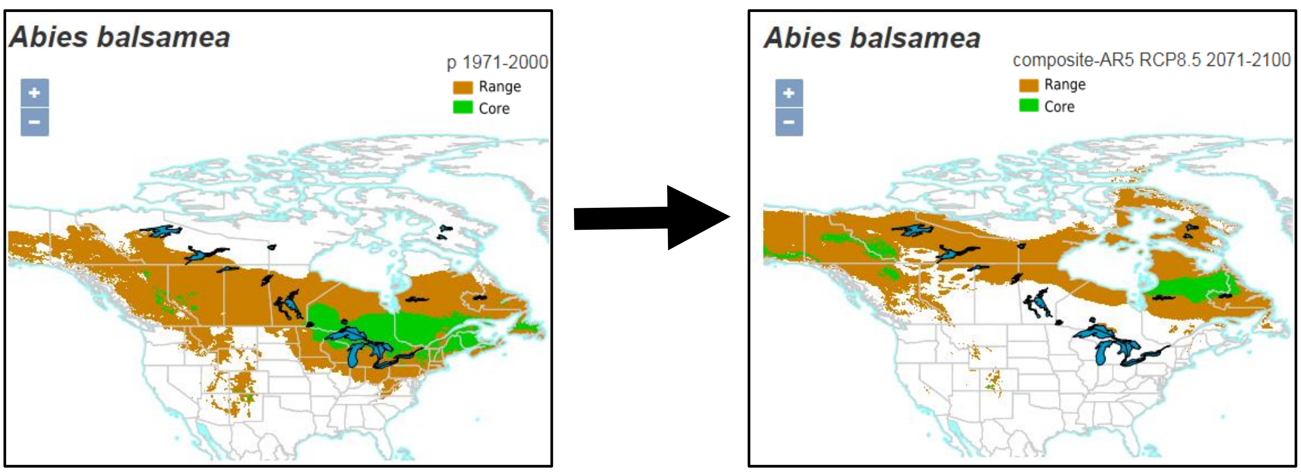
Climate models for Midland region. Each point represents a single model-simulated temperature/precipitation response to the RCP 8.5 scenario. Statistically downscaled data (Bias Corrected Spatial Disaggregation; BCSD) derived from 12 CMIP5 global climate models: ACCESS1.0, CanESM2, CCSM4, CNRM-CM5, CSIRO-Mk3-6.0, GFDL-ESM2G, HadGEM2-CC, HadGEM2-LR, INM-CM4, MPI-ESM-LR, MRI-CGCM3, MIROC5 (PCIC, 2014). All the models project warmer conditions and most project wetter conditions.

Appendix 3. Trees and Climate Change

Georgian Bay Islands National Park

- **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).
- 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.
- No species was projected to "improve" from within "Range" to "Core".





			2041-2070		2071-2100	
Common_Name	**Scientific_Name**	**Current**	**Range**	**Trend**	**Range**	**Trend**
Alternate-Leaf Dogwood	Cornus alternifolia	Core	Range	Worsening	Range	Worsening
American Beech	Fagus grandifolia	Core	Range	Worsening	Range	Worsening
American Chestnut	Castanea dentata	Range	Range	Stable	Range	Stable
American Elm	Ulmus americana	Core	Core	Stable	Core	Stable
American Mountain-Ash	Sorbus americana	Range	Range	Stable	Absent	Potential Extirpation
Balsam Fir	Abies balsamea	Core	Absent	Potential Extirpation	Absent	Potential Extirpation
Balsam Poplar	Populus balsamifera	Core	Range	Worsening	Range	Worsening
Basswood	Tilia americana	Core	Range	Worsening	Range	Worsening
Bitternut Hickory	Carya cordiformis	Range	Range	Stable	Range	Stable
Black Ash	Fraxinus nigra	Range	Range	Stable	Range	Stable
Black Cherry	Prunus serotina	Core	Range	Worsening	Range	Worsening
Black Oak	Quercus velutina	Range	Range	Stable	Range	Stable
Black Spruce	Picea mariana	Range	Absent	Potential Extirpation	Absent	Potential Extirpation
Black Walnut	Juglans nigra	Range	Range	Stable	Range	Stable
Black Willow	Salix nigra	Range	Range	Stable	Range	Stable
Blue-Beech	Carpinus caroliniana	Range	Range	Stable	Range	Stable
Bur Oak	Quercus macrocarpa	Range	Range	Stable	Range	Stable
Butternut	Juglans cinerea	Core	Range	Worsening	Range	Worsening
Eastern Hemlock	Tsuga canadensis	Core	Range	Worsening	Range	Worsening
Eastern Redcedar	Juniperus virginiana	Range	Range	Stable	Range	Stable
Eastern White Cedar	Thuja occidentalis	Core	Range	Worsening	Absent	Potential Extirpation
Eastern White Pine	Pinus strobus	Core	Range	Worsening	Absent	Potential Extirpation
Gray Birch	Betula populifolia	Core	Range	Worsening	Absent	Potential Extirpation
Green/Red Ash	Fraxinus pennsylvanica	Core	Core	Stable	Core	Stable
Ironwood	Ostrya virginiana	Core	Core	Stable	Core	Stable
Jack Pine	Pinus banksiana	Range	Range	Stable	Absent	Potential Extirpation
Largetooth Aspen	Populus grandidentata	Core	Range	Worsening	Absent	Potential Extirpation
Manitoba Maple	Acer negundo	Core	Core	Stable	Core	Stable
Northern Hackberry	Celtis occidentalis	Range	Range	Stable	Range	Stable
Peachleaf Willow	Salix amygdaloides	Core	Range	Worsening	Range	Worsening
Pin Cherry	Prunus pensylvanica	Core	Range	Worsening	Range	Worsening
Pin Oak	Quercus palustris	Range	Range	Stable	Range	Stable
Red Maple	Acer rubrum	Core	Core	Stable	Core	Stable
Red Mulberry	Morus rubra	Absent	Range	Potential Colonization	Range	Potential Colonization
Red Oak	Quercus rubra	Core	Range	Worsening	Range	Worsening
Red Pine	Pinus resinosa	Core	Range	Worsening	Absent	Potential Extirpation
Red Spruce	Picea rubens	Core	Range	Worsening	Absent	Potential Extirpation
Sassafras	Sassafras albidum	Range	Range	Stable	Range	Stable
Shagbark Hickory	Carya ovata	Range	Range	Stable	Range	Stable
Showy Mountain Ash	Sorbus decora	Range	Absent	Potential Extirpation	Absent	Potential Extirpation
Silver Maple	Acer saccharinum	Core	Range	Worsening	Range	Worsening
Striped Maple	Acer pensylvanicum	Core	Range	Worsening	Absent	Potential Extirpation
Sugar Maple	Acer saccharum	Core	Range	Worsening	Range	Worsening
Swamp White Oak	Quercus bicolor	Range	Range	Stable	Range	Stable
Sycamore	Platanus occidentalis	Range	Range	Stable	Range	Stable
Tamarack	Larix laricina	Core	Absent	Potential Extirpation	Absent	Potential Extirpation
Trembling Aspen	Populus tremuloides	Core	Range	Worsening	Absent	Potential Extirpation
White Ash	Fraxinus americana	Core	Range	Worsening	Range	Worsening
White Birch	Betula papyrifera	Core	Range	Worsening	Absent	Potential Extirpation
White Oak	Quercus alba	Range	Range	Stable	Range	Stable
White Spruce	Picea glauca	Range	Absent	Potential Extirpation	Absent	Potential Extirpation
Yellow Birch	Betula alleghaniensis	Core	Range	Worsening	Range	Worsening