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Supplemental Climate Information for Bruce Peninsula National Park and Fathom Five National Marine Park

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Contents

Preface

This is a supplement to the "Let's Talks about Climate Change: Great Lakes Region" report (Parker, 2017) and is intended to support climate change discussions at Bruce Peninsula National Park and Fathom Five National Marine 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 21^{st} century. We are currently tracking RCP 8.5.

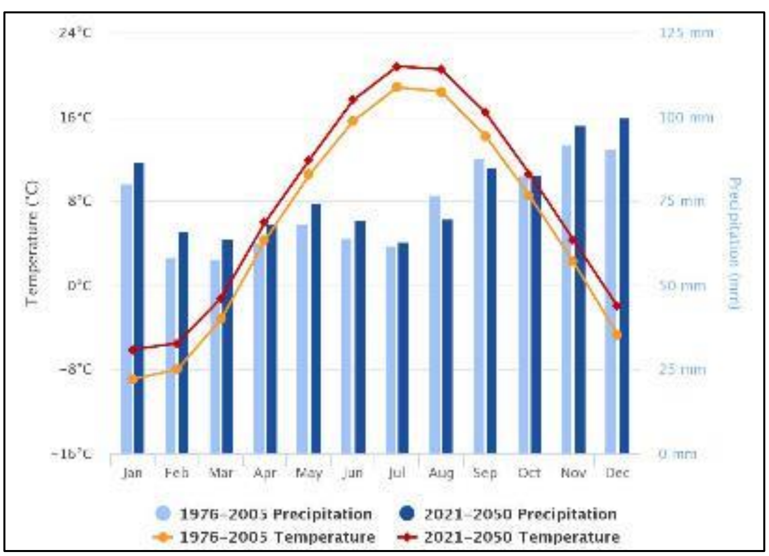
This is a site focussed document and to understand the larger climate change context please consult Canada's changing climate assessment reports (e.g., Bush and Lemmen, 2019; Warren and Lemmen, 2014) and the Intergovernmental Panel on Climate Change assessment reports (e.g., IPCC, 2014). With respect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

Disclaimer

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.

Highlights

- Mean annual air temperature in the region has increased by ~1˚C since 1916, with the greatest increase occurring during winter and nighttime periods.
- Mean annual temperature for the region is projected to increase by ~2.1˚C by 2021-2050 and ~4.3˚C by 2051-2080 (RCP 8.5).
- The number of extreme heat days (+30˚C) per year is projected to increase from 0.8 days to 21.3 days by 2051-2080 (RCP 8.5).
- Growing season has already increased by ~17 days since 1900 and is projected to increase an additional 86 days by 2100 (RCP 8.5).
- Precipitation is variable, most projections suggest a slight increase (9% by 2050-2080) with greater increase in winter and spring and a decrease in summer. More is expected to fall in intense events with associated flooding. The “one in 100 year” event is projected to be closer to a “one in 25 year” event and happen more unpredictably.
- Mean wind speed has decreased and is projected to continue to decrease, however, extreme events are projected to have higher wind speeds.
- Lake Huron is projected to warm by ~3˚C and the ice free period increase by 45-62 days by 2071-2100.
- Lake Huron levels are projected to fluctuate within historical range of variability, several models suggest the mean level may be lower, while at least one suggests higher.
- Wildfire season length is projected to increase by 20-40 days by 2040-2070. Conditions for more intense fire behaviour are projected.
- Climatic envelopes are projected to change (northward at 3 km/yr) and will no longer be suitable for many species, particularly those with northern affinities. For instance, a 42% turnover in bird species is projected by 2100. Plant hardiness zone will change and no longer be suitable for 1000 species.
- Visitation is expected to increase, particularly in the autumn.
- Human health issues include the impact of extreme heat events and the northward movement of vector-borne diseases such as Lyme disease and Ehrlichia.
- Assets and infrastructure will be exposed to more extreme weather events and wildfire.



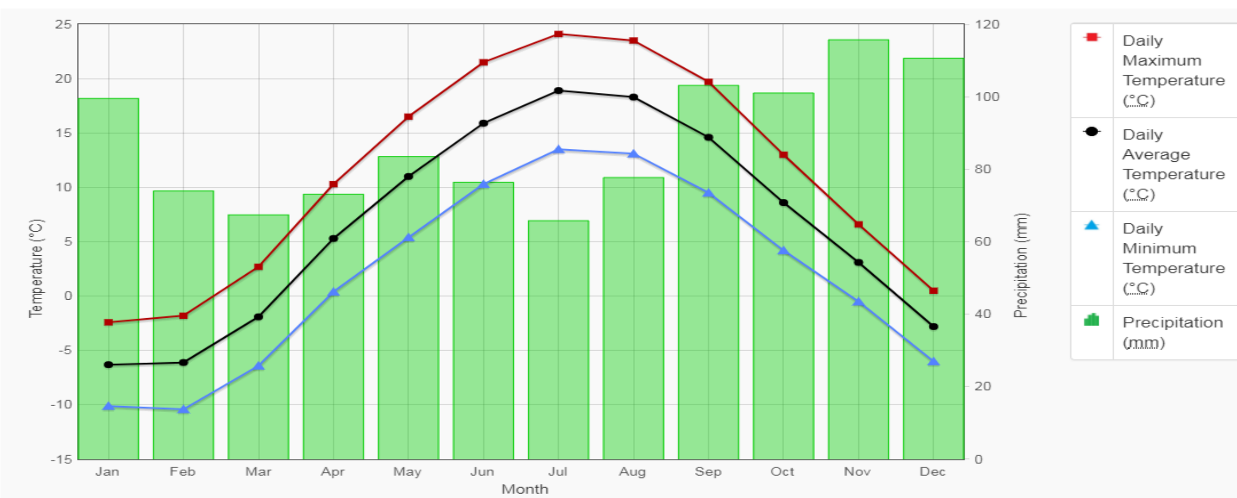
Tobermory climograph (RCP 8.5). Modelled monthly mean temperature and total precipitation for the 1976-2005 baseline and 2021-2050 future projection. Figure source: Climate Atlas of Canada (https://climateatlas.ca/).

1. Historic Climate

Moderated by its maritime location, the climate of Bruce Peninsula National Park and Fathom Five National Marine Park (BP/FF) is humid and temperate with warm summers (daily mean of 18.5˚C) and cool winters (daily mean of -6.1˚C). The summer months are dominated by hot, humid air masses originating in the Pacific Ocean and the Gulf of Mexico (with extreme maximums reaching 35˚C). Winters have an increase in Pacific air which is displaced over the season by cold Arctic currents (with extreme minimums as low as -36˚C). The most prolonged cold periods occur when large Arctic high pressure air masses stall over Hudson Bay. Spring and autumn represent transitional periods; the autumn typically being the most turbulent with a relatively high frequency of storms.

Lake Huron tends to buffer macroclimatic extremes. In the spring and summer, the colder lake cools coastal areas by a few degrees. Conversely, in the autumn and winter the warmer lake moderates temperatures, often delaying frost for several weeks. Moisture picked up from the lake by prevailing winds can cause lake effect fog, rain or snow. The annual mean water temperature for Lake Huron is 8.8˚C, with a maximum mean of 21.1˚C and a minimum mean of 1.1˚C. Mean maximum ice cover for Lake Huron is 51.7%.

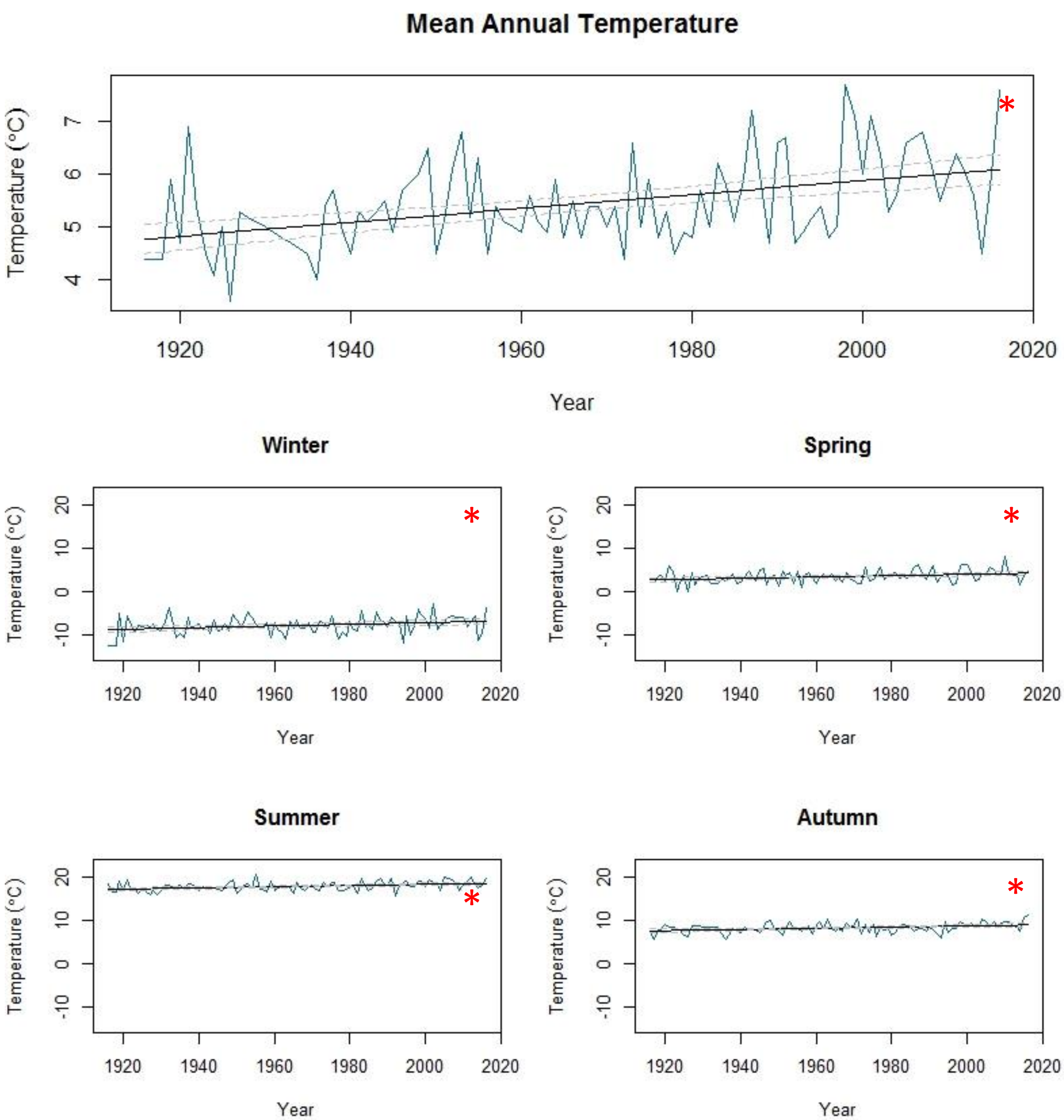
Winds are predominately from the southwest to west, with mean speeds of 10 km/hr in summer and 14 km/hr in the other seasons. Normal wave height is 0.7 m during the summer and may exceed 3 m during strong wind events. Some spectacular storms, especially in the autumn and winter, can experience winds >80 km/hr and wave heights >5 m.



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

1.1 Temperature

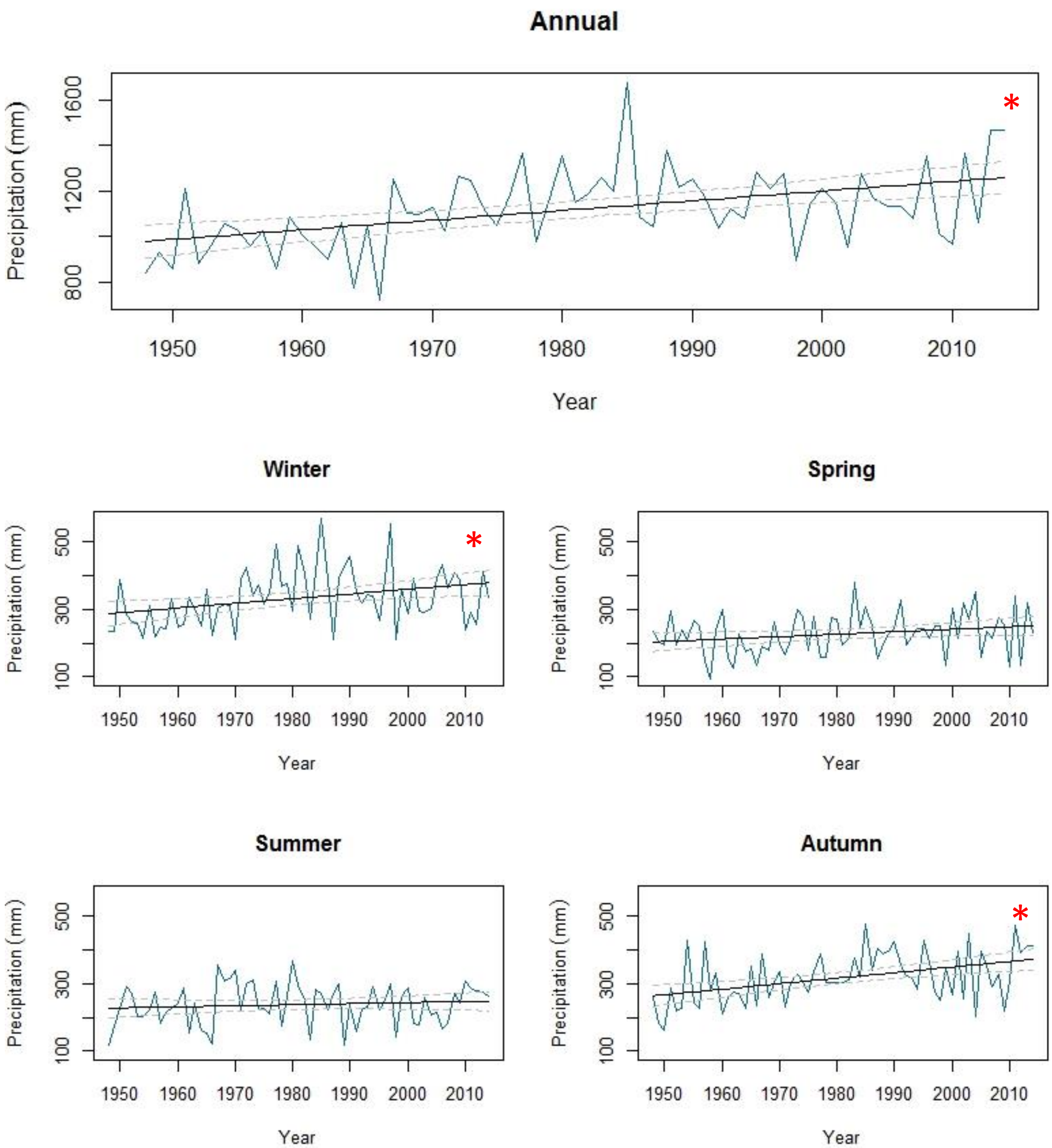
Gore Bay is the closest meteorological station (6092920) with long term temperature data in the AHCCD (ECCC, 2017). Trends from 1916 to 2016 determined using a generalized linear model (R Core Team, 2017) including 95% confidence intervals. "*" = statistically significant trend ($P<0.05$).



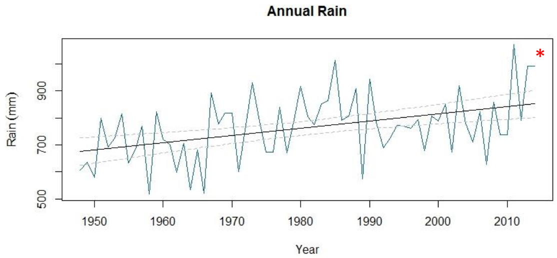
Gore Bay mean annual and seasonal temperature. A statistically significant ($P<0.05$) increase observed in mean annual and seasonal temperature. Mean annual temperature has increased by ~1°C since 1916. Of all the seasons winter temperature has increased the greatest, ~1.5°C since 1916.

1.2 Precipitation

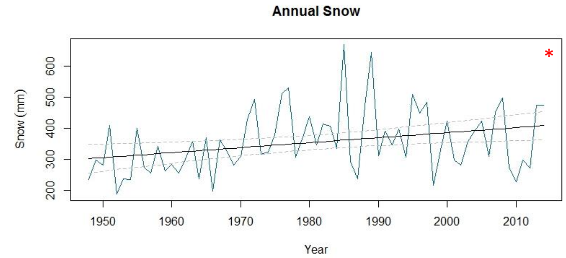
Wiarton is the closest meteorological station (6119500) with long term precipitation data in the AHCCD (ECCC, 2017). Trends from 1948 to 2014 determined using a generalized linear model (R Core Team, 2017) including 95% confidence intervals. "*" = statistically significant trend ($P<0.05$).



Wiarton total annual and seasonal precipitation. Total annual precipitation demonstrated a statistically significant increase ($P<0.05$), ~281 mm (29%) since 1948. Winter (Dec, Jan, Feb) and autumn (Sep, Oct, Nov) demonstrated a statistically significant ($P<0.05$) increase, the greatest being observed for autumn, ~107 mm (41%).



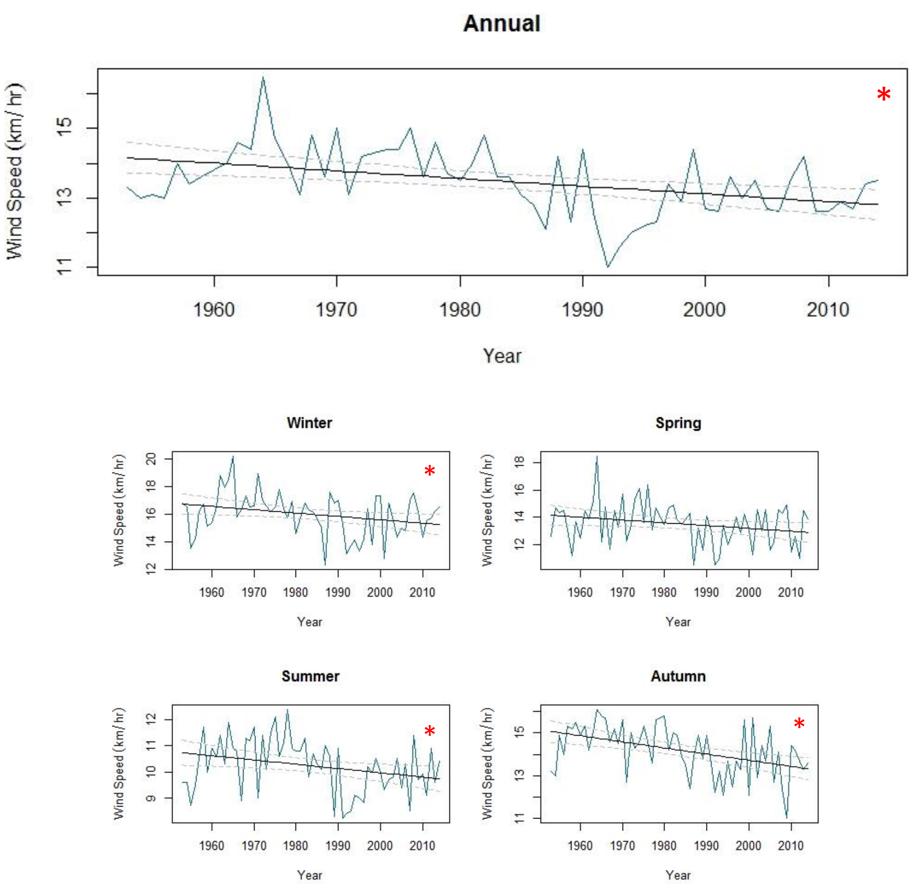
Wiarton total annual rain demonstrated a statistically significant (P<0.05) increase since 1948, ~175 mm (26%).



Wiarton total annual snow demonstrated a statistically significant (P<0.05) increase since 1948, ~105 mm (35%).

1.3 Surface Wind Speed

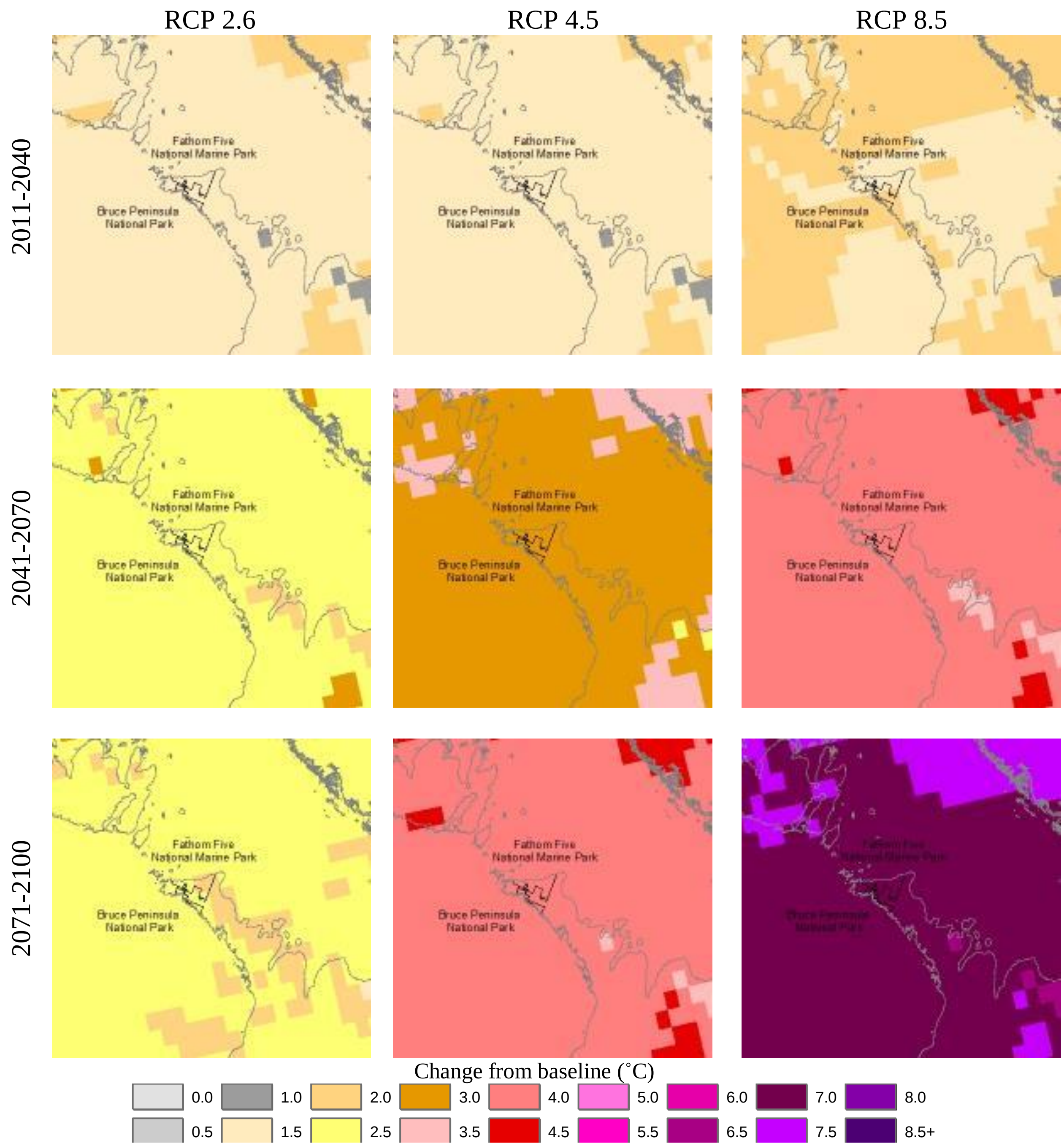
Wiarton is the closest meteorological station (6119500) with long term wind data in the AHCCD (ECCC, 2017). Trends from 1953 to 2014 determined using a generalized linear model (R Core Team, 2017) including 95% confidence intervals. "*" = statistically significant trend (P<0.05).



Wiarton mean annual and seasonal wind speeds. Mean annual wind speeds have demonstrated a statistically significant (P<0.05) decrease, ~1.4 km/hr (10%) since 1953. Seasonally, winter (Dec, Jan, Feb), summer (Jun, Jul, Aug) and autumn (Sep, Oct, Nov) have all demonstrated a statistically significant (P<0.05) decrease, the greatest being observed for autumn, ~1.9 km/hr (13%) since 1953.

2. Projected Climate Trends

2.1 Temperature



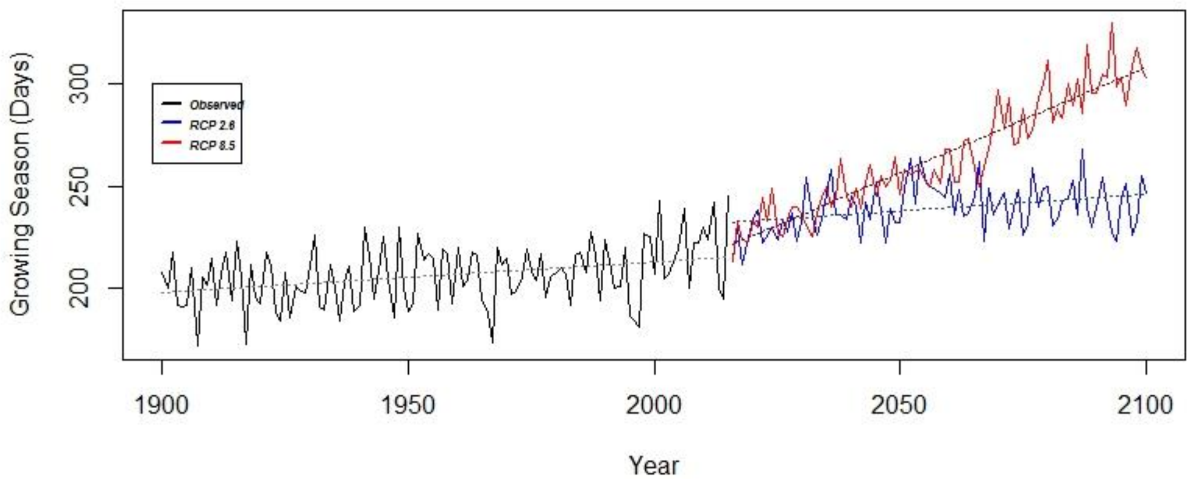
Projected mean annual temperature increase for the Bruce Peninsula from a 1980-2010 baseline. Composite projection of CanESM2, CESM1CAM5, HADGEM2ES and MIROCESM. Data source: Natural Resources Canada, Canadian Forest Service, http://cfs.nrcan.gc.ca/projects/3 (Price *et al.*, 2011).

Temperature projections for the BP/FF area from PCIC (2014):

- Mean annual temperature is projected (RCP 4.5-RCP 8.5) to increase by 1.9-2.1°C by 2021-2050 and 2.9-4.3°C by 2051-2080.
- Winter time is projected to warm the greatest (e.g., 3.7-5.3°C by 2051-2080).
- The nighttime period is projected to warm faster than the daytime period.
- The number of +30°C days is projected to increase from 0.8 days/year (1976-2005 baseline) to between 9.4 (RCP 4.5) and 21.3 (RCP 8.5) days/year by 2051-2080.
- The number of -30°C days is projected to decrease from 0.8 days/year (1976-2005 baseline) to between 0.2 (RCP 4.5) and 0.1 (RCP 8.5) days/year by 2051-2080.

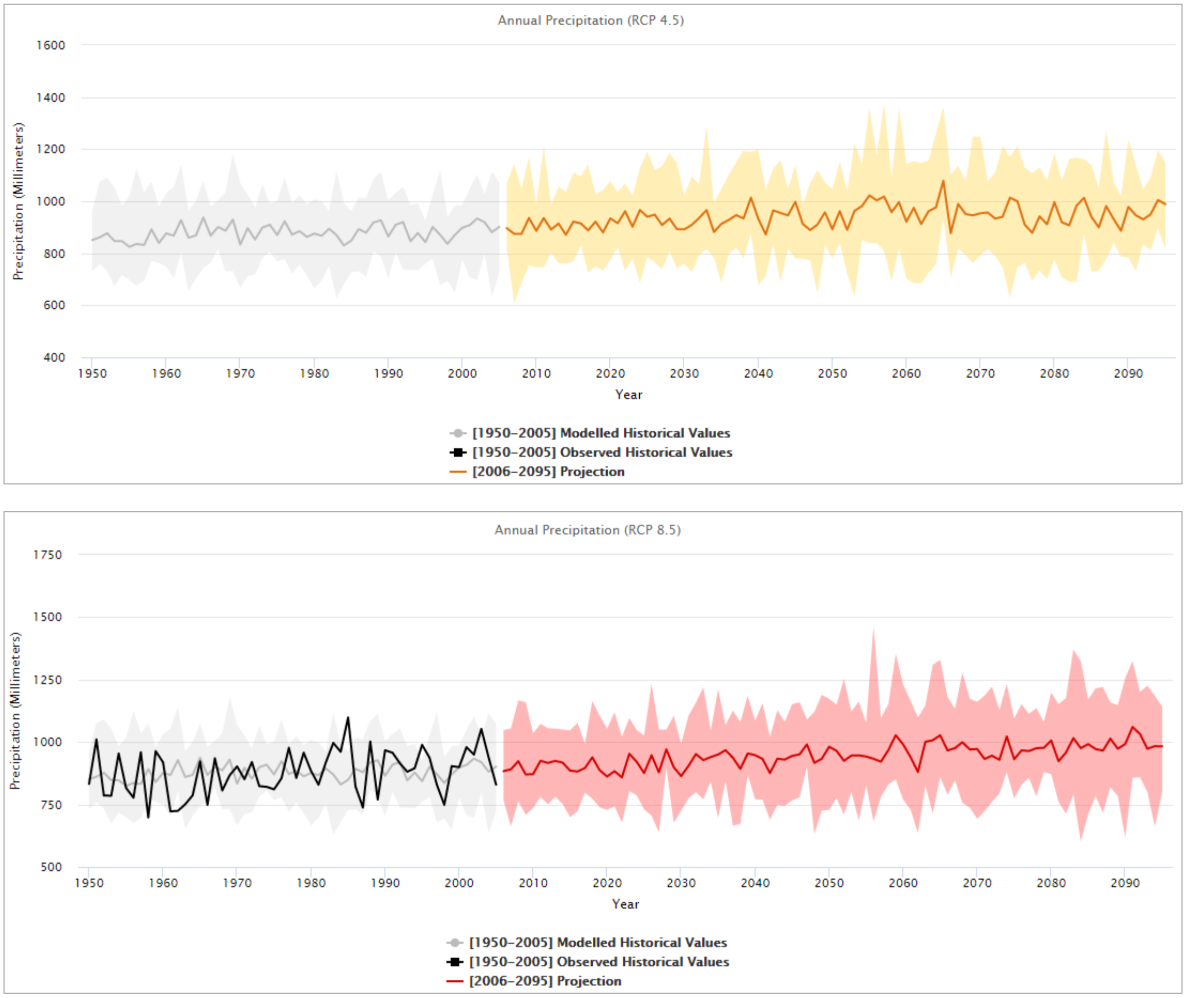
Growing Season

Growing Season is calculated as the number of days between the last occurrence of 0°C in spring and the first occurrence of 0°C in autumn. The metric is a widely used indicator of plant photosynthetic activity (http://www.nrcan.gc.ca/forests/climate-change/forest-change/18470). Data courtesy of Dan McKenney and John Pedlar, Canadian Forest Service. Generalized linear model developed in R (R Core Team, 2017).



Growing Season Length for Tobermory, ON. The historic period and the RCP 2.6 and 8.5 future scenarios all demonstrate a statistically significant (P<0.05) increase in growing season. Since 1900 growing season has increased by ~17 days and may increase an additional 86 days under RCP 8.5.

2.2 Precipitation



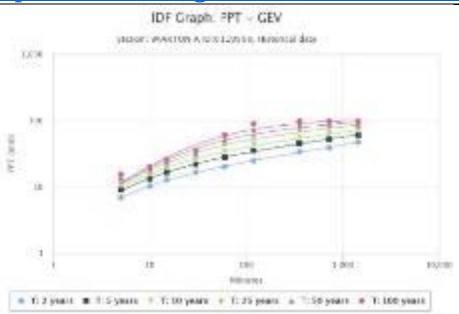
Observed and projected total annual precipitation for the Tobermory area. Statistically downscaled data derived from 12 CMIP5 global climate models (PCIC, 2014). Both the RCP 4.5 and RCP 8.5 scenarios project an increase in the mean estimate for total annual precipitation of 9% by 2051-2080. See Appendix 2 for scatterplot of model projections. Figure source: Climate Atlas of Canada, https://climateatlas.ca/.

Other precipitation projections:

- 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.*, 2012a; Deng *et al.*, 2016; Wang *et al.*, 2015). It is projected that the mean number of days/year with heavier precipitation (+20 mm) will increase from 5.7 (1950-2005) to 6.4 (2021-2050) to 7.0 (2051-2080) (PCIC, 2014). As well, reduced ice cover and greater wind fetch 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).

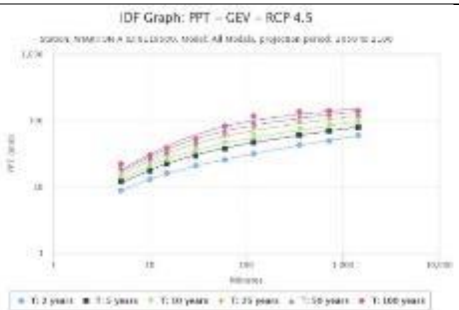
Rainfall Intensity, Duration and Frequency (IDF)

These rainfall IDF values are calculated with IDF_CC Tool 3.0 (http://idf-cc-uwo.ca/; Simonovic *et al.* (2017)) using Generalized Extreme Values (GEV). The Ontario Ministry of Transport also maintains an accessible IDF database, http://www.mto.gov.on.ca/IDF_Curves/terms.shtml.



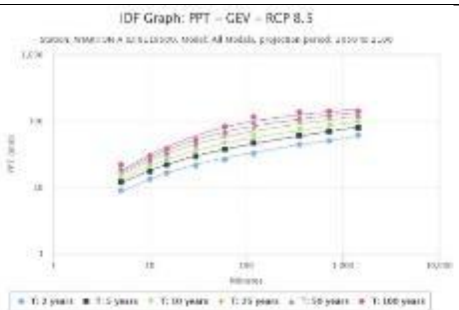
Baseline total precipitation amounts (mm) for Wiarton from 1973-2007.

T (years)	2	5	10	25	50	100
5 min	7.02	9.19	10.68	12.64	14.15	15.69
10 min	10.44	13.35	15.18	17.38	18.93	20.41
15 min	12.95	16.77	19.19	22.12	24.21	26.21
30 min	16.85	22.22	25.67	29.90	32.96	35.92
1 h	20.41	28.55	34.92	44.29	52.34	61.39
2 h	25.11	35.79	44.97	59.70	73.44	90.04
6 h	34.23	46.18	56.32	72.41	87.26	98.45
12 h	39.27	53.17	64.07	80.11	89.70	98.45
24 h	47.97	60.89	69.67	81.05	89.70	98.45



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

T (years)	2	5	10	25	50	100
5 min	8.88	12.25	14.25	17.46	20.27	22.54
10 min	13.18	17.83	20.32	24.26	27.57	30.27
15 min	16.35	22.38	25.67	30.86	35.24	38.82
30 min	21.27	29.64	34.32	41.67	47.90	53.05
1 h	25.92	38.04	46.43	59.95	71.98	83.26
2 h	31.97	47.53	59.99	79.23	97.25	118.24
6 h	43.46	61.18	75.46	96.78	116.79	137.20
12 h	49.82	70.74	85.41	108.59	128.97	141.98
24 h	60.62	81.13	93.04	112.21	128.97	141.98



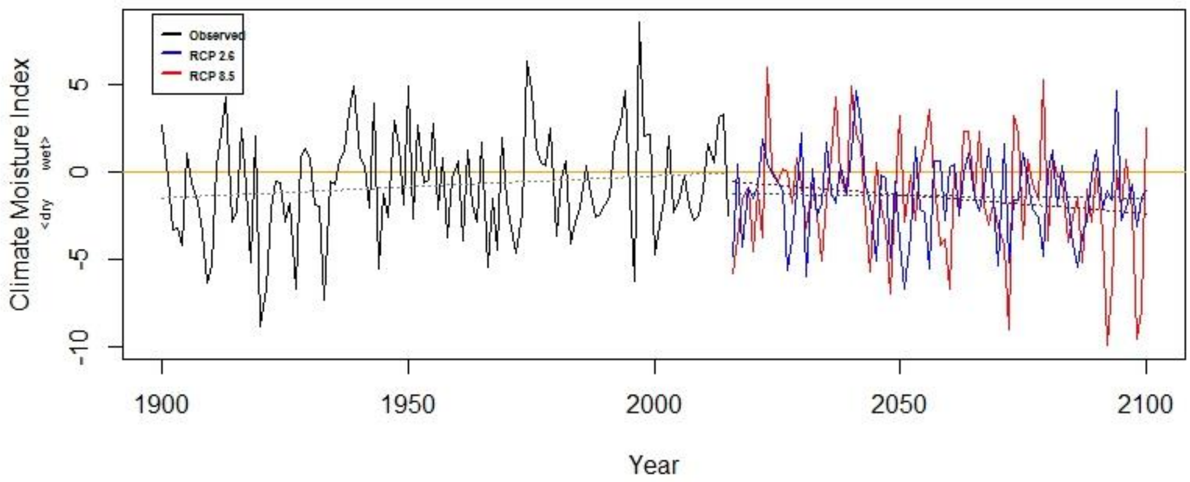
Projected (2050-2100) precipitation (mm) for Wiarton using an ensemble of models and **RCP 8.5**.

T (years)	2	5	10	25	50	100
5 min	9.07	12.21	14.45	17.49	19.90	22.43
10 min	13.42	17.73	20.63	24.35	27.14	29.95
15 min	16.65	22.27	26.07	30.97	34.67	38.40
30 min	21.67	29.50	34.85	41.80	47.09	52.46
1 h	26.54	37.99	46.88	59.84	70.90	83.25
2 h	32.84	47.68	59.95	78.95	96.10	116.21
6 h	44.61	61.44	75.25	96.45	115.42	137.53
12 h	51.01	70.74	86.05	108.39	126.60	141.40
24 h	61.86	80.89	94.35	112.40	126.60	141.40

Wiarton IDF observations and projections. Observe that today's "one in 100 year" rainfall event (i.e., 61.39 mm/hr) is projected to be closer to a "one in 25 year" event by 2050-2100 for both RCP scenarios and the future "one in 100 year" rainfall event is projected to increase in intensity (i.e., ~83 mm/hr).

Climate Moisture Index

The Climate Moisture Index (CMI) is calculated as the difference between annual precipitation and potential evapotranspiration. A positive CMI value indicates wet conditions and a negative value indicates dry conditions (http://www.nrcan.gc.ca/forests/climate-change/forest-change/17772). Data courtesy of Dan McKenney and John Pedlar, Canadian Forest Service. Generalized linear model developed in R (R Core Team, 2017).



Climate Moisture Index (CMI) for Tobermory, ON. No statistically significant ($P<0.05$) trend observed for CMI values over the historic period or RCP scenarios. Future CMI projections are estimated to be negative (dry) 68-72% of years, an increase from 60% for the historic period (1900-2015).

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.

- Cheng *et al.* (2014) project a 30-50% increase in wind gust events in excess of 70km/yr by 2081-2100 for Wiarton.
- Projections for BP/FF illustrate a decrease in mean wind speeds of 1-3% for the Lake Huron side and an increase of 1-3% for the Georgian Bay side (Yao *et al.*, 2012), regardless of the trend extreme events are projected to have higher wind speeds (McDermid *et al.*, 2015).
- Desai *et al.* (2009) report increased wind speeds over Lake Superior due to a weakening of the water-air temperature gradient.

3. Climate Change Impacts

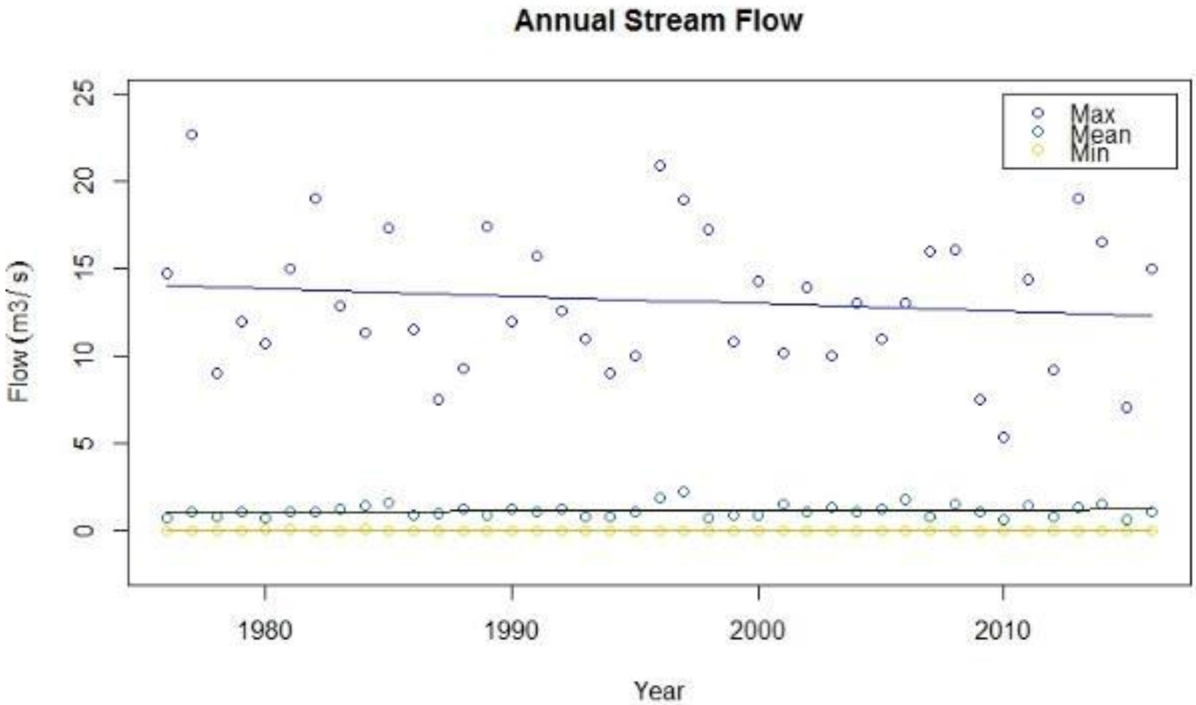
3.1 Water Temperature and Levels

Lake Huron

- Lake summer surface water temperature for eastern Lake Huron and Georgian Bay has increased by 0.11 and 0.07˚C/year respectively 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 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).
- Lake level data is available for the Tobermory Hydrographic Station (02FA003) from 1962 to present day (e.g., 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 of 2.2 m at this station.
- 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).
- Phosphorus loading into lake is expected to be higher in spring due to increased precipitation and runoff from agricultural fields and decrease in summer (Collingsworth *et al.*, 2017).

Inland Waters

While there are a few discrete water flow and level records for some lakes and streams in BP/FF, there is no long term dataset on which to assess trends. The closest hydrographic station is maintained by Environment and Climate Change Canada, located on the Stokes River at Hwy. 6 (Station ID: 02FA002, summary data link).

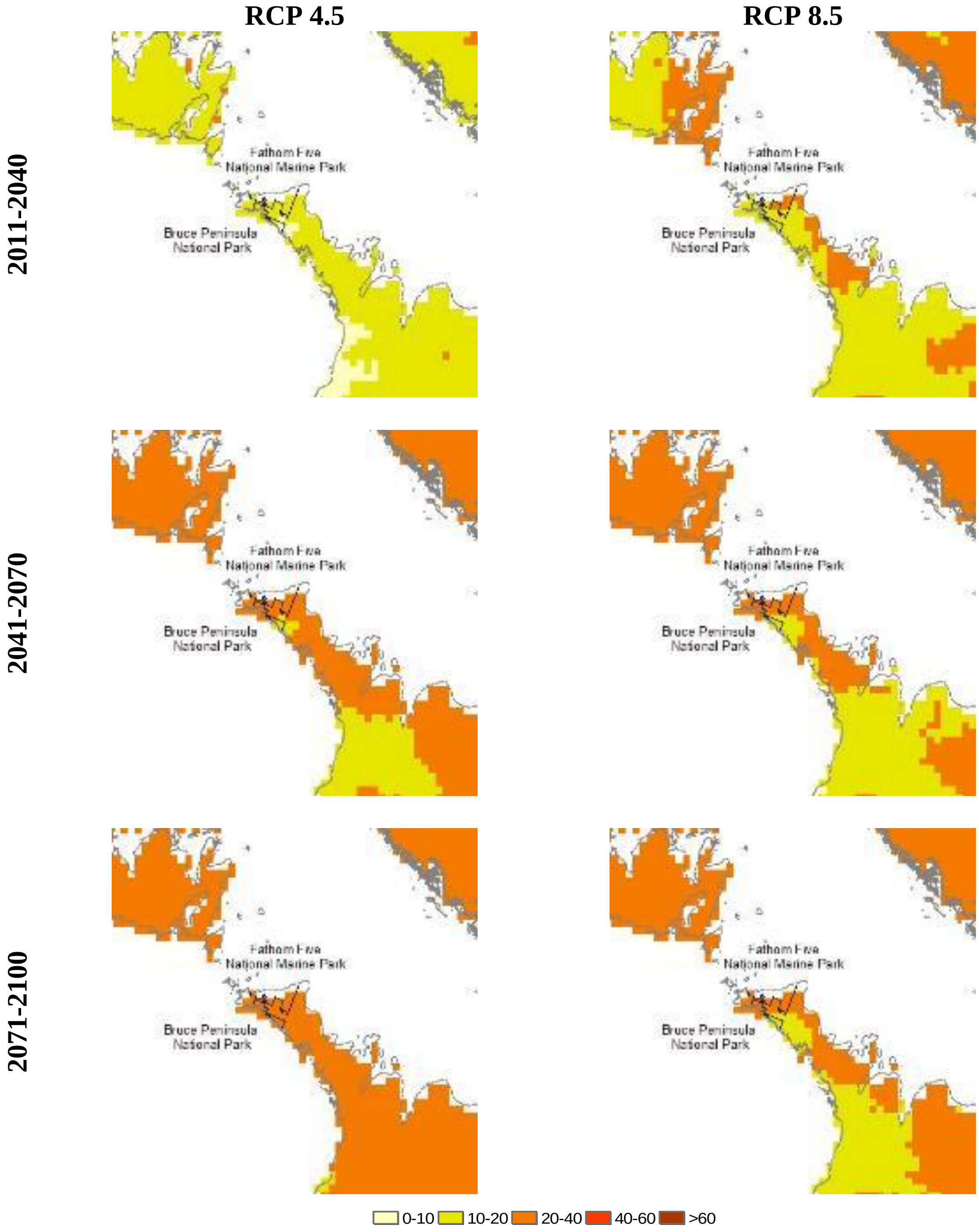


Stokes River annual flow data (HYDAT database, Jan. 17, 2018 release). Although a statistically significant ($P<0.05$) trend was not demonstrated for mean, max or min values, a slight declining trend is noted for maximum and minimum annual flows while mean flow shows a slight increase. Changing land use patterns may be a factor in this context. It is worth noting that 3 of the top 10 maximum peak flows on record (1976-2016) have occurred since 2010, the highest flow was recorded on January 30, 2013 (coincided with a thunderstorm and temperatures >8˚C). The majority of peak flows occur in March or April and may be attributed to rain on snow events.

Additional information on inland waters:

- The ice free period for the inland waters of Bruce County is projected to increase by 9.6 to 22.6 days by 2041-2070, with spring break-up occurring 1.7 to 7.2 days earlier and freeze-up 7.9 to 15.4 days later (Minns *et al.*, 2014).
- Stream temperatures are expected to increase as air temperatures increase (Chu, 2015). Brook Trout is an example of a species in BP/FF already vulnerable to stream temperature maximums in Willow and Dorcas Creeks and are known to occupy groundwater discharge and shaded riparian areas as refugia during summer. This cooling benefit could be reduced as groundwater warms or riparian areas are opened (e.g., beavers, logging, etc…) (Meisner *et al.*, 1988).
- Maximum spring runoff is occurring earlier and with a lower amplitude, flooding from more extreme precipitation events is expected to increase (Adamowski *et al.*, 2013; Cheng *et al.*, 2012b; Cunderlik and Ouarda, 2009; Jones *et al.*, 2015; Karl *et al.*, 2009).
- Chu (2015) indicates (Figure 3) that the wetlands in BP/FF area have a high vulnerability to drying due to changes in air temperature and precipitation by the 2080s.

3.2 Wildfire



Projected increase in wildfire season for the Bruce Peninsula area. 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.

Additional information on wildfire:

- 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 for Ontario, including the Bruce Peninsula, and predict a province-wide increase in the number of wildfires. In considering the climate projections for BP/FF, spring precipitation is only projected to increase by 5.6% for every degree warming and summer precipitation is projected to decline by 0.7% per every degree warming, thus an increase risk due to drier conditions is possible.
- 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). In the context of BP/FF and in particular maturing jackpine (S2) and assumed increase in dead balsam fir (M3) stands, a potential increase in fuel types/loads to support more intense conditions may have occurred since last assessed using 1994 imagery (Del Degan and Masse et Associes Inc., 2007).
- 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).
- An increase in deciduous species may reduce the amount of crown fire and total fuel consumption (Terrier *et al.*, 2013). However, spring time before leaf-out, still remains a potentially higher risk wildfire period in BP/FF (Del Degan and Masse et Associes Inc., 2007).

3.3 Biodiversity

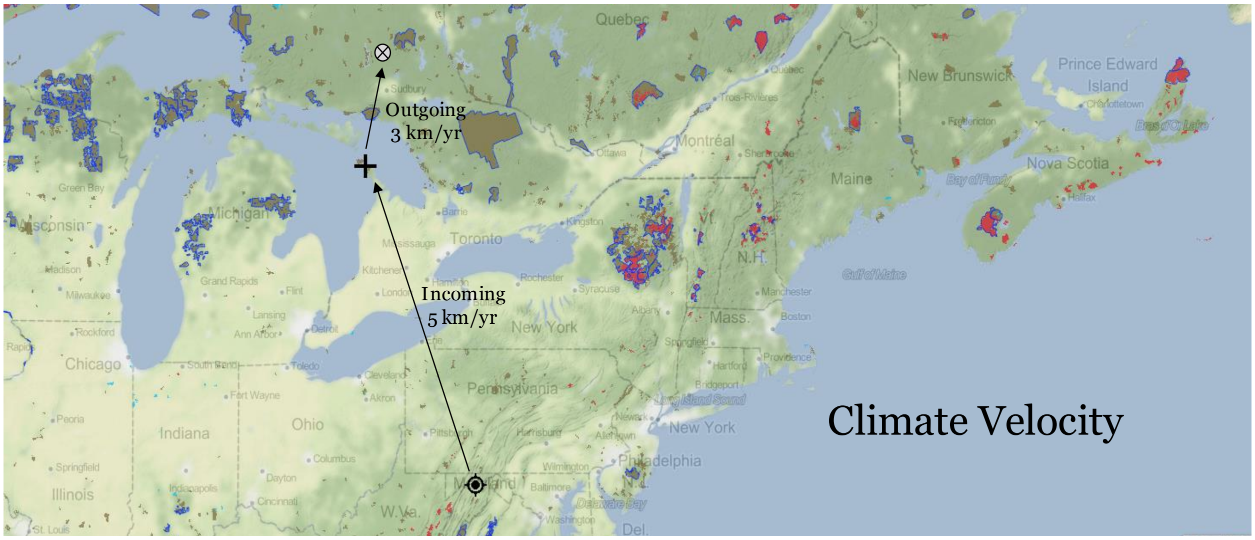
Biodiversity is the variety of genes, species and ecosystems and is essential to our social, economic and ecological well-being. "Agricultural expansion, over-exploitation and introduction of invasive alien species have been the main drivers of biodiversity loss in the recent past, but several lines of research suggest that climate change could become a prominent, if not leading, cause of extinction over the coming century" (Pacifici *et al.*, 2015; Thomas *et al.*, 2004). The latest "Living Planet Report" (WWF, 2017), cites climate change as a key driver of wildlife loss and reports that half of Canada's monitored species (451 of 903) are in decline, and of those, the average decline is 83%.

The effects of climate change on biodiversity are fairly well documented and include (e.g., Nantel *et al.*, 2014; Nituch and Bowman, 2013):

- 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.
- Change to ecosystem services.

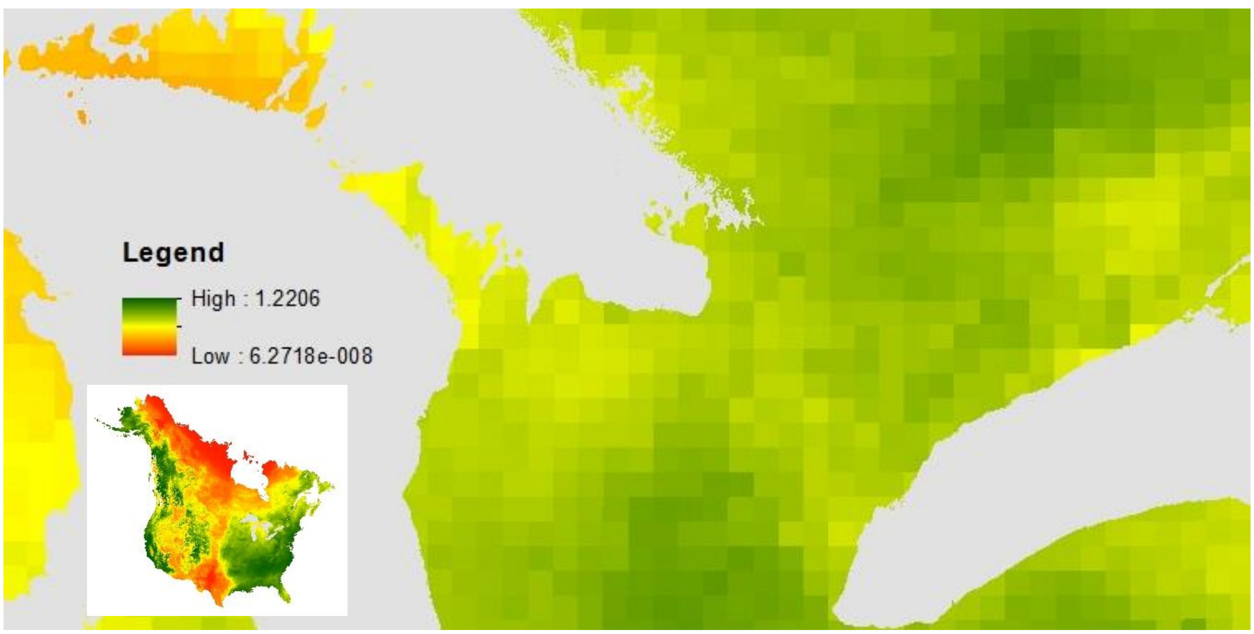
Climate Velocity

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 BP/FF (2080's, RCP 8.5) determined using AdaptWest's Climate Displacement Tool. The forward or outgoing velocity is estimated to be **3 km/yr**, while the backward or incoming velocity is estimated to be **5 km/yr**.

Plant Species

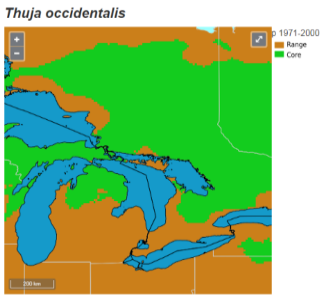


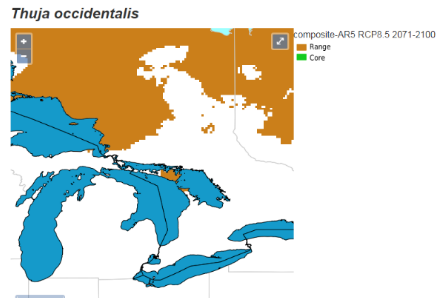
Projected climate refugia areas for tree species. Refugia index based on niche-based velocities for 324 tree species derived from McKenney *et al*. (2011). The refugia values for BP/FF are moderate (0.1 – 0.13). Inset image of Canada/USA. Date source: AdaptWest (https://adaptwest.databasin.org/), for study details see Stralberg *et al.* (2018).

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/). A query of this database revealed a future decline in the number of species in BP/FF (45.2N, -81.6W), see Table 1 and Appendix 3.

Table 1. Potential plant species richness for BP/FF based on current and future plant hardiness projections.

	1971-2000	2011-2040	2041-2070	2071-2100
Full Range	1291	1230	664	245
Core Range	550	390	102	26





Eastern white cedar (*Thuja occidentalis*) is an example of a species whose core and full range is projected to change. Currently the Bruce Peninsula includes core range, but by the end of century it is projected to decline. More models and information for this species at: http://planthardiness.gc.ca/index.pl?m=9b&lang=en&speciesid=1001217. Most of the tree species in BP/FF considered dominant or co-dominnant will experience similar declines, e.g., balsam fir and american beech will no longer be within their climate envelopes (core or full rnage), and sugar maple will no longer be within its core range, but will still be within its full range.

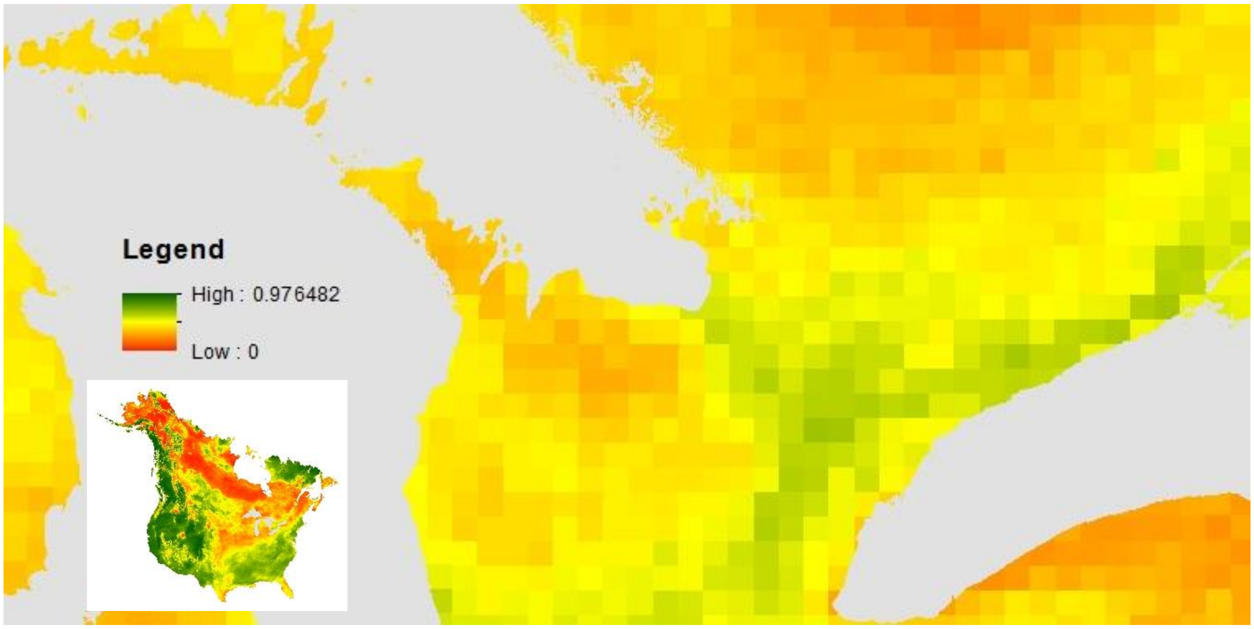
Additional information on plants:

- BP/FF is a transition zone with species at both their northern and southern range. As the climate envelope for boreal tree species (e.g., black spruce, white spruce, jack pine, balsam fir, trembling aspen) becomes less suitable (see reference to "deborealize" in Taylor *et al.*, 2017), conditions will become more favourable for Great Lakes-St. Lawrence species (e.g., white pine, red pine, sugar maple, red oak) (e.g., McKenney *et al.*, 2010; Walker *et al.*, 2002; Warren *et al.*, 2013).
- Using future climatic envelopes for 63 native tree species in Ontario, Crowe and Parker (2011) modelled the optimal location for additional reserves, both with and without the need for migration, to protect these representative species. The base of the Bruce Peninsula (5) was identified as one potential location.
- Plant productivity may increase due to increased CO_2, that is, if species are not otherwise limited by habitat conditions (e.g., soil, moisture, nutrients, light, or pollinators) or disturbances (e.g., fire, flooding, or drought) (Warren *et al.*, 2013).
- Climate change could create conditions which are more favourable for invasive species, and coupled these two impacts presents an important threat to BP/FF's biodiversity (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

(https://toronto.ctvnews.ca/hot-dry-weather-accelerated-toronto-s-emerald-ash-borer-tree-crisis-1.3044828) (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).

- Brinker *et al.* (2018) determined that eastern prairie fringed orchid (*Platanthera leucophaea*) and lakeside daisy (*Tetraneuris herbacea*) are highly vulnerable to climate change in the Lake Huron basin.

Bird Species



Projected climate refugia areas for songbird species. Refugia index based on niche-based velocities for 268 songbirds derived from Distler *et al.* (2015). The refugia values for BP/FF are moderate to low (0.18 – 0.2). Inset image of Canada/USA. Data source: AdaptWest (https://adaptwest.databasin.org/), for study details see Stralberg *et al.* (2018).

Future climate suitability was for bird species in BP/FF was assessed in 2019 by Audubon and Parks Canada (see methods in: Langham *et al.*, 2015; Wu *et al.*, 2018). Potential bird species turnover by 2050 for Bruce Peninsula NP was estimated to be 39% in summer and 45% in winter and for Fathom Five as 41% in summer and 49% in winter (RCP 8.5). See Appendix 4.

Additional information on birds:

- Based on changing climatic conditions Lindsay *et al.* (2016) project that for the BP/FF area the percent species turnover for migratory bird species could increase from 12% in 2011-2040 to 35% by 2071-2100. The percent species turnover for all bird species could increase from 16% in 2011-2040 to 42% by 2071-2100. Species turnover is calculated as a composite measure of species loss (i.e., % of species currently in a cell whose projected future range does not include the cell) and species gain (i.e., % increase in species due to range expansion).
- 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).

- Rempel and Hornseth (2017) completed a climate change vulnerability assessment for wood thrush and eastern meadowlark. While the assessment confirmed that these species are highly vulnerable to climate change, their persistence in the BP/FF area was projected through to 2100.

Other Terrestrial Species

- 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.
- A vulnerability assessment for the eastern massasauga rattlesnake predicts that the northern Bruce Peninsula 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.
- The distribution and impacts of pathogens and parasites are expected to increase with warmer temperatures and the northward migration of species (Marcogliese, 2008; 2016).

Aquatic Species

- A recent shift to smaller diatom species in the Great lakes may be attributed to warming waters (Bramburger *et al.*, 2017), however, it appears Lake Huron is not responding to climatic drivers as quickly as Lakes Ontario and Superior (Reavie *et al.*, 2016; Wang *et al.*, 2012).
- Prolonged periods of low lake levels with minimal fluctuations is shown to reduce coastal wetland area and species diversity (Langer *et al.*, 2018; Midwood and Chow-Fraser, 2012; Mortsch *et al.*, 2006). During the 1999-2014 low period experienced in FF coastal wetlands became stranded, disconnecting potential spawning and nursery habitats, and exposed lakebeds were more vulnerable to invasive phragmites and narrow-leaved cattail (Parker *et al.*, 2015).
- 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).

- The first record of white bass in FF occurred in 2013 (pers. com. S. Campbell). This is a temperate species known to prefer warmer waters.
- 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 potential impact of less ice cover on spawning shoals in FF is uncertain.
- Warmer spring and summer temperatures have been shown to have a positive influence on yellow perch and walleye recruitment in Lake Huron (Collingsworth *et al.*, 2017; Honsey *et al.*, 2016).
- While water temperatures in the inland lakes are projected to increase there is a high probability that conditions will remain thermally suitable for smallmouth bass in the 2050s and 2080s, there is, however, a very low probability they will remain suitable for walleye (e.g., in Cyprus Lake) (Van Zuiden *et al.*, 2016).

3.4 Visitor Experience and Operations

Visitor Experience

Visitation Patterns

Although visitation patterns are monitored in BP/FF 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

- Although not specific to BP/FF, 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.
- Dorcas Bay and other recreational beaches 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 to Flowerpot Island and navigational safety near the islands and shoals (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 including BP/FF 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, including BP/FF, by 2041-2070 (Ogden *et al.*, 2014).
- Heat waves in the Grey Bruce Health Unit region are projected to increase from 0.10/year to 2.21/year by the 2080s (Gough *et al.*, 2016).
- Changing weather and increased temperature can affect the rate of photochemical smog formation (e.g., ozone). However, future ozone exceedances (>80 ppb) for the Grey Bruce Health Unit region only suggests an increase from todays 9 days/year to 10 days/year by the 2080s (Gough *et al.*, 2016).
- 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). At BF/FF 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.*, 2012a; 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 BP/FF, in light of the information in this report, expected concerns could include:

- Flooding from intense rainfall and winter rain events, overwhelming surface drainage capacity, particularly undersized or debris filled culverts, and damaging facilities, washing out roads, etc…
- Freezing rain or hail damage to buildings and power/communication lines.
- Longer wildfire season and more intense burns, especially given the high urban interface.
- Increased lake storm intensity and less ice cover increases risk of coastal flooding and erosion. Although BP/FF has relatively little coastal infrastructure, there may be a need to clean up debris washed in from other areas.
- Longer seasonal use of trails and roads (one benefit, 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).
- Summer drought increases water demands and may exceed system capacity.
- The energy demands for cooling buildings will increase.

Of related interest, the "Public Infrastructure Engineering Vulnerability Committee" (PIEVC, 2008) undertook an assessment of risks to the water supply system near Point Pelee National Park (Genivar, 2013) and surface drainage near Rouge National Urban Park (Genivar, 2010; 2011). Concerns with freezing rain (e.g., transmission lines) and culvert capacity are highlighted in these reports.

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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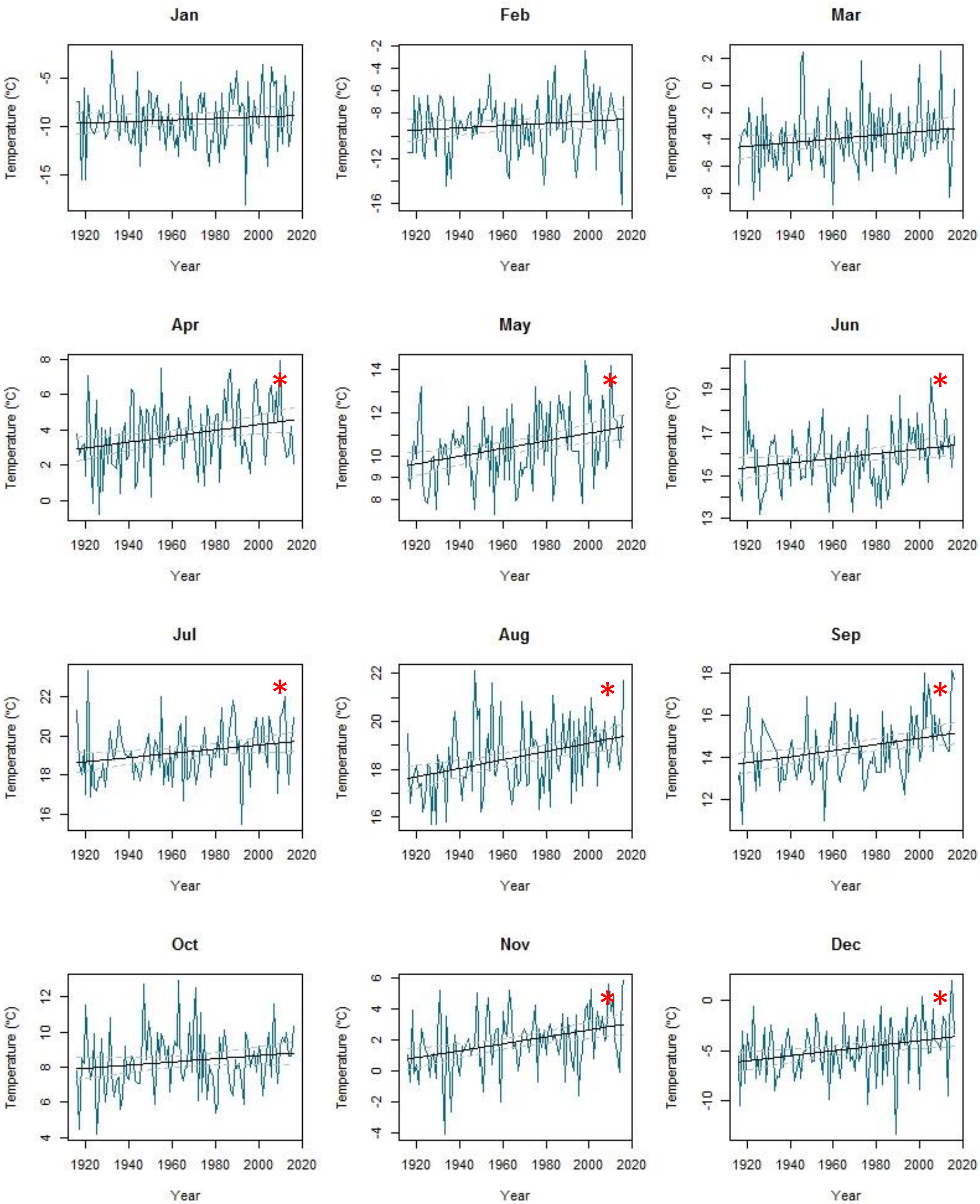
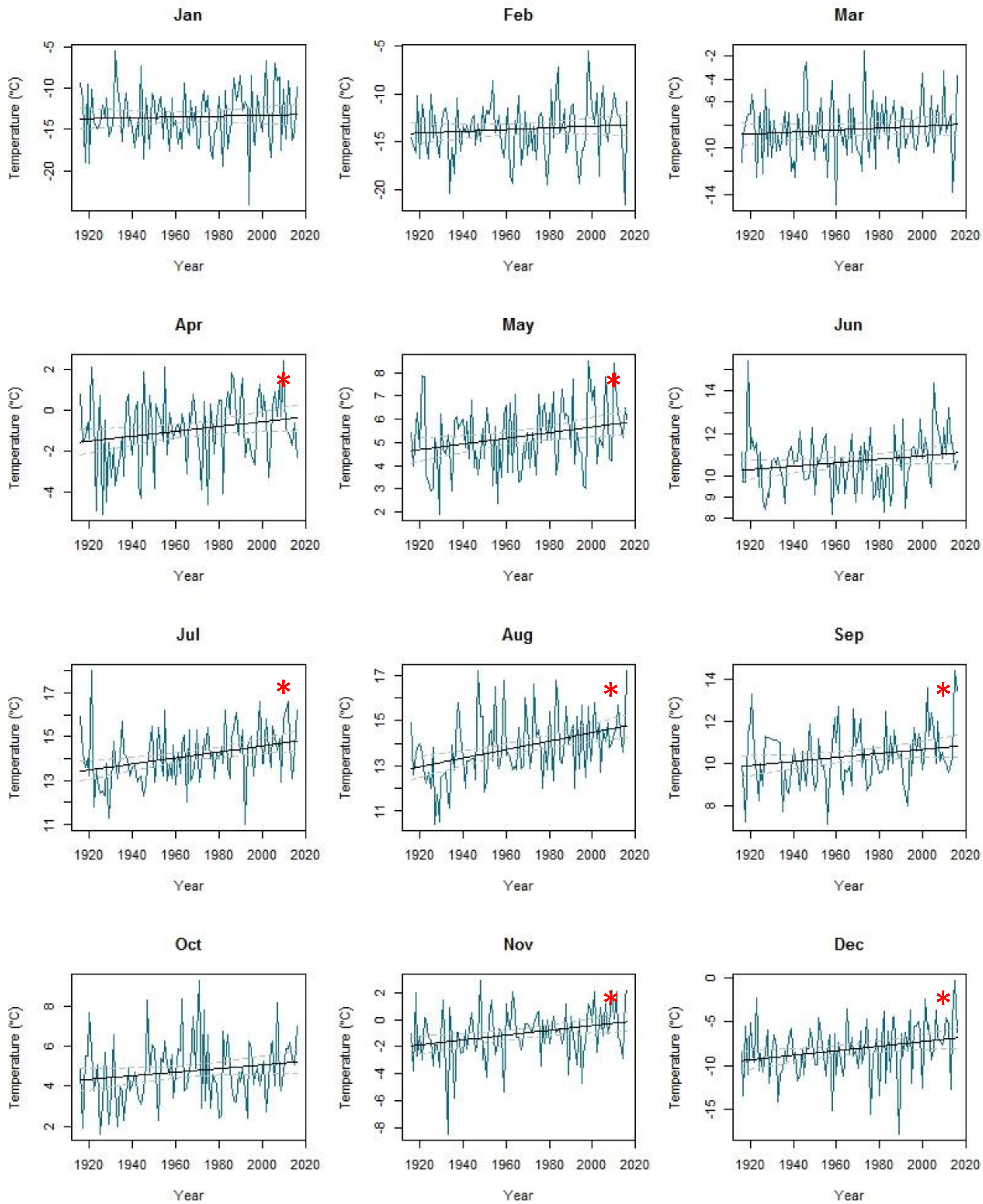
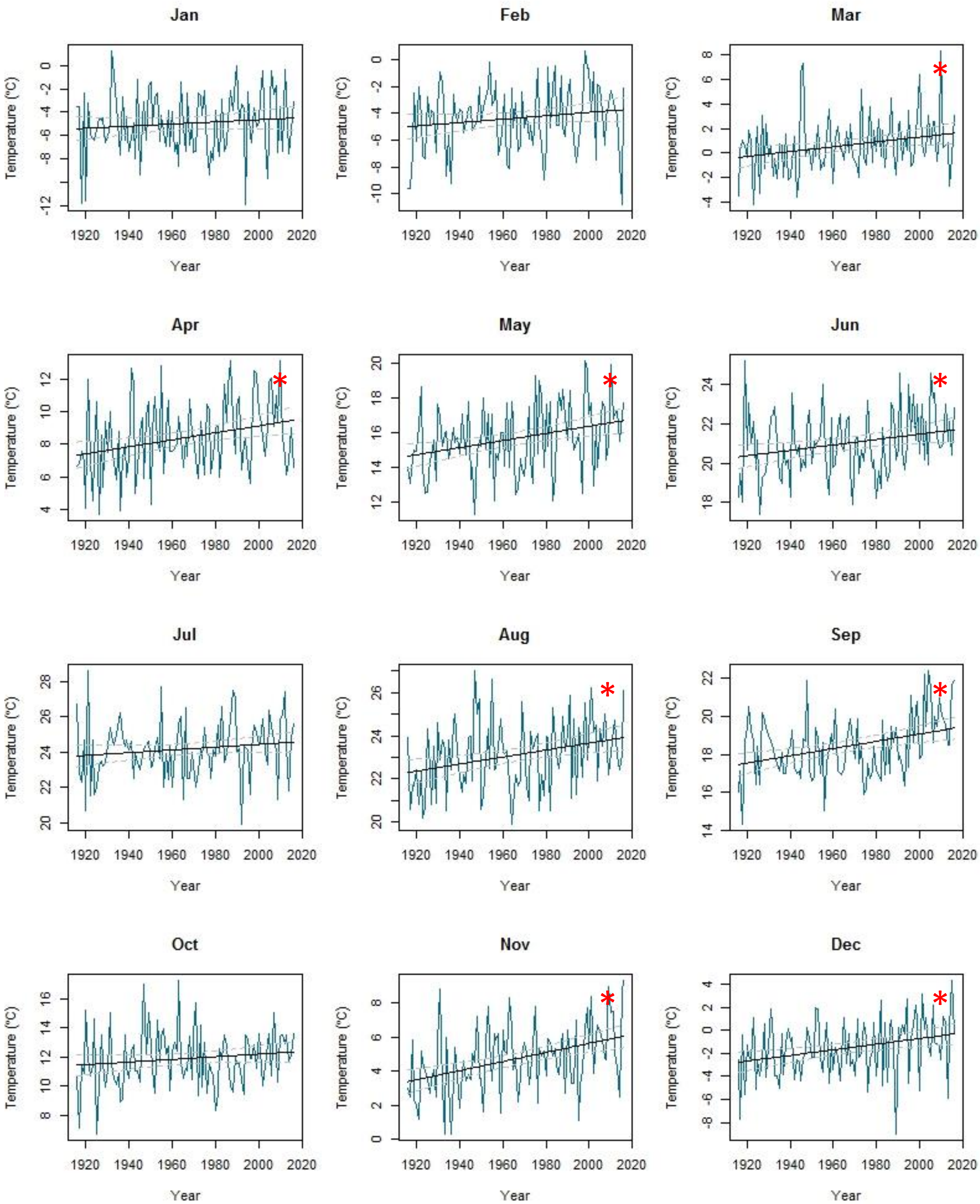
Appendix 1. Additional Climate Trends



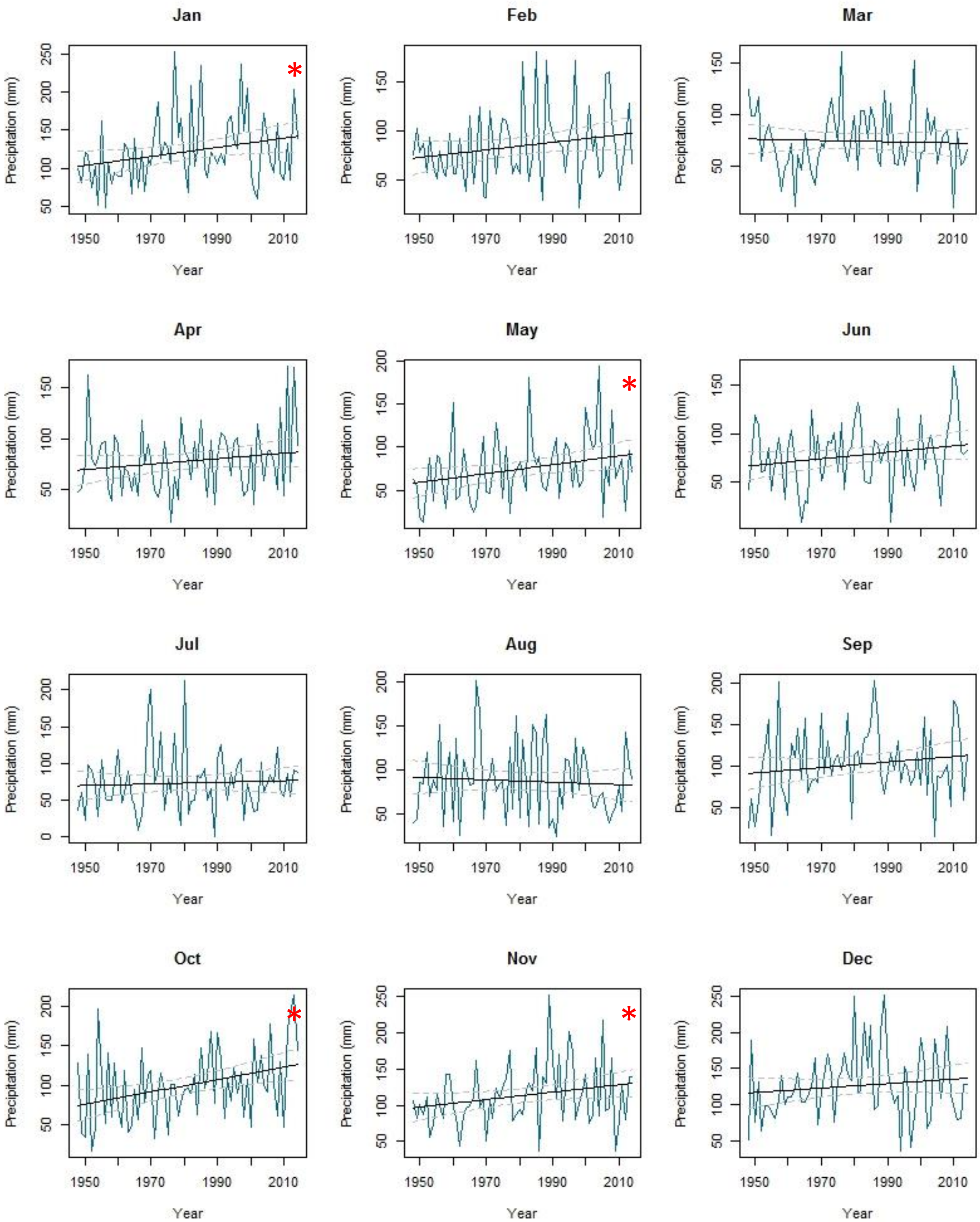
Gore Bay mean monthly temperature. Jan, Feb, Mar and Oct did not demonstrate a statistically significant ($P<0.05$) increase. Dec demonstrated the greatest increase, ~2°C since 1916.



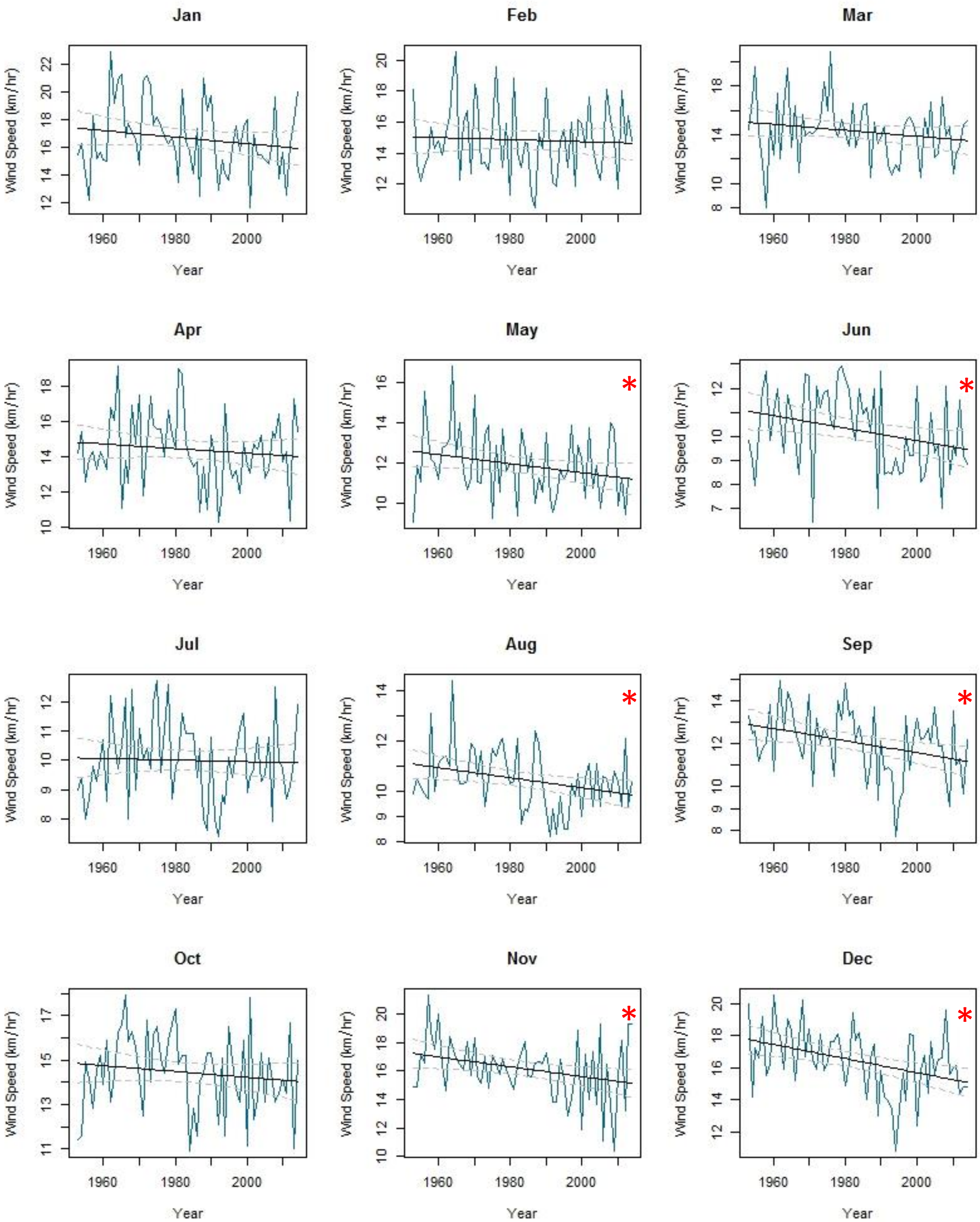
Gore Bay mean monthly <u>minimum</u> temperature. Jan, Feb, Mar, Jun and Oct did not demonstrate a statistically significant ($P<0.05$) increase in mean monthly minimum temperatures (i.e., nighttime). Dec demonstrated the greatest increase, ~2°C since 1916.



Gore Bay mean monthly <u>maximum</u> temperature. Jan, Feb, Jul and Oct did not demonstrate a statistically significant ($P<0.05$) increase in mean monthly maximum temperatures (i.e., daytime). Nov demonstrated the greatest increase, ~2.1°C since 1916.

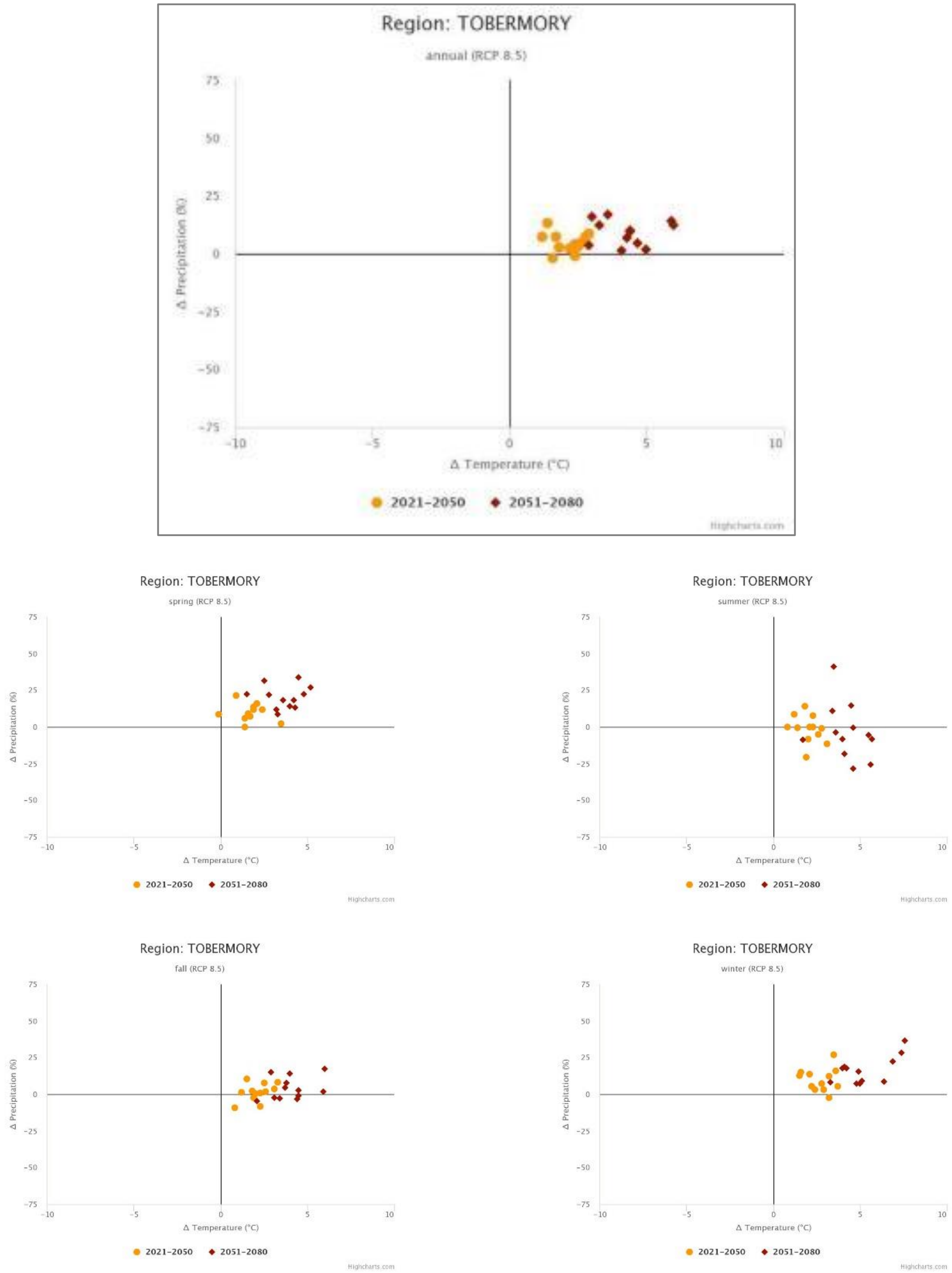


Wiarton total monthly precipitation. Total monthly precipitation has demonstrated a statistically significant increase ($P<0.05$) in Jan, May, Oct and Nov since 1948. The greatest increase being observed in Oct, ~51 mm (69%). Although not statistically significant ($P<0.05$), Mar and Aug both demonstrated a declining trend.



Wiarton mean monthly wind speeds. Mean monthly wind speeds have demonstrated a statistically significant ($P<0.05$) decrease in May, Jun, Aug, Sep, Nov and Dec since 1953. The greatest decrease being observed for Dec, ~2.9 km/hr (16%) since 1953.

Appendix 2. Scatterplots for Temperature and Precipitation

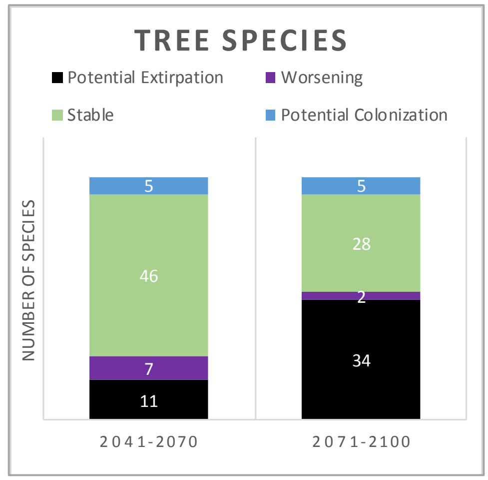


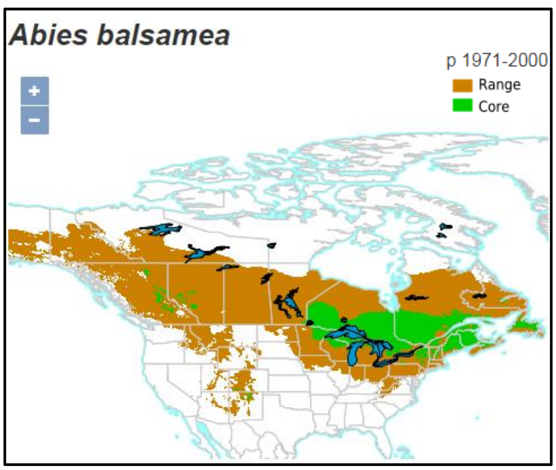
Climate models for Tobermory area (10km x 10km grid). Each point represents a single model-simulated temperature/precipitation response to the RCP 8.5 scenario. Statistically downscaled data (Bias Corrected Spatial Disaggregation; BCSD) derived from 12 CMIP5 global climate models: ACCESS1.0, CanESM2, CCSM4, CNRM-CM5, CSIRO-Mk3-6.0, GFDL-ESM2G, HadGEM2-CC, HadGEM2-LR, INM-CM4, MPI-ESM-LR, MRI-CGCM3, MIROC5 (PCIC, 2014). Summer precipitation appears to have the most uncertainty, i.e., it may be wetter or drier.

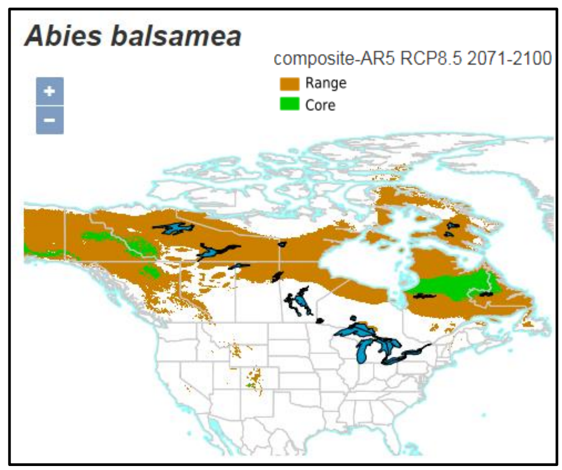
Appendix 3. Trees and Climate Change

Bruce Peninsula National Park and Fathom Five National Marine 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 within the Plant Hardiness of Canada database, http://planthardiness.gc.ca/.
- Some species are 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".







Common Name	Scientific Name	Current Range	2041-2070 Range	2041-2070 Trend	2071-2100 Range	2071-2100 Trend
Alternate-Leaf Dogwood	Cornus alternifolia	Range	Range	Stable	Absent	Potential Extirpation
American Beech	Fagus grandifolia	Range	Range	Stable	Absent	Potential Extirpation
American Chestnut	Castanea dentata	Range	Range	Stable	Absent	Potential Extirpation
American Elm	Ulmus americana	Range	Range	Stable	Range	Stable
American Mountain-Ash	Sorbus americana	Range	Range	Stable	Absent	Potential Extirpation
Balsam Fir	Abies balsamea	Range	Absent	Potential Extirpation	Absent	Potential Extirpation
Balsam Poplar	Populus balsamifera	Core	Range	Worsening	Range	Worsening
Basswood	Tilia americana	Range	Range	Stable	Range	Stable
Bebb Willow	Salix bebbiana	Core	Range	Worsening	Absent	Potential Extirpation
Bitternut Hickory	Carya cordiformis	Range	Range	Stable	Absent	Potential Extirpation
Black Ash	Fraxinus nigra	Range	Range	Stable	Range	Stable
Black Cherry	Prunus serotina	Range	Range	Stable	Range	Stable
Black Gum	Nyssa sylvatica	Absent	Range	Potential Colonization	Range	Potential Colonization
Black Hawthorn	Crataegus douglasii	Core	Absent	Potential Extirpation	Absent	Potential Extirpation
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 Ash	Fraxinus quadrangulata	Absent	Absent	Not Applicable	Absent	Not Applicable
Blue-Beech	Carpinus caroliniana	Range	Range	Stable	Range	Stable
Bur Oak	Quercus macrocarpa	Range	Range	Stable	Range	Stable
Butternut	Juglans cinerea	Range	Range	Stable	Absent	Potential Extirpation
Cherry Birch	Betula lenta	Absent	Absent	Not Applicable	Absent	Not Applicable
Chokecherry	Prunus virginiana	Core	Range	Worsening	Range	Worsening
Common Hoptree	Ptelea trifoliata	Absent	Absent	Not Applicable	Absent	Not Applicable
Cucumber Tree	Magnolia acuminata	Range	Range	Stable	Absent	Potential Extirpation
Downy Serviceberry	Amelanchier arborea	Range	Absent	Potential Extirpation	Absent	Potential Extirpation
Eastern Hemlock	Tsuga canadensis	Range	Range	Stable	Absent	Potential Extirpation
Eastern Redcedar	Juniperus virginiana	Range	Range	Stable	Range	Stable
Eastern White Cedar	Thuja occidentalis	Range	Range	Stable	Range	Stable
Eastern White Pine	Pinus strobus	Range	Range	Stable	Range	Stable
Fireberry Hawthorn	Crataegus chrysocarpa	Core	Absent	Potential Extirpation	Absent	Potential Extirpation
Gray Birch	Betula populifolia	Range	Range	Stable	Absent	Potential Extirpation
Green/Red Ash	Fraxinus pennsylvanica	Range	Range	Stable	Range	Stable
Ironwood	Ostrya virginiana	Range	Range	Stable	Range	Stable
Jack Pine	Pinus banksiana	Range	Absent	Potential Extirpation	Absent	Potential Extirpation
Kentucky Coffeetree	Gymnocladus dioicus	Absent	Range	Potential Colonization	Range	Potential Colonization
Largetooth Aspen	Populus grandidentata	Range	Range	Stable	Absent	Potential Extirpation
Manitoba Maple	Acer negundo	Range	Range	Stable	Range	Stable
Mountain Maple	Acer spicatum	Range	Range	Stable	Range	Stable
Northern Hackberry	Celtis occidentalis	Range	Range	Stable	Range	Stable
Ohio Buckeye	Aesculus glabra	Range	Range	Stable	Range	Stable
Pawpaw	Asimina triloba	Range	Range	Stable	Range	Stable
Peachleaf Willow	Salix amygdaloides	Range	Range	Stable	Range	Stable
Pin Cherry	Prunus pensylvanica	Range	Range	Stable	Range	Stable
Pin Oak	Quercus palustris	Range	Range	Stable	Absent	Potential Extirpation
Pussy Willow	Salix discolor	Core	Range	Worsening	Absent	Potential Extirpation
Red Maple	Acer rubrum	Range	Range	Stable	Range	Stable
Red Mulberry	Morus rubra	Absent	Range	Potential Colonization	Range	Potential Colonization
Red Oak	Quercus rubra	Range	Range	Stable	Range	Stable
Red Pine	Pinus resinosa	Range	Range	Stable	Absent	Potential Extirpation
Round-leaved Serviceberry	Amelanchier sanguinea	Range	Absent	Potential Extirpation	Absent	Potential Extirpation
Saskatoon Berry	Amelanchier alnifolia	Core	Range	Worsening	Absent	Potential Extirpation
Sassafras	Sassafras albidum	Absent	Range	Potential Colonization	Range	Potential Colonization
Shagbark Hickory	Carya ovata	Range	Range	Stable	Absent	Potential Extirpation
Showy Mountain Ash	Sorbus decora	Range	Absent	Potential Extirpation	Absent	Potential Extirpation
Shumard Oak	Quercus shumardii	Absent	Range	Potential Colonization	Range	Potential Colonization
Silver Maple	Acer saccharinum	Range	Range	Stable	Range	Stable
Smooth Serviceberry	Amelanchier laevis	Range	Absent	Potential Extirpation	Absent	Potential Extirpation
Speckled Alder	Alnus rugosa	Range	Range	Stable	Absent	Potential Extirpation
Staghorn Sumac	Rhus typhina	Range	Range	Stable	Absent	Potential Extirpation
Striped Maple	Acer pensylvanicum	Range	Absent	Potential Extirpation	Absent	Potential Extirpation
Sugar Maple	Acer saccharum	Range	Range	Stable	Range	Stable
Swamp White Oak	Quercus bicolor	Range	Range	Stable	Absent	Potential Extirpation
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
Tulip Tree	Liriodendron tulipifera	Absent	Absent	Not Applicable	Absent	Not Applicable
White Ash	Fraxinus americana	Range	Range	Stable	Range	Stable
White Birch	Betula papyrifera	Core	Range	Worsening	Absent	Potential Extirpation
White Oak	Quercus alba	Range	Range	Stable	Range	Stable
White Spruce	Picea glauca	Range	Range	Stable	Absent	Potential Extirpation
Yellow Birch	Betula alleghaniensis	Range	Range	Stable	Absent	Potential Extirpation

Appendix 4. Birds and Climate Change

Tables from a 2019 assessment by the National Audubon Society and Parks Canada. Climate suitability projections by 2050 under the high-emissions pathway for all birds currently present at the park based on both Parks Canada and Bird Studies Canada observation data from 1980 to 2018, plus those species for which climate at the park is projected to become suitable in the future. "**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. Observations of late-season migrants may result in these species appearing as present in the park when they may only migrate through. Species are ordered according to 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

A. Bruce Peninsula National Park

Common Name	Summer Trend	Winter Trend
Brant	-	Potential colonization
Canada/Cackling Goose	x	Improving
Mute Swan	-	Potential colonization
Gadwall	Potential extirpation^	Potential colonization
Eurasian Wigeon	-	Potential colonization
American Wigeon	-	Potential colonization
American Black Duck	x	Improving
Mallard	Improving^	Improving
Blue-winged Teal	Potential extirpation	-
Northern Shoveler	Stable^	-
Northern Pintail	Potential extirpation	-
Canvasback	-	Potential colonization
Ring-necked Duck	x	Improving

Common Name	Summer Trend	Winter Trend
Greater Scaup	-	Improving^
Lesser Scaup	-	Improving
Surf Scoter	-	Potential colonization
White-winged Scoter	-	Improving
Black Scoter	-	Improving
Long-tailed Duck	-	Improving
Bufflehead	x	Improving
Common Goldeneye	x	Improving
Hooded Merganser	x	Improving^
Common Merganser	-	Stable
Red-breasted Merganser	Improving	Improving^
Ruddy Duck	-	Potential colonization
Ruffed Grouse	x	Potential extirpation
Wild Turkey	x	Stable
Red-throated Loon	-	Potential colonization

Common Name	Summer Trend	Winter Trend
Common Loon	Potential extirpation	Stable^
Pied-billed Grebe	x	Potential colonization
Horned Grebe	-	Improving
Red-necked Grebe	-	Worsening^
Double-crested Cormorant	x	Potential colonization
American Bittern	Potential extirpation	Potential colonization^
Great Blue Heron	Improving	Potential colonization
Great Egret	Improving	-
Green Heron	Improving	-
Black-crowned Night-Heron	x	Potential colonization
Northern Harrier	Stable^	Improving
Sharp-shinned Hawk	x	Improving
Cooper's Hawk	x	Improving
Northern Goshawk	x	Worsening
Bald Eagle	x	Potential extirpation
Red-shouldered Hawk	Improving	-
Red-tailed Hawk	Improving	Improving
Rough-legged Hawk	-	Worsening
Virginia Rail	x	Potential colonization
Black-bellied Plover	-	Potential colonization
Killdeer	Improving	-
Solitary Sandpiper	Stable	-
Greater Yellowlegs	Stable	-
Upland Sandpiper	Potential extirpation	-
Ruddy Turnstone	-	Potential colonization^

Common Name	Summer Trend	Winter Trend
Sanderling	-	Potential colonization
Dunlin	-	Potential colonization^
Wilson's Snipe	Potential extirpation	-
American Woodcock	x	Potential colonization
Bonaparte's Gull	-	Potential colonization
Mew Gull	-	Potential colonization
Ring-billed Gull	Worsening^	Improving
Herring Gull	Stable	Improving^
Thayer's Gull	-	Potential colonization
Great Black-backed Gull	x	Improving
Rock Pigeon	Stable	Stable
Mourning Dove	Improving	Worsening
Yellow-billed Cuckoo	Improving	-
Black-billed Cuckoo	Stable	-
Eastern Screech-Owl	x	Improving
Great Horned Owl	x	Improving
Snowy Owl	-	Worsening
Great Gray Owl	x	Potential extirpation^
Common Nighthawk	Improving	-
Chimney Swift	Improving	-
Ruby-throated Hummingbird	Worsening	-
Belted Kingfisher	Stable	Potential colonization
Red-headed Woodpecker	Improving	Potential colonization
Red-bellied Woodpecker	Improving	Improving

Common Name	Summer Trend	Winter Trend
Yellow-bellied Sapsucker	Potential extirpation	-
Downy Woodpecker	Improving	Worsening
Hairy Woodpecker	Potential extirpation	Worsening
Black-backed Woodpecker	-	Potential extirpation
Northern Flicker	Stable	Potential colonization
Pileated Woodpecker	Potential extirpation	Potential extirpation
American Kestrel	x	Potential colonization
Merlin	x	Potential colonization^
Peregrine Falcon	x	Potential colonization
Olive-sided Flycatcher	Potential extirpation	-
Eastern Wood-Pewee	Stable	-
Yellow-bellied Flycatcher	Potential extirpation	-
Acadian Flycatcher	Potential colonization	-
Alder Flycatcher	Potential extirpation	-
Willow Flycatcher	Improving	-
Least Flycatcher	Potential extirpation	-
Eastern Phoebe	Stable	-
Great Crested Flycatcher	Stable	-
Eastern Kingbird	Stable	-
Loggerhead Shrike	Improving	-
Northern Shrike	-	Worsening
White-eyed Vireo	Improving	-
Yellow-throated Vireo	Improving	-
Warbling Vireo	Stable	-

Common Name	Summer Trend	Winter Trend
Red-eyed Vireo	Worsening	-
Blue Jay	Stable	Stable
American Crow	Worsening	Worsening
Fish Crow	Potential colonization	-
Common Raven	Potential extirpation	Potential extirpation
Horned Lark	Stable	Improving
Northern Rough-winged Swallow	Improving	-
Purple Martin	Improving	-
Tree Swallow	Worsening	-
Barn Swallow	Improving	-
Cliff Swallow	Stable	-
Carolina Chickadee	Potential colonization	-
Black-capped Chickadee	Worsening	Stable
Tufted Titmouse	Potential colonization	-
Red-breasted Nuthatch	Potential extirpation	Worsening
White-breasted Nuthatch	Improving	Stable
Brown Creeper	Potential extirpation^	Improving
House Wren	Improving	-
Winter/Pacific Wren	-	Potential colonization
Sedge Wren	Improving	-
Carolina Wren	Potential colonization	Potential colonization
Blue-gray Gnatcatcher	Improving	-
Golden-crowned Kinglet	Potential extirpation	Improving
Ruby-crowned Kinglet	Potential extirpation	Improving
Eastern Bluebird	Stable	-

Common Name	Summer Trend	Winter Trend
Veery	Potential extirpation	-
Gray-cheeked Thrush	Stable	-
Swainson's Thrush	Potential extirpation	-
Hermit Thrush	Potential extirpation	Potential colonization
Wood Thrush	Improving	-
American Robin	Worsening	Improving
Gray Catbird	Improving	Potential colonization
Brown Thrasher	Stable	Potential colonization
Northern Mockingbird	Potential colonization	Potential colonization
European Starling	Improving	Improving
Bohemian Waxwing	-	Worsening
Cedar Waxwing	Worsening	-
Snow Bunting	-	Worsening
Ovenbird	Potential extirpation	-
Worm-eating Warbler	Potential colonization	-
Northern Waterthrush	Potential extirpation	-
Blue-winged Warbler	Improving	-
Golden-winged Warbler	Worsening	-
Black-and-white Warbler	Potential extirpation	-
Tennessee Warbler	Potential extirpation	-
Nashville Warbler	Potential extirpation	-
Mourning Warbler	Potential extirpation	-
Common Yellowthroat	Worsening	-
Hooded Warbler	Improving	-

Common Name	Summer Trend	Winter Trend
American Redstart	Potential extirpation	-
Northern Parula	Potential extirpation	-
Magnolia Warbler	Potential extirpation	-
Bay-breasted Warbler	Potential extirpation	-
Blackburnian Warbler	Potential extirpation	-
Yellow Warbler	Stable	-
Chestnut-sided Warbler	Potential extirpation	-
Black-throated Blue Warbler	Potential extirpation	-
Palm Warbler	-	Potential colonization^
Pine Warbler	Stable^	Potential colonization
Yellow-rumped Warbler	Potential extirpation	Potential colonization
Black-throated Green Warbler	Potential extirpation	-
Canada Warbler	Potential extirpation	-
Eastern Towhee	Improving	-
American Tree Sparrow	-	Stable
Chipping Sparrow	Stable	Potential colonization
Clay-colored Sparrow	Potential extirpation	-
Field Sparrow	Improving	Potential colonization
Vesper Sparrow	Improving	-
Savannah Sparrow	Worsening	Potential colonization
Grasshopper Sparrow	Improving	-
Fox Sparrow	-	Potential colonization

Common Name	Summer Trend	Winter Trend
Song Sparrow	Worsening	Improving
Lincoln's Sparrow	Potential extirpation	-
Swamp Sparrow	Worsening	Potential colonization
White-throated Sparrow	Potential extirpation	Improving
White-crowned Sparrow	Stable	Improving
Dark-eyed Junco	x	Improving
Scarlet Tanager	Stable	-
Northern Cardinal	Improving	Improving
Rose-breasted Grosbeak	Worsening	-
Indigo Bunting	Stable	-
Bobolink	Worsening	-
Red-winged Blackbird	Improving	Potential colonization
Eastern Meadowlark	Stable	Potential colonization

Common Name	Summer Trend	Winter Trend
Rusty Blackbird	-	Potential colonization
Brewer's Blackbird	Stable	-
Common Grackle	Improving	Stable
Brown-headed Cowbird	Improving	Potential colonization
Baltimore Oriole	Improving	-
Pine Grosbeak	-	Worsening
House Finch	Improving	Improving
Purple Finch	Potential extirpation	Stable
White-winged Crossbill	Potential extirpation	Worsening
Common Redpoll	-	Worsening
Pine Siskin	Potential extirpation	Potential extirpation
American Goldfinch	Stable	Stable
Evening Grosbeak	-	Potential extirpation
House Sparrow	x	Improving

B. Fathom Five National Marine Park

Common Name	Summer Trend	Winter Trend
Brant	-	Potential colonization
Canada/Cackling Goose	x	Improving
Mute Swan	-	Potential colonization
Gadwall	Potential extirpation^	Potential colonization
Eurasian Wigeon	-	Potential colonization
American Wigeon	-	Potential colonization

Common Name	Summer Trend	Winter Trend
American Black Duck	x	Improving
Mallard	Improving^	Improving
Blue-winged Teal	Potential extirpation	-
Canvasback	-	Potential colonization
Ring-necked Duck	-	Potential colonization
Lesser Scaup	-	Potential colonization
Surf Scoter	-	Potential colonization

Common Name	Summer Trend	Winter Trend
White-winged Scoter	-	Improving
Black Scoter	-	Improving
Long-tailed Duck	-	Improving
Bufflehead	-	Improving
Common Goldeneye	-	Improving
Hooded Merganser	x	Improving^
Common Merganser	-	Stable
Red-breasted Merganser	Improving	Improving^
Ruddy Duck	-	Potential colonization
Ruffed Grouse	x	Potential extirpation
Wild Turkey	x	Stable
Red-throated Loon	-	Potential colonization
Common Loon	Potential extirpation	Improving^
Pied-billed Grebe	-	Potential colonization
Horned Grebe	-	Improving
Red-necked Grebe	-	Stable^
Double-crested Cormorant	x	Potential colonization
American Bittern	-	Potential colonization^
Great Blue Heron	Improving	Potential colonization
Great Egret	Potential colonization	-
Green Heron	Improving	-
Black-crowned Night-Heron	x	Potential colonization
Northern Harrier	Stable^	Potential colonization
Sharp-shinned Hawk	x	Potential colonization
Cooper's Hawk	-	Potential colonization

Common Name	Summer Trend	Winter Trend
Bald Eagle	x	Potential extirpation
Red-shouldered Hawk	Improving	-
Red-tailed Hawk	Improving	Improving
Rough-legged Hawk	-	Worsening
Virginia Rail	x	Potential colonization
Black-bellied Plover	-	Potential colonization
Killdeer	Improving	-
Ruddy Turnstone	-	Potential colonization^
Sanderling	-	Potential colonization
Dunlin	-	Potential colonization^
Wilson's Snipe	Potential extirpation	-
American Woodcock	x	Potential colonization
Bonaparte's Gull	-	Potential colonization
Mew Gull	-	Potential colonization
Ring-billed Gull	Worsening^	Improving
Herring Gull	Stable	Improving^
Thayer's Gull	-	Potential colonization
Great Black-backed Gull	x	Improving
Rock Pigeon	Stable	Stable
Mourning Dove	Improving	Worsening
Black-billed Cuckoo	Stable	-
Eastern Screech-Owl	-	Potential colonization
Great Horned Owl	x	Improving
Common Nighthawk	Improving	-
Chimney Swift	Improving	-

Common Name	Summer Trend	Winter Trend
Ruby-throated Hummingbird	Worsening	-
Belted Kingfisher	Worsening	Potential colonization
Red-headed Woodpecker	-	Potential colonization
Red-bellied Woodpecker	Potential colonization	Potential colonization
Yellow-bellied Sapsucker	Potential extirpation	-
Downy Woodpecker	Improving	Worsening
Hairy Woodpecker	Potential extirpation	Worsening
Northern Flicker	Stable	Potential colonization
Pileated Woodpecker	Potential extirpation	Potential extirpation
American Kestrel	x	Potential colonization
Merlin	x	Potential colonization^
Peregrine Falcon	-	Potential colonization
Olive-sided Flycatcher	Potential extirpation	-
Eastern Wood-Pewee	Stable	-
Yellow-bellied Flycatcher	Potential extirpation	-
Acadian Flycatcher	Potential colonization	-
Alder Flycatcher	Potential extirpation	-
Willow Flycatcher	Improving	-
Least Flycatcher	Potential extirpation	-
Eastern Phoebe	Stable	-
Great Crested Flycatcher	Stable	-
Eastern Kingbird	Improving	-
Warbling Vireo	Stable	-

Common Name	Summer Trend	Winter Trend
Red-eyed Vireo	Worsening	-
Blue Jay	Stable	Stable
American Crow	Worsening	Worsening
Fish Crow	Potential colonization	-
Common Raven	Potential extirpation	Potential extirpation
Horned Lark	-	Potential colonization
Northern Rough-winged Swallow	Improving	-
Purple Martin	Improving	-
Tree Swallow	Worsening	-
Barn Swallow	Improving	-
Cliff Swallow	Stable	-
Carolina Chickadee	Potential colonization	-
Black-capped Chickadee	Worsening	Worsening
Tufted Titmouse	Potential colonization	-
Red-breasted Nuthatch	Potential extirpation	Worsening
White-breasted Nuthatch	Improving	Stable
Brown Creeper	Potential extirpation^	Improving
House Wren	Improving	-
Winter/Pacific Wren	-	Potential colonization
Carolina Wren	Potential colonization	Potential colonization
Blue-gray Gnatcatcher	Improving	-
Golden-crowned Kinglet	Potential extirpation	Improving
Ruby-crowned Kinglet	-	Potential colonization
Veery	Potential extirpation	-

Common Name	Summer Trend	Winter Trend
Swainson's Thrush	Potential extirpation	-
Hermit Thrush	Potential extirpation	Potential colonization
Wood Thrush	Improving	-
American Robin	Worsening	Improving
Gray Catbird	Improving	Potential colonization
Brown Thrasher	-	Potential colonization
Northern Mockingbird	Potential colonization	Potential colonization
European Starling	Improving	Stable
Bohemian Waxwing	-	Worsening
Cedar Waxwing	Worsening	-
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	-
Mourning Warbler	Potential extirpation	-
Common Yellowthroat	Worsening	-
Hooded Warbler	Potential colonization	-
American Redstart	Potential extirpation	-
Northern Parula	Potential extirpation	-

Common Name	Summer Trend	Winter Trend
Magnolia Warbler	Potential extirpation	-
Blackburnian Warbler	Potential extirpation	-
Yellow Warbler	Stable	-
Chestnut-sided Warbler	Potential extirpation	-
Black-throated Blue Warbler	Potential extirpation	-
Palm Warbler	-	Potential colonization^
Pine Warbler	Stable^	Potential colonization
Yellow-rumped Warbler	Potential extirpation	Potential colonization
Black-throated Green Warbler	Potential extirpation	-
Canada Warbler	Potential extirpation	-
Eastern Towhee	Improving	-
American Tree Sparrow	-	Stable
Chipping Sparrow	Stable	Potential colonization
Field Sparrow	Potential colonization	Potential colonization
Vesper Sparrow	Potential colonization	-
Savannah Sparrow	-	Potential colonization
Grasshopper Sparrow	Potential colonization	-
Fox Sparrow	-	Potential colonization
Song Sparrow	Stable	Improving
Swamp Sparrow	Worsening	Potential colonization
White-throated Sparrow	Potential extirpation	Improving
White-crowned Sparrow	-	Potential colonization

Common Name	Summer Trend	Winter Trend
Dark-eyed Junco	x	Improving
Northern Cardinal	Improving	Improving
Rose-breasted Grosbeak	Worsening	-
Indigo Bunting	Stable	-
Red-winged Blackbird	Improving	Potential colonization
Eastern Meadowlark	-	Potential colonization
Rusty Blackbird	-	Potential colonization
Common Grackle	Improving	Stable
Brown-headed Cowbird	Improving	Potential colonization

Common Name	Summer Trend	Winter Trend
Baltimore Oriole	Improving	-
Pine Grosbeak	-	Worsening
House Finch	Improving	Improving
Purple Finch	Potential extirpation	Stable
Common Redpoll	-	Worsening
Pine Siskin	Potential extirpation	Potential extirpation
American Goldfinch	Improving	Stable
Evening Grosbeak	-	Potential extirpation
House Sparrow	x	Improving