CLIMATE CHANGE AND PUBLIC HEALTH IN GREY BRUCE HEALTH UNIT

Current Conditions and Future Projections

2017

ABOUT THIS REPORT

This report was completed as part of a Master of Public Health practicum placement by Gillian Jordan of Lakehead University during the summer of 2017 under the supervision of Robert Hart and Alanna Leffley of Grey Bruce Health Unit.

Acknowledgements

Much of this report was inspired by past work conducted by Stephen Lam, Krista Youngblood, and Dr. Ian Arra. This report is meant to build upon and accompany these previous reports to assist in furthering climate change-related understanding and planning of adaptation activities in Grey Bruce.

Special thanks to Bob Hart and Alanna Leffley for their guidance and assistance throughout the report process; additional thanks to Virginia McFarland for her help with data analysis.

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EXECUTIVE SUMMARY

The climate has been changing in the Grey Bruce region. Since the 1950's, the annual mean temperature in Wiarton, Ontario has increased by 0.8°C ($p=0.02$). Total annual precipitation has also increased by 207mm ($p<0.05$) during the same period. Projections indicate that this upward trend is expected to continue, with the rate of change dependent on our future greenhouse gas emissions (1; 2; 3).

Climate change, through changes in mean climactic conditions and increased variability in weather patterns may have a wide array of direct and indirect impacts on human health (4). In 2016, the Ministry of Health and Long-Term Care published a technical document to assist public health units in Ontario in beginning the process of assessing local climate change risk and impact and planning for future adaptive measures (1). Inspired by this framework, the Grey Bruce Health Unit undertook a local review of six public health hazard areas which may be impacted by climate change. These included;

- Extreme temperature
- Extreme weather
- Stratospheric ozone condition
- Air quality
- Vector-borne disease
- Food and waterborne illness

Utilizing local data where possible, the current status of each of the identified hazard areas was assessed. Provincial and national climate change projections were then used to illustrate potential changes each risk may undergo as the climate continues to change. Finally, these conditions and projections were linked to possible health impacts, highlighting populations more vulnerable to the effects.

Likely impacts of climate change affecting public health in Grey Bruce Health Unit include;

- Increased risk of vector-borne illnesses
  - An overall increase in temperature, including warmer spring and fall seasons, will help encourage the growth and establishment of vector populations capable of transmitting West Nile Virus and Lyme disease
- Changes in water quality and safety
  - Increases in total annual precipitation will negatively impact surface water quality through contamination from agricultural and residential runoff
  - This may be of most concern for recreational water quality and the potability of water for those who privately draw their drinking water from surface water sources
- Continued and possible increased occurrences of winter and summer storms
  - Continued occurrences of frequent snowsqualls, winter storms, and thunderstorms with the potential for these to increase with changing temperature and precipitation patterns
  - Storms may have direct health impacts such as injury or secondary impacts such as disrupting critical services and infrastructure conducive to health
  - Extreme weather occurrences may also complicate response efforts for other emergency events

For the following risk areas, more research is required to adequately assess risk and potential impact in the local population. Risks requiring more research include;

- Impact of moderate and extreme heat and cold
    - Based on observations from Wiarton, Grey Bruce does not experience many periods of extreme heat; however, other neighboring areas including Collingwood and Goderich do experience more hot days and nights suggesting that conditions do differ greatly across the region
    - Rates of cold and heat-related emergency department visits and hospitalizations suggest that some of the Grey Bruce population is at risk for temperature-related illness
    - Further investigation of temperature and temperature-related morbidity and mortality could help to better understand the local situation
- Impact of temperature and precipitation on food and waterborne illness
    - Commonly reported food and waterborne illnesses occur more frequently in summer months
    - With available climate data, additional work could be done to assess potential relationships between temperature and rainfall and food and waterborne illness or on water quality

Several limitations were encountered throughout this study. First, all long-term climate data for the Grey Bruce region was acquired from the Wiarton weather station. Conditions in Wiarton do not adequately represent those in other parts of the region, especially in in-land communities and municipalities located in the far southern regions of our area. Short-term climate data from Wiarton and surrounding communities outside of Grey Bruce were useful in producing an overview of recent conditions; however, due to normal seasonal fluctuations, trends were not calculated for temperature, precipitation, or weather events occurring since the year 2000 due to the large impact start and end date data have on short-term trends and the possibility of falsely concluding that no changes have taken place. In addition to issues with establishing accurate exposure, measuring public health outcomes associated with climate change and relating them back to these exposures is very difficult due to multiple other pathways and influences on human injury and illness.

Despite these limitations, assessing current conditions and projecting future risks in the local context can help to prioritize the planning of adaptive activities for future mitigation of these hazards. Planning for adaptation should include local partners, including those involved in environmental activities, emergency response, and those who work closely with any vulnerable populations identified in order to best promote and protect the health and safety of the Grey Bruce populations from the impacts of climate change.

INTRODUCTION

Climate Change

There is clear evidence to support that the climate is changing. Across the province of Ontario and around the world, there have been marked differences in historical annual temperature and precipitation patterns with unprecedented changes in these observed from the 1950's onwards (2).

The annual weather conditions we experience are influenced by many factors. One major influence is the El Niño–Southern Oscillation (*ESNO*) cycle, which describes fluctuations in ocean and atmospheric temperatures, usually over periods lasting nine to twelve months, that occur approximately every two to seven years (5). During these cycles, cooler or warmer than average surface temperatures are experienced due to temperature fluctuations in the Pacific Ocean resulting in impacts to weather conditions in Canada as well as globally (5).

Although temperature fluctuations from year-to-year are expected due to the ESNO cycle, it is clear that the climate has been steadily warming. The Intergovernmental Panel on Climate Change (IPCC), the global leader in climate change research, reports that the period from 1983 to 2012 was likely the warmest 30-year period in the last 1400 years in the Northern Hemisphere (2).

In Canada, the annual average surface temperature has warmed by 1.5°C over the period of 1950 to 2010 (6). Environment Canada reports that the national average temperature for the year 2016 was 2.1°C above the baseline average temperature from 1961-1990, making 2016 the fourth warmest year on record in Canada since observations began in 1948, with the warmest year occurring in 2010 (7). Nationally, 2016 was also among the 10 wettest years recorded (7). This warming is expected to continue, with the rate dependant on the projection used based on future emissions of greenhouse gases (2), including carbon dioxide and methane, among others (8).

In a recent report by the Ministry of Health and Long-Term Care (MOHLTC), Environment Canada temperature projections for the Mid-21st Century (2045-2065) are presented. These projections use several Representative Concentration Pathways (RCPs) in their modelling, meant to represent different atmospheric greenhouse gas concentration scenarios over a period of time. In RCP 8.5, it is assumed that it is "business as usual", with little or no change in global greenhouse gas remediation efforts; whereas RCP 2.6 represents a scenario where aggressive mitigation efforts are implemented, resulting in lower atmospheric greenhouse gas emissions (1).

Using these RCP models, estimates of seasonal temperature increases and changes in precipitation are able to be calculated and mapped, incorporating past conditions and local geography in to future climate projections. Although it is recognized that climate projections are not a perfect science due to the many different factors, both natural and human-generated, that may impact the greater environment (4), we cannot dismiss climate change as simply a possibility, but recognize it as a certain prognosis with a range of possible side-effects, the severity of which will be determined by the actions we are currently undertaking.

The Grey Bruce Area

Overview

Grey and Bruce counties are located in Southwestern Ontario, surrounded by Lake Huron and Georgian Bay to the north-east and north-west, and bordered by Huron County Health Unit, Perth District Health Unit, Wellington-Dufferin-Guelph Health Unit, and Simcoe Muskoka District Health Unit to the interior southeastern section.

The Grey Bruce region presents a diverse mix of geographies and land uses over the 8,600 km^2 collectively covered. Coastal regions of Lake Huron and Georgian Bay host many of the larger communities in both Grey and Bruce counties. The Niagara Escarpment, which sweeps through Grey County and up the Bruce Peninsula, is a designated United Nations Biosphere Reserve and contains a wide array of natural habitats and a diverse range of species, attracting thousands of tourists each year (9). To the interior, over one million acres of land are used for farming of crops, including hay, grains, soybeans, corn, fruits, nuts, and wheat, as well as livestock (10).

The 2016 population of Grey and Bruce counties was a total of 161,977, with county populations of 93,830 and 68,147 respectively (11); between 2011 and 2016, the population of Grey Bruce grew by 2.1%. The most populous centre is the City of Owen Sound with a population of 21,341, followed by the town of Saugeen Shores with 13,715 residents. Remaining towns and municipalities range in population from approximately 1,000 to 12,000. Saugeen First Nation Saugeen 29 and Neyaashiinigmiing First Nation Neyaashiinigmiing 27 are located in Bruce County with populations of 1,041 and 615 respectively (11).

The average age of the population in Grey Bruce is older than Ontario as a whole at 45.1 years old, with 16 of 19 municipalities having senior populations at or above the Ontario rate (12). In the 2016 census, those aged 15-64 accounted for 61% of the population; those aged 65 and older made up 24%, and those aged 14 or less made up 15%. Single-detached dwellings account for 80% of dwellings in Grey Bruce with an average household size of 2.3 persons per dwelling (12). Grey Bruce also hosts a sizeable number of vacation homes, accounting for about 23% of private dwellings (12).

Weather Stations and Locations

Meteorological reporting by Environment Canada for the Grey Bruce area is largely based on climactic observations from the Wiarton A weather station, located at the Wiarton Keppel International Airport (13). In operation since the 1940's, it provides the most complete and detailed climate information for the Grey-Bruce area as a reporting station for both Transport Canada and the World Meteorological Organization (14).

Station operation and data availability outside of Wiarton varies; although historically many of the communities in Grey and Bruce have hosted Environment Canada Weather stations, few currently remain. Stations currently operational in Thornbury and Kincardine are not WMO-reporting stations and are therefore limited in the type of climate data they routinely collect and report.

For the purposes of this report, data from several neighbouring stations were observed. These stations are often used in formulating weather reports for nearby communities within the Grey Bruce area even though they fall outside of the district. These stations were chosen based on proximity and data availability in order to attempt to gain a better understanding of climactic variations across Grey-Bruce.

The stations selected include Collingwood (15), Goderich (16), Mount Forest AUT (17) and Tobermory RCS (18). Further details on these stations, their locations, and comparability with neighbouring communities within Grey-Bruce are available in Appendix 1 - Weather Station Information.

In addition to regional comparison sites, monthly observations from the London International Airport weather station (19), used in the weather reporting for the community of Stratford, were used when comparing Grey Bruce Health Unit with Perth Health Unit, which has similar demographic characteristics but is located more south and inland from Lake Huron.

The availability of complete climate data sets representative of the Grey Bruce area was one challenge encountered when undertaking a review of past and present climactic conditions. Although excellent data is available from the Wiarton airport, it is recognized that conditions differ across Grey and Bruce counties due to the diverse range of geographic variability in this area. While data used was the best found, there are still many incidents of missing values within the datasets, especially for precipitation, humidex, and wind chill values. Because of this, data presented may not be an entirely accurate representation of the actual conditions experienced during the periods discussed.

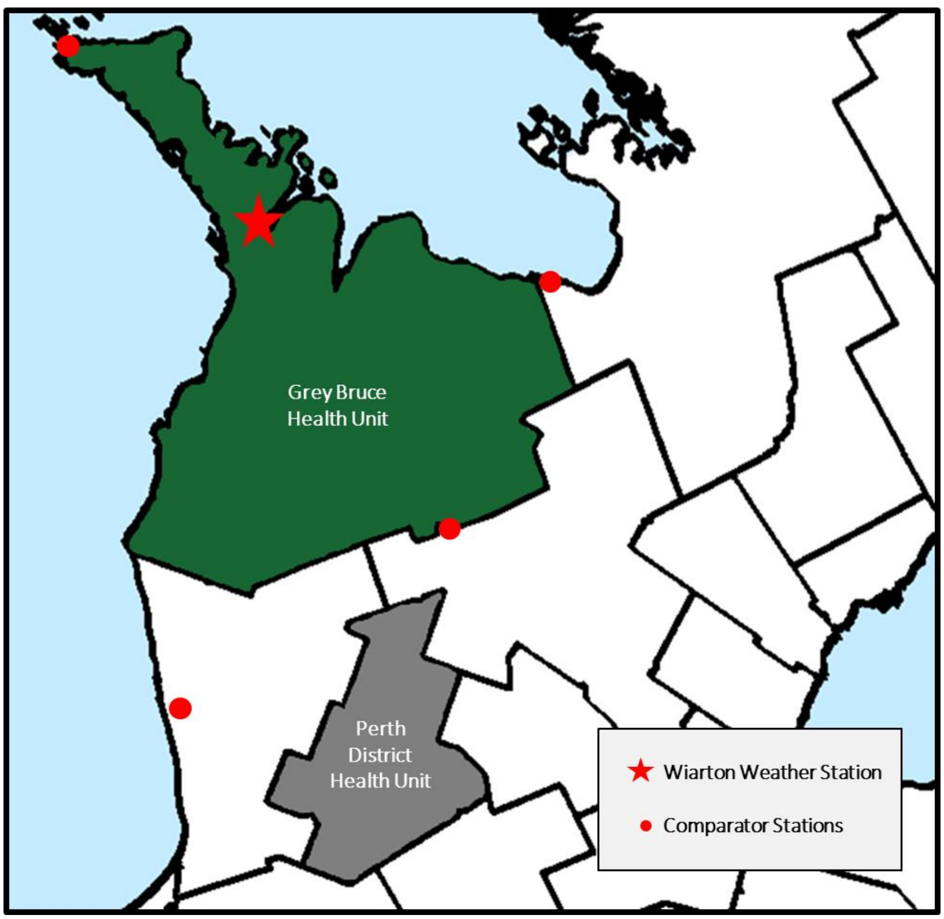


Image 1: Map of Local Environment Canada Weather Station Locations
Base Map: Statistics Canada 2015 Southern Ontario Health Regions
All station locations on map are approximate

Historical Climate Data

Examining historical climate data is important in illustrating how current conditions differ from those of the past. Throughout this report, climate data, primarily from the past two decades, are used in examining recent occurrences of weather events and possible public health impacts; however, it is often difficult to identify significant trends in short-term climactic data, especially where observations are highly variable over time. The IPCC cautions against drawing conclusions based on trends observed in short records as they are very sensitive to start and end dates and often do not reflect long-term climate trends (2).

Although significant changes in precipitation and temperature since the year 2000 may not be easily identifiable due to El Niño occurrences, examining these short-term patterns in addition to long-term trends observed in data from the past seven decades may be helpful in gaining a better understanding of the local impacts of climate change.

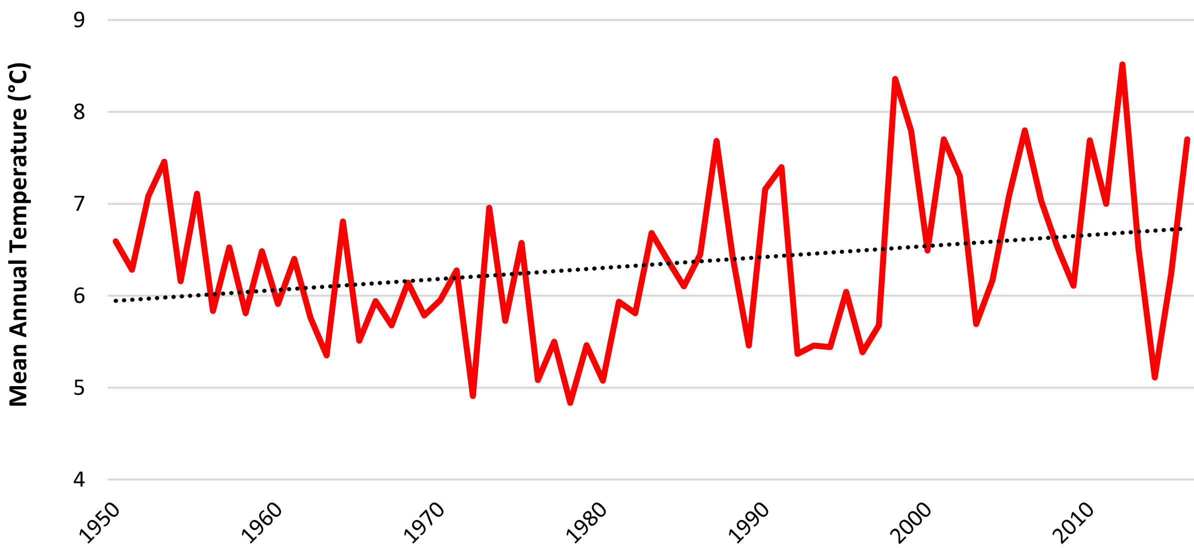


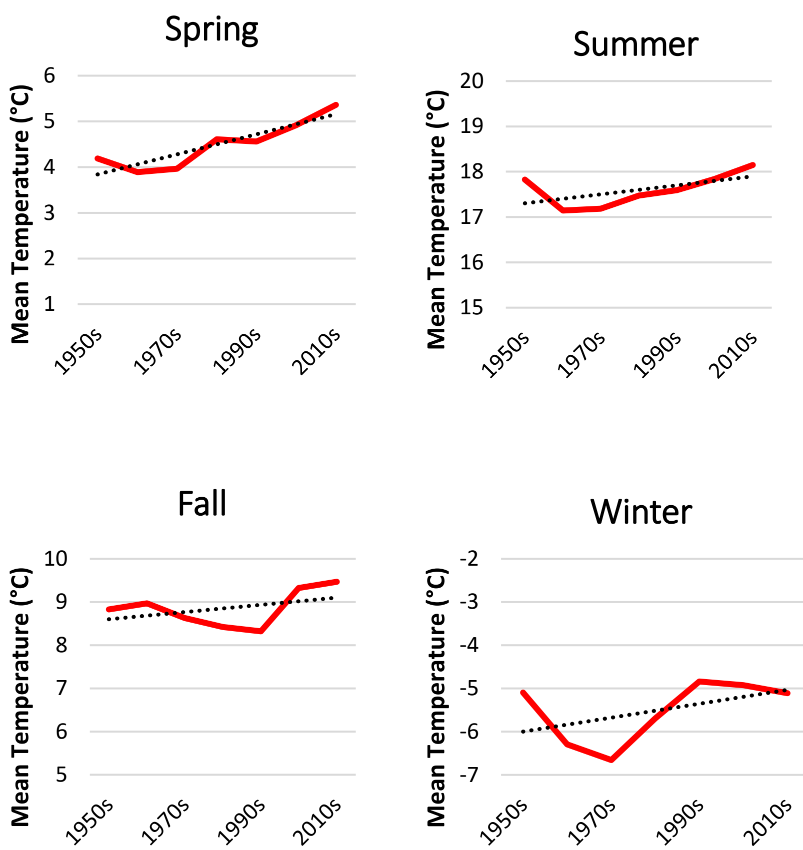
Figure 1: Annual Mean Temperature, Wiarton ON 1950-2016
Source: Environment and Climate Change Canada Historical Weather Data (14)

Figure 1 shows the annual mean temperature in Wiarton, Ontario from 1950 until 2016. Annual mean temperature fluctuates from year to year; however, over time, the annual trend observed is an increase of 0.8°C (*p=0.023*) since 1950, with the warmest year occurring in 2012. Of all four seasons, a significant warming trend of 1.3°C (*p=<0.05*) was observed in the spring months (March, April and May) over the same period (Figure 2). This warming trend was not found to be significant in summer (*0.6°C, p=0.17*), winter (*1°C, p=0.27*), or fall (*0.5°C, p=0.36*) months.

Across the province of Ontario, long-term temperature trends in other locations have also shown warming over time. During the same period of 1950-2016, London, Ontario (Appendix 2) experienced a significant warming trend of 1.1°C (*p<0.01*). In Toronto and Thunder Bay, annual trends from 1900 to 2012 show an increase of 2.2°C and 2.1°C respectively.

Figure 2: Mean Seasonal Temperatures by Decade, Wiarton ON

Source: Environment and Climate Change Canada Historical Weather Data (14)



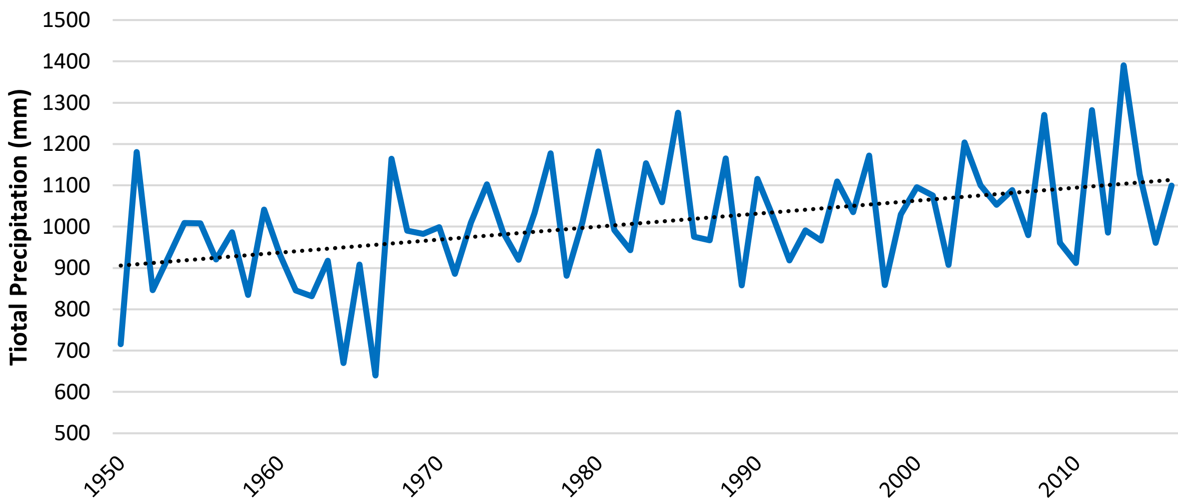


Figure 3: Annual Total Precipitation, Wiarton ON 1950-2016

Source: Environment and Climate Change Canada Historical Weather Data (14)

Changes in precipitation patterns are also associated with a changing climate, though these changes will not be uniform. While some areas will experience more wet weather, others may become more prone to drought (2). Since 1950, the trend observed in total annual precipitation in Wiarton (Figure 3) is an increase of 207mm (*p<0.05*); however, when observing this trend across seasons (Figure 4), a significant trend was seen in mean monthly precipitation in the fall (September, October, and November), with an increase of 23mm between 1950 and 2016 (*p=0.05*). Trends were not significant for summer (*9mm, p=0.29*), winter (*13mm, p=0.19*), or spring (*15mm, p=0.07*) precipitation. The total annual precipitation trend for London, Ontario (Appendix 2) was not significant for the same time period of time (*60mm, p=0.34*).

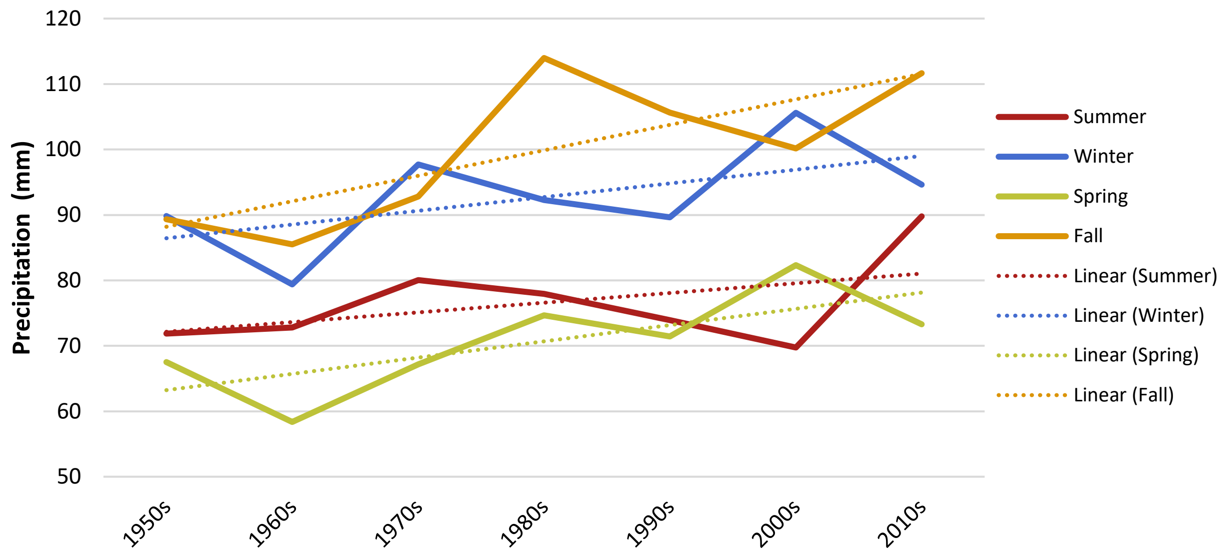


Figure 4: Seasonal Mean Monthly Precipitation by Decade, Wiarton ON
Source: Environment and Climate Change Canada Historical Weather Data (14)

PRIORITY HAZARDS

In 2016, the Ministry of Health and Long-Term Care (MOHLTC) released the *Ontario Climate Change and Health Toolkit* (1) to help guide public health units in incorporating climate change assessment and planning in to their work. The toolkit provides a framework for taking preliminary steps in identifying and assessing potential hazards related to climate change. Suggested target areas include extreme temperatures, extreme weather, air quality, food and waterborne disease, vector borne disease, and stratospheric ozone condition (20).

Figure 5, adapted from Anthony J. McMichael's *Processes and Pathways through which Climate Change Influences Human Health* (21) illustrates the wide array of impacts climate change may have directly and indirectly on human health through various social and environmental means.

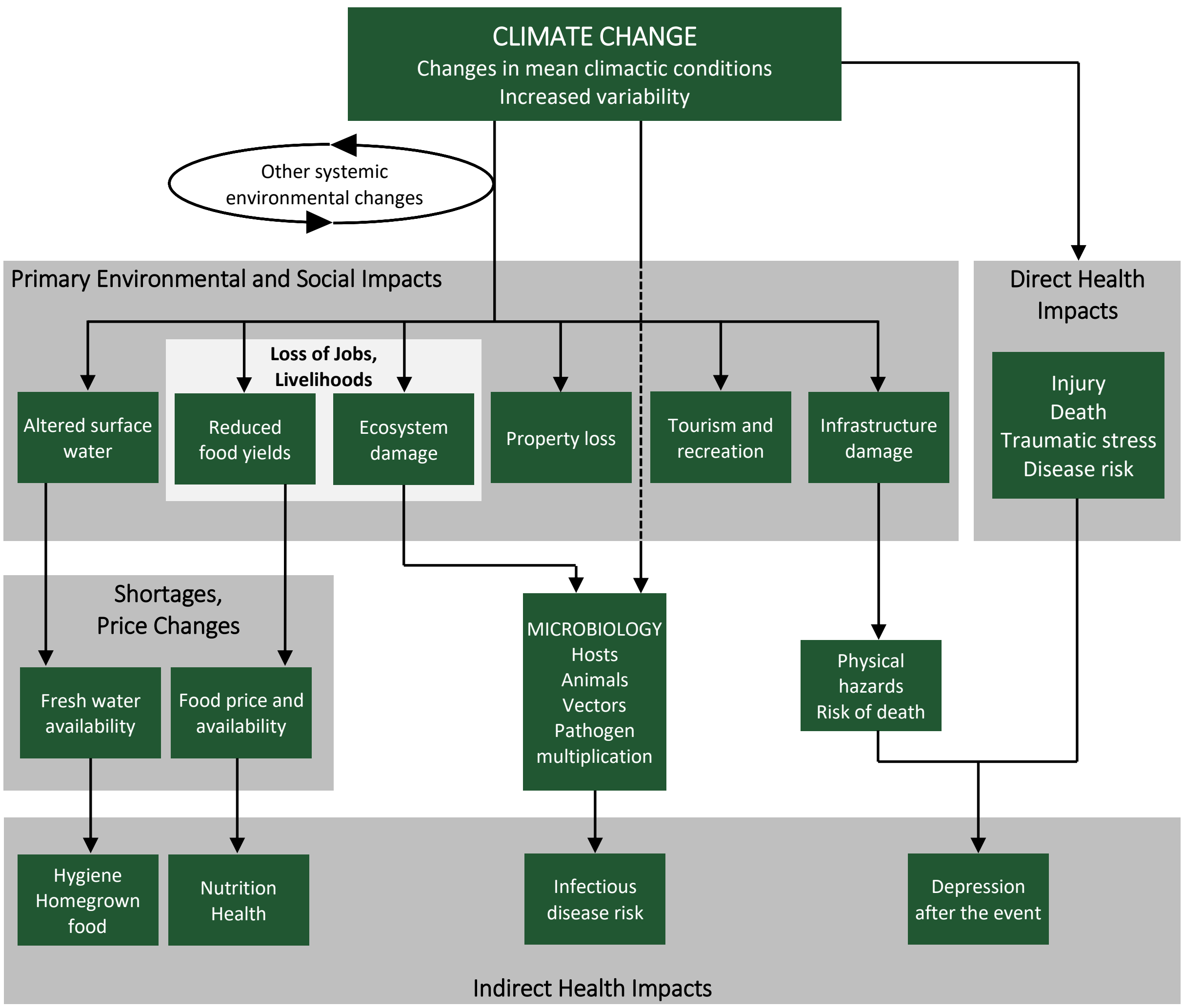


Figure 5: Climate Change Impacts on Human Health

Source: Adapted from "Globalization, Climate Change, and Human Health" by McMichael, A., 2013 (21)

Direct impacts to health include those many would quickly associate with weather-related or emergency events. Injury due to wind, storms, or slips and falls in icy winter conditions, illness due to heat-stroke or exposure to contaminated water during a flood, or death due to drowning or other extreme weather events are easily quantifiable results of climactic conditions which may increase as the climate changes.

Less easy to identify are those indirect impacts, where changes in climate affect mediating factors which in turn may negatively or positively impact human health and wellbeing. Increases in temperature and precipitation and changes in patterns of extreme weather events may touch many areas of our natural and social environment and are more difficult to measure and predict.

As stated by McMichael (4), "in view of residual uncertainties in modelling, how the climate system will respond to future higher levels of greenhouse gases, and uncertainties over how societies will develop economically, technologically, and demographically, formal predictions of future health effects cannot be made"; however, despite a lack of formal predictions, dismissing or ignoring climate change and related public-health hazards fails to fulfill the mission of protecting and promoting a healthier future for the population that we serve.

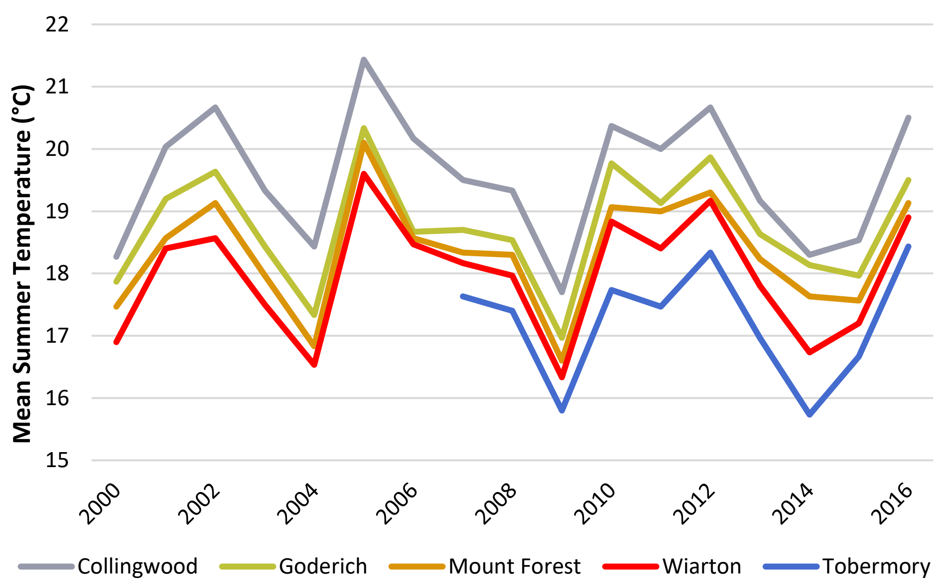
I. Extreme Temperature

Extreme Heat

Increasing temperatures and opportunity for more extremely hot days are anticipated outcomes of climate change. The global surface temperature is expected to continue to rise throughout the 21st Century, as is the frequency and duration of extreme heat events (2).

Mean summer temperatures for Wiarton, as well as Collingwood, Goderich, Mount Forest, and Tobermory were calculated for the period of 2000-2016 (Figure 6). As it is often difficult to observe trends in short-term data due to normal climate variability, annual trends were not calculated. During this time, Collingwood consistently experienced warmer summer temperatures than other areas in the region, with Wiarton and Tobermory experiencing cooler temperatures.

Figure 6: Mean Summer Temperatures in the Grey Bruce Region 2000-2016
Source: Environment and Climate Change Canada Historical Weather Data (15; 16; 17; 75; 18)



The warmest summer across all areas occurred in 2005. It should be noted that, though located inland and approximately 90 kilometers southwest of Collingwood and the shores of Georgian Bay, Mount Forest experiences cooler temperatures in both summer and winter months, due to a high elevation of 415 metres. It is expected that a similar cooling effect may also be experienced in Durham and surrounding areas with similarly high elevations. The mean summer temperature in London, Ontario for the period of 2000-2016 was 20°C, compared to 18°C in Wiarton. Under "business as usual" projections, average summer temperatures could increase by 2.6 to 3.9°C by the Mid-21st Century (1).

Of public health interest are extended periods of extreme heat due to the potential impact on human health. In addition to rising temperatures, the frequency and duration of extreme heat events are expected to increase with the changing climate (2).

Environment Canada will declare a heat alert if forecasted temperatures are expected to meet the following criteria for two or more consecutive days (22);

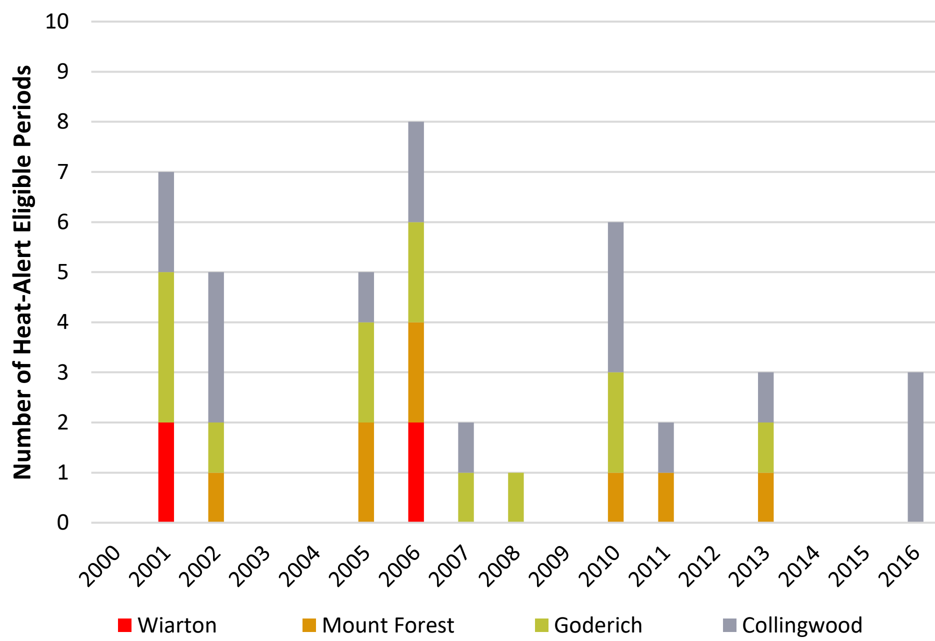
- The daily maximum temperature is ≥31°C and the daily minimum temperature is ≥20°C; or,
- The humidex value is ≥40.

This criteria is different than the definition of a heat wave, which is classified as three or more consecutive days with maximum temperatures greater than 32°C (23; 24).

Heat Alert-eligible events do not happen frequently in Grey Bruce (Figure 7), likely due to the cooling effect of Georgian Bay and Lake Huron. During the period of 2000-2016, Heat Alert-eligible periods were seen most frequently in Collingwood, which experienced about one event per year. Wiarton experienced these heat events much less frequently, with an average of 0.2 events per year. In London, Ontario, these events were experienced approximately 1.2 times per year for the 2000-2016 period (Appendix 3).

Figure 7: Number of Heat Alert-eligible Events in the Grey Bruce Region 2000-2016

Source: Environment and Climate Change Canada Historical Weather Data (15; 16; 17; 75; 18)



During the period of 2000-2016, 85 Heat Alert days were declared by Environment Canada for the Grey Bruce region (Figure 16), despite the region actually experiencing a much lower number of Heat Alert- eligible days. Of the four heat alert-eligible periods Wiarton experienced and the 17 experienced by Collingwood, the range of actual extreme heat days in Grey-Bruce during this period is 8-42 days (mean across all locations = 24 days). This discrepancy demonstrates the issues encountered when using centralized climate data, such as forecasts from south-central Ontario, to make blanket predictions for outside regions.

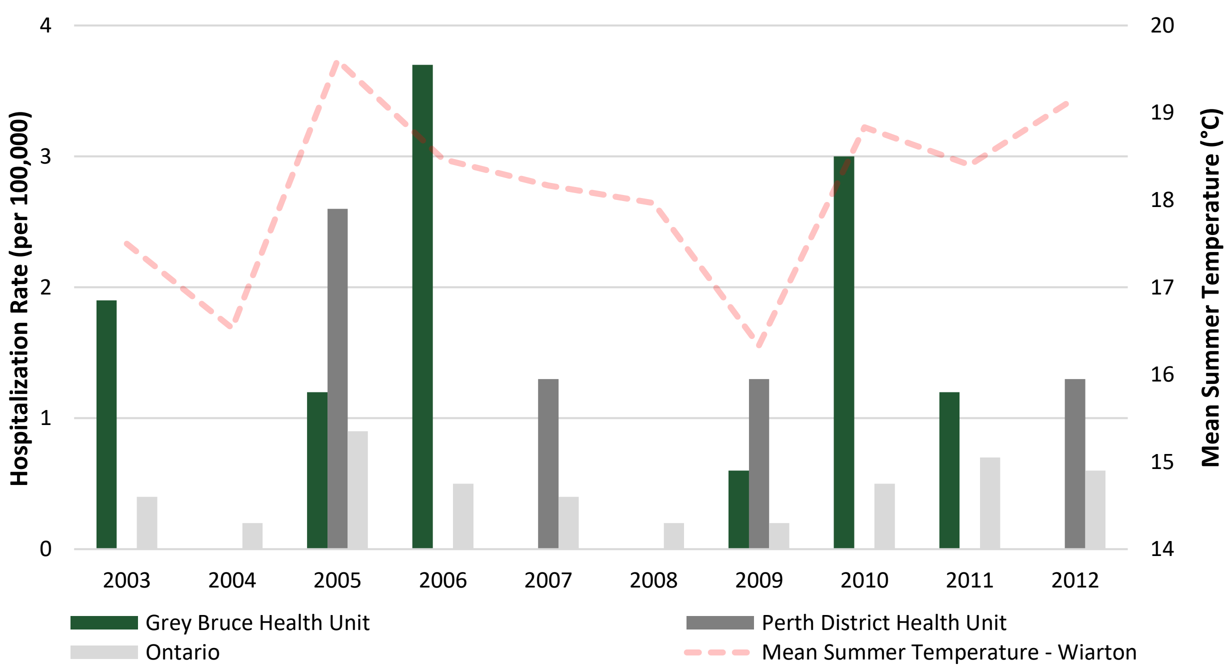
The Ministry of Health and Long-Term Care's Ontario Climate Change and Health Modelling study uses heatwaves to quantify extreme heat events (24). Heatwaves are extended periods of intense heat; during the period of 2000-2016, only Collingwood experienced conditions meeting the threshold for a heat-wave designation; these events occurred in 2002, 2006, and 2010. Using Collingwood as a reference community, the average number of heat waves per year in the Grey Bruce area is approximately 0.2 per year, consistent with the findings from the MOHLTC report (-0.562 – 0.5 heatwaves per year) (24). During the same period, London, Ontario experienced ten heat wave events, with a frequency of 0.6 heatwave events per year (Appendix 3).

It is predicted that the frequency of heat wave events will remain quite low in Grey Bruce for the next several decades. Climate modelling predicts that by the 2050s, Grey Bruce will still be experiencing less than one such event a year (0.72 per year), while the southernmost portions of the province begin to experience more. By 2080, Grey Bruce could experience an average of 2.21 heat waves per year under the MOHLTC's climate projects (24).

Periods of extreme heat may cause illness and death, especially in those most vulnerable to its effects. Figure 8 presents the rate of extreme heat-related hospitalizations in Grey Bruce Health Unit, Perth District Health Unit, and the average rate for Ontario. This data from Public Health Ontario uses information from the National Ambulatory Care Reporting System, Discharge Abstract Database, and the Vital Statistics Database to identify health outcomes related to extreme weather events (25). In 2006, the Grey Bruce region experienced the highest number of extreme heat-events for the period of 2000-2016 (Figure 7);

Figure 8: Crude Rate of Hospitalizations due to Extreme Heat in Grey Bruce Health Unit, Perth District Health Unit, and Ontario 2003-2012

Source: Public Health Ontario, Extreme Weather Ontario Health Profile (25)



this corresponds with the highest rate of heat-related hospitalizations in Grey Bruce Health Unit for the period of 2003-2012, despite the mean summer temperature being lower than the previous year.

The rate of emergency department visits related to extreme heat and mean summer temperature in Wiarton can be found in Appendix 5. In this chart, peaks in emergency department rates more closely mirror peaks in mean summer temperature experienced in Wiarton; however, results should be interpreted with caution, especially when comparing these rates to provincial averages, due to differing availability and use of physician and emergency department services between urban and rural areas.

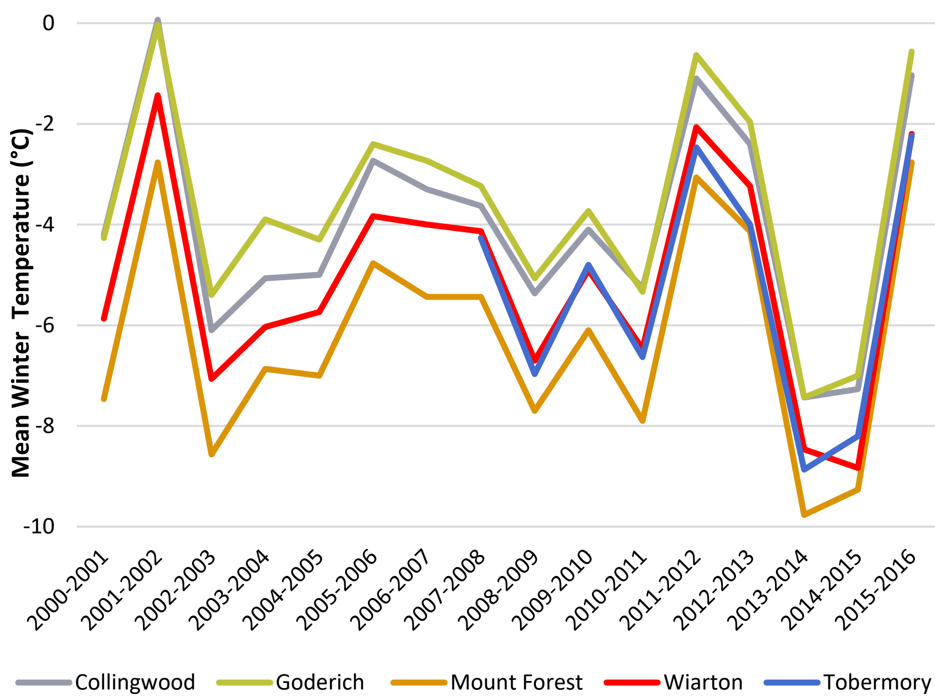
Despite experiencing cooler summers and less frequent extreme heat events in Grey Bruce Health Unit than in other areas of the province, it appears that some members of the Grey Bruce population may be negatively impacted by periods of warmer than average or extremely warm weather. In a recent study by Bai et al. (26), the burden of hospitalizations attributable to cold and heat were examined in the entire population of Ontario for the period of 1996-2016, focusing on hospitalizations from hypertensive disease, diabetes, and arrhythmia, morbidities often exacerbated by temperature extremes. Many studies have shown that there is increased mortality in periods of extreme heat (4; 27); however, Bai's findings suggests that, in the Ontario context, moderate temperatures were of greater impact on rates of hospitalizations when compared to extreme temperatures. For diabetes related hospitalizations, 10.9% were attributable to moderate temperatures (75^{th} percentile), versus only 0.9% related to extreme heat (99^{th} percentile) (26).

In addition to heat-related illness, warming weather across the Grey Bruce region has the potential to impact many other systems closely related to temperature, such as vector dispersion patterns and food safety and security, as discussed in coming sections of this report.

Extreme Cold

Climate change is expected to decrease the frequency of cold temperature extremes and cold-related mortality in some regions; however, occasional extreme cold winters are expected to continue to occur (2). Figure 9 illustrates the mean winter temperatures for the months of December, January, and February for Wiarton and surrounding areas for the period of 2000-2016. Once again, trends were not calculated due to the short-term nature of this data.

Figure 9: Mean Winter Temperatures in the Grey Bruce Region 2000-2016
Source: Environment and Climate Change Canada Historical Weather Data (15; 16; 17; 75; 18)



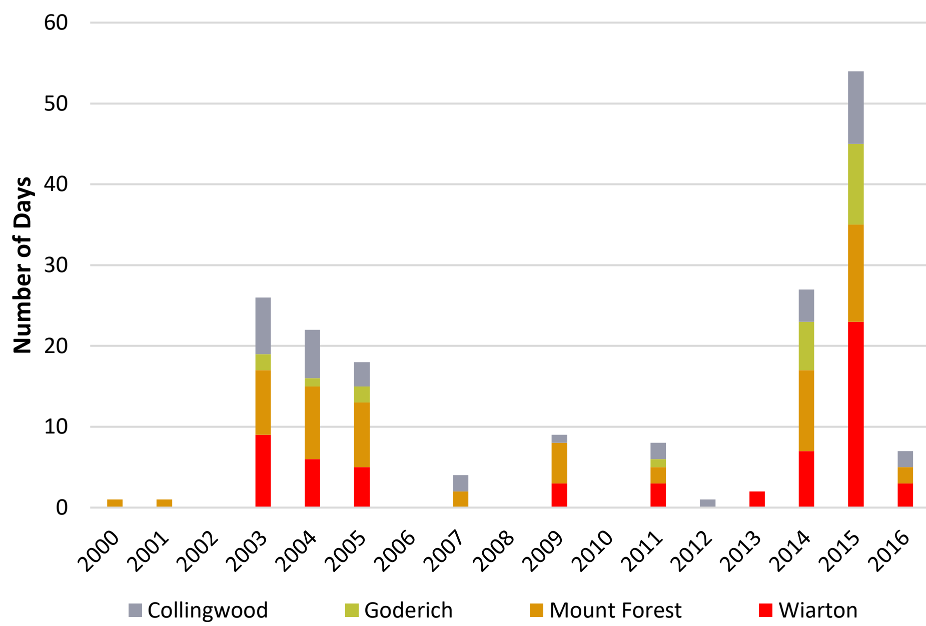
Nationally, the average temperature for the winter of 2015/2016 was 4°C above the baseline reference period, making it the second warmest winter on record since 1948 (28). Although the winter of 2013/2014 was the coldest experienced in Grey Bruce over the past 17 years, the national mean winter temperature was only 0.4°C below baseline temperatures, making it only the 24th coldest winter on record, with the coldest occurring in 1971/1972 which was 3.6°C below the baseline (29). Based on RCP 8.5 projections, winter temperatures in Ontario are expected to rise by 3.4°C to 5.4°C by the Mid-21st century. With extensive mitigation efforts, winter temperatures are still excepted to increase more than summer temperatures, with a median increase of 2.2°C by the 2050s (1).

An extreme cold warning may be issued by Environment Canada when the temperature or wind chill is expected to reach -30°C or colder for two or more hours (22). To allow for better comparability between extreme cold events and the rate of hospitalizations related to excessive cold (Figure 11), extreme cold events were tabulated based on calendar year rather than the December to February winter period.

Temperatures of -30°C or less before factoring in wind chill are not common in Grey Bruce. Between 2000 and 2016, Wiarton only experienced six days with pre-wind chill temperatures of -30°C or less, with four of these events occurring during in February of 2015.

The majority of extreme cold days experienced in and around the Grey Bruce area are due to wind chill, with Wiarton and Mount Forest experiencing the most extreme cold days, averaging 3.5 extreme cold days per year (Figure 10). By comparison, London, Ontario experiences about 2.2 extreme cold event days per year (Appendix 3), the same frequency as experienced in Collingwood.

Figure 10: Number of Extreme Cold Event Days in Grey Bruce 2000-2016
Source: Environment and Climate Change Canada Historical Weather Data (15; 16; 17; 75; 18)



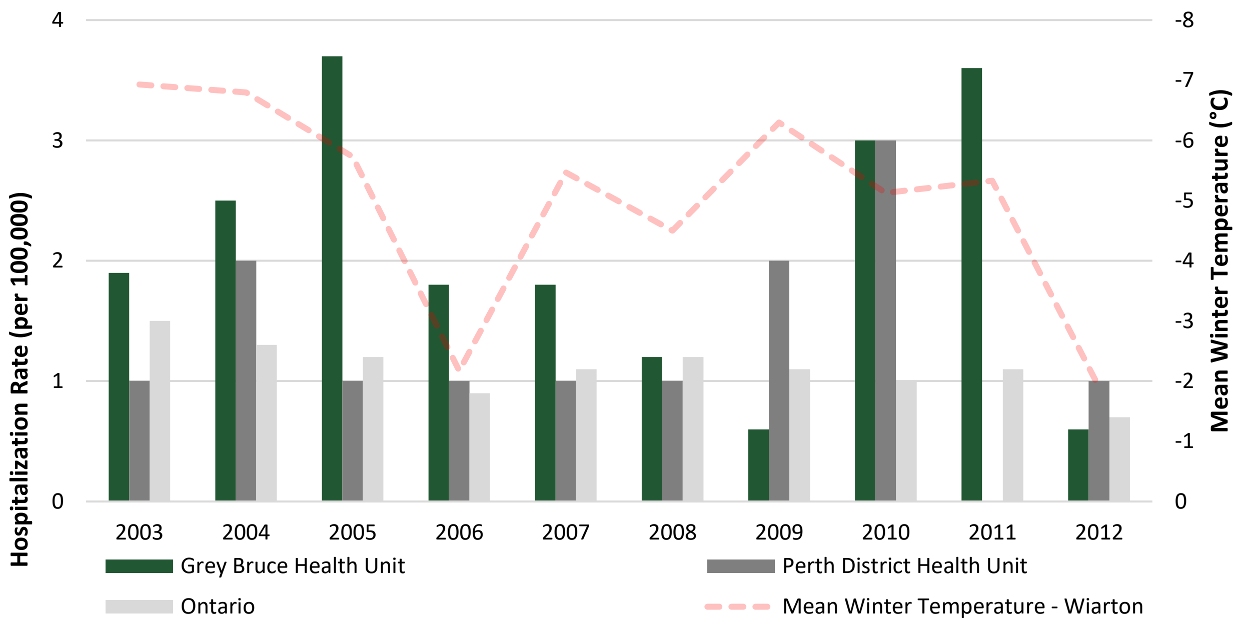
Compared to hospitalizations due to extreme heat, of which 19 cases were identified during the period of 2003-2012, 34 cases were identified during the same period due to extreme cold (25).

Figure 11 shows the rate of extreme cold-related hospitalizations for Grey Bruce Health Unit, Perth District Health Unit, and the average rate for the province of Ontario. Unfortunately, data availability is limited, and the cold winter years of 2014 and 2015 are not captured in the available PHO dataset at the time of this report. The highest rates observed were in 2005 and 2011, years which do not correspond with lowest mean winter temperatures or higher numbers of extreme cold days for the specified period. Rates of extreme cold-related emergency department visits can be found in Appendix 5.

Figure 11: Crude Rate of Hospitalizations due to Extreme Cold in Grey Bruce Health Unit, Perth District Health Unit, and Ontario 2003-2012

Source: Public Health Ontario Ontario Health Profile (25)

In the aforementioned study by Bai et al. (26), moderate cold (25th percentile), rather than extreme cold (1st percentile), was found to be a greater risk factor in Ontario hospitalizations for hypertension. Moderate cold was also found to be attributed to the greatest fraction of all-cause mortality in Canada, as well as in many other developed countries, rather than days with temperature extremes (30).



Vulnerability and Adaptation

Summary

- Under "*business as usual*" climate change projections, summer temperatures are expected to increase by 2.6 to 3.9°C and winter temperatures are expected to increase 3.4 to 5.4°C across Ontario by the Mid-21st century
- Approximately 0.2 to 1 extreme heat events are experienced in Grey Bruce each year
- Currently, the frequency of extreme heat events in Grey Bruce is low compared to other areas and is only expected to increase slightly over the next several decades
- Extreme cold events occur more frequently than extreme heat events with an average of approximately 3.5 events occurring per year
- Extreme heat and cold events are experienced at different frequencies across the region
- Nineteen heat-related hospitalizations and 34 cold-related hospitalizations occurred in Grey Bruce Health Unit between 2003 and 2012
- Rates of cold and heat-related emergency department visits and cold-related hospitalizations are routinely higher than provincial rates
- Studies suggest that health impacts of moderate heat and cold may be of greater concern than extreme heat and cold

Those identified as being at increased risk of impacts related to heat and cold include (20; 4; 31):

- Seniors
- Children
- Pregnant women
- Those with pre-existing medical conditions, including cardiovascular or respiratory disease
- Socioeconomically disadvantaged populations
- Those facing challenges with access to adequate shelter or housing, including access to heat and/or air conditioning
- Outdoor workers or others engaging in outdoor activities
- People in thermally stressful occupations

In most populations, temperature thresholds exists; when temperatures exceed these thresholds, increased temperature-related morbidity or mortality can be seen. This threshold is based on many factors, including biological sensitivity, socioeconomic factors, and geography and local climate (32; 31). In Grey Bruce, aging and socioeconomically disadvantaged populations struggling with access to adequate housing and the socially isolated or those living in rural areas with limited access to health and social services may be of interest when considering possible adaptive strategies and activities.

Environment and Climate Change Canada is responsible for monitoring and reporting on forecasted periods of extreme heat and cold. In Ontario, the Ministry of Health and Long-term Care has published a harmonized heat warning system to guide health unit response to extreme heat events (33). As demonstrated, Grey Bruce experiences extreme heat events much less frequently than is declared by Environment Canada; however, Grey Bruce does experience occasional extreme heat events, as well as heat-related emergency department visits and hospitalizations.

Despite the lower risk of extreme heat events, alerts from Environment Canada and local forecasts and conditions should be monitored, and advanced warning messages released when required. To ensure preparedness for these events which may increase slightly in frequency, partnerships with local community agencies should be established, especially those actively involved with socioeconomically disadvantaged populations and the elderly (33). Further engagement with these partners may help to identify areas of need, such as whether current services and responses to extreme heat events are adequate, or if their experiences indicate further areas of need. It is also important to consider the impact these events may have on populations outside of the immediate Owen Sound area, as some smaller, rural communities experience higher levels of material deprivation (34), limited access to health and social services, and experience different climactic conditions than those reported at the Wiarton Weather station.

Other adaptive measures in dealing with extreme temperature conditions include increasing public and partner awareness on the impacts of extreme heat and cold on health, improving access to adequate shelter and thermally sufficient housing, improving overall health status (4), and increasing staff, public, and partner knowledge of the mechanisms and broader impacts of climate change.

II. Extreme Weather

Precipitation

In comparing precipitation to mean summer and winter temperatures for the period of 2000-2016, patterns of annual precipitation in the Grey Bruce region (Figure 12) are much more irregular. Although Wiarton appears to routinely receive more precipitation than other locations, short-term patterns of consistently wetter or drier locations are not as clear as in the hierarchical distribution of average temperatures. Nationally, the wettest year on record was in 2005 which was 15.6% above the baseline average; however, precipitation amounts differ greatly by climate region (7). Whereas 2016 was nationally among the 10 wettest years on record (7), the Great Lakes region, including Grey Bruce, saw abnormally dry conditions and some areas of moderate drought during this time (35).

Figure 12: Total Annual Precipitation in the Grey Bruce Region 2000-2016

Source: Environment and Climate Change Canada Historical Weather Data (15; 16; 17; 75; 18)

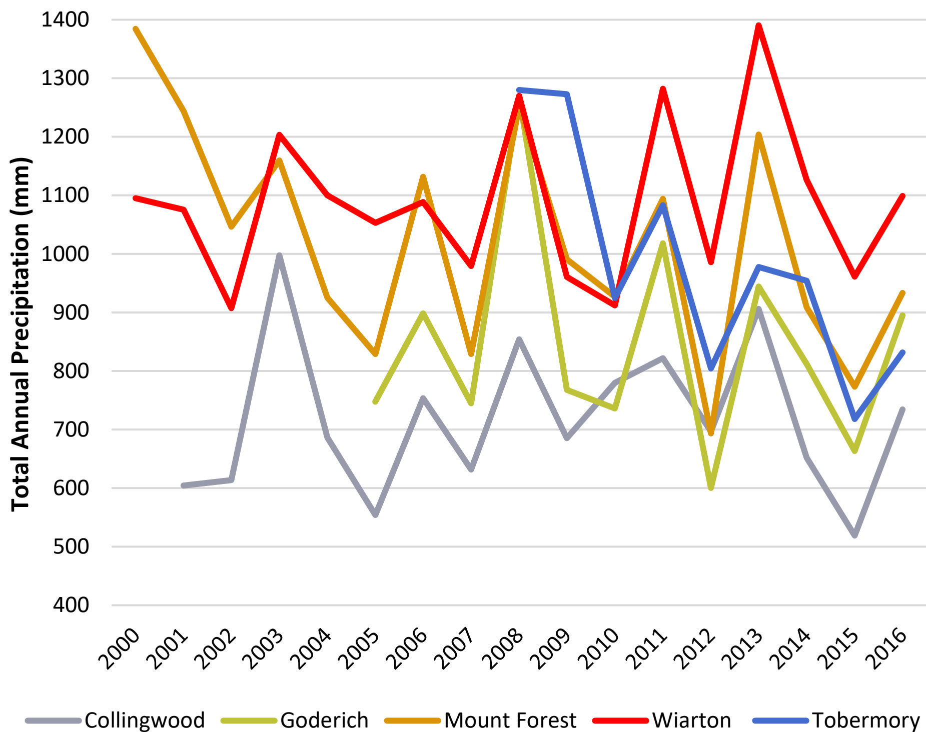


Figure 13 illustrates seasonal precipitation variations in Wiarton for the period of 2000-2016. Total precipitation, reported in millimetres, is the total amount of liquid precipitation, determined by weight. Where snow is reported separately, as is done by the Wiarton Station, water equivalent of snow is calculated and converted in to millimetres as snow to liquid ratio varies between snow type; however, for the purposes of this report, one centimetre of snow was considered to be equal to one millimetre of precipitation, a common liquid ratio as reported by Environment Canada (36).

Most snowfall occurring in Wiarton takes place during winter months of December, January and February. Spring and fall seasons commonly experience periods of mixed precipitation, with seasonal precipitation differing greatly across years. In Figure 3, a long-term annual upwards trend of 230mm was observed in total annual precipitation in Wiarton for the period of 1950 to 2016, with a significant increase seen in the fall months. In the last 17 years, fall months in Wiarton have experienced more total precipitation than throughout the other seasons.

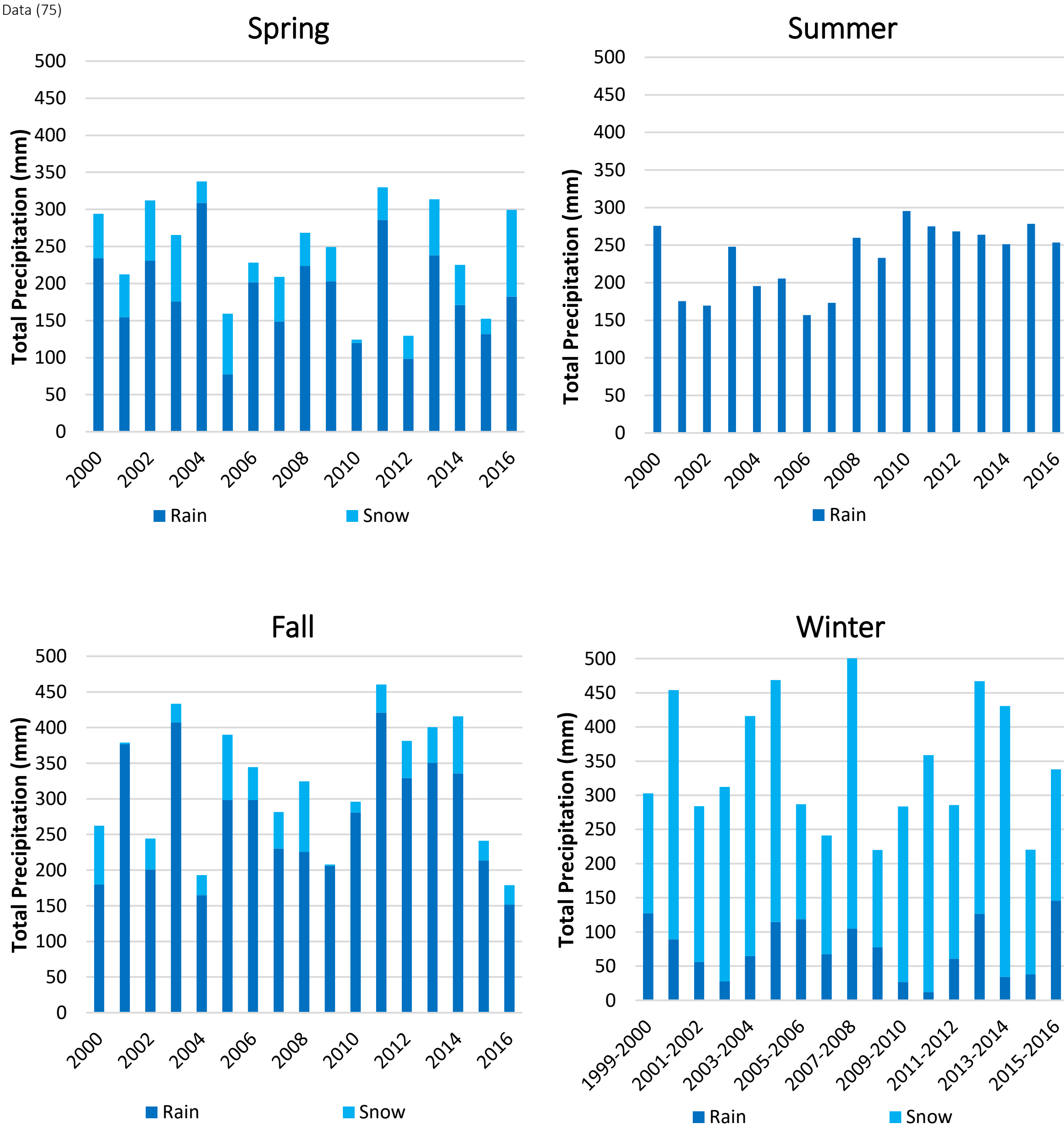


Figure 13: Seasonal Rain and Snow, Wiarton ON 2000-2016

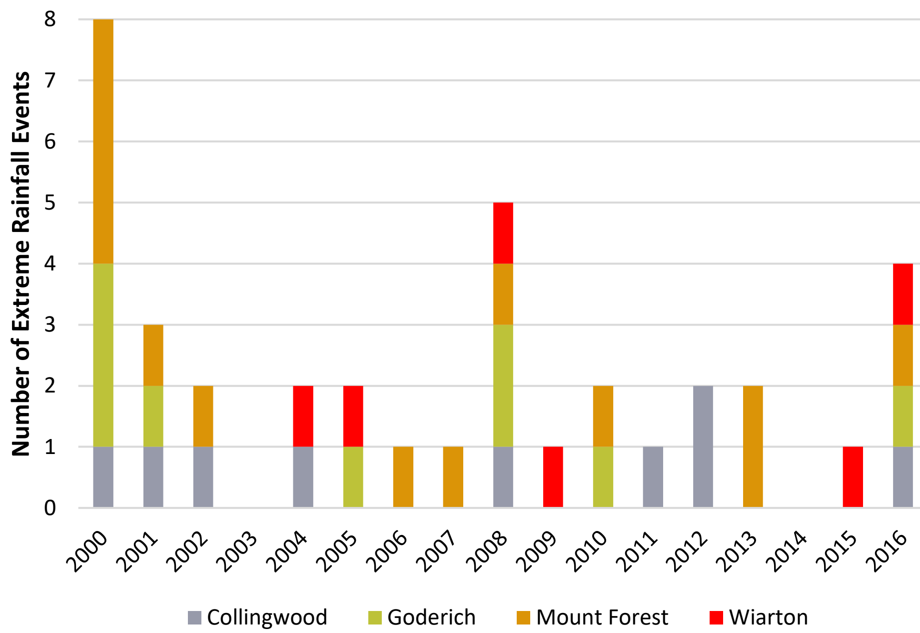
Source: Environment and Climate Change Canada Historical Weather Data (75)

Extreme precipitation events can occur in the form of rain or snow; however, warning thresholds are set differently depending on which type is occurring. A rainfall warning may be issued by Environment Canada if 50mm of rain or more is expected within 24 hours, or if 75mm or more is expected within 48 hours (22). A snowfall warning may be issued by Environment Canada if 15cm or more of snow is expected to fall within 12 hours or less (22).

As some weather locations do not differentiate by precipitation type, it was assumed that all precipitation falling between November and March was in the form of snow unless otherwise indicated. Data is missing for Collingwood for the years of 2000 and 2001, and for Goderich from 2000 to 2004, so actual occurrences of extreme precipitation events during this period are possibly higher than shown.

Figure 14: Number of Extreme Rainfall Events in the Grey Bruce Region 2000-2016

Source: Environment and Climate Change Canada Historical Weather Data (15; 16; 17; 75; 18)



Over the period of 2000-2016, Wiarton experienced six extreme rainfall events. Collingwood and Goderich each experienced nine extreme rainfall events during the same period, with Mount Forest experiencing the most with 13 (Figure 14).

Based on events observed in Wiarton, the frequency of extreme rainfall events is less than one (0.35) event per year, which is the same as experienced in London, Ontario (Appendix 3) and consistent with findings from the MOHLTC report (24). Based on projections, the frequency of these extreme precipitation events is only expected to increase slightly over the next several decades, with little change anticipated for the Grey-Bruce region (24); however, a slow and steady increase in total annual precipitation for both Grey and Bruce counties is excepted under RCP 8.5 scenarios in projections by York University, with regular total annual rainfalls of 1200-1300mm possible by 2100 (3).

Extreme snowfall events were much more common, with 97 occurrences in Wiarton during the period of 2000-2016, slightly less than the 101 which occurred in Mount Forest during the same period. These events were less common in Collingwood and Goderich with 37 and 43 events respectively. London, Ontario experienced 98 extreme snowfall events during the same period (Appendix 3), putting the frequency of extreme snowfall events for Grey Bruce and Perth District at 5.7 events per year.

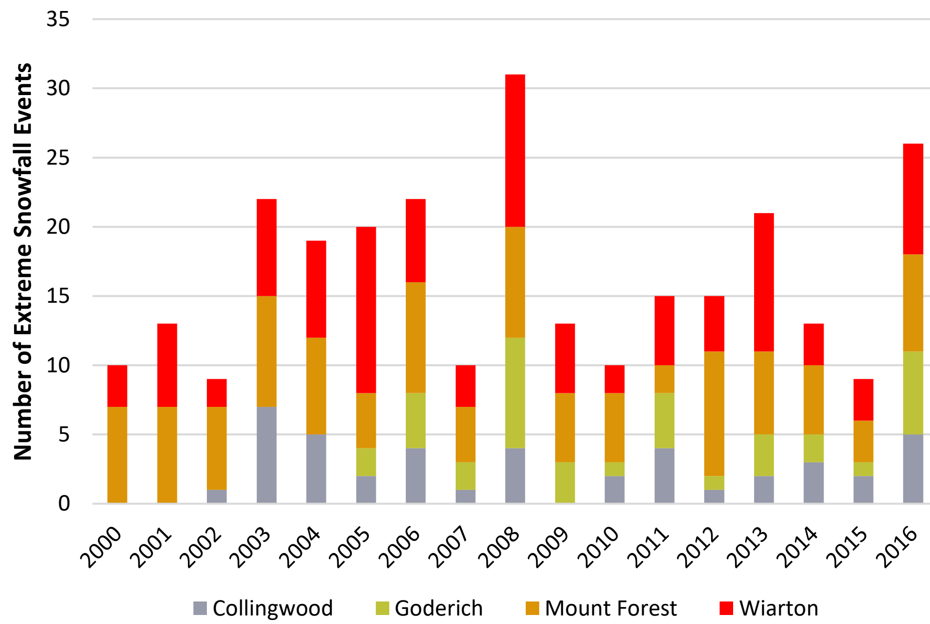


Figure 15: Number of Extreme Snowfall Events in the Grey Bruce Region 2000-2016
Source: Environment and Climate Change Canada Historical Weather Data (15; 16; 17; 75; 18)

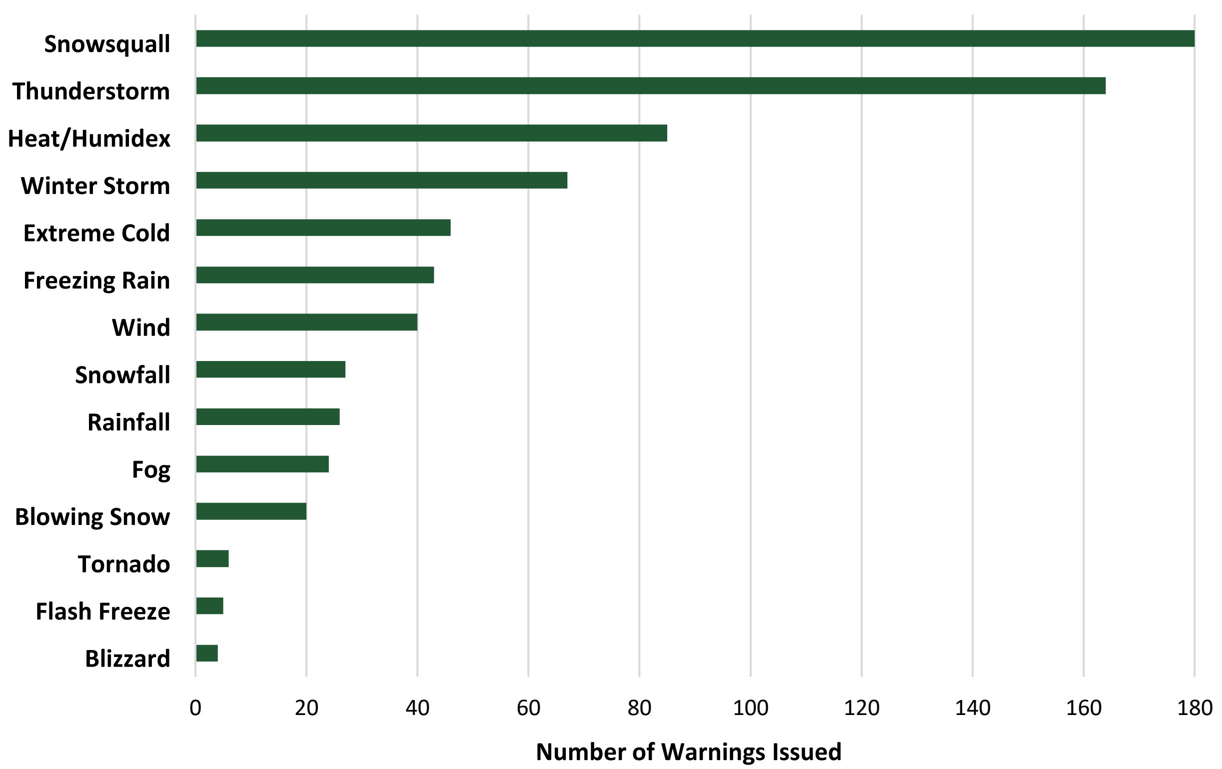
Unlike heat and cold-related illness, the impacts of excessive precipitation are harder to quantify. Though direct injury may occur in the event of flooding or mudslides or due to a combination of precipitation and other adverse conditions during winter or summer storms (discussed in the coming section *Storms and Severe Weather*), many potential outcomes are further removed from the actual precipitation events, including potential impacts to the environment, vector-borne disease, and their subsequent impact on human health, as discussed further in this report.

Storms and Severe Weather

There are many other types of extreme weather events that may impact the Grey Bruce region. Combinations of high winds, temperature variations, and precipitation can form in to hazardous conditions, such as winter storms, snow squalls, freezing rain, thunderstorms, and tornados. Climate change is expected to impact the frequency and severity of these events (2).

Though Environment Canada publishes threshold criteria for all of these events, they are more difficult to identify using accessible historical climate data. In order to estimate the prevalence of these storm events in Grey Bruce, Environment Canada text-based weather bulletins were procured through a data request to Environment Canada. All bulletins for Grey Bruce for the period of 2000-2017 were extracted and events were tabulated based on the text-based notices. Watches or warnings, as opposed to special weather statements, were considered to be a storm warning event; however, it is recognized that not all watches and/or warnings issued by Environment Canada produce a storm event, as they are issued in advance of the event as a precautionary measure rather than a record of an actual occurrence. Often, bulletins for watches or warnings are issued multiple times per day, or a watch is upgraded to a warning; in these cases, the event was only counted as one occurrence for that day. Occasionally, multiple extreme weather events occur on the same day; these events were separated based on their description and counted as individual occurrences. A summary of these weather warnings can be found in Figure 16.

Figure 16: Number of Extreme Weather Warnings in the Grey Bruce Region 2000-2016
Source: Environment Canada Historical Weather Bulletin Data (76)



Of all extreme weather events, snowsquall events occurred most frequently. Snowsqualls are characterized by bursts of heavy snowfall and reduced visibility, with or without blowing snow (22).

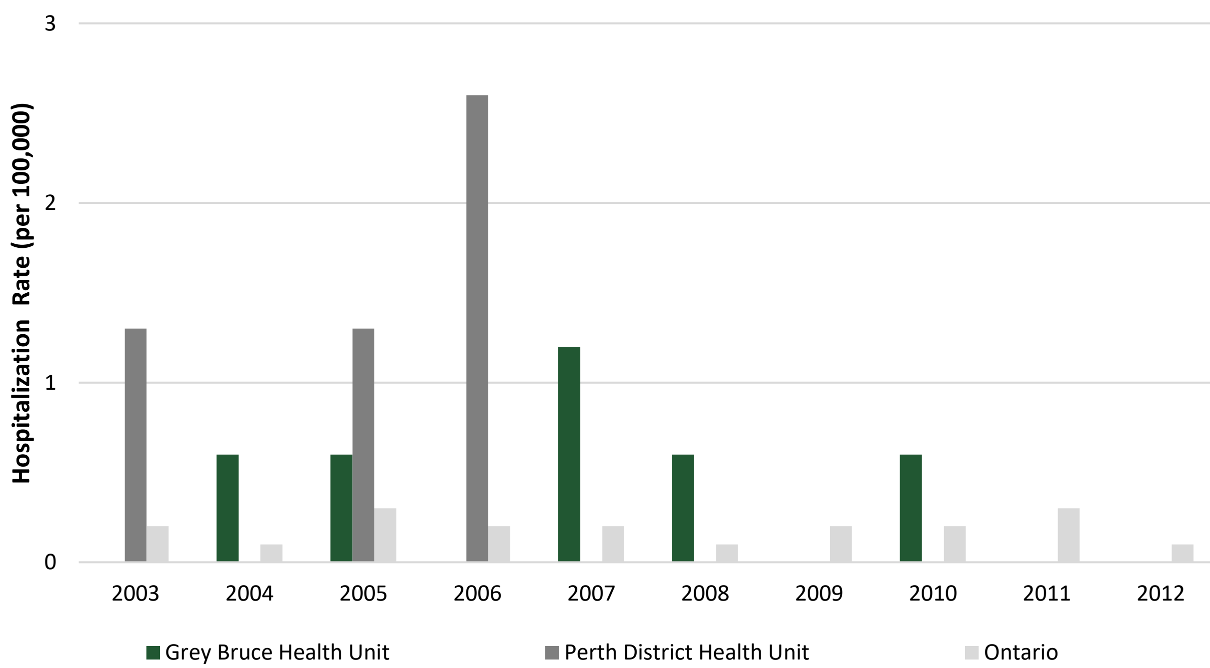
Thunderstorms, consisting of heavy rains, high winds, and potential for hail (22), were also frequent occurrences in Grey Bruce. Occasionally, extreme thunderstorms may produce a tornado; six tornado warnings were issued in Grey-Bruce between 2000 and 2016. During this period, two major storm events causing extensive damage and injury are recorded in the Canadian Disaster Database for the Southwestern Ontario area, including severe thunderstorms in April of 2000 and several tornadoes in August of 2015 (37).

Extreme heat and extreme cold both appear in the top five most commonly occurring extreme weather events in Grey Bruce, along with winter storms, which include significant snowfall in combination with other extreme winter conditions, such as freezing rain or strong winds (22).

Hospitalizations due to extreme weather other than heat or cold are much less common. During the reporting period of 2003-2012, only six such hospitalizations were reported (Figure 17). Whereas heat and cold may have the potential to aggravate certain conditions like respiratory or cardiovascular disease requiring hospitalization, it could be speculated that extreme weather events may be more apt to cause injury rather than illness. Rates of emergency department visits due to extreme weather are included in Appendix 5. During the reporting period, 117 cases of weather-related emergency department visits were experienced in Grey Bruce.

Figure 17: Crude Rate of Hospitalizations due to Other Extreme Weather in Grey Bruce Health Unit, Perth District Health Unit, and Ontario 2003-2012

Source: Source: Public Health Ontario Extreme Weather Ontario Health Profile (25)



Because of the wide variety of extreme weather events experienced in Grey Bruce, it is difficult to make connections between these events and impacts on health without additional data, such as season of occurrence (e.g. winter or summer-related extreme weather events), or further information about the outcome. In the future, events involving water and wind are thought to potentially cause greater impact than heat-related events due to the high variability and lower predictability than temperature (38).

Like temperature and precipitation, extreme weather events have the potential to impact systems beyond direct human health effects. Extreme weather events may impact the environment as well as infrastructure such as roads, electrical and water systems. Winter storms and snowsqualls, which are common in the area, may also make transportation or access to medical or other essential services difficult, potentially complicating response to other public health emergency situations.

Image 2: Flooding in Chatsworth, 2016
Source: James Masters, The Owen Sound Sun Times, Postmedia Network

In April of 2016, flooding of the North Saugeen River occurred due to excessive amounts of rainfall. This 1 in 200-year flood caused the evacuation of over 50 homes and business in the Willamsford and McCullough Lake areas. Fortunately, no lives were lost, but extensive damage was caused to some homes in the area (80; 79)

Vulnerability and Adaptation

Summary

- Total annual precipitation amounts are expected to increase
- Extreme events including water and wind are highly variable and hard to predict
- On average, Grey Bruce experiences less than one extreme rainfall event per year [0.35/yr]; the frequency of these events is not expected to increase much over the next several decades
- Extreme snowfall events occur more frequently, with an average of six events per year
- Snowsqualls and thunderstorms were the two most frequently occurring extreme weather events in Grey Bruce [11/yr and 10/yr]
- Rates of hospitalizations due to extreme weather are low, with six cases reported between 2003 and 2012
- Weather related emergency department visits were more common (117 cases), and rates of these visits were consistently higher than provincial rates for 2003-2012

Extreme weather may impact public health directly and indirectly. Those identified as being at increased risk include (31; 20):

- Seniors
- Children
- Pregnant women
- Socioeconomically disadvantaged populations
- Those with mobility limitations or cognitive constraints
- People who use alcohol, illicit substances, or take medication
- Those living in flood-prone areas

In the event of an extreme storm or weather-related emergency, preparedness and ability to respond and cope are important considerations. For the elderly, young children, pregnant women, or those with issues with mobility or cognition, responding to emergency weather events may be difficult due to various limitations (1). Similar to extreme heat and cold, those who are socioeconomically disadvantaged, living in vulnerable situations or are socially isolated may also be at increased risk due issues in preparing for and responding to periods of extreme weather, as well as accessing required services during or after a storm (31).

Moderate and extreme rainfall and snowfall may also be challenging for seniors and those with mobility issues due to increased risk of injury due to slips and falls (20). In addition to risks and response related to flooding, increased rainfall may further negatively impact those living in substandard housing through the encouragement of moisture buildup and mould, affecting indoor air quality. Flooding or increased rainfall may also impact water quality and risk of infectious illness, as discussed in Section V – The Environment.

Continued emergency management planning will be integral in increasing adaptive capacity in the event of extreme weather events. Cross-sector collaboration, including partnerships between counties and municipalities, public health, agencies responsible for critical infrastructure, emergency response, health and medical services, mental health and social services, and those dealing with vulnerable populations, will be beneficial to continued discussions on planning for weather-related emergency events, or how weather may impact the response to other types of emergencies (20).

In the community, personal preparedness should be promoted, including ensuring households equip themselves with a 72-hour emergency kit suitable to their specific needs (39). Like heat and cold, further communications with partners currently working with vulnerable populations could help to better understand issues those in the community are currently facing in preparing for and responding to extreme weather events. Further examination of trends related to emergency department visits due to extreme weather events may also help to identity areas of need in the community.

III. Air Quality

Air Pollution

Common air pollutants of interest include ground-level ozone (O_3), fine particulate matter ($PM_{2.5}$), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and carbon monoxide (CO) (40). Many of these pollutants are released through human activities, including industrial processes, agriculture, and the burning of fossil fuels for transportation and residential purposes (40). In addition to the contribution that pollutants like carbon monoxide and nitrogen dioxide make to global greenhouse gas concentrations and the broader impacts of climate change, high levels of air pollution can cause a myriad of negative health impacts, including eye, nose, and throat irritation, exacerbation of respiratory conditions and allergies, aggravation of chronic obstructive pulmonary disease and asthma, and increased risk of cardiovascular disease and death (1).

The Canadian Ambient Air Quality Criteria (Table 1) outlines the suggested maximum concentration levels of priority air pollutants which may adversely impact public health and the environment; these values are used in the calculation of the Air Quality Health Index (AQHI). In the event that the AQHI is forecast to be at a high risk level, with a value of seven to ten for three or more hours, a Smog and Air Health Advisory may be issued (41). Alternatively, a Precautionary Special Air Quality Statements may be issued if the AQHI risk level is expected to be high for only one to two hours (42). For the purposes of this report, Smog and Air Health advisory days were used to represent poor air quality events.

Table 1: Canadian Ambient Air Quality Criteria

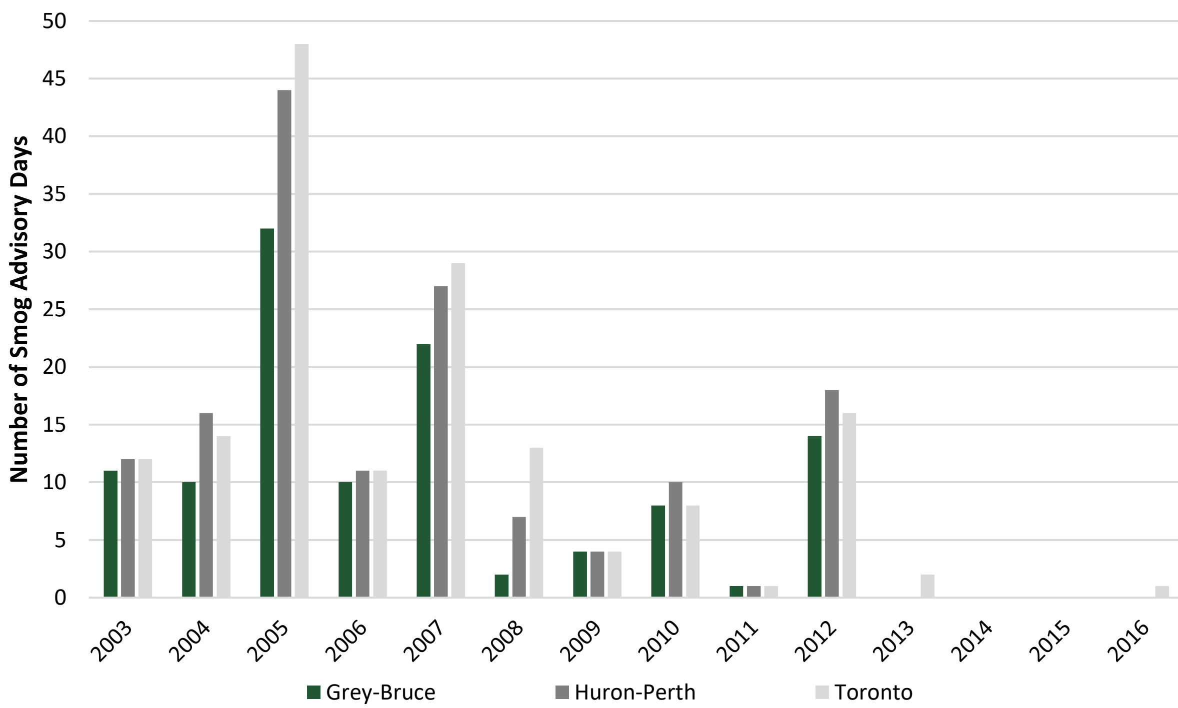
Source: Ministry of The Environment and Climate Change **(40)**

Canadian Ambient Air Quality Criteria (AAQC) (40)				
Contaminant	1-hour AAQC	8-hour AAQC	24-hour AAQC	Annual AAQC
O_3	80ppb	-	-	-
$PM_{2.5}$	-	-	28µg/m^3	-
NO_2	200ppb	-	100ppb	-
SO_2	250ppb	-	100ppb	20ppb
CO	30ppm	13ppm	-	-

Air quality information for the Grey Bruce area is recorded at the air quality monitoring station in Tiverton (43), a small community located 15 kilometers north of Kincardine. A 2015 study conducted by the Ontario Ministry of Environment and Climate Change indicated that air quality readings from the Tiverton station were adequately representative of air quality in other areas of Grey Bruce despite being located to the far south-west of the rest of the region (44).

Since 2012, there have been no Smog and Air Health Advisories issued in Grey Bruce (Figure 18). Ten year trends for priority pollutants have generally been decreasing based on readings from the Tiverton station, with the exception of small increases in ozone (↑2%) and nitrogen dioxide (↑4%) since 2006 (40). In Grey Bruce, ground-level ozone concentrations appear to be slightly higher in summer and only occasionally exceed the Canadian Ambient Air Quality Criteria suggested maximum of 80ppb (45). The 2015 annual mean concentrations of PM2.5 in Tiverton was 6.4µg/m^3, which is below the Canadian Ambient Air Quality Standard of 10µg/m^3 per annum (40). $PM_{2.5}$ concentrations have been higher in Tiverton since 2013 compared to previous years; however, new monitoring practices implemented in 2013 have likely resulted in much of this increase. Prior to 2013, a significant (p=0.035) decrease was seen in PM2.5 concentrations in the Grey Bruce area since 2003, with no daily exceedances recorded since 2008 (45).

Figure 18: Smog Advisory Days in Grey Bruce, Huron-Perth and Toronto 2003-2016
Source: Ministry of the Environment and Climate Change Ontario (43)



In general, air quality in the province has been improving over the past ten years through effective air quality initiatives, including the phase-out of coal-fired generating stations, emissions trading regulations, emissions controls in Ontario smelters, and drive clean testing of vehicle emissions (40). Based on temperature projections alone, air pollution events are anticipated to increase over the coming decades; however, in Grey Bruce, this increase is expected to be quite small, with only one additional ozone exceedance expected in the late 21st-century compared to baseline periods (24). This prediction does not take in to account the impact of other pollutants, or the possible influence of changing transboundary transport of air pollutants between Canada and the United States (24).

UV Index

The UV index is a Canadian invention; using ozone conditions and ultraviolet (UV) measurements, the UV index is calculated in order to inform the public of the strength of the sun's rays and their need to take sun safety precautions. The UV index ranges from zero, representing low exposure to UV rays, to 11+, or extreme exposure risk (46).

The ozone layer in the upper atmosphere provides protection to the earth from the sun's UV rays. Greenhouse gases responsible for climate change and other industrial chemicals can destroy the ozone layer, hindering its ability to block UV rays from reaching the earth's surface, resulting in higher UV exposure, especially in peak summer months (47; 1).

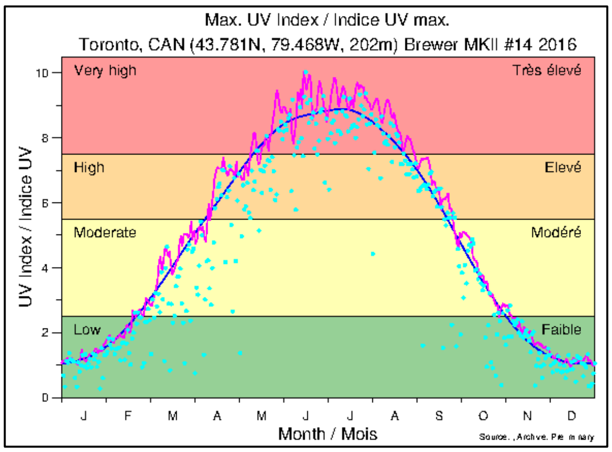


Figure 19: Maximum UV Index, Toronto 1991
Source: Environment and Climate Change Canada Daily UV Index Graphs (48)

Figure 19 and Figure 20 illustrate the daily maximum UV index in Toronto and area for 1999 and 2016. In the most recent chart from 2016, actual daily readings are indicated with cyan dots. The blue line represents UV index estimates using normal pre-1980's ozone values, with the red or magenta lines indicating the UV index using the current day's ozone conditions (48). Compared to 1991, 2016 has seen more days with a UV index above eight, in the very high risk category, suggesting increased risk of harmful levels of UV exposure. Though the ozone has been slowly recovering since mitigation efforts were put in place, the UV index remains elevated above pre-1980's values. Despite this improvement, many ozone-depleting chemicals are still in use across the globe, and ozone conditions may continue to worsen due to use of these chemicals and greenhouse gas emissions (47).

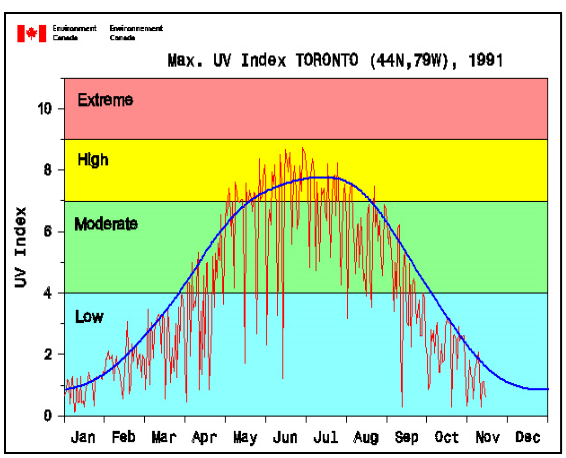


Figure 20: Maximum UV Index, Toronto 2016
Source: Environment and Climate Change Canada Daily UV Index Graphs (48)

Overexposure to UV radiation may cause sunburns, premature skin aging, eye problems, weakening of the immune system, and skin cancer, including melanoma and non-melanoma cancers (49).

Over 90% of cases of melanoma, one form of skin cancer, are caused by UV radiation (50), and rates of melanoma skin cancer continue to rise across Canada, especially in men (51). In Grey Bruce, about 39 people a year are diagnosed with skin melanoma. Age-standardized rates of melanoma in Grey Bruce increased 33% for the period of 2000-2009 compared to the 1990-1999 rate. The age-standardized melanoma incidence rate in Grey Bruce for the period of 2000-2009 was 27% higher than the provincial rate, with 18 new cases per 100,000 population compared to 14 per 100,000 provincially. From 2000-2009, approximately seven deaths a year in Grey Bruce were attributable to melanoma, equating to a similar melanoma mortality rate as the Province of Ontario (approximately 3 deaths per 100,000 population) (52). Non-melanoma skin cancers, including squamous cell and basal cell carcinomas are expected to increase over the coming decades with projections stating potential increases by 24.6% and 13% respectively by the 2080s (24).

Vulnerability and Adaptation

Summary

- Air quality in Grey Bruce is generally good
- No Smog Advisories have been issued for Grey Bruce since 2012
- Maximum daily UV index has increased since the 1990s with the summer months experiencing more days with a very high UV index
- About 39 new cases of melanoma are diagnosed in Grey Bruce every year
- Melanoma incidence rates are higher in Grey Bruce than rates for all of Ontario
- Rates of non-melanoma skin cancers are projected to rise over the coming decades

Those at increased risk of impacts from poor air quality include seniors, children, socioeconomically disadvantaged populations, those with cardiovascular, respiratory or other chronic health conditions, and those who smoke tobacco (20). Although air quality in Grey Bruce is good, current conditions should not be taken for granted. Continued work on improving air quality through reducing emissions, encouraging active transportation, and supporting broader legislation that protects provincial and global air quality could help to maintain current air quality status (20).

Those at increased risk of cancer from UV exposure are children, outdoor workers, persons with skin conditions, and those participating in outdoor recreation activities, especially those who do not take sun precautions (20). Promotional activities on sun safety should be continued targeting those identified as populations at increased risk.

IV. Vector-borne Disease

West Nile Virus

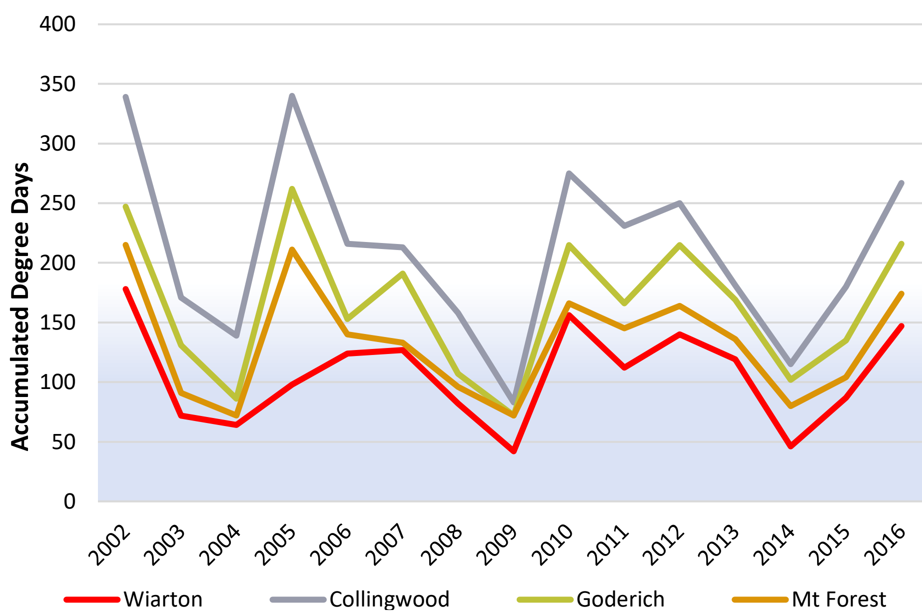
West Nile Virus (WNV) is a vector-borne disease transmitted to humans by the bite of an infected mosquito. The *Culex pipiens/restuans* mosquito species are the primary vector of WNV in the Ontario. In nature, WNV cycles between these mosquitoes and birds; a higher abundance of infected mosquitoes may result in a higher risk of transmission of the virus to humans. Once a human or other mammal acquires the virus they are considered a dead-end host and cannot further pass it along making mosquitoes the primary vector for this illness (53).

There are several key climactic factors that contribute to mosquito survival and propagation of WNV in the mosquito population. Warmer temperatures, especially early on in the summer, can increase both the amount of mosquitoes, as well as the rate at which WNV can replicate inside of the mosquito vectors (53). Colder winter temperatures may also impact mosquito survival during overwintering which in turn can result in a decreased mosquito population the following summer. Precipitation may also influence mosquito survival; whereas mosquito populations have been found to be more abundant during summers with moderate amounts (15-35mm) of average daily precipitation (54), heavy precipitation can potentially hinder mosquito populations through the flushing and disruption of pooled water breeding grounds (4).

The primary indicator used to predict mosquito population establishment is the measurement of accumulated degree days. One degree day occurs when the mean daily temperature is 1°C above the reference temperature of 18.3°C. For every additional degree above this reference temperature, an additional degree day occurs (55).

Figure 21: West Nile Virus Accumulated Degree Days in the Grey Bruce Region 2000-2016

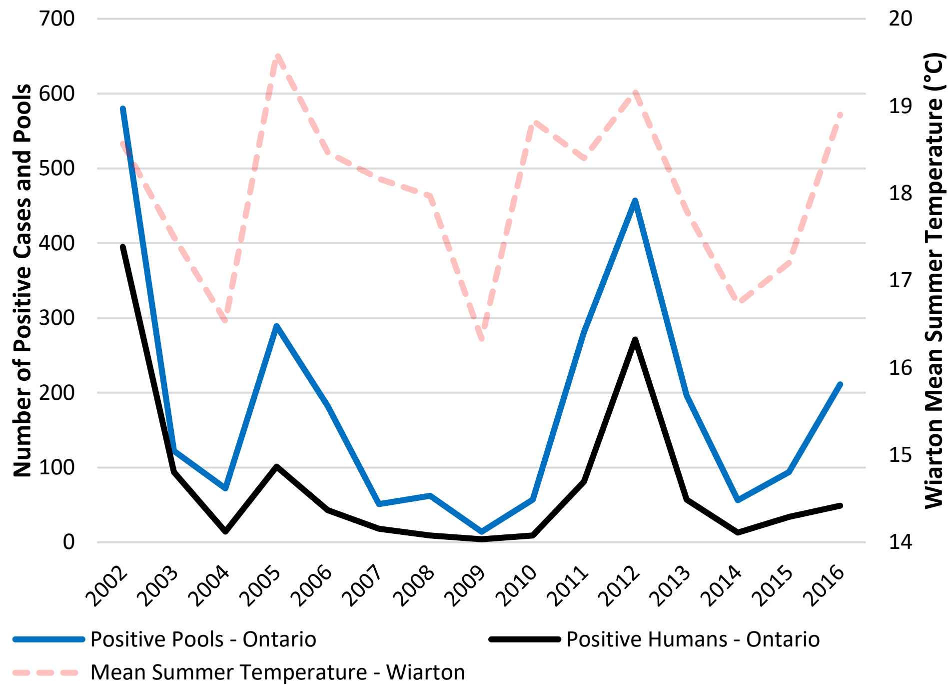
Source: Environment and Climate Change Canada Historical Weather Data (15; 16; 17; 75; 18)



Degree days are counted using a running total for the entire summer season; accumulated degree days for Grey Bruce can be found in Figure 21. Although positive mosquito pools may be found in the province as early as 30 accumulated degree days (ADD), most positive pools are found at 140 ADD and beyond, with human cases beginning to occur in double-digit numbers across the province at about 180-200 ADD (55).

Figure 22 : West Nile Virus Positive Pools and Human Cases in Ontario 2002-2016

Source: Public Health Ontario West Nile Virus Surveillance (77)



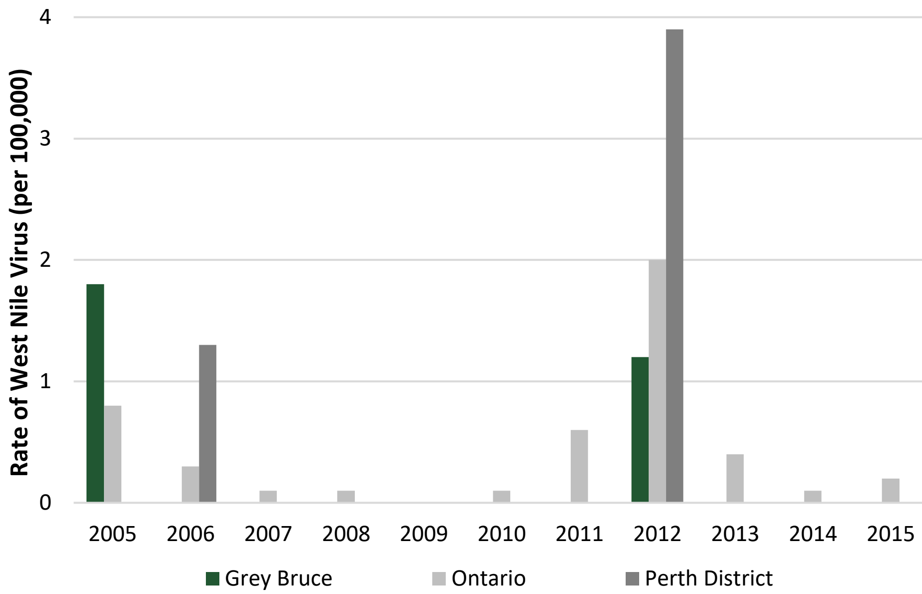
In Ontario, vector surveillance in the form of adult mosquito trapping is conducted to monitor the occurrence of WNV positive pools across the province to act as an early warning system for WNV (53). Vector surveillance was conducted by Grey Bruce Health Unit between the years of 2003 and 2008; during this time, no positive mosquito pools were found. Because of this, surveillance was discontinued (45), until the mid-summer months of 2017, when a WNV mosquito pool was found in Collingwood, close to the border of Grey Bruce Health Unit. At the time of this report, mosquito traps have been placed in Hanover, Owen Sound, and Heathcote to monitor WNV activity for the remainder of the season. More extensive WNV surveillance activities are anticipated for the summer of 2018.

Figure 22 shows the WNV positve cases and mosquito pools in Ontario for the period of 2000-2016. Across the province, WNV activity peaked in 2002 and 2012. The incidence of WNV infection in humans in Grey Bruce has remained relatively low (Figure 23), with the occurance of cases following spikes in activity throughout the rest of the province.

West Nile Virus infection often goes unnoticed, as most people who are infected with WNV have no or very mild symptoms. Those who are symptomatic may experince common flu-like symptons from two to 15 days after infeciton. In less than one percent of those who are infected, serious symptoms of WNV encephalitis may develop and may include muscle weaknesses and paralysis (56).

Figure 23: Crude Rate of Human Cases of West Nile Virus in Grey Bruce Health Unit, Perth District Health Unit, and Ontario 2005-2015

Source: Public Health Ontario Reportable Disease Trends in Ontario (71)



As WNV is highly temperature-dependant, projections from the MOHLTC and Environment Canada predict that the risk of WNV will continue to increase as temperatures rise. By the mid-21st century, Grey Bruce is expected to eperience over 500 ADD (1), compared to the average of approximatley 100 annual ADD currently experienced in Wiarton.

Lyme Disease

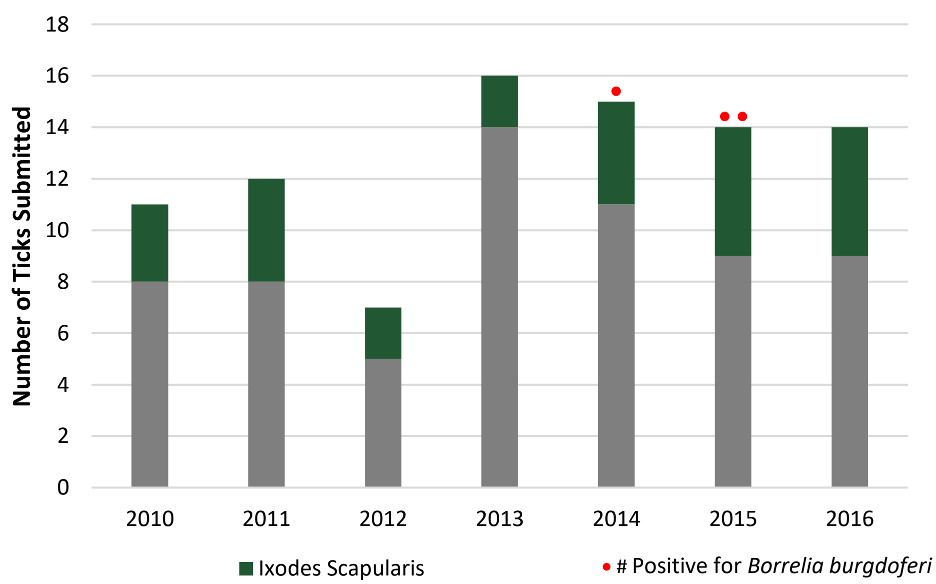
Lyme disease is a bacterial disease transmitted to humans by the bite of an infected *Ixodes scapularis*, commonly known as a blacklegged or deer tick (53). A tick's lifecycle depends on blood meals, primarily from migratory birds and other small animals in the early stages of life, from which *Borrelia burgdorferi* is contracted and transmitted until the later adult stage, where ticks begin feeding on larger animals, which may include deer, dogs and humans. This cycle usually occurs over the duration of two years (57).

Ticks may travel far distances on migratory birds, so the presence of a tick does not necessarily mean populations are established in an area, as ticks can survive up to one moult, quest and feed in an unsuitable habitat, providing opportunity for human contact (53); however, climate change has likely helped more of these deposited ticks become established in areas where they have not been previously found (58).

Established populations are capable of completing their lifecycle and reproducing; these tick populations are most commonly found in areas with deciduous or mixed forests (53) with a dense understory and relative abundance of leafy vegetation (58). Similar to mosquitoes and WNV, tick populations are temperature sensitive; degree days have been used by some researchers to estimate the risk of tick establishment across the province using a reference temperature of 0°C. Areas with more degree days above 0°C saw increased blacklegged tick populations (58), and warmer weather is anticipated to reduce time to establishment in areas without endemic populations through changes in migratory bird populations and increased geographic areas of suitability (59).

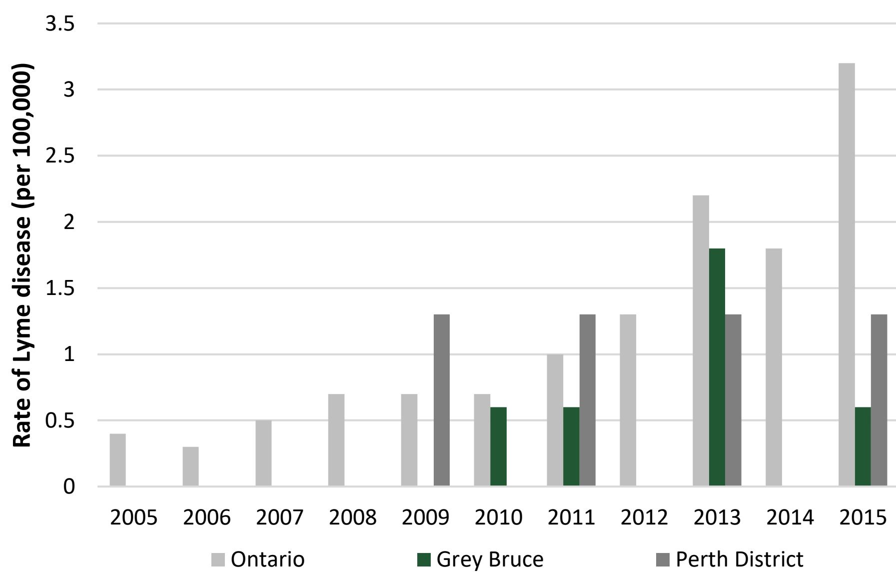
Figure 24: Locally Acquired Human Tick Submissions, Grey Bruce Health Unit 2010-2016

Source: Grey Bruce Health Unit Tick Submissions (78)



Between 2010 and 2016, 25 blacklegged ticks were submitted from humans within the Grey Bruce area, with three testing positive for *Borrelia burgdorferi* (Figure 24), the bacteria that causes Lyme disease (60). Though it is expected that the increasing number of ticks recently submitted may be due in part to tick populations beginning to establish in the area, increased media attention surrounding ticks and Lyme disease has helped to put the issue in the public spotlight over the past several years. If members of the public find a feeding tick on the body they are encouraged to submit it to the Health Unit for identification and testing. Increased awareness of Lyme disease and the availability of this service has likely contributed to an increase in submissions, making it difficult to quantify true changes in regional tick establishment. Based on projections by Ogden et al, the majority of the Grey Bruce area will be at high risk for blacklegged tick population establishment by 2020 with remaining regions up the peninsula following through the 2050s (61; 59).

Figure 25: Rate of Human Cases of Lyme Disease in Grey Bruce, Perth District, and Ontario 2005-2015
Source: Public Health Ontario Reportable Disease Trends in Ontario (71)



Six cases of Lyme disease were reported in Grey Bruce Health Unit between the years of 2005 to 2015 (Figure 25), and while case occurrences are still sporadic in Grey Bruce, provincially, rates of Lyme disease have been increasing. The symptoms of Lyme disease differ from person to person which may lead to difficulties in identification and diagnosis of the illness. Though some cases may develop a distinct bull's eye rash at the site of the bite, rashes are not always present, and many will experience mild flu-like symptoms or symptoms which may mimic other illnesses. Left untreated, severe symptoms may develop which can last from months to years; these symptoms are also highly variable between cases and can include muscle weakness, joint pain, and neurological and heart disorders (62).

Vulnerability and Adaptation

Summary

- Both West Nile Virus and Lyme disease are temperature sensitive
- Currently, Wiarton usually accumulates less than 150 WNV degree days
- Collingwood and Goderich regularly accumulated 200 or more WNV degree days
- By the Mid-21st century, regions in Grey Bruce could accumulate over 500 WNV degree days, increasing risk of positive pools and human infection
- Rates of Lyme disease have been increasing across the province
- Blacklegged tick populations could potentially become endemic in the Grey Bruce area within the next ten years

Those identified as being at increased risk for acquiring or suffering adverse consequences from vector-borne illness include (56; 20):

- Seniors
- Children
- People with supressed or developing immune systems
- People spending greater time outdoors for work or recreation

Through observing current conditions and future climate projections, it appears that WNV and Lyme disease have the potential to become prevalent threats in certain areas of Grey Bruce in the near future. With a large ageing population, abundance of outdoor workers, and major outdoor tourist attractions including the Niagara Escarpment, more cases of vector-borne disease in humans and animals should be anticipated.

Risks and locations of ponteitally acquiring West Nile Virus or Lyme disease will differ by geographic location in the region. WNV is most commonly found in more urbanized areas where there are more catchment basins and areas of standing water (53). Incraesed construction and urbanization could help to facilitate mosquito breeding and amplification of WNV. Incraesed surveillance of vectors, monitoring of local degree day discrepencies between municipalities in order to identify target areas, and public and partner communication regrading reducing risk by eliminating stagnant water and wearing appropriate protection while outdoors should be undertaken to help adapt to this changing risk.

For Lyme disease, monitoring of blacklegged tick submissions and locations of acquisition should be continied along with public awareness and education campaigns. As new populations and potential establishment is identified, more outreach may be required with health and social services (20) to ensure relevant agencies and care providers are aware of local risk areas in order to facilitate access to appropriate diagnosis, treatment and care.

V. The Environment

As our climate changes, so too will the environment around us. As illustrated in Figure 5, climate change has broad social and environmental impacts beyond the potential direct negative implications to human health (21). Of public health interest is the impact climate change may have on food and water availability and quality due to changes in temperature, precipitation, and other extreme weather events, as discussed in earlier sections of this report, as well as the broader ecological impacts which may affect population health in other ways.

Food

Safe food is food that is free from harmful contaminants including pathogens such as Salmonella or E. coli. Foodborne pathogens can multiply rapidly when exposed to warm temperatures, making temperature abuse a common cause of foodborne illness. In periods of warmer summer temperatures, increased notifications of non-specific foodborne illness have been known to occur, with strong associations seen between extreme heat and salmonellosis cases in Europe (4).

Figure 27 illustrates the seasonal variation in common communicable diseases in Grey Bruce Health Unit. These infections are often acquired through the consumption of contaminated food or water, though other modes of transmission are also possible. With the exception of Giardiasis, commonly a waterborne illness, all other infections are seen more frequently in summer months of June, July and August. Although the transmission of infectious diseases is complicated, effected by extrinsic social, economic, climactic, and ecological conditions, as well as intrinsic human immunity (21), warmer weather in the summer season combined with common summertime activities such as camping, large outdoor gatherings and farmers markets, may impact personal and commercial food safety capabilities which in turn could increase the risk of foodborne illness.

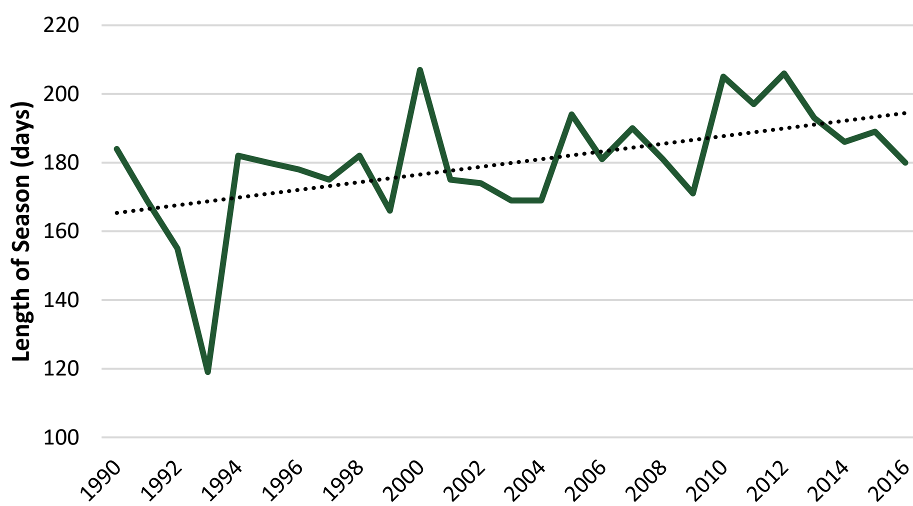
In Grey Bruce, agriculture continues to be an important industry, with over 4000 farms operational across Grey and Bruce Counties. Key products include livestock, hay, grains, fruits, soybeans, corn, and other miscellaneous crops (10).

Climate change may impact local farm production in various ways. In Ontario, the growing season is expanding. The growing season is considered to begin 10 days after the average daily temperature reaches 5°C and continues until the minimum daily temperature reaches 0°C, or October 31st (63). Approximate growing season lengths for Grey Bruce based on climate data from Wiarton can be found in Figure 26. Since 1990, there has been a significant ($p<0.01$) increase of six days in the local growing season. Further substantial increases are projected by the end of the current century (64).

The length of the growing season is important in determining crop growth and distribution. Warmer weather and longer growing seasons can result in new crop opportunities and better crop yields; however, these changes may also result in the introduction and proliferation of invasive species of plants and pests which may negatively impact local food production (64). This may be especially true in the harvest of naturally occurring or traditional foods which are foraged, rather than farmed (65). Temperature and weather extremes may also impact agriculture, as extreme heat, early frost, dry or wet seasons, and storms or high winds may damage crops and affect yields. Extreme heat and cold events may also result in illness or death in various livestock populations (66).

Figure 26: Length of Growing Season, Wiarton ON 1990-2016

Source: Environment and Climate Change Canada Historical Weather Data (75)



Water

Recreational and drinking water quality may also be impacted by climate change. In Grey Bruce, drinking water is obtained from both surface and groundwater sources, with approximately 32% of residents in Grey and Bruce counties relying on private water systems for obtaining potable water (45).

In general, the surface water quality for the majority of the Grey Bruce area in 2013 was considered healthy or very healthy, with water quality improving as distance from agricultural operations increased (45; 67). Similarly, groundwater wells monitored by the Saugeen Valley Conservation Authority were found to be very healthy, with average nitrate and chloride concentrations below the provincial drinking water standards (45; 67). At the time these results were reported in 2013, no monitoring wells existed for the Penetangore, Beatty, or Rocky Saugeen River watershed areas (45).

Since 2007, the beach management program at Grey Bruce Health Unit has undergone significant changes (45). In 2016, eight beaches were routinely monitored, with beach water sampling conducted biweekly for the duration of the summer. Two locations on Georgian Bay and six locations on Lake Huron were sampled. No adverse samples were reported during the 2016 season. As the number of beaches sampled each season has changed, it is difficult to compare the frequency of beach postings from year to year. In a historical review of beach postings since 2012, most adverse samples occurred after periods of rain (≥5mm) and in warmer temperatures (≥20°C) (68). The highest number (*n=19*) of beach postings occurred in the summer of 2010. 2010 was also the wettest summer experienced in Grey Bruce (Figure 13) since 2004 when the beach monitoring program began.

Heavy rains and flooding have been known to be associated with higher incidences of diarrheal illness due to contaminated water (21). Contamination of ground and surface water sources through runoff from agricultural operations, residential storm sewers, and wastewater treatment systems is a concern, especially in periods of heavy rain, flooding, or during spring thaw. In addition to bacteria, runoff may contain chemicals and fertilizers such as nitrogen and phosphorous which can encourage the growth of toxic blue-green algae. Warmer water temperatures are also more conducive to the growth of blue green algae (69). Slight increases in water temperature in the Great Lakes have been recorded since the 1990's, likely to due to warmer springtime temperatures and earlier thawing of winter ice (70). This warming, along with the introduction of nutrients from agricultural runoff, may also negatively impact fish populations and encourage growth of invasive aquatic species (45).

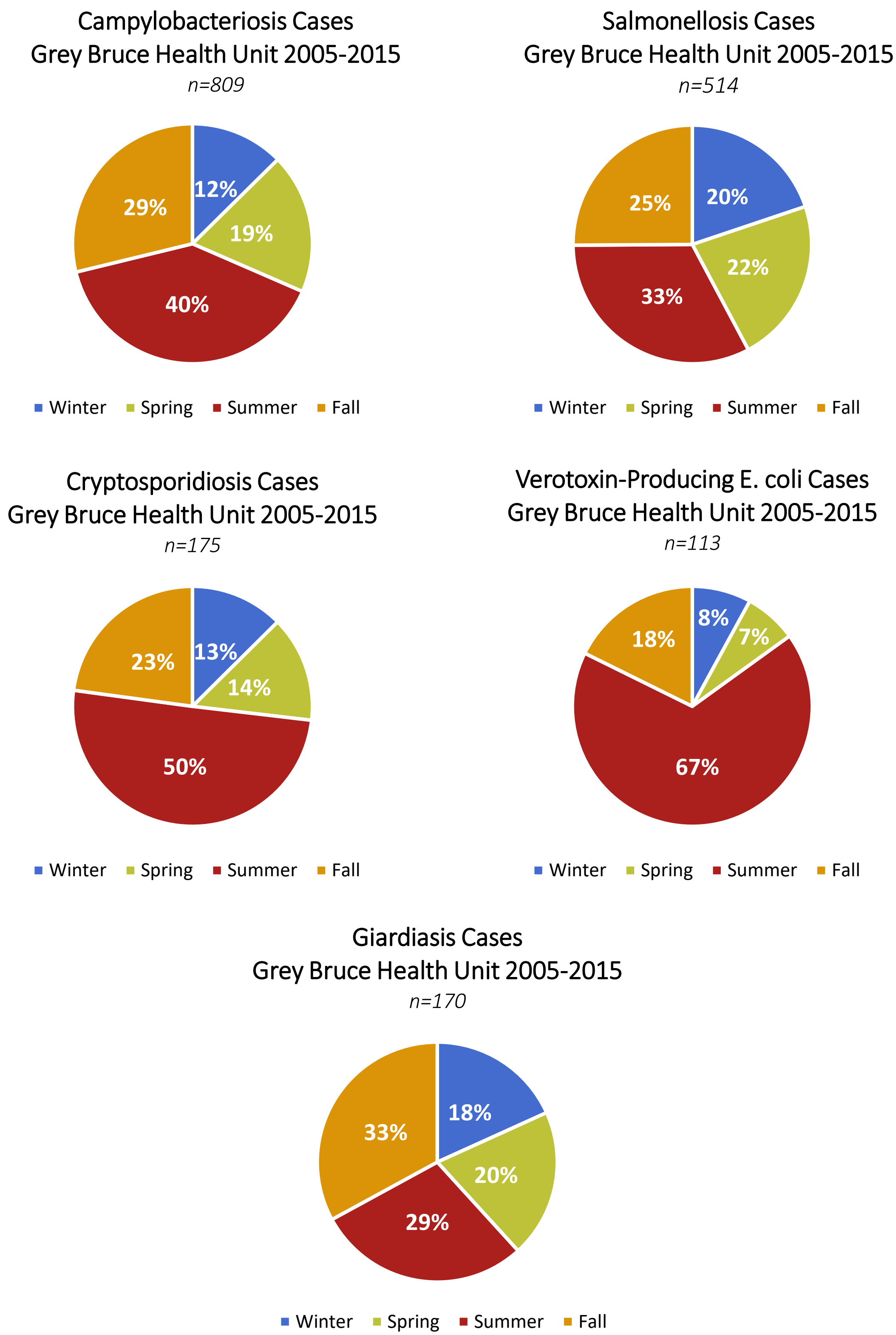


Figure 27: Seasonal Occurances of Common Food and Waterborne Illnesses, Grey Bruce Health Unit 2005-2015
Source: Public Health Ontario Reportable Disease Trends in Ontario (71)

Vulnerability and Adaptation

Summary

- More food and waterborne illness occurs during the summer than in the other seasons and may be impacted by increasing temperature and rainfall
- Recreational water quality is impacted by moderate rainfall amounts
- Warmer spring and fall temperatures expand the growing season and impact crop opportunities and yields
- Warmer temperatures and increased precipitation may contribute to more blue-green algal blooms in local inland lakes

Those potentially at increased risk of impacts due to changes in food and water safety and availability include (20; 4):

- Socioeconomically disadvantaged populations
- Indigenous populations utilizing traditional foods
- Children, the elderly, and people with suppressed or developing immune systems
- Those relying on private water systems for potable water, including insecure wells and surface water
- People engaging in recreational water activities, especially children
- Those relying on local crops as a food source

Extreme weather, precipitation, and temperature may adversely affect health indirectly by impacting food and water safety and availability. Increased precipitation may impact water quality through agricultural and residential runoff entering drinking and recreational water sources. Those relying on private water sources, especially insecure sources such as shallow wells and surface water, may be at increased risk of acquiring a waterborne illness if water is not properly treated before using. As water treatment systems cost money to maintain, access to safe, potable water may be an issue for some living in rural communities without communal drinking water sources.

Many popular tourist attractions in the Grey Bruce area involve accessing recreational water bodies. Those engaging in aquatic activities may be at increased risk of exposure to waterborne illness such as *E. coli* infection, with children being more susceptible due to their developing immune systems and tendency to ingest water while swimming (72). Recreational water quality is known to deteriorate with large winds and precipitation. During heavy rain events or flooding, storm water may overwhelm wastewater treatment infrastructure and discharge in to rivers, lakes and streams, as occurred in Owen Sound after periods of heavy rain in Spring of 2016 (73).

In addition to source water monitoring and protection, public education and awareness of risks associated with water contamination will be important in future adaptive measures. As weather and water quality can change rapidly, enabling the public to make informed decisions about recreational water hazards could help them to mitigate their risk (74). Continued support should be given to those using private water systems, ensuring they are aware of the impact precipitation and flooding may have on the quality of their water and offering assistance to those who may be struggling to access safe, potable water where possible. Across the Grey Bruce region, residents should be encouraged to be prepared with an emergency supply of potable water for use in the event that water service is disrupted, especially those in rural areas who may not have immediate access to other sources in the event of an emergency (39). Important partnerships in advancing adaptive measures should include municipalities responsible for urban planning, critical water and wastewater infrastructure, and public beach monitoring and maintenance, conservation authorities, and organizations working with rural or isolated communities who may have issues accessing safe potable water sources.

Although climate change may impact food safety due to issues with keeping hazardous foods cold in warmer weather or in the event of a power outage, changes in temperature and precipitation may also impact local and global food availability (21). Locally, many Grey Bruce residents may utilize foods produced in the area, especially during the summer months. Some members of the Aboriginal community report continued harvesting of traditional plants and animals for use as food, medicine, or for ceremonial uses (65). The importance of the use of these locally-available foods for both cultural and sustainability reasons should not be downplayed; however, it is not anticipated that local changes to the environment and growing season will greatly impact food security of those in the area, as many will rely on commercially available foods for the bulk of their diet. Those relying heavily on local foods as a main source of nutrition, income, or for cultural purposes may feel the most impact from changes in crop yield and availability as the growing season changes and new pests and plant species are able to flourish in Grey Bruce. Further reaching, as climate change impacts other regions of the world more severely, commercial food prices may be effected, creating issues around food affordability and security, especially for socioeconomically disadvantaged populations. Agency collaboration and support of programs and initiatives aimed at addressing existing food security will be important in addressing current issues and preparing for additional challenges anticipated in the future.

RECOMMENDATIONS

It is extremely likely that climactic conditions will continue to change, including changes to temperature and precipitation means and increased variability in weather patterns, through continued emissions of greenhouse gases (2). Through these changes, public health may be directly or indirectly impacted in various ways (21).

Based on findings from this report, the following activities are recommended to further local understanding of the impacts of climate on public health in order to facilitate planning of adaptive measures;

Extreme Temperature
Further study should be done to examine the local impacts of temperature, both moderate and extreme, on the local population, focusing on the effects of heat and cold on vulnerable populations, including the elderly, socioeconomically disadvantaged, those who are socially isolated, and those facing issues with adequate housing.

Extreme Weather
Future predictions of extreme weather are harder to generate due to the variability of wind and precipitation (38). Grey Bruce is already experiencing frequent snowsquall, thunderstorm, and winter storm events. Although it is hard to determine how the frequency of these events will change in coming decades, it can be expected that these types of weather events will continue to occur. Extreme weather can impact public health directly, through injury or illness related to events like flooding and lightning strikes, and also indirectly through damage to infrastructure and the environment, as well as through complicating response to other emergency events. The Health Unit should be prepared to respond to extreme weather events with both direct and indirect impacts in collaboration with municipal partners in order to minimize potential adverse effects to human health.

Air Quality
Despite findings indicating air quality in the Grey Bruce is relatively good, the Health Unit should continue advocating for programs and policies which encourage reductions in air pollution and the continued monitoring of conditions. In relation to UV exposure, monitoring of melanoma and non-melanoma skin cancers in the area and sun safety promotional activities should be continued to help mitigate this risk.

Vector-borne Disease
Extension of the warm season creates opportunity for establishment of vectors responsible for the transmission of Lyme disease and West Nile Virus in the Grey Bruce area. Continued surveillance of blacklegged tick populations and increased surveillance of mosquitoes is recommended in order to increase awareness of the current risk and track changes moving forward. As risk for infection increases with population establishment, further educational work may be required with the public as well as the medical community.

The Environment

Precipitation and temperature are already affecting water quality and length of the growing season in Grey Bruce. Those utilizing private water sources for potable water, and those more heavily relying on locally grown foods for income and nutrition may be more impacted than others as these changes continue. Access to affordable food and potable water should be monitored along with the effects of temperature and precipitation on both recreational and water quality.

In addition to local response, it is recognized that climate change is a global issue. The health unit should be actively involved in programs and initiatives supporting and working towards collaboratively mitigating global climate change through the reduction of greenhouse gas emissions and the protection of the environment.

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APPENDICES

Appendix 1 - Weather Station Information

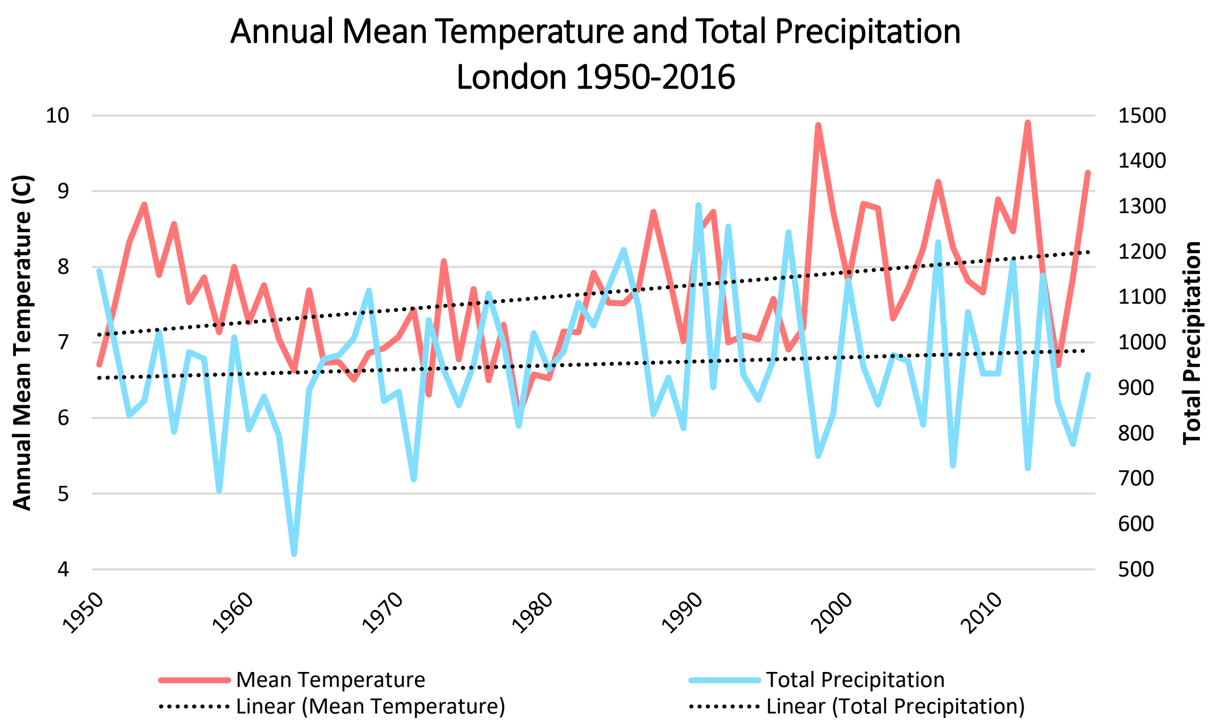
(15; 16; 17; 18; 75)

COLLINGWOOD	GODERICH	WIARTON	MOUNT FOREST	TOBERMORY
Station: Collingwood (6111792)	**Station:** Goderich (6122847)	**Station:** Wiarton A (6119498)	**Station:** Mount Forest AUT (6145504)	**Station:** Tobermory RCS (6128330)
Location: 44°43’00.000”N 80°13’00.000”W	**Location:** 43°46’00.000”N 81°43’00.000”W	**Location:** 44°44’39.000”N 81°06’31.000”W	**Location:** 43°59’00.000”N 80°45’00.000”W	**Location:** 45°14’00.000”N 81°38’00.000”W
Elevation: 179.80m	**Elevation:** 213.70m	**Elevation:** 221.90m	**Elevation:** 414.50m	**Elevation:** 213.50m
Neighbouring Municipalities: • Blue Mountains • Meaford • Owen Sound	**Neighbouring Municipalities:** • Huron-Kinloss • Kincardine • Saugeen Shores	**Neighbouring Municipalities:** • Southern Bruce Peninsula • Georgian Bluffs • Owen Sound	**Neighbouring Municipalities:** • West Grey • Southgate • South Bruce	**Neighbouring Municipalities:** • Northern Bruce Peninsula
Comparator Station: Thornbury Slama	**Comparator Station:** Kincardine	**Comparator Station:** Owen Sound	**Comparator Station:** Hanover	**Comparator** N/A
Operational: 1968 – 2005	**Operational:** 1870-2006	**Operational:** 1965-2006	**Operational:** 1972-2008	
Mean Difference: ±1°C (0-3°C) ±2mm (0-16mm)	**Mean Difference:** ±1°C (0-6°C) ±2mm (0-35mm)	**Mean Difference:** ±1°C (0-6°C) ±2mm (0-26mm)	**Mean Difference:** ±1°C (0-6°C) ±3mm (0-72mm)	

MONTHLY MEAN CLIMATE COMPARISONS – JANUARY 2004	*Mean Max Temp (°C)*	*Mean Min Temp (°C)*	*Mean Temp (°C)*	*Extreme Max Temp (°C)*	*Extreme Min Temp (°C)*	*Total Precip (mm)*
Collingwood	-6	-14	-10	13	-28	91
Thornbury	-6	-14	-10	12	-28	165
Owen Sound	-6	-13	-10	13	-25	223
Wiarton	-6	-15	-11	11	-27	138
Mount Forest	-7	-16	-12	11	-30	88
Hanover	-6	-15	-11	13	-31	189
Goderich	-4	-11	-8	12	-22	ND
Kincardine	-5	-11	-8	11	-22	208

MONTHLY MEAN CLIMATE COMPARISONS – JUNE 2004	*Mean Max Temp (°C)*	*Mean Min Temp (°C)*	*Mean Temp (°C)*	*Extreme Max Temp (°C)*	*Extreme Min Temp (°C)*	*Total Precip (mm)*
Collingwood	22	12	17	33	4	33
Thornbury	21	10	16	32	3	48
Owen Sound	21	10	16	31	4	55
Wiarton	20	9	15	30	3	73
Mount Forest	22	10	16	30	3	55
Hanover	23	9	16	29	1	80
Goderich	21	12	16	29	4	88
Kincardine	23	12	17	30	3	84

Appendix 2 – Historical Temperature and Precipitation, London, Ontario

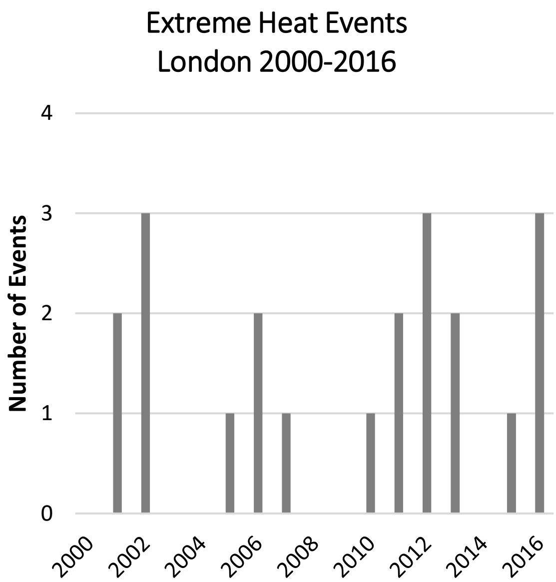


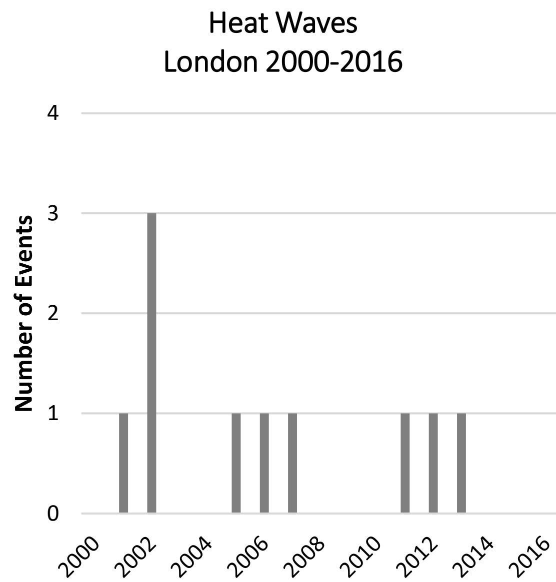
Annual Mean Temperature and Total Precipitation, London ON 1950-2016

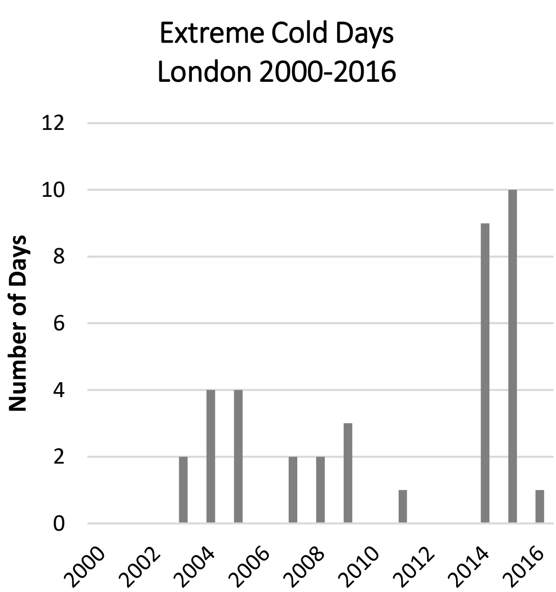
Source: Environment and Climate Change Canada Historical Weather Data (19)

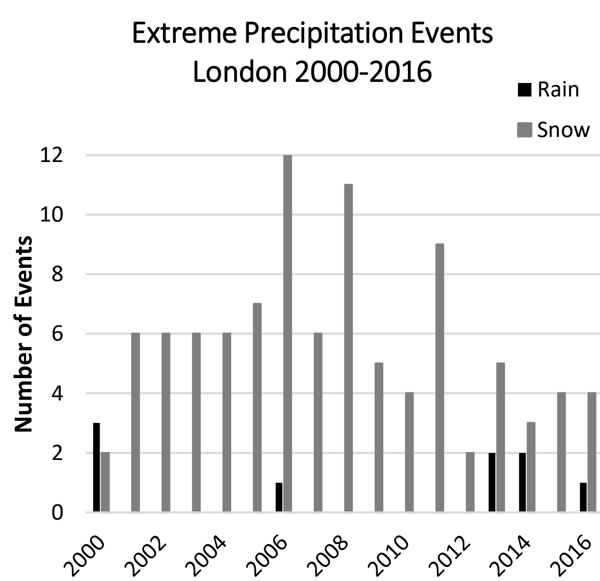
Appendix 3 - London, Ontario Weather Event Overview

Weather data for Perth District Health Unit is obtained from weather stations in London, Ontario (19).

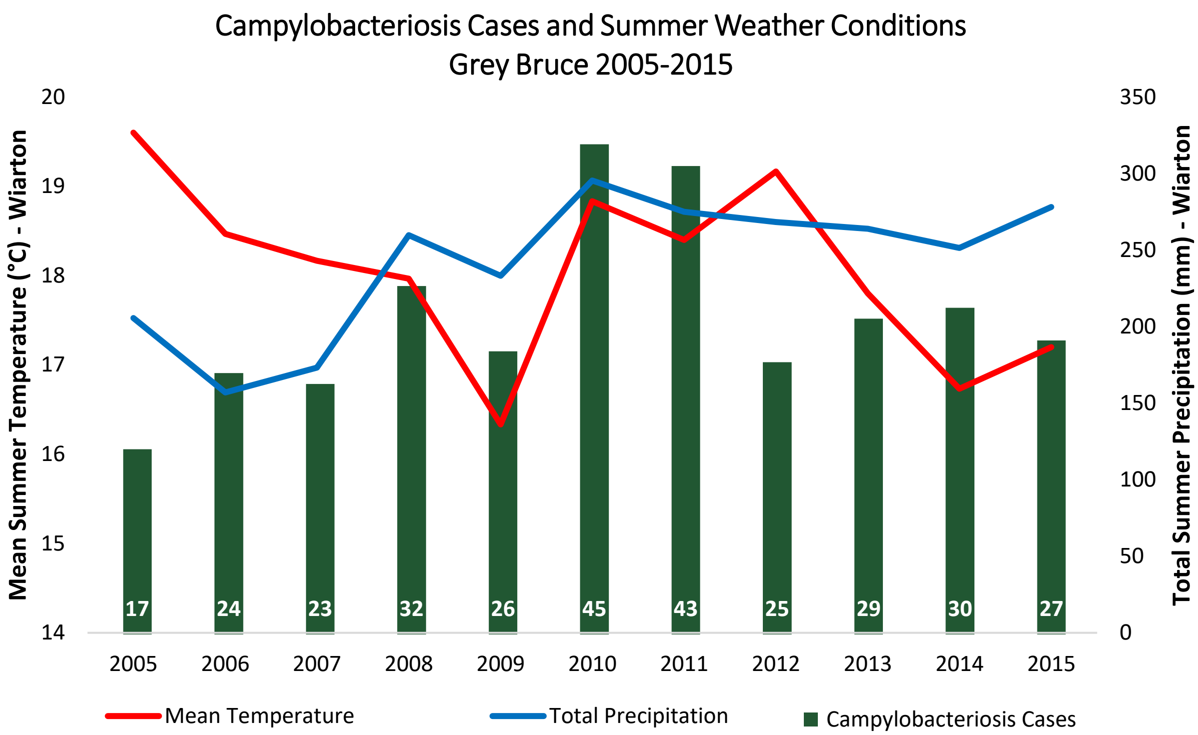


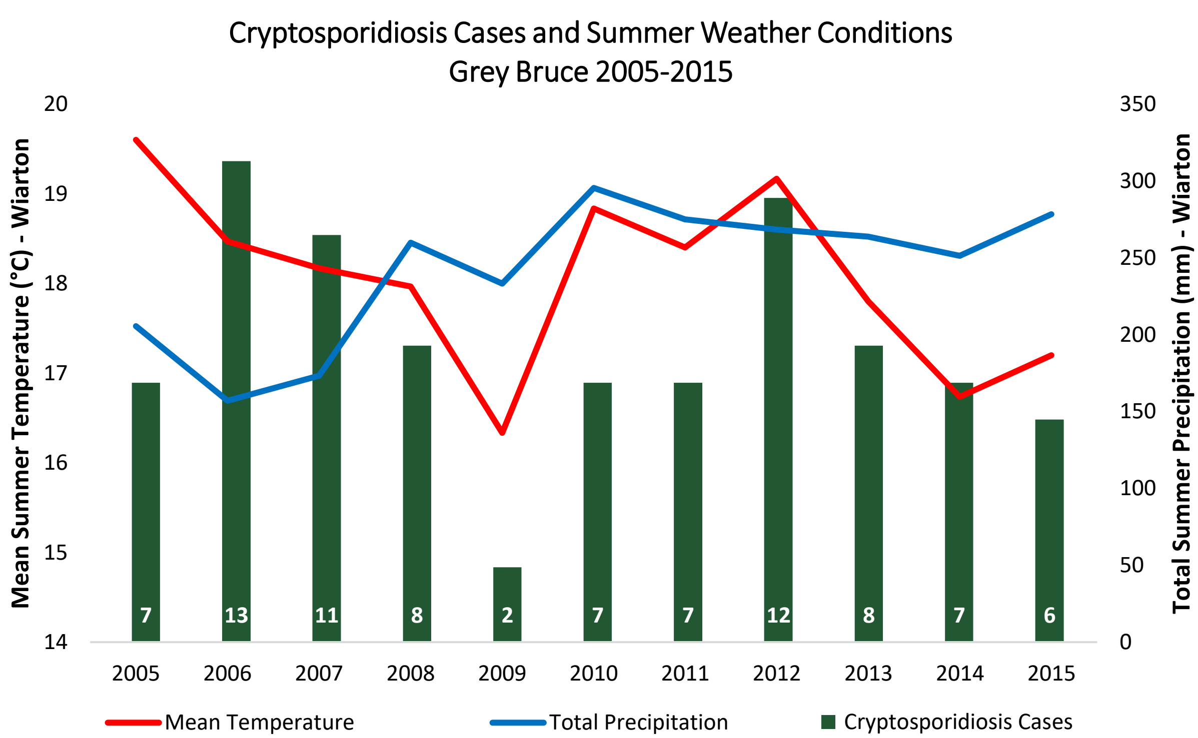


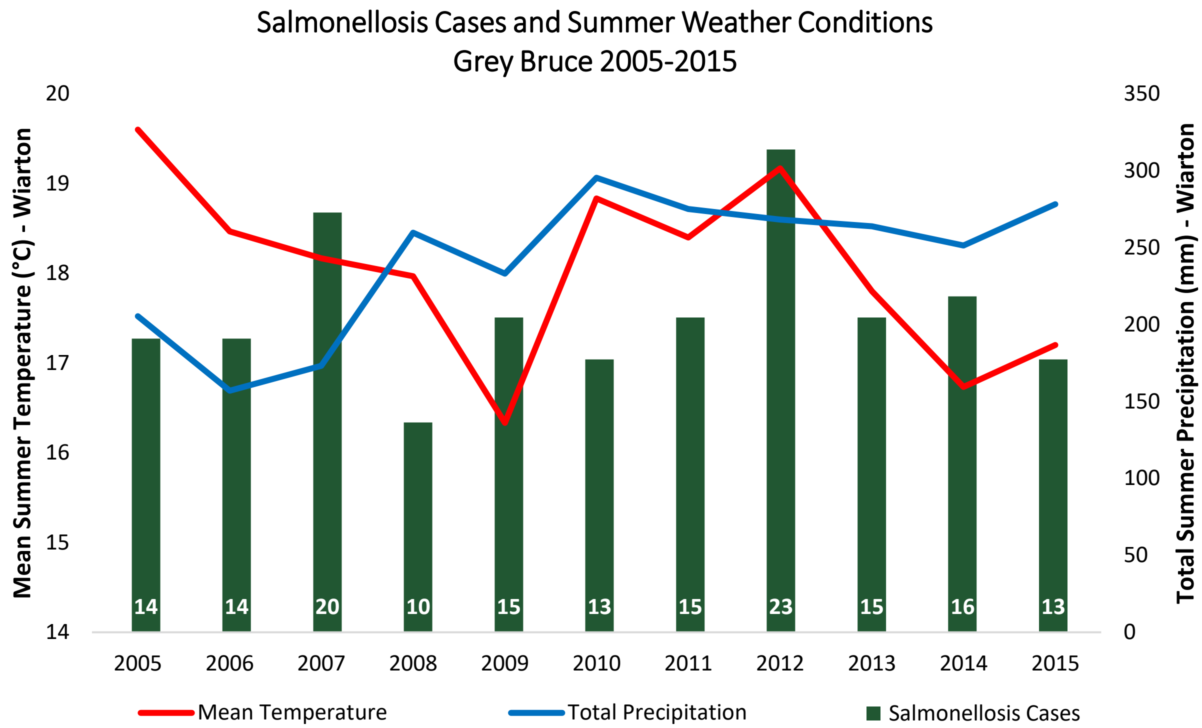


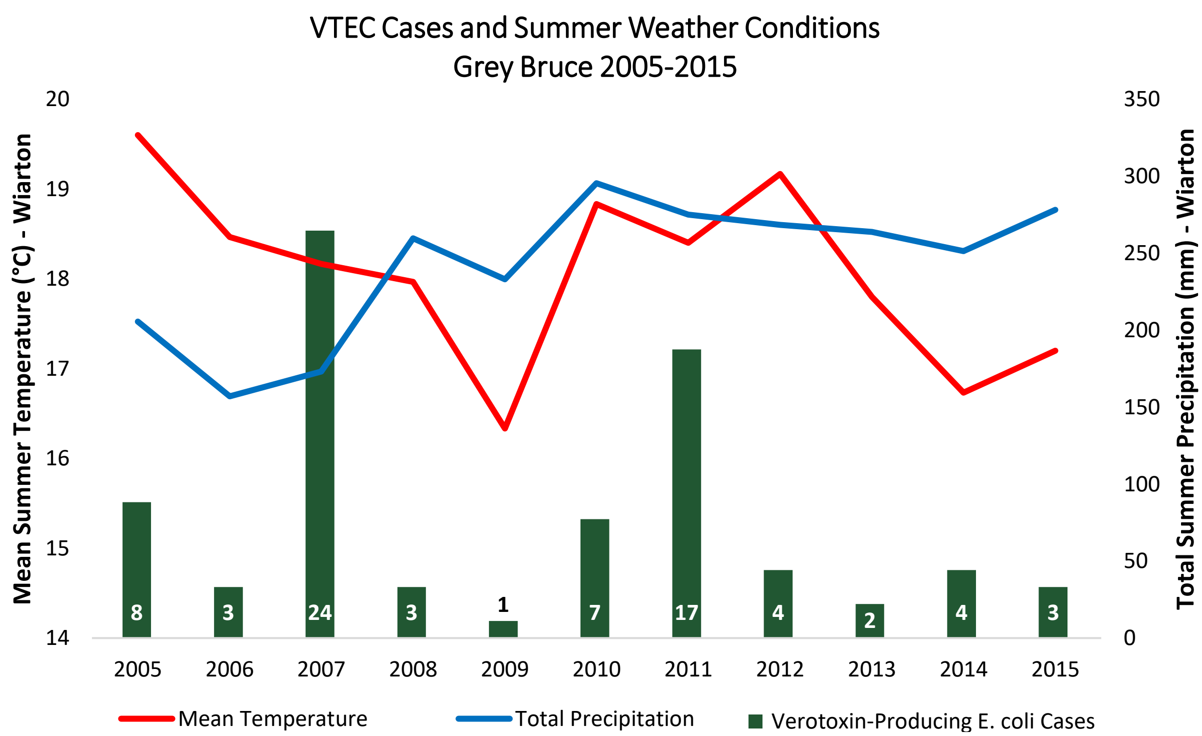


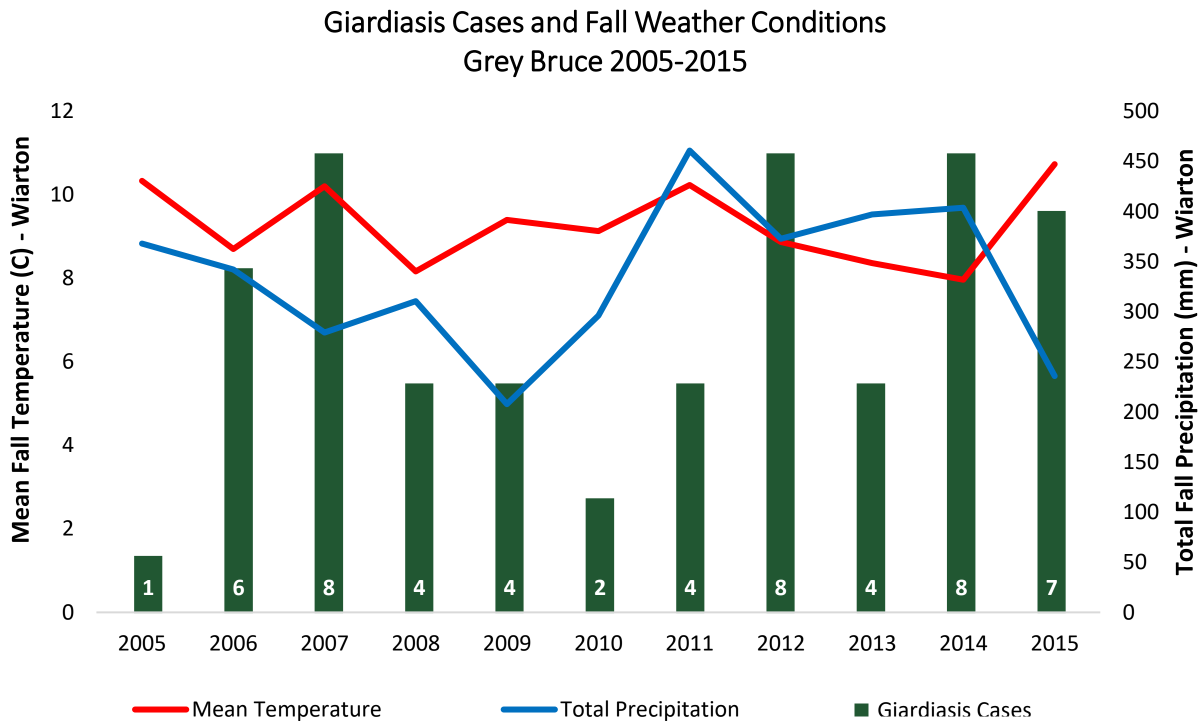
(75; 71)


Campylobacteriosis Cases and Summer Weather Conditions
Grey Bruce 2005-2015
Mean Summer Temperature (°C) - Wiarton
Total Summer Precipitation (mm) - Wiarton
20
19
18
17
16
15
14
350
300
250
200
150
100
50
0
17
24
23
32
26
45
43
25
29
30
27
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Mean Temperature
Total Precipitation
Campylobacteriosis Cases


Cryptosporidiosis Cases and Summer Weather Conditions
Grey Bruce 2005-2015
Mean Summer Temperature (°C) - Wiarton
Total Summer Precipitation (mm) - Wiarton
20
19
18
17
16
15
14
350
300
250
200
150
100
50
0
7
13
11
8
2
7
7
12
8
7
6
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Mean Temperature
Total Precipitation
Cryptosporidiosis Cases

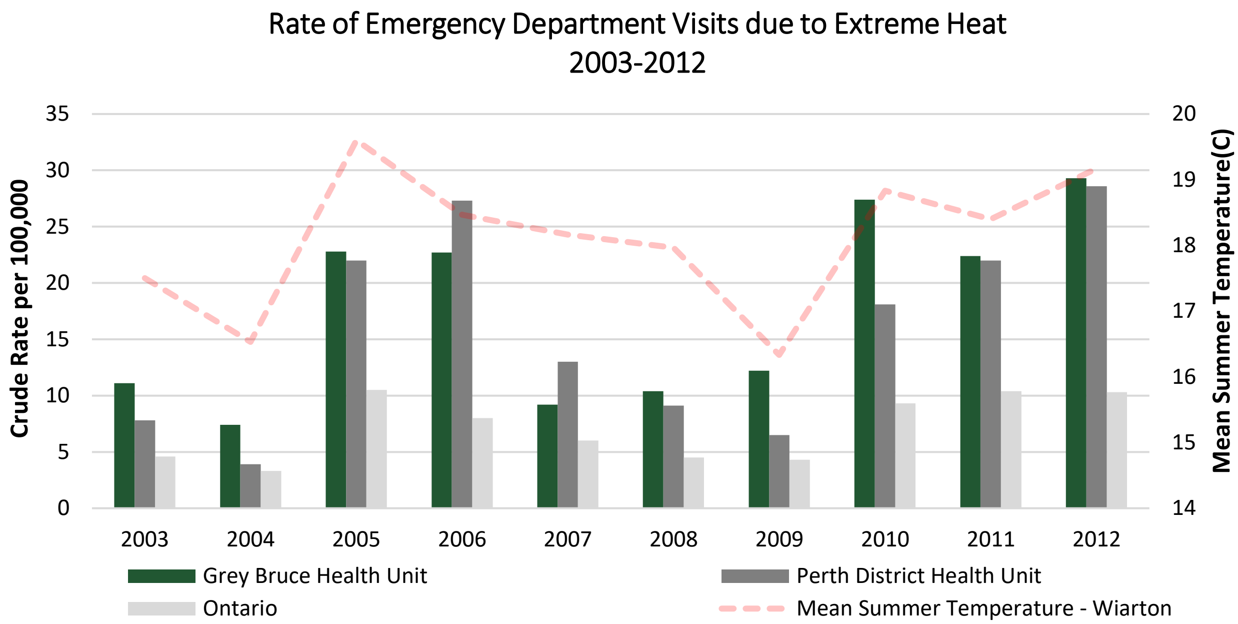

Salmonellosis Cases and Summer Weather Conditions
Grey Bruce 2005-2015
Mean Summer Temperature (°C) - Wiarton
Total Summer Precipitation (mm) - Wiarton
20
19
18
17
16
15
14
350
300
250
200
150
100
50
0
14
14
20
10
15
13
15
23
15
16
13
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Mean Temperature
Total Precipitation
Salmonellosis Cases

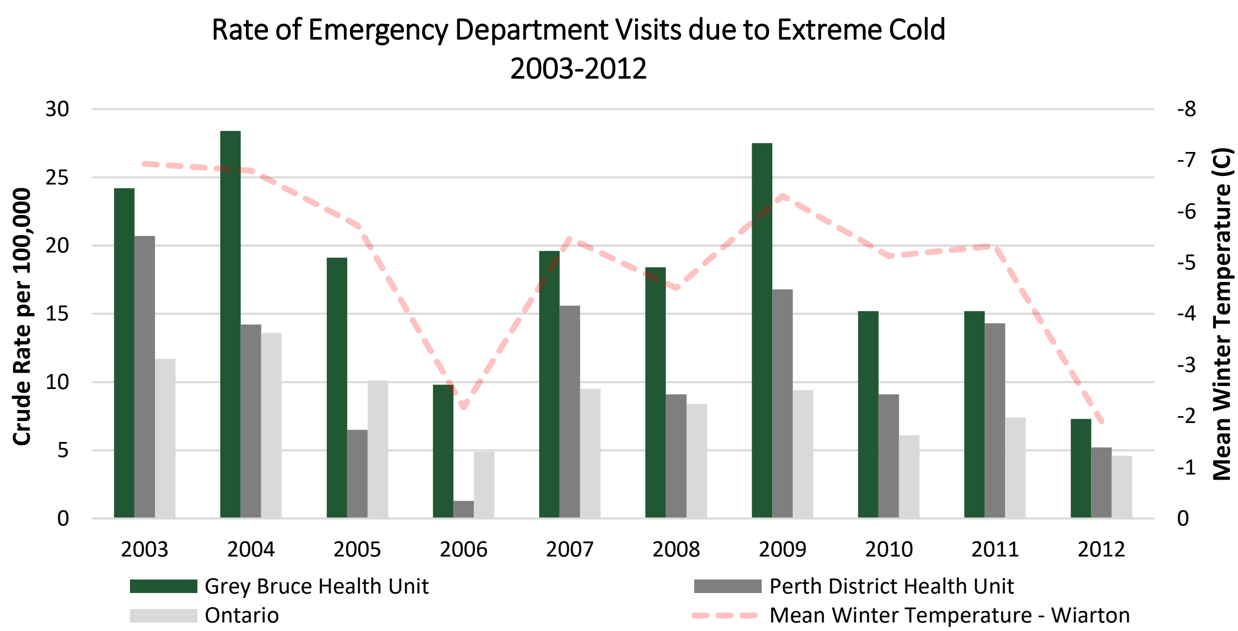

VTEC Cases and Summer Weather Conditions
Grey Bruce 2005-2015
Mean Summer Temperature (°C) - Wiarton
Total Summer Precipitation (mm) - Wiarton
20
19
18
17
16
15
14
350
300
250
200
150
100
50
0
8
3
24
3
1
7
17
4
2
4
3
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Mean Temperature
Total Precipitation
Verotoxin-Producing E. coli Cases

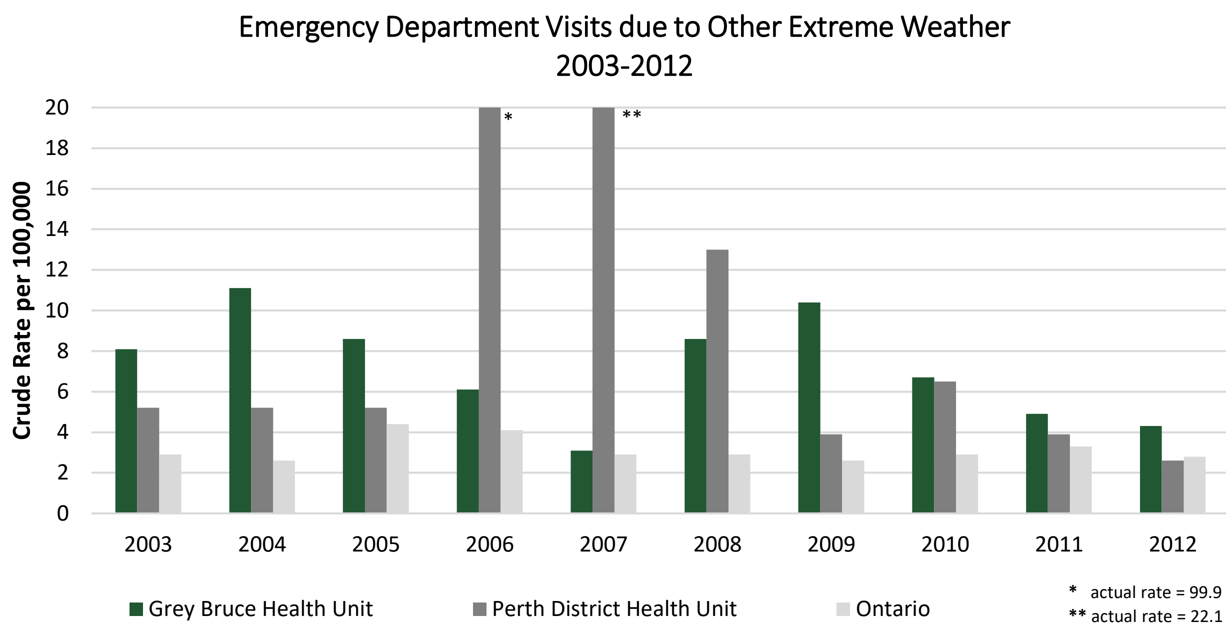

Giardiasis Cases and Fall Weather Conditions
Grey Bruce 2005-2015
Mean Fall Temperature (C) - Wiarton
Total Fall Precipitation (mm) - Wiarton
0
2
4
6
8
10
12
0
50
100
150
200
250
300
350
400
450
500
1
6
8
4
4
2
4
8
4
8
7
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Mean Temperature
Total Precipitation
Giardiasis Cases

Appendix 5 - Weather-related Emergency Department Visits 2003-2012

(75; 25)






Emergency Department Visits due to Other Extreme Weather
2003-2012
Crude Rate per 100,000
20
18
16
14
12
10
8
6
4
2
0
*
**
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
Grey Bruce Health Unit
Perth District Health Unit
Ontario
* actual rate = 99.9
** actual rate = 22.1