CLIMATE CHANGE – IMPACTS ON KAHSHE AND BASS LAKES

What's happening in Ontario and Muskoka?

In a comprehensive report by the Muskoka Watershed Council (MWC) published in 2016 (Sale et al., 2016) the potential impacts of a changing climate on the terrestrial and aquatic resources as well as the people of Muskoka have been discussed and projected into the mid-century (2041 - 2070). This work has spawned several summaries, fact sheets and workshop reports in 2017 and 2018 and links to these studies have been included as additional reading for anyone who wants to better understand how the projected change in our climate may unfold and impact the aquatic and terrestrial health of our properties and our treasured lakes in future years.

Since then, two more recent climate change documents have been reviewed and both generally support the findings of the MWC's 2016 report. The first (Hoegh-Guldberg, 2018), was a Special Report prepared by the United Nations Intergovernmental Panel on Climate Change (IPCC) that built on the most recent 2014 IPCC AR5 (Fifth Annual Report) and was titled as noted below. The second, edited by Bush and Lemmen (2019) was a recently released Government of Canada document on Canada's Changing Climate

So what does the MWC's 2016 modelling for Muskoka tell us? First, a quick look at how this was carried out. Very briefly, the MWC's 2016 climate modelling for a typical site in Muskoka utilized a massive store of climate data generated and maintained by the IPCC. The data were assembled by a collaboration of 26 climate research centers worldwide and comprised 3.3 petabytes (over three million gigabytes) of stored climate data. The modelling included over 800 projections of the global climate, generated by 61 different Global Climate Models (GCMs) running under four specific greenhouse gas mitigation scenarios. The behavior and reliability of these models is validated on an ongoing basis and it has been demonstrated that they are able to reproduce past trends in such things as temperature very well, and precipitation somewhat less well.

Two of these greenhouse gas reduction scenarios were utilized in the MWC's 2016 report for Muskoka. The two selected were:

- RCP8.5, a scenario (often termed 'business-as-usual') in which we continue to use fossil fuels as the primary source of energy for our economy, and:
- RCP4.5, one in which the global community makes a sufficient change to its fuel sources to the extent that we limit warming of global mean temperature to 2°C by 2100.

A third, more aggressive emission reduction scenario (RCP2.6) which would be required to limit average global warming to 1.5°C was not included in the projected temperature increases, as there was no convincing evidence that world leaders were committed to meeting this goal.

Based on these two scenarios, projected changes (compared to historical climate records for the period from 1971-2000) in the climate of the Muskoka area by mid-century (2041-2070) include:

- Average daily mean temperatures are projected to be 3-4°C warmer each month, with 7-times more summer days above 30°C and 64% more winter days above freezing;

- Under the more realistic RCP4.5 scenario, temperature changes would fall in the 2-3°C range.
- For the summer months of concern to most cottagers (May to September), the projected monthly mean increases were 3.4°C for the RCP8.5 (business-as-usual) scenario and 2.5°C for the more aggressive greenhouse gas reduction RCP4.5 scenario.
- In the precipitation model, the projected changes included an overall 10% increase in precipitation, and a shift towards 17% more precipitation from late fall to early spring and similar or somewhat less precipitation through summer and early fall;
- There will be fewer, but more pronounced storm events with precipitation deluges and high winds.

A review of the two more recent publications identified above indicates that the projected temperature increases for Muskoka as presented in the MWC report (Sale et al., 2016) appear to be reasonable projections based on the more recent climate monitoring and modelling that has been conducted and published. However, as the MWC projections were based on a mid-century time period, this needs to be considered, as under that shorter timeframe, the MWC's projected temperature increases appear to fall at the higher end of more recent (2019) projections contained in the Canadian Government document (Bush et al). In that document, some additional projections for average annual temperature increases in Ontario for three 20-Year periods through to the end of the century are provided. As for the earlier MWC report, these increases are projected under an RCP4.5 emission reduction scenario (medium level of carbon emission reduction). The values presented are for the 50th percentile of 29 model runs with the bracketed values shown for the 25th and 75th percentiles. The increases in temperature are based on comparisons to a reference period of 1986-2005.

Location	Average Annual Temperature Increase[1]		
	2016-2035	2046-2065	2081-2100
Ontario	1.3°C (0.8-1.6°C)	2.4°C (1.8-2.8°C)	3.2°C (2.3-3.8°C)

[1]temperature increases based on comparison to reference period from 1986-2005

These findings are essentially the same as those projected for this emission reduction scenario earlier in the 2016 MWC document.

How realistic are these projected temperature increases? This question has been discussed and debated by prominent climate research scientists and the discussion appears to focus around the reality of the emission reduction assumptions that went into the development of the various RCP scenarios. From that discussion, there appears to be some consensus that the "business-as-usual" assumptions that went into the RCP8.5 scenario should be considered more of a worst case scenario in terms of coal and other fossil fuel use as we move towards the end of the century. At the other end of the emission reduction scenario (RCP2.6), the emission reductions possible under this scenario appear overly optimistic, given the lack of significant progress to date. As such, the RCP4.5 scenario appears to be the most relevant and achievable carbon reduction scenario.

There has also been extensive work on the development of alternative emission reduction scenarios for use with the various global climate models that are being tested alongside the RCP scenarios, and the findings will appear in the next IPCC assessment report.

The projected impacts of these changes in temperature and precipitation over the Muskoka region are projected to include:

- Flooding, particularly during winter and spring, is likely to be substantially more severe than at present, especially in colder years when above normal snowpack develops.
- Increased evaporation and plant transpiration and dryer soils in the summer, resulting in less water available to nourish wetlands, provide stream flow, and keep our lake levels high.
- Drought and a greater risk of forest loss or changes in species composition due to insects and diseases as well as from fires.
- Lakes will be ice-free for longer (later freeze over and earlier ice melt), warm up more during the ice-free season and be at greater risk of deteriorating water quality.
- Algal blooms will be more frequent and there will be changes in the ecology of our lakes and in the composition of aquatic species.

A few things to note, particularly regarding the warming that is projected for the Muskoka area.

- The daily average temperature increases referred to above are projections, not predictions, and are based on a massive global dataset; however, they also involve a large number of assumptions in both the greenhouse gas reduction scenarios as well as in other biological responses.
- Although the projections were developed for a mid-century scenario (now 30 years ahead), the temperature increases are based on comparisons to historical climate data for the period from 1970 to 2000. As such, the projections represent the change in daily mean temperatures over an approximate 70 year period. While many of these projected changes are unlikely to have major impacts on the scenic, recreational or economic value of our lakes and waterfront properties, some may be of greater concern more generally throughout Muskoka and locally at specific locations.

How will these changes in our climate impact our lakes?

As noted in the 2018 Report Card on climate change (MWC, 2018), the potential impacts of climate change can be demonstrated through several types of measurements, including:

- Changes in air and water temperatures.
- Changing patterns of precipitation.
- Changes in water levels and open water time periods.

However, before any generalized conclusions can be drawn from the measurement data, it is important to understand the statistical tools that scientists utilize to draw these conclusions and project or interpolate them into the future. For simplicity, this can be best explained using two general terms:

- Non-Significant Trend or Relationship
    - Data that appear to show an increasing or decreasing trend or the presence of a relationship between two or more sets of climate variables, but the trend or relationship is not sufficiently robust enough or too variable to rule out with certainty at the 95% level of probability that it was due to chance or some other unknown factor.

- Statistically Significant Trend or Relationship
    - This type of trend or relationship has been evaluated and there is a large enough data set and/or a minimal level of variability to conclude at a 95% or higher level of probability that it is associated with the cause being investigated.

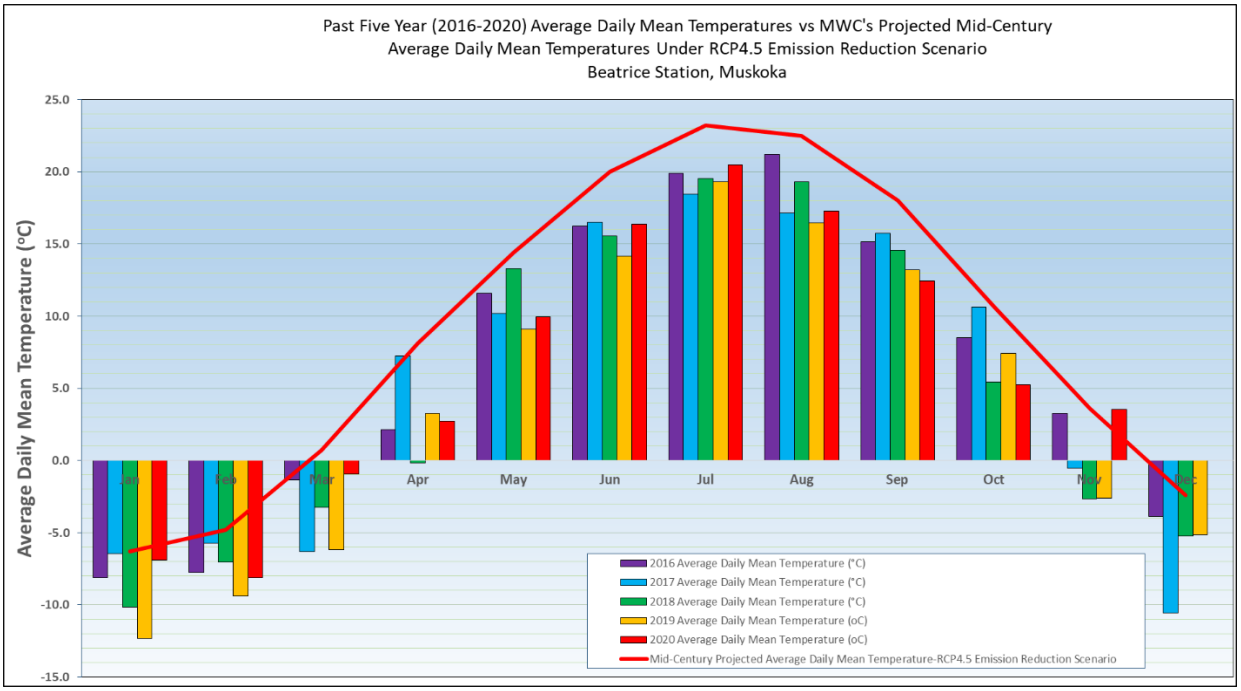
As the more limited sampling and analysis history and the small sample size from Kahshe and Bass Lakes is unlikely ever to be comprehensive enough to generate statistically significant conclusions regarding climate change, we are fortunate that a comprehensive investigation of the impacts of climate change on nearby lakes in Muskoka has been conducted by aquatic scientists at the Dorset Environmental Science Centre (DESC) of the Ontario Ministry of the Environment, Conservation and Parks (MECP). As such, while it is recognized that climatic impacts on a lake ecosystem will vary depending on the size, depth and chemical composition as well as other features of the lake, there is merit in examining these changes as the research that has been undertaken has utilized climatic data that is typical of what we experience in this local area.

Based on the Sale et al. (2016) report, projected changes in the above measurable components are likely to impact the aquatic and terrestrial resources of Kahshe and Bass Lakes as follows:

Air and lake water warming	▪ Increased summer and fall water temperature, leading to more algal blooms, changes in lake water chemistry and in aquatic and zooplankton survival and population diversity. ▪ Increased lake water evaporation resulting in lower summer and fall lake levels, loss of wetlands and forest cover due to drought, insects, disease and fire. ▪ Increases in open-water, ice-free times and effects on fish spawning and planktonic food supply for aquatic life. ▪ Lower water levels as the recreational season progresses will result in the exposure of more rocks and limit the extent of navigable waters.
Increased spring and winter precipitation	▪ Increased snow melt and rain water runoff contributing to high water levels in spring, resulting in shoreline erosion, nutrient leaching to the lake, loss of shoreline habitat from waves and dock damage.

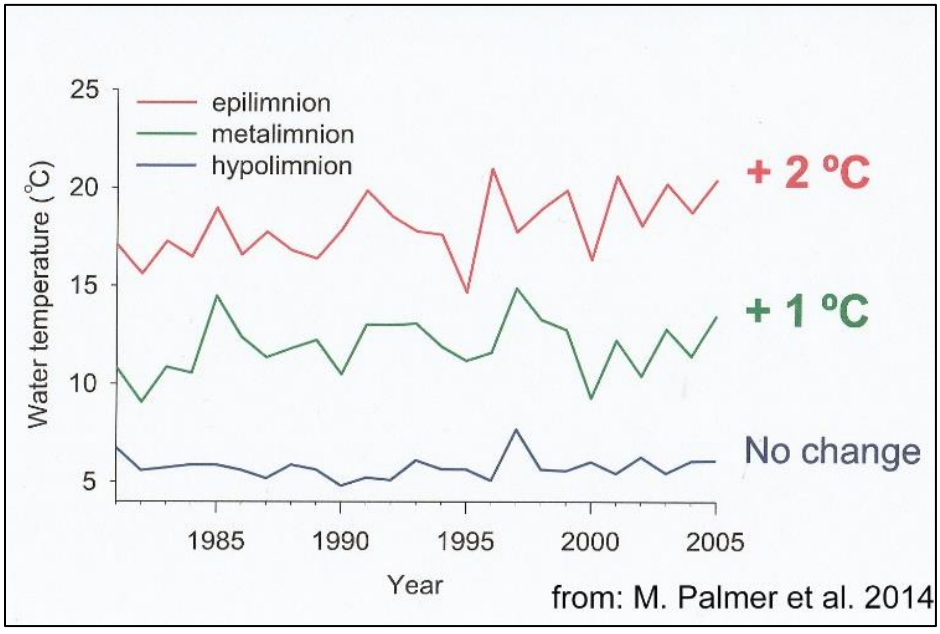
To give some perspective on how the projected increases in temperature that were identified in the MWC's 2016 report relate to temperatures currently being observed in Muskoka, the actual temperatures upon which the increases were calculated have been compared to observed temperatures at a nearby weather station over the past five years (2016-2020).

The chart below shows this comparison.

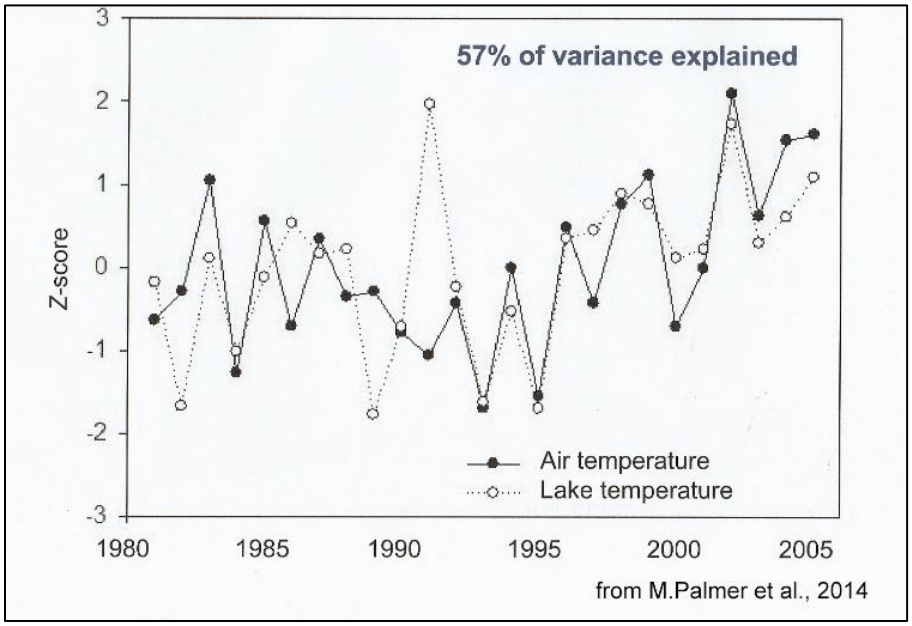


The five columns for each month of the year represent the average daily mean temperature for each month from 2016 through 2020, while the projected mid-century temperatures under a realistic emission reduction scenario (RCP4.5) are shown as the red line.

This chart clearly demonstrates that the projected temperatures at mid-century are clearly within the realm of possibility given our current climate status. The Muskoka temperature data also reflect the fact that 2016 and 2020 were the warmest years on record for Canada (Bush et al., 2019). It should also be noted that air temperatures in Canada have increased at roughly double the global mean rate, with Canada's mean annual temperature having risen about 1.7ºC (likely range 1.1ºC – 2.3ºC) over the 1948–2016 period (Bush et al., 2019). In Ontario, the Bush et al. (2019) report confirms that the annual average temperature increase over this same period was 1.3°C, with a seasonal break-out as follows: Winter (+2.0°C); Spring (+1.5°C); Summer (+1.1°C); and Fall (+1.0°C).



In addition to the MWC's summary report by Sale et al. (2016), Palmer et al. (2014) have provided a very comprehensive report on some of the changes that have been documented in a study of seven lakes in Muskoka from 1981 through 2005 and these are depicted in the following charts, as

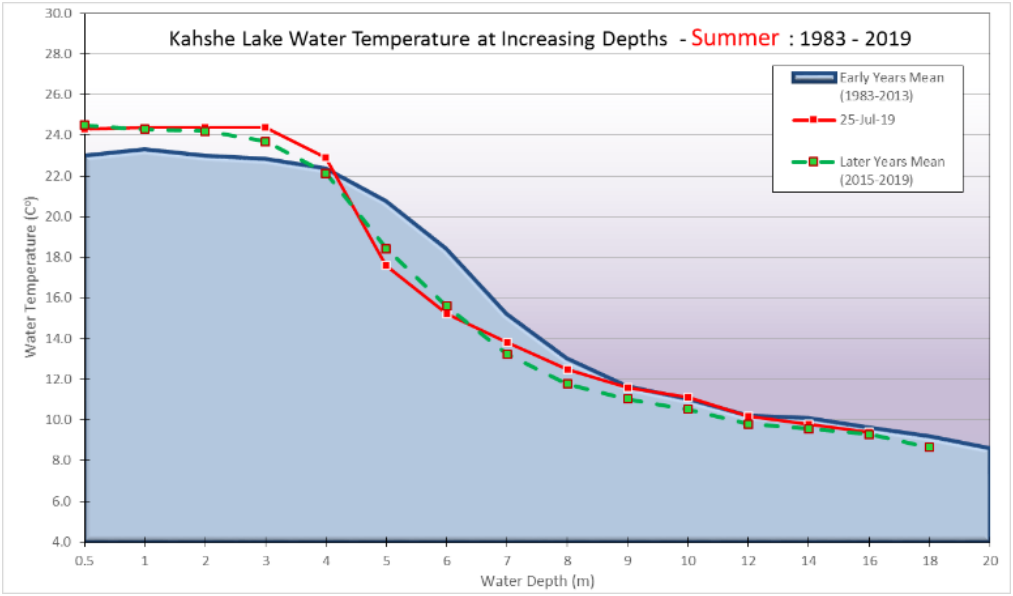


they provide some perspective as to how Kahshe and Bass Lakes may respond.

As noted in the above chart, Palmer et al. (2014) documented a statistically significant trend of lake warming of both the surface (epilimnion) and the intermediate layer (metalimnion) of 2°C and 1.2°C, respectfully over the 25 year period from 1981-2005.

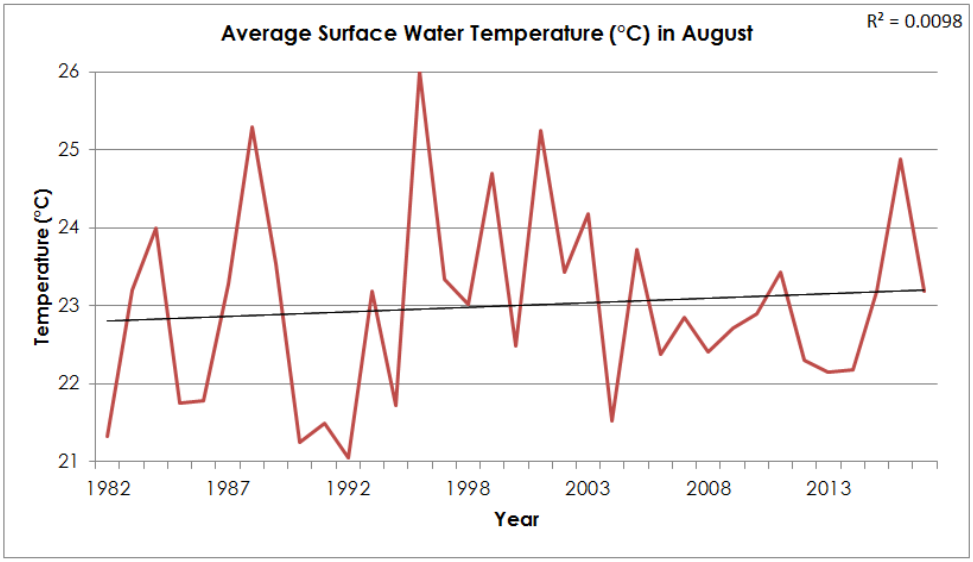
They also examined the relationship between these surface water findings and air temperatures over this period and not surprisingly, found air temperature to be the most important predictor of water temperature (as shown in the above chart). A statistically significant relationship between air and lake temperature was recorded, with 57% of the variance explained by this variable. Of particular note was that this relationship between air and water temperatures was statistically significant only in the month of September.

So is lake warming happening in Kahshe or Bass Lakes? The short answer is that although we do have a reasonably robust record of water temperature dating back to the early 1980s, there is not enough data to demonstrate a statistically significant warming trend for either lake, and it is unlikely that we will ever have enough data to support a conclusion at the level of probability that is required to satisfy typical statistical confidence. That said, the already posted Lake Steward reports have examined lake water temperatures at increasing depths in order to track whether any trends are starting to emerge



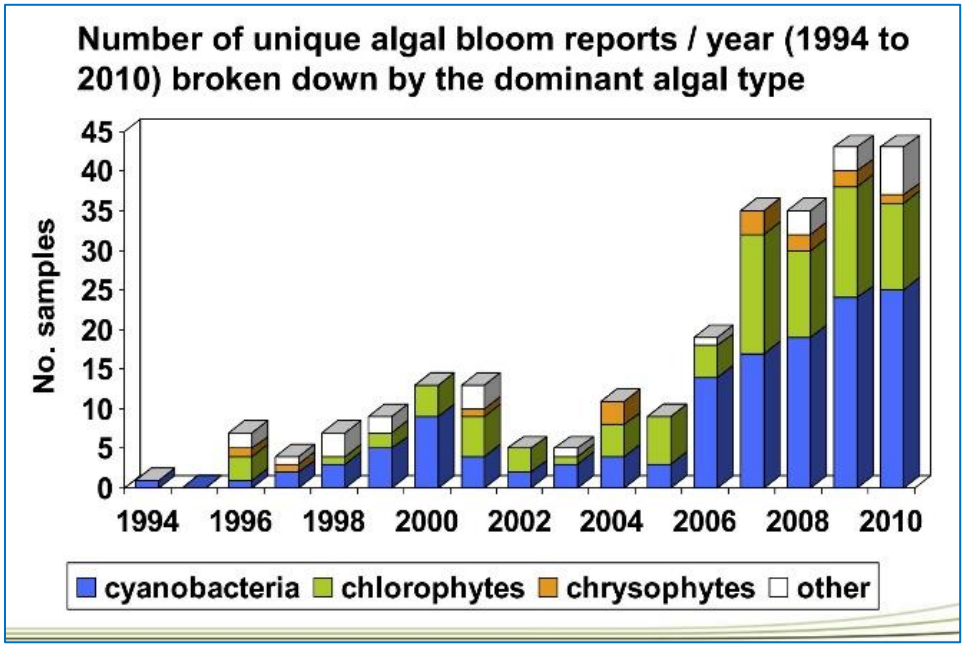
Water temperatures in Kahshe Lake in 2019 and also during the period from 2015-2019 are charted above and appear warmer than in the past down to a depth of about 4m. A similar finding (not shown) has been demonstrated in the more shallow Bass Lake, although the depth of warming is limited to the upper 2m.

While these findings are generally in agreement with the findings of Palmer et al. (2014) who have evaluated surface water temperatures across several Muskoka lakes, they cannot be directly compared due to the different times of the year that measurements are taken. As such, it is unlikely that the District Municipality of Muskoka (DMM) water temperature readings that are taken every other year on Kahshe Lake will ever be directly comparable to the statistically significant findings of water warming generated by Palmer et al., (see figure on page 5).



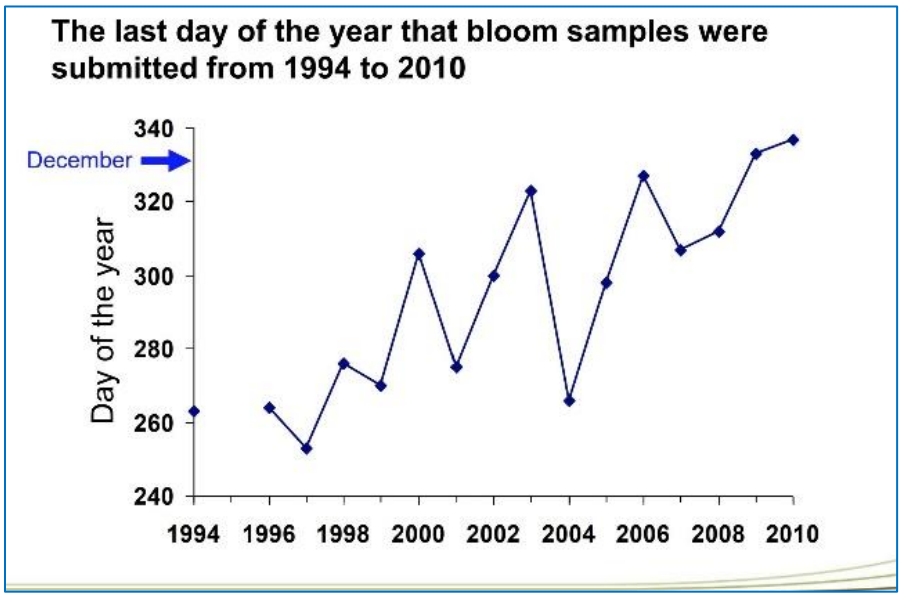
Average summer surface water temperature (0.5 meters depth) in various lakes in Muskoka. The trend line indicates that surface water temperature is increasing.

This is underscored by examining the adjoining chart from the 2018 MWC Report Card on Climate Change (MWC, 2018a). The data for surface water (0.5m depth) temperatures in August from 164 Muskoka lakes over the period from 1982-2016 do demonstrate that summer surface water temperatures in Muskoka's lakes have increased slightly over the past 35 years. However, even when over 160 lakes are utilized, this upward trend in surface water temperature is not statistically significant at the 95% level of probability.



While the tracking of water temperatures as described above has not confirmed statistically significant warming trends on an individual lake basis, there is general agreement that a warming climate could be involved in the development of blue-green algal blooms (referred to as Harmful Algal Blooms - HABs) which

are being detected at increasing frequency and later in the year over the past few years. This trend is shown the two charts from the Ministry covering the period from 1994 through 2010 (Winter, 2014).



The increasing trend in frequency of HABs in the Simcoe and Muskoka area is now tracked by the Simcoe Muskoka Health Unit, and their summary of impacted lakes is shown below for the period from 2018 through 2020.

Year	Blue-Green Algal Bloom Impacted Lakes	Number of Bloom Alerts
2018	Three Mile, St. John, Leonard, Rosseau, Lamont Creek	6
2019	Three Mile, Brandy, Bass (not ours), Echo, St. John, St. George, MacLean	8
2020	Three Mile, Brandy, St. John, Black, Leonard, Simcoe, Bruce, Muskoka, Silver, Stewart, Little, Ten Mile, Otter and **Kahshe** Lakes	18

Unfortunately, as noted in the above table, a documented blue-green algal bloom requiring health-based water use restrictions has now been confirmed on Kahshe Lake.

As such, we must continue our efforts to reduce the levels of phosphorus and nitrogen in our lakes to further minimize the potential for algal blooms that appear to be associated with increasing water temperatures under a changing climate.

Next, let's look at changes to the ice-free period – i.e. open water duration. Obviously, there are two possible components to this finding:

- Later freeze-over in the fall
- Earlier ice-out in the spring.

The MWC (2018a) in their 2018 Report Card on Climate Change have examined these two variables for a larger set of Muskoka lakes and their findings are shown in the chart below labelled as Figure 2.

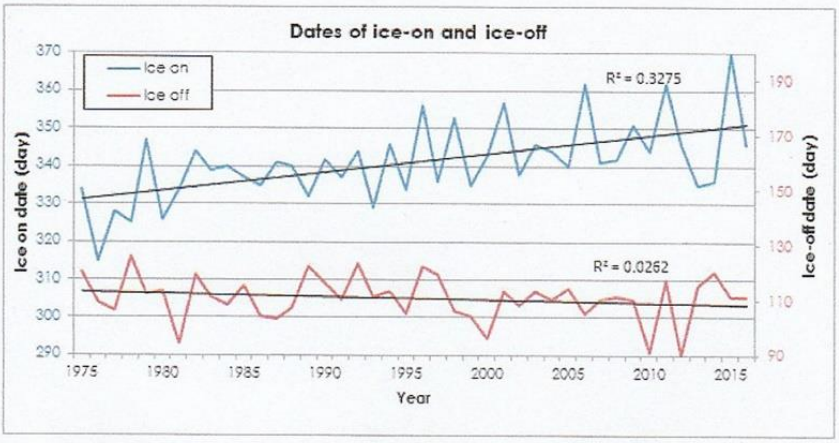
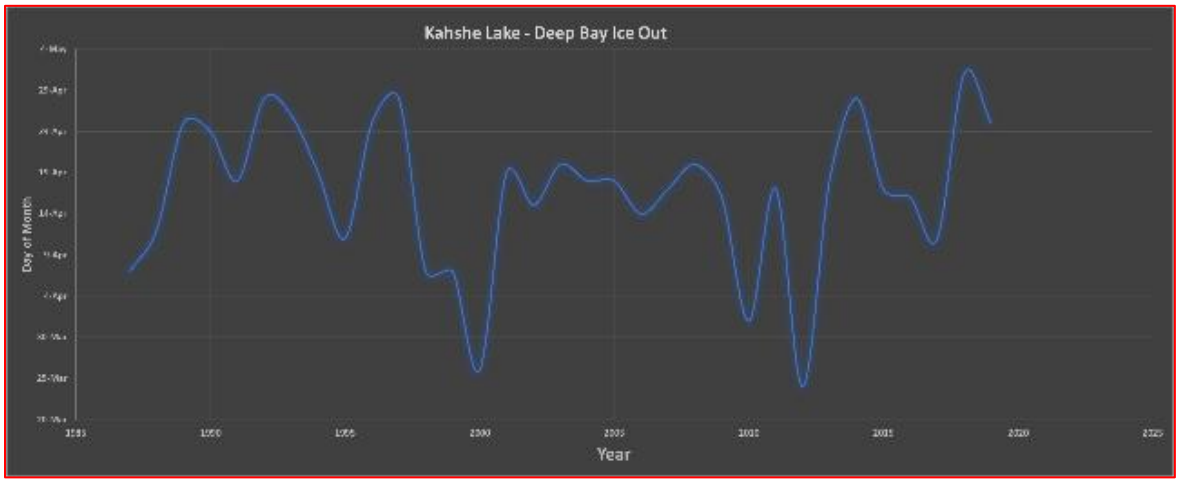


Figure 2. Dates of ice-on and ice-off at various lakes in Muskoka from 1975 to 2017. The date of first ice freeze up (ice-on) is plotted (blue line, left-hand axis) as the Julian day for each year. The date the lake opened in spring (ice off) is plotted (red line, right-hand axis) also as the Julian day for each year. (Julian day is the day number where 1 January = day 1 and 31 December = day 365.) The trend towards a later freeze up in the fall is statistically significant, while the slight advance in ice-off date is not significant.

Based on the results from various Muskoka lakes from 1975 to 2017, they conclude that freeze over (blue line) is happening later in the year and this change is statistically significant. However, the time of the year when ice melts in the spring, while appearing to be trending earlier, is not confirmed to be statistically significant.

Unfortunately, there are no fall freeze-over data for Kahshe or Bass Lake; however, as shown in the chart below (with thanks to R. Cronin and M. Wayling), we do have a record of ice-out times for the Deep Bay area of Kahshe Lake dating back to 1987. Not surprisingly, these ice-out records show no apparent trend, and are in general agreement with those for the larger Muskoka lakes study which also found no significant trend towards earlier spring ice-out times.



Summary

This report presents and discusses the findings of ongoing efforts to evaluate potential and suspected existing climate change impacts in the Muskoka area and more specifically, on Kahshe and Bass Lakes. For a more general overview of projected climate impacts, the reader is referred back to the Overview document.

The projected impacts of changes in temperature and precipitation over the Muskoka region are expected to include:

- Warming of lakes and longer ice-free periods resulting in changes in aquatic survival and diversity as well as deteriorating water quality.
- Flooding, particularly during winter and spring due to more pronounced storm events and above normal snowpack melting.
- Drying of soils resulting in less water available to nourish wetlands, provide stream flow, and keep our lake levels high.
- Drought and a greater risk of forest loss or changes in species composition due to insects and diseases as well as from fires.
- More frequent lake contamination with toxic and other types of algal blooms and the ingress of some invasive species.

The report identifies the major findings from the study of changes to many lakes in the Muskoka area and these are highlighted below:

- Evidence of statistically significant warming of surface lake waters using data from 1981-2005;
- Evidence of a statistically significant relationship between September air and lake water warming during the period from 1981-2005;
- Evidence of a statistically significant delay in lake freeze-over, and thus a longer open-water condition using Muskoka lake data from 1975-2017.

On a local area basis, the evaluation of air and water monitoring data has revealed some general trends that appear to be consistent with the changes identified via the larger Muskoka lakes data set; however, it is recognized that the 35 year records of water temperature for Kahshe and Bass Lakes are unlikely to ever generate statistically significant findings, as the climatic variability is too great to satisfy the requirement for levels of probability greater than 95%.

However, there is no escaping the reality that both lakes have physical and chemical features similar to those throughout the Muskoka area, and as such, the projected increases in air temperature that lie ahead are likely to manifest at some time on a local level. This is supported by secondary evidence of lake warming throughout Muskoka in the form of algal bloom development which has been recorded in increasing numbers of lakes for the periods from 1994 to 2010 and from 2018 to 2020. Unfortunately, that now includes Kahshe Lake in 2020.

Although we are unlikely to ever identify a statistically significant trend of increased air and water warming, a change in precipitation patterns or an extended open-water duration through the annual monitoring of Kahshe or Bass Lakes, we need to remain vigilant in these assessment efforts and undertake even greater diligence in reducing nutrient enrichment. We can do this by:

- Pumping out and having our septic systems (tanks/leaching beds) inspected on a regular basis.
- Managing our shorelines to keep them as natural and as vegetated as possible to minimize soil erosion directly into the lake and to provide a cooling influence on the water by providing shade and minimizing sunlight penetration. and,
- Completely avoiding the use of phosphorus or nitrogen fertilizers on any existing lawns, gardens or flower beds in the vicinity of the shoreline.
- Avoiding the use of any boat cleaning products that contain phosphorus, especially in and around the water.

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