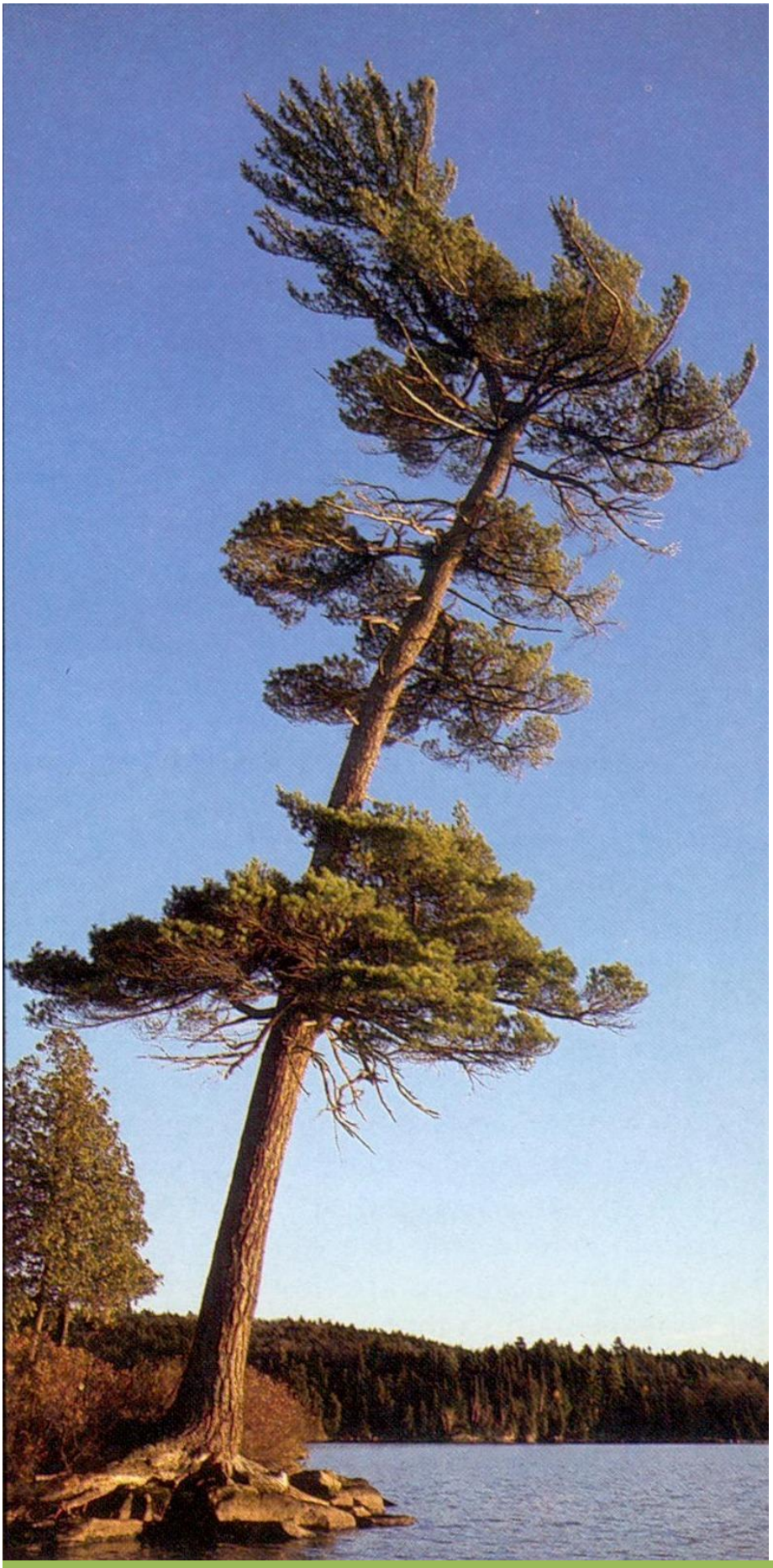

Climate Change and Adaptation in Muskoka

April 2010

Muskoka
WATERSHED COUNCIL

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Acknowledgements

Climate change is the biggest environmental threat currently facing the health of the watershed. How we adapt and live within this changing environment will impact our social, economic and environmental well-being long into the future. The Climate Change and Adaptation report was initiated by Ken Black, an ardent champion of the watershed who firmly believes in good environmental stewardship. Through his writings and educational activity he provides information and encourages people to live responsibly.

Muskoka Watershed Council has also relied on the technical expertise of several local scientists to provide the depth and insight into many aspects of this very challenging topic. Neil Hutchinson, Isobel Heathcote, Ken Riley and Tom Clark all graciously agreed to write specific sections that highlight the impact climate change may have and how we might be able to adapt not only to manage the change but also, in some cases, benefit from a new climatic reality. Without their expertise our understanding of the potential impacts and adaptations for climate change would be incomplete.

Although we sincerely appreciate the input and work of the volunteer authors, the Council takes full responsibility for the final product. The final position and all recommendations are the consensus position of the full Council. The Council also takes full responsibility for any errors.

Executive Summary

Climate change will have a significant impact on the Muskoka watersheds over the next 100 years. Although mitigation is necessary to reduce future climate change impacts, the climate would continue to warm until the end of the current century, even if all carbon emissions ceased today. Adaptation is required to address the impact of climate change in Muskoka.

Between 1948 and 2006, Ontario's average temperature increased by 1.3^0C. Projections made by the Ontario Ministry of the Environment indicate average temperatures over the Great Lakes Basin, including Muskoka watersheds, are likely to continue to increase between 2 and 4^0 C by 2050. The Ministry of the Environment goes on to predict that precipitation may increase by up to 20% by 2050 in all but the summer months, when little or no change is projected. Rising air and water temperatures are already shortening the ice cover season, exposing water to evaporation for more of the year.

Warmer water combined with stronger winds and a longer ice-free period is likely to increase the volume of water evaporating from the surface of lakes. Increased evaporation from the land surrounding the lakes, especially in summer, is likely to reduce the flow in rivers after the spring runoff. In the long term, the most obvious combined result is likely to be a fall in the average lake levels of the four lower Great Lakes currently projected to be between 15 and 115 cm over the next 40 years.[1]

More moisture in a warmer atmosphere is expected to cause an increase in extreme weather events – rain, snow, drought, heat waves, wind, and ice storms. There are indications that this trend has already begun. Weather is also likely to be more variable and less predictable.

Both natural areas and socio-economic aspects of the watershed will be impacted by climate change.

Surface Water

Warmer summers will see increased evaporation of water from lake surfaces and increased transpiration of water by wetlands and forests, meaning less runoff, less water and longer periods of drought. As the watershed gets drier, wetlands will dry out and surface water temperatures will become warmer. Ice will form later in the fall and leave earlier in the spring. The longer ice-free season and warmer surface waters will cause the lakes to stratify earlier.

Earlier onset and stronger, deeper stratification will mean less cold water habitat for lake trout and an increase risk of total loss of oxygen (anoxia) in lakes leading to an

[1] Mortsch, L., E. Snell, and J. Ingram, 2006. "Climate variability and changes within the context of the Great Lakes Basin" in *Great Lakes Coastal Wetland Communities: Vulnerability to Climate Change and Response to Adaptation Strategies.*

internal phosphorus load and the potential for blue green algae blooms (cyanobacteria).

Water quantity may be the most important integrator of response to climate change and should be monitored. Methods to hold back spring freshet and storm waters and release it slowly, sustaining streams during periods of drought and increasing recharge to groundwater, should be explored. Approaches to active lake management should also be explored with the province.

Forests and Wetland

Climate change will have three potential impacts on the forests and wetlands in Muskoka:

- Disease and Insects – as winters are less severe, more invasive species will survive in local forests.
- Extreme weather – The frequency and intensity of extreme weather and climatic events – such as thunderstorms and windstorms, hailstorms, ice storms, intense precipitation events, drought, heat waves, and abnormally warm winters – are likely to increase and this may be apparent by 2030 according to the Ministry of Natural Resources (MNR). More frequent storm events will have significant financial implications as a result of power outages, cleanup operations, and damaged forests.
- Drought – Drought will likely not have as significant an impact on forest health as other climate change factors due to the location of the watershed in the lee of the Great Lakes.

Climate change will increasingly make both animal species and local populations of tree species less well adapted to the climate where they occur. For some species, this will reduce growth at the centre of their range and increase growth closer to the northern end of their distribution. Northward movement of the climate is predicted to be +/- 3 km/year; a tree species' ability to migrate is typically < 1 km/yr. As a result, habitats will change in unknown ways and reaction to changing climate will be species specific. It is anticipated that generalist species, such as beaver, racoons and squirrels, will fare better than some of the unique specialist species found in local forests such as pileated woodpeckers and grey jays.

On the other hand, Muskoka should be in a position to benefit from production of wood products near to major markets. Ironically, despite the rough time that forest products companies have had recently, future prospects may be much brighter, if climate change-appropriate economic policies are put in place.

Biodiversity

Biodiversity can be defined as the range of plant and animal life both in a particular region and across the landscape. These systems in turn depend on a complex and interlinked set of ecological processes, and the physical systems – water, air, soil, and nutrients – on which they depend. It has taken millions of years, through cycles of

fluctuating temperatures, precipitation, and atmospheric concentrations of carbon dioxide, for these systems to evolve.

A healthy ecosystem, with high biodiversity, provides important services to human society. A warmer climate will increase the rate of such processes as photosynthesis, plant growth, decomposition, and nutrient cycling. Disturbance regimes, including fire, insect pests, and invasive species, will also likely increase in frequency and severity in a warming climate, and will test the ability of existing ecosystems to withstand change. Since much of Muskoka's economy derives from its natural environment, it will be important to build on the resilience of those systems as an essential component of adaptation to climate change.

It will be difficult to separate the impact of climate change from other ecosystem stressors such as urban development, alien invasive species, and habitat fragmentation. Careful regional land-use planning, creation of buffer zones, and protection of connected wildlife corridors are necessary to ensure that seemingly innocuous changes on the land surface do not have unintended consequences for biodiversity in a changing climate.

Community Infrastructure

Disruptions to critical community infrastructure as a result of climate change – including water treatment and distribution systems, energy generation and transmission, as well as transportation and residential damage – are likely. Periodic assessment of the risks, in light of climate projections followed by a review of the design standards for new transmission and distribution systems, will be required as trends become clearer, including shifts in the tracking of ice storms.

Human Health

Projections of milder winters suggest that the stresses associated with living in a colder climate will diminish in the years ahead; however, there may be increased risks of illness and premature death as a result of heat waves, smog episodes and ecological changes that support the spread of mosquito and tick-borne diseases such as West Nile Virus, Lyme Disease, and even malaria as the climate changes.

The results will be not only more serious threats to human health, but increased costs and stresses on existing healthcare services and facilities. Clearly, there will be a need for more attention to long-term planning for healthcare in Muskoka.

Tourism

Muskoka's tourism sector is projected to experience some challenges. Winter recreation, like snowmobiling, will suffer some decline and is expected to disappear completely by 2050. In contrast, the season for warm weather activities like golf is expected to increase. Muskoka can anticipate a longer season for recreational water

activities such as swimming and boating. However, there may be a negative impact on water quality.

While the total value of tourism and its ancillary recreational equipment suppliers is unlikely to decrease and could even increase, there will be a shift in the balance of outdoor recreation from winter to warm weather activities.

Agriculture

Warmer summer and winter temperatures will increase the duration of the spring and fall growing season, and expand the range of crops that can be grown. However, the frequency and severity of summer dry periods and droughts will increase the risk of growing these crops. Higher levels of carbon dioxide will promote faster growth, but studies show that nutritional quality may be reduced. Increased winter precipitation will result in faster spring runoff, increasing the risk of soil erosion. Rising temperatures are also expected to increase the potential spread of pests and diseases.

Adaptation to climate change includes the recognition of the small size and isolated nature of Muskoka farms as an important advantage in slowing the spread of crop and animal pest and disease epidemics. The higher organic matter in soils will reduce runoff and erosion due to higher winter precipitation and extreme weather events. The high landscape diversity found on Muskoka's farmland will facilitate the migration of plant, animal and micro-organism species to new habitats, and provide havens for the evolution of new biodiversity.

Conclusions and Recommendations

1. Implement the following actions:
    a. Encourage the District Municipality of Muskoka and Area Municipalities to develop a regional natural heritage strategy that will provide buffer zones and refuges and protection of connected wildlife corridors across the watershed, including areas of farmland and forests.
    b. Work with other watershed interests to develop monitoring programs, waste management programs, and sound land use policies that reduce human impact on the watershed.
    c. Protect wetlands as they are a link between terrestrial and aquatic habitats.
    d. Protect natural areas that can hold back spring freshet and stormwater.
    e. Prevent topsoil removal.
    f. Require appropriate studies in order to understand the impact of land use change on the hydrologic cycle.
2. Develop partnerships with a wide variety of organizations that value an ecologically sound watershed to identify climate change issues and develop adaptation strategies. This may include forestry, agriculture, and provincial and municipal interests and organizations, as well as private landowners and naturalists.
3. Support local resources-based industries including forestry and agriculture.
4. Increase awareness and training of young resource sector workers such as young farmers, loggers and mineral aggregate workers on issues such as water harvesting, endangered species and habitat, and the need to maintain connected natural areas.
5. Encourage active acquisition of land that fits landscape conservation targets.
6. Continue to advocate provincially, nationally, and internationally to reduce carbon dioxide emissions and support local adaptation strategies.
7. Exploration of new technologies:
    a. Periodic assessments of the risk in light of climate projections
    b. Review of design standards.
8. Advocate for strong provincial and municipal regulatory framework to address both climate change mitigation and adaptation.

It is recommended that the Muskoka Watershed Council establish a steering committee to design a process engaging all affected parties to assess vulnerability of Muskoka's watersheds to changing climatic conditions and to identify specific watershed-based strategies for adaption to climate change.

Climate Change in Muskoka: Challenges and Opportunities

The Climate section of the 2007 Muskoka Watersheds Report Card offered an initial look at the changing climate and provided background information related to the history of climate change and human influence on climate change. It identified trends related to temperature, precipitation levels, and global carbon dioxide concentrations. It began to identify some of the implications of those changes for Muskoka watersheds.

Climate is the general or average weather conditions of a certain region, including temperature, rainfall, and wind. Weather is the state of the atmosphere at a given time and place, with respect to the same variables of temperature, rainfall and wind. In other words, climate is the long-term trends and weather is the day-to-day manifestation of those same variables. The 2010 Report Card will address climate change with the understanding that short-term weather patterns will be variable.

Today (2010), some basic facts related to climate change are unchallenged among a clear majority of scientists working in the leading climate research centres and universities around the globe:

- 350 parts per million CO_2 is the number that leading scientists say is the safe upper limit for carbon dioxide in the atmosphere. Current $C0_2$ levels are 390 parts per million;
- $C0_2$ levels continue to rise at the rate of 2 parts per million a year as emission rates track on the high side of most predictions;
- $C0_2$ levels have now risen by 110 parts per million, an increase of 39 % over pre-industrial levels of 280 parts per million, with two-thirds of that increase occurring in the past 50 years;
- $C0_2$ levels are now 30 per cent higher than at any time over the last 650,000 years, and the rate of rise is unprecedented;
- $C0_2$ is a potent greenhouse gas that stays in the atmosphere for 100 years, and the link between $C0_2$ and temperature rise is considered fundamental robust physics;
- Global temperatures are increasing decade after decade. In January 2010, the World Meteorological Organization (WMO) reported "The decade of the 2000s (2000–2009) was warmer than the decade spanning the 1990s (1990–1999), which in turn was warmer than the 1980s (1980–1989)."[2]
- Measurements, not just at weather stations but also by aircraft and satellite, indicate that earlier projections of temperature increases may have been underestimated;
- Recent research reports (Feb. 2010) on a two-year study led by Canadian Dr. David Barber and involving 370 scientists from around the world confirmed the

[2] World Meteorological Organization http://www.wmo.int/pages/mediacentre/press_releases/pr_869_en.html.

melting of the Arctic icepack "much faster than our most pessimistic projections."[3]

Global emissions of carbon dioxide and other greenhouse gases are on track to reach the atmospheric concentration threshold of 450 parts per million within decades. At that point, there's a high probability that average global temperatures, which are already 1 degree C higher than in 1850, will be at least 2 degrees Celsius higher.

If average temperatures were to reach 5 degrees C higher than 1850 – a level we could easily reach within a century under a business-as-usual scenario – computer modeling suggests that changes to the physical geography of the planet become probable: ecosystems will face collapse and human civilization could change dramatically.

Those projections reflect the positions of thousands of climate researchers around the world, and organizations such as the UN's Intergovernmental Panel on Climate Change, the US Global Change Research Program, and National Academies of Sciences from 13 different countries. NASA, the World Meteorological Organization and the National Oceanic and Atmospheric Administration (U.S.), have all declared the 2000s as the hottest decade ever.

The overwhelming scientific opinion indicates that the current steady increase in greenhouse gas emissions must change in the next decade to a steady decrease in greenhouse gas emissions if we are to have any reasonable chance of keeping the global rise in temperature down to manageable levels. Delay risks environmental and economic impacts that may be impossible to handle.

At the same time, it is imperative to recognize that science — the de facto source of dependable knowledge about the natural world — cannot deliver an unqualified, unanimous answer about something as complex as climate change. Consensus does not equal certain truth — in science certain truth does not exist because of the possibility of new information being discovered. That is a major feature of the scientific method.

What does it all mean for Canada, Ontario and, more particularly, Muskoka? This section of the 2010 Muskoka Watersheds Report Card will further expand some of the themes in the 2007 Report Card. It will identify some of the current projections related to the impacts of climate change on our part of the world, as well as the mitigations and adaptations required to reduce some of the negative impacts.

It will attempt to do that using a balanced approach to the available science, focusing primarily on scenarios that seem "most likely," rather than either "best case" or "worst case" scenarios, and it will strive to identify both the challenges and the opportunities that the world's changing climate offers Muskoka.

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[3]Barber, D. Global Newshttp://news.globaltv.com/technology/Arctic+vanishing+faster+than+most+pessimistic+models+researcher/2532081/story.html.

It draws heavily on the findings of some recent and comprehensive studies and reports prepared by senior levels of government and the Ontario Water Resources Association, including:

- From *Impact to Adaptation: Canada in a Changing Climate 2007* released by Natural Resources Canada (NRC).
- The report of the Expert Panel on climate change entitled *Adapting to Climate Change in Ontario* released in late 2009 by the Ontario Ministry of the Environment.
- The recently released report of the Canadian Water Resources Association (CWRA) May 2009 workshop entitled *Adaptation to Climate Change: Understanding Water Management Needs.*
- 2008-09 Annual Report *Climate Change Action Plan by the* Ontario Ministry of the Environment.

As well, some sections of the report will reference research that more specifically reflects data and findings based on research in Muskoka, central Ontario, or the Great Lakes Basin of which the watersheds of Muskoka are a part. Those studies will be identified.

Background Information

Between 1948 and 2006, Ontario's average temperature increased by 1.3 degrees C. Projections within the MOE report indicate average temperatures over the Great Lakes Basin that includes Muskoka watersheds are likely to continue that trend to higher levels of between 2 degrees and 4 degrees C by 2050. Precipitation may increase by up to 20% by 2050 in all but the summer months, when little or no change is projected. Rising air and water temperatures are already shortening the ice cover season, exposing water to evaporation for more of the year.

Warmer water, combined with stronger winds and a longer ice-free period, is very likely to increase the volume of water evaporating from the surface of the lakes. Increased evaporation from the land surrounding the lakes, especially in summer, is likely to reduce the flow in rivers after the spring runoff. In the long term, the most obvious combined result is likely to be a fall in the average lake levels of the four lower Great Lakes currently projected to be between 15 and 115 cm over the next 40 years.[4]

More moisture in a warmer atmosphere is expected to cause an increase in extreme weather events – rain, snow, drought, heat waves, wind, and ice storms. Weather is also

[4] Mortsch, L., E. Snell, and J. Ingram, 2006. "Climate variability and changes within the context of the Great Lakes Basin" in *Great Lakes Coastal Wetland Communities: Vulnerability to Climate Change and Response to Adaptation Strategies.*

likely to be more variable and less predictable. There are indications for Muskoka's public works departments that this trend has already begun.

The MOE Climate Change Action Plan report summarized the overall situation as follows:

> Climate change is not a future threat. It is changing weather today, threatening our communities and quality of life...Even under the most optimistic scenarios for tackling greenhouse gas (GHG) emissions, these effects are expected to persist well beyond the end of this century, affecting generations long into the future. These effects will increasingly create a strain on our economy, be a hazard to our health, and a threat to our quality of life.

The CWRA report highlighted several themes that have particular significance for this report and for future action in Muskoka.

- While recognizing the "need for strong and coordinated government leadership, at all levels of government but especially at the provincial level," it also stressed that "adaptation to climate change will require local action; for example through source water protection planning, low-water response programs, and stormwater management."

- Planning at a watershed level provides an effective framework for climate change adaptation, by providing long-range planning and implementation tools for the management of water resources and aquatic ecosystems. The integration of climate change scenarios into watershed planning also creates a scientifically defensible means to assess climate-related impacts on issues such as flood risk and infrastructure design.

- New decision-making environment and communication networks that offer better knowledge and data sharing will be necessary as we grapple with climate change. This in turn demands improved communication within and between watersheds and jurisdictions, and coordinated data collection and research.

- It also noted the importance of undertaking "no-regrets" actions immediately. For example, water conservation makes sense regardless of climate, as does reduction of wasteful practices such as spray irrigation and excessive lawn watering.

- Given the degree of uncertainty inherent in future climate conditions, ecosystem responses, and our ability to mitigate and adapt to climate change, enhanced community and institutional capacity for decision-making in a dynamic and highly uncertain environment is essential.

- Even with a strong planning framework, an uncertain future means that we must "learn as we go" in our water management strategies. An adaptive-management approach to managing climate change that parallels the current approach being examined for the Lake Ontario Management Plan is stressed.

It is worth noting that at least some of the themes and recommended approaches in the CWRA report have proven their worth in Muskoka. Examples that may contain elements deserving of consideration in meeting the challenges and building on the opportunities presented by the changing climate in Muskoka include:

- The Muskoka Watershed Council focuses on issues at a watershed level and includes representatives of neighbouring municipalities and agencies among its members. It utilizes data sharing and decision-making environments and communication networks in monitoring and communicating data related to watershed health. It advocates no-regrets strategies.

- Savour Muskoka was formed in 2004 and brings together representatives from the agricultural, hospitality, retail, and micro-processing industries to promote the Muskoka/Parry Sound region as a dynamic culinary tourism destination. Their success in working within and between watersheds and jurisdictions, and building enhanced community and institutional capacity in support of healthy environments and economic growth, offers a model worthy of emulation.

- While still in its infancy, the Muskoka Envirocredits initiative features many of the approaches identified in the CRWC report including working within and between watersheds and jurisdictions in Muskoka and Parry Sound, and no-regrets strategies that offer climate change mitigation and adaptation, enhanced watershed health, and economic benefits through a strengthened forestry sector.

- There are cooperative approaches within and between the District Municipality of Muskoka and neighbouring conservation authorities in planning for source water protection. The District Municipality of Muskoka is divided between two watershed regions. The southern portion of the District is part of the South Georgian Bay-Lake Simcoe Watershed Region encompassing the Nottawasaga Valley Conservation Authority, the Lake Simcoe Region Conservation Authority, the Severn Sound Environmental Association and the Black-Severn River watersheds; the Muskoka River watershed is a separate watershed region.

The following sections of this report have been written by a number of experts and practitioners in various fields and provide more specific insights into the potential impacts of climate change in Muskoka along with suggested adaptations. The topic areas are discussed under two headings – those related to the natural areas of water, forests and wetlands, and biodiversity; and those impacting more directly on socio-economic activity such as community infrastructure, tourism, human, health and agriculture.

Natural Impacts

Muskoka's Surface Water

Neil Hutchinson

Artists say that lakes are the mirror of the soul. Scientists would say the same thing in a different way: lakes are the mirror of the watershed – the soul and reflection of upstream landscape and watershed processes. Water falls from the sky, runs downhill and is captured in depressions to form lakes. Lakes therefore integrate the total of the processes affecting them, natural and human. Lakes also store centuries of watershed history in their sediments – and understanding their responses to past changes can help us predict their responses to future changes.

We can start with the basic responses to a warming climate. The most recent predictions are for an average temperature increase of 2 - 4°C for the Muskoka region and 20% more precipitation, though not in the summer months.

Warmer summers will see increased evaporation of water from lake surfaces and increased transpiration of water by wetlands and forests, meaning less runoff, less water and longer periods of drought. We may see more precipitation earlier in the winter as Georgian Bay takes longer to freeze and the prevailing winds pick up its moisture to drop it on Muskoka. Warmer winters will see more winter thaws and winter rains such that the large thaw and flooding we saw in January 2009 may become a more commonplace occurrence. If the snowpack is reduced due to mid-winter thaws then less snow pack remains for the March and April freshet and we could see an earlier onset of drought and lower water levels.

Slight changes in the balance between precipitation and evapotranspiration can have dramatic effects but exact prediction is difficult. We know from reconstructions of lake histories from their sediments that temperature increases that were smaller than those predicted for our future have, in the past, seen much of Lake Winnipeg revert to a wetland, and Lake Huron tens of metres below current levels. Lake Superior would appear very vulnerable to a drier climate in the west (which reduces its inflows) and a longer ice-free season (which increases evaporation from its surface). As Lake Superior water levels drop, so do those in the lower lakes.

As the watershed gets drier, wetlands will dry out. This will result in a faster rate of oxidation of peat stored in the wetlands which will accelerate the increase of CO_2 to the air, creating a positive feedback loop of accelerating global warming. The loss of peat will also reduce the export of dissolved organic carbon (DOC) to our lakes – the familiar "tea colour" of Brandy Lake will become less intense. Changes in DOC dynamics will have effects (as yet unknown) on metal and nutrient dynamics in lakes.

What does a warmer climate mean to the lakes themselves? The first answer is the easiest – surface waters will be warmer. Perhaps our first swim of the year (at least for adults) will occur on May 24 instead of July 1. But other changes are related to this

simpler change. Ice will form later in the fall and leave earlier in the spring. The longer ice-free season and warmer surface waters will cause the lakes to stratify earlier – an earlier onset of their familiar summer pattern of 6 - 10m of a warm surface layer over colder, denser deep waters that do not mix with the surface waters again until they cool in the fall. Warmer surface temperatures not only bring the stratification earlier, they make it more stable.

Earlier onset and stronger, deeper stratification means less cold water habitat for lake trout, a longer period of oxygen demand in the cold, deep waters and less volume of deep waters to assimilate the increased oxygen demand. The result is less oxygen in the deep waters – a problem for lake trout but also increasing the risk of total loss of oxygen (anoxia) in lakes that are deep enough to stratify but not really deep. At this point there is a risk of internal phosphorus load from anoxic lake sediments – another source of phosphorus that is available to algae in midsummer (especially those species that are able to migrate vertically to take advantage of it) but also in the fall when the lakes turn over again. We have already seen this pattern in Sturgeon Bay of Georgian Bay. Other inlets of Georgian Bay are low in oxygen (hypoxic) now. An earlier stratification may have a dramatic effect in these waters and produce conditions of anoxia and internal nutrient load. Blue green algae (cyanobacteria) and their associated toxins may become more familiar than the sporadic blooms seen in Sturgeon Bay, Three Mile Lake and Brandy Lake.

So what can we do about it?

Changes in Muskoka's climate must be reflected in changes to how we manage our lakes. Presently our local management efforts are focused on those actions that we can control locally – we run good monitoring programs, minimize our nutrient inputs through excellent sewage treatment, develop wise policies for land use and lake management, and support the great research in lake ecology that has come out of the Ministry of the Environment's (MOE) research labs in Dorset. Locally, the District government may need to expand its excellent lake water quality program and work with MNR/MOE to expand and fine tune means of monitoring water quantity – lake levels, stream flows and periods of drought. Water quantity may be the most important integrator of response to climate change. Some responses to this could be simple. A recent study by University of Alberta scientists showed that allowing beaver populations to increase in the landscape produced many small but leaky dams. These held back spring freshet and stormwaters and released it slowly, sustaining streams during periods of drought and increasing recharge to groundwater.

The acid rain focus of the 1980s showed us that local influence could change policies throughout North America to reduce acid emissions. We must now put the same effort into worldwide efforts to reduce carbon dioxide emissions. We could start by recognizing that our recreational economy in Muskoka is supported by per-capita carbon dioxide emissions that are among the highest in the world. How can we build a more sustainable economy? But locally, and in the meantime, we must now manage lakes to adapt to changes in the climate – we can't solve the carbon dioxide problem

locally but we may be able to manage the response to the large changes in lake dynamics highlighted above.

Active lake management will require a change in attitudes, both locally and among our provincial and federal regulators. It is possible to manage changes in thermal structure and oxygen status of lakes to prevent their worst consequences, should society's values accept this form of adaptation. It has been done safely in the USA for decades through active lake management techniques such as aerating or mixing lakes and by adding chemicals to the water to lock up nutrients in the bottom sediments. The technology and methods are well established and some have been tried experimentally in Ontario. We will, of course, need to find the regulatory structures to ensure that techniques are used safely and wisely.

Woodlands and Wetlands

Tom Clark

Although forests and wetlands are complex ecosystems, their positive role in moderating climate change is clear. Forests and wetlands hold large amounts of carbon in their plant life. Even dead plants that build up on the bottom of wetlands and on the forest floor contain far more carbon than urban or agricultural land. In general old forests hold more carbon than young ones, but as they age, the storage rate declines. Young forests hold less carbon but absorb a lot in order to grow quickly. Wetlands behave in a similar way. In fact, wetlands, like peat bogs, can store carbon for millennia, because the level of decay in the bottom of a bog is very low, due to a higher acid level. However, the growth rate of plants in a bog is also very low. The balance between absorbing carbon quickly, and holding onto it for a long time is one of the questions that scientists are looking into now.

There have been a number of reports that attempt to describe what irregular climate is going to do to Ontario's forests and wetlands over the next few decades. The Natural Resources Canada 2007 report summarizes the national implications of climate change indicating that there are three main issues in Muskoka that are most compelling, although it would be hard to say which may ultimately have the greatest impact:

- Disease and Insects – generally referred to as "forest health," affect many aspects of the life of trees;
- Extreme weather – leads to physical damage to trees during extreme weather events like ice storms;
- Drought – adds stress to trees, and potentially some additional risk from fire.

Forests and wetlands in Muskoka can lock up carbon (and pollutants) for generations. Unlike the south of the province where there has been years of land conversion, Muskoka still benefits from a biologically productive environment. Opportunity exists to continue to benefit from our natural environment far into the future if there is a strong stewardship program and forest management embraces a range of adaptation measures.

Forest Health – Insects and Disease

Forest health is often dependent on keeping insect populations in balance. When there is a new, invasive insect this balance is hard to maintain. Most notable is the vast area of British Columbia's forest that has been defoliated by the Pine Beetle. In Muskoka, there have not been massive insect or disease impacts to date but the balance seems to be shifting in favour of the invasive insects.

The fast spread of introduced species through our forests is the tip of an iceberg of species that arrive every year in Muskoka, at least partly because weather conditions are less hostile. Some bring benefits, like the introduction of the wild turkey, but destructive species, including many insects, are coming too. Harsh climate and weather conditions have kept Muskoka's forests and wetlands supporting a relatively small number of species. Every new species upsets that balance, some more than others. If a large number of species arrive in a short time then the balance can become very skewed, causing other local plant and animal species to drop to low levels.

The list of new insects approaching Muskoka is long. One threat is the Asian longhorn beetle[5] that could reduce the number and health of one of our most symbolic and beautiful species, the sugar maple. Previously, exotic insects have brought Dutch elm disease (a fungus); first observed in Canada in 1944, it is still killing older elms today. The gypsy moth caused moderate to severe defoliation of 6,400 km^2 of forest in Ontario and Quebec between 1982 and 1987.[6] In Muskoka the damage was most noticeable on oak trees.

Cold winters that have historically kept some insects out of Ontario will occur less frequently, resulting in possible expansions of insect ranges. For example, mountain pine beetle, which in recent years expanded its range into boreal forests in northern Alberta, may reach Ontario's pine forests before 2050. White pine is not the primary target of this beetle, but it does use other species in the absence of its host. Jack pine is very likely to be affected, although this is not widely distributed in Muskoka.

Impacts of existing insect fauna are increasing in distribution, area, duration, and intensity. In Muskoka damage can be seen commonly from hemlock looper, spruce budworm, and forest tent caterpillar.[7] It is likely that the status of some insects will change from relatively innocuous to severely disruptive and there will be increased uncertainty about the timing and magnitude of major insect outbreaks.

Drought, extreme weather events, and high temperatures add stress to wetlands and woodlands, and increase insect and disease outbreaks by weakening the trees' ability

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[5] Natural Resources Canada-- http://imfc.cfl.scf.rncan.gc.ca/insecte-insect-eng.asp?gelD=1000095&ind=A.

[6] Natural Resources Canada -- http://imfc.cfl.scf.rncan.gc.ca/questions-eng.html.

[7] Natural Resources Canada -- http://imfc.cfl.scf.rncan.gc.ca/insecte-insect-eng.asp?gelD=9374.

to withstand additional stress. As a result, most diseases are expected to increase within Ontario forests, and none are anticipated to decline.[8]

Extreme Weather

The frequency and intensity of extreme weather and climatic events, such as thunderstorms and windstorms, hailstorms, ice storms, intense precipitation events, drought, heat waves, and abnormally warm winters, are likely to increase and this may be apparent by 2030 according to MNR.[9] The effect of ice storms on maple forests was studied by OMNR following the 1998 eastern Ontario event and was shown to have the effect of reducing syrup output for a number of years after.

The windstorm that occurred across southern Ontario in the early summer of 2009 was reported for its human impact. The forest impact was also massive, and cleanup will be continuing for a number of years. Renewal activities, where they are possible, are expensive and not budgeted for by any level of government. More frequent storm events will have significant financial implications.

Drought

Current climate change models are imprecise as to the change in precipitation that can be expected in Muskoka over the next several decades. Although the report of the Expert Panel on climate change released by the MOE in 2009 states that precipitation may increase by up to 20% by 2050 in all but the summer months, other reports suggest a possible 10% decline in precipitation in the winter months[10]. With respect to the impact on forests, the change in precipitation as a result of climate change will likely not have as significant an impact on forest health as other climate change factors. Muskoka may be lucky due to our location in the lee of the Great Lakes; increased drought may be counterbalanced by increased precipitation in other seasons.

What may be more significant is how that precipitation is received. With the potential for more ice storms, more intense rainstorms, and wind storms, extreme weather may be more of a concern.

The most visible effect of drought in Muskoka is the brown hill tops that have occurred a few times in the last decade, when there has been one of those slightly longer, slightly hotter Muskoka summers. Muskoka's rocky glaciated hilltops suffer more from drought simply because the soils are often shallow and hold less water.

In the summer season, the projected increases in summer temperatures with no or little increase in precipitation would increase the frequency and severity of drought by

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[8] Colombo, S.J. 2008. Ontario's Forests and Forestry in a Changing Climate. Ontario Forest Research Institute. OMNR 31 pp.

[9] Ibid.

[10] S.J. Colombo, D.W. McKenney, K.M. Lawrence and P.A. Gray. 2007. Climate Change Projections for Ontario: Practical Information for Policymakers and Planners. Ontario Ministry of Natural Resources, Applied Research and Development Branch. Climate Change Research Report CCRR-05. Sault Ste. Marie, ON.

elevating evapotranspiration[11]. As a result, some predict that there may be lower stream/lake levels and smaller and fewer wetlands.

Although trees can generally recover from a short drought period, they may become weakened and more susceptible to insects and disease. The complex interaction of trees with insects and disease makes it difficult to project the timing and extent of effects of climate change on these disturbances. However, if drought increases, tree stress, the occurrence and severity of insect and disease outbreaks are also likely to increase.[12]

Adaptation and Opportunities

Climate change will increasingly make both animal species and local populations of tree species less well adapted to the climate where they occur. For some species, this will reduce growth at the centre of their range and increase growth closer to the northern end of their distribution. The long lives of trees and their slow natural migration means that natural processes will be unable to move seed fast enough to match changing climate. Northward movement of the climate is predicted to be +/- 3 km/year; a tree species' ability to migrate is typically < 1 km/yr. As a result, habitats will change in unknown ways and reaction to changing climate will be species specific.

Forest managers may consider planting non-local species; however, this needs to be carried out with consideration of potential negative consequences. According to the UN's International Panel on Climate Change, sustainable forest management that maintains forest carbon stocks and provides a sustained yield of wood products provides the best long-term climate change mitigation strategy for forests. Wood products from forests store carbon and can also reduce greenhouse gas emissions from fossil fuels

Solid wood products have considerably lower energy intensity than building materials such as steel, aluminum, and concrete. Muskoka should be in a position to benefit from production of wood products near to major markets. Ironically, despite the rough time that forest products companies have had recently, future prospects may be much brighter if climate change appropriate economic policies are put in place.

Conclusions and Recommendations

The effort and financial resources required to re-establish a natural landscape is well beyond the Province of Ontario let alone even the largest municipalities. Taking action now to develop sound economic strategies for the forestry industry that are based on ecological principles will ensure a healthy forestry industry in the future. As a watershed community we need to develop objectives for our landscape by establishing a balance between natural and man-made land uses. Clear minimum standards at a landscape level for these land uses that meet conservation, investment and aesthetic

[11] Colombo, S.J. 2008. Ontario's Forests and Forestry in a Changing Climate. Ontario Forest Research Institute. OMNR 31 pp.

[12] Ibid.

requirements are necessary. These community values must then be incorporated into a watershed-wide strategic plan and supported by municipal planning documents that ensure that we do not slip below the established standards. A Natural Areas Strategy developed and implemented by the District Municipality of Muskoka in conjunction with Area Municipalities would provide this strategic guidance. The Muskoka Watershed Council Report Card can then report progress, change, and losses to the public.

Specific strategies to achieve a long-term ecological balance should include:

1. Watershed-based strategic plans that recognize future challenges, encourage species diversity, and address other climate change adaptation activities.
2. Partnerships with a wide variety of organizations that can work together to identify climate change impacts and develop cooperative adaptation strategies. This may include the forestry, agriculture, private landowners, naturalists, provincial and municipal interests and organizations.
3. Active acquisition of land that fits landscape conservation targets.

Biodiversity

Isobel Heathcote

Biodiversity can be defined as the range and variability of genes, species, and ecosystems both within a region and across the landscape. These systems in turn depend on a complex and interlinked set of ecological processes, and the physical systems – water, air, soil, and nutrients – on which they depend. It has taken millions of years, through cycles of fluctuating temperatures, precipitation, and atmospheric concentrations of carbon dioxide, for these systems to evolve. The survival of individual species has depended on their ability to adapt their growth characteristics and shift their ranges in response to changing environmental conditions. Until the last two centuries, however, that evolution took place in landscapes that were largely undisturbed by human activity.

Today, human development, including urbanization and industrial growth, has led to the fragmentation of natural habitat into smaller, disconnected patches in much of the developed world. In many areas, species are now confined to these patches, limiting their breeding opportunities and reducing their genetic diversity. In Muskoka, while much habitat remains in a relatively undisturbed condition, development pressure, including new residential construction and supporting infrastructure, continues to increase. At a landscape level it will be important to maintain an appropriate mix of open land/ agricultural/mature forest/ regenerating forest/ small bush lots (both privately managed and protected) as well as wetland and lakefront ecosystems to ensure the long-term health of the watershed. A warming climate will add additional stress to Muskoka ecosystems that are already undergoing change from other forces.

The following sections describe how climate change may be expected to affect Muskoka's terrestrial and aquatic ecosystems.

Ecosystem Goods and Services

A healthy ecosystem, with high biodiversity, provides important services to human society, not just in the production of food, timber, and other products, but also by regulating water quality and flows, reducing flooding, and moderating local climates. Ecosystem goods and services also include things like pollination services – essential for food production – and carbon storage. In the United States, for example, there is enough carbon stored in trees and forest products to offset about 20 percent of U.S. fossil fuel carbon emissions.[13,14] Climate change has the potential to impact these valuable goods and services by changing physical conditions such as air temperature and moisture levels, and the rate of fundamental processes like photosynthesis. Biodiversity has already been reduced throughout much of Ontario and the rest of Canada through human activities. Climate change will accelerate those losses unless we are careful to include biodiversity protection measures in our climate change adaptation strategies.

Ecosystem Processes

A warmer climate will increase the rate of the fundamental processes on which ecosystem function depends, including photosynthesis, plant growth, decomposition, and nutrient cycling. The growing season will be longer and that, combined with plentiful carbon dioxide in the atmosphere, will encourage plants to grow faster. We may well see faster, more abundant weed growth, for example, while the impact on mature forests may be less noticeable. On the other hand, faster growth rates could also improve the efficiency with which plant species use water, and increase their tolerance to drought. More rapid plant growth may be offset by earlier death and faster decay rates. As a result, the processes that we rely on to maintain soil fertility may be altered in unexpected ways.[15] These kinds of changes are difficult to predict accurately, but could have a profound impact on ecosystem composition and resilience to change.

Climate change will affect how much precipitation falls as rain as opposed to snow, and this in turn will affect the flow regimes of lakes and rivers, and the moisture content

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[13] Pacala, S., R. Birdsey, S. Bridgham, R.T. Conant, K. Davis, B. Hales, R. Houghton, J.C. Jenkins, M. Johnston, G. Marland, and K. Paustian, 2007: The North American carbon budget past and present. In: *The First State of the Carbon Cycle Report (SOCCR): The North American Carbon Budget and Implications for the Global Carbon Cycle* [King, A.W., L. Dilling, G.P. Zimmerman, D.F. Fairman, R.A. Houghton, G. Marland, A.Z. Rose, and T.J. Wilbanks (eds.)]. Synthesis and Assessment Product 2.2. National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, NC, pp. 29-36.

[14] Gutierrez, B.T., S.J. Williams, and E.R Thieler, 2009: Ocean coasts. In: *Coastal Elevations and Sensitivity to Sea-level Rise: A Focus on the Mid-Atlantic Region* [J.G. Titus (coordinating lead author), K.E. Anderson, D.R. Cahoon, D.B. Gesch, S.K. Gill, B.T. Gutierrez, E.R. Thieler, and S.J. Williams (lead authors)]. Synthesis and Assessment Product 4.1. U.S. Environmental Protection Agency, Washington, DC, pp. 43-56.

[15] Janetos, A., L. Hansen, D. Inouye, B.P. Kelly, L. Meyerson, B. Peterson, and R. Shaw, 2008: Biodiversity. In: *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States* [Backlund, P., A. Janetos, D. Schimel, J. Hatfield, K. Boote, P. Fay, L. Hahn, C. Izaurralde, B.A. Kimball, T. Mader, J. Morgan, D. Ort, W. Polley, A. Thomson, D. Wolfe, M.G. Ryan, S.R. Archer, R. Birdsey, C. Dahm, L. Heath, J. Hicke, D. Hollinger, T. Huxman, G. Okin, R. Oren, J. Randerson, W. Schlesinger, D. Lettenmaier, D. Major, L. Poff, S. Running, L. Hansen, D. Inouye, B.P. Kelly, L. Meyerson, B. Peterson, and R. Shaw (eds.)]. Synthesis and Assessment Product 4.3. U.S. Department of Agriculture, Washington, DC, pp. 151-181.

of wetlands. Warmer springs and summers can be expected to bring more extreme weather events, such as severe thunderstorms and tornadoes,[16] and therefore have the potential to increase the frequency and severity of natural disturbances such as wind and fire. Upland forests in particular are expected to experience prolonged periods of drought, and will be more susceptible to fire. Where fires are set by humans, for example to burn off cover on agricultural land or open ground, drier conditions may encourage the spread of fire to neighbouring forests.

Some scientists believe that climate change will encourage the spread of certain diseases and parasites, and create conditions in which insect pests can thrive. There is also evidence that warmer temperatures can affect the immune responses of individual plant and animal species, making them more vulnerable to diseases and pathogens. For example, wood frogs and bullfrogs are already under threat of infectious diseases like chytridiomycosis and ranaviral disease.[17,18] A warmer climate would place additional stress on these species and reduce their ability to cope with infection.[5,19] Warmer weather will also disrupt animal hibernation and feeding cycles.[20] Bears will likely emerge earlier from their dens, and while blackfly season could start earlier, drier conditions may mean fewer blackflies and mosquitoes through the summer months. The impacts of forest insect pests like spruce budworm, jack pine budworm, and forest tent caterpillar are expected to increase, both because the climate will be more hospitable for those species and because Muskoka's forests will be more vulnerable to attack because of stress from heat and drought.[21]

Temperature changes can even affect the ratio of males to females in some animal populations. For example, there is evidence that some reptile species experience an increase in male offspring when temperatures increase.[22] Fewer females in the population means less reproductive potential. Over time, we could expect to see changes in ecosystem composition, as some species fail to reproduce successfully while others flourish.

In aquatic systems, temperature and precipitation changes will likely mean an earlier spring melt, larger spring flows, and longer, drier summers. Wetland areas may be particularly at risk. In 2000, the United Nations Environment Programme's World

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16 Etkin, E. David, 1995. Beyond the year 2000, more tornadoes in western Canada? Implications from the historical record. Atmospheric Environmental Services, Downsview, ON.

17 Carey, C., Cohen, N., and L. Rollins-Smith. 1999. Amphibian declines: an immunological perspective. *Developmental and Comparative Immunology*. 23(6): 459-427.

18 Gantress J., Maniero G.D., and N. Cohen.2003.Development and characterization of a model system to study amphibian immune responses to iridoviruses. *Virology*. 311 (2): 254-262.

19 Battin, J., M.W. Wiley, M.H. Ruckelshaus, R.N. Palmer, E. Korb, K.K. Bartz, and H. Imaki, 2007: Projected impacts of climate change on salmon habitat restoration. *Proceedings of the National Academy of Sciences*, **104(16)**, 6720-6725.

20 Blehert, B.S., Hicks, A.C., Behr, M., Meteyer, C.U., Berlowski-Zier, B.M., Buckles, E.L., Coleman, J.T.H., Darling, S.R., Gargas, A., Niver, R., Okoniewski, J.C., Rudd, R.J., and W. B. Stone. 2008. Bat White-nose syndrome: an emerging fungal pathogen? *Science*. October 30, 2008.

21 Volney WJA, Fleming RA (2000) Climate change and impacts of boreal forest insects. *Agriculture Ecosystems and Environment* **82**: 283-294.

22 Janzen, F. J. (1994) Climate change and temperature-dependent sex determination in reptiles. *Proceedings of the National Academy of Sciences.* Vol 91, Number 16, Pages 7487-7490.

Conservation Monitoring Centre reviewed the vulnerability of world ecosystems to climate change (UN website: http://www.unep-wcmc.org/climate/default.aspx). They estimated that a warming of 3° to 4° C would eliminate 85% of the world's remaining wetland areas. In a warmer climate, wetland areas will experience more variable water levels and periodic drying, making it difficult for moisture-loving plant and animal species to thrive.

In lakes and streams, several factors could affect the ability of fish populations to reproduce successfully. High spring flows and more violent storms will wash away fish eggs incubating in stream sediments. The remaining eggs will hatch earlier with warmer stream temperatures, and faster metabolic rates will cause the young fish to grow more rapidly and eat more food. But there is no guarantee that the insects on which these young fish depend will be available in sufficient numbers at the right time of the year, so the hatchlings may not survive. Finally, as average water temperatures increase and water levels drop, conditions will gradually become less hospitable for coldwater sport fish species, such that lakes where existing coldwater species are already stressed may no longer be able to support those highly prized species.

Ecosystem Composition

The species composition of ecosystems will almost certainly change as the climate warms. Different ecosystems will respond differently to climate change, depending on existing conditions, the presence of other stressors such as pollution or habitat fragmentation, the degree of change, and how able their species are to adapt to the new conditions. Some species are able to shift their ranges easily, because of their size, growth rate and, in the case of plants, the ways in which their seeds disperse. Others – for example, forest plants in highly fragmented landscapes – shift much more slowly, perhaps only a few metres a year.[23] Even if a species is successful in moving to a new region, it may not be able to survive in the new setting if it does not have access to the physical conditions (soil, moisture levels, habitat structure) and food species it requires.[24,25]

In a changing climate, species that are "habitat specialists" – those that are adapted to a particular type of habitat and food source, such as the pileated woodpecker – are much more likely to experience significant declines than habitat "generalists," for example crows. Similarly, species that are fixed in place, like freshwater clams and bottom-dwelling invertebrate organisms, will be more at risk than mobile species like birds or fish. Yet even small invertebrates are important prey for larger animals, so a decline in their numbers and diversity will have consequences for higher levels of the food web.

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[23] Varrin, R., J. Bowman, and P.A. Gray. 2007. The Known and Potential Impacts of Climate Change on Biodiversity in Ontario's Terrestrial Ecosystems: Case Studies and Recommendations for Adaptation. Climate Change Research Report CCRR-09, Applied Research and Development Branch, Ontario Ministry of Natural Resources, Sault Ste. Marie, Ontario. 48pp.

[24] Taylor, P. D., L. Fahrig, K. Henein, and G. Merriam. 1993. Connectivity is a vital element of landscape structure. *Oikos*, 68: 571-572.

[25] Colombo, S.J. 2008. Forests and Forestry in a Changing Climate. Climate Change Research Report CCRR-12. Ministry of Natural Resources, Sault Ste. Marie, Ontario. 21pp.

Plant and animal species that reproduce quickly and disperse easily are most likely to succeed in a changing climate, both because they are well adapted to change and because they will be able to take advantage of gaps left by less successful colonizers. The result could well be fewer species overall – lower biodiversity – and simpler ecosystem composition. Again, it is difficult to predict these kinds of changes with certainty. However, we should not expect that more southern ecosystems, for example the "Carolinian" forests typical of Virginia and the Carolinas, will simply shift northward intact. Rather, as some species' ranges grow and others contract, the result will be new combinations of species that are unlike any ecosystems we now recognize.

In regions where there is already extensive habitat fragmentation, for example in southwestern Ontario, climate change will likely have a significant impact on the structure and function of remaining habitat. In less disturbed areas, including Muskoka, we can help build resilience to climate change by retaining as much contiguous, intact habitat as possible and avoiding fragmentation of habitat into disconnected patches.[10,26,27,28]

Alien Invasive Species

Alien invasive species may be particularly well suited to a changing climate, because of their rapid growth rates and ability to withstand a range of environmental conditions.[29] Most do not require external pollinators or seed dispersers, and can therefore spread quickly once they are present in a hospitable location. In a warming climate, they may be better able to migrate and establish themselves, out-competing native plants for habitat and nutrients. Landscapes that are already disturbed by overgrazing or clearance may be especially susceptible to invasion[30], but even natural systems may be at risk.

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[26] Travis, J.M.J. 2003. Climate change and habitat destruction: A deadly anthropogenic cocktail. Proceedings of the Royal Society (London B), 270:467-473.

[27] Inkley, D.B., M.G. Anderson, A.R. Blaustein, V.R. Felzer, B. Griffith, J. Price, and T.L. Root. 2004. Global Climate Change and Wildlife in North America. *Technical Review* 04-2, The Wildlife Society, Bethesda, Maryland, U.S.A

[28] Opdam, P., D. Wascher. 2004. Climate change meets habitat fragmentation: Linking landscape and biogeographical scale levels in research and conservation. *Biological Conservation* 117:285-297.

[29] Rahel, F.J., and J.D. Olden. 2008. Assessing the effects of climate change on aquatic invasive species. *Conservation Biology*, 22(3): 521-533.

[30] Ryan, M.G., S.R. Archer, R. Birdsey, C. Dahm, L. Heath, J. Hicke, D. Hollinger, T. Huxman, G. Okin, R. Oren, J. Randerson, and W. Schlesinger, 2008: Land resources. In: *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States* [Backlund, P., A. Janetos, D. Schimel, J. Hatfield, K. Boote, P. Fay, L. Hahn, C. Izaurralde, B.A. Kimball, T. Mader, J. Morgan, D. Ort, W. Polley, A. Thomson, D. Wolfe, M.G. Ryan, S.R. Archer, R. Birdsey, C. Dahm, L. Heath, J. Hicke, D. Hollinger, T. Huxman, G. Okin, R. Oren, J. Randerson, W. Schlesinger, D. Lettenmaier, D. Major, L. Poff, S. Running, L. Hansen, D. Inouye, B.P. Kelly, L. Meyerson, B. Peterson, and R. Shaw (eds.)]. *Synthesis and Assessment Product* 4.3. U.S. Department of Agriculture, Washington, DC, pp. 75-120.

Conclusions

Muskoka's rich and varied natural resources are among its greatest assets, and the foundation of much of the region's economy. Biodiversity and healthy ecosystem function contribute to those assets, providing essential ecological goods and services. Climate change will place new stresses on Muskoka's species and ecosystems, especially where habitat is already affected by poorly managed land clearance and development. Disturbance regimes, including fire, insect pests, and alien invasive species, will likely increase in frequency and severity in a warming climate, and will test the ability of existing ecosystems to withstand change. Since much of Muskoka's economy derives from its natural environment, it will be important to build the resilience of those systems as an essential component of adaptation to climate change.

It can be difficult to separate the impact of climate change from other ecosystem stressors such as urban development, alien invasive species, and habitat fragmentation.[31] Changes in one part of a watershed (for example new suburban development), can alter water flows and change wetland function, shorelines, river habitats, and upland forests, in turn changing the ways that water and nutrients flow through the system into lakes and streams.

In Muskoka, we must approach such changes with caution, to ensure that seemingly innocuous changes on the land surface do not have unintended consequences for biodiversity in a changing climate. This will require both good private land stewardship and public management and regulation. For example, careful regional land-use planning, creation of buffer zones and refuges where necessary, and protection of connected wildlife corridors throughout the region will be required. This is a big task in our large and complex region. Therefore it will be important to prioritize our biodiversity conservation efforts, so as to focus on the needs of the most sensitive species and ecosystems.

Wetlands are particularly valuable as a link between terrestrial and aquatic ecosystems, and their high biodiversity makes them an important focus of protection. Elsewhere, measures that protect valued ecosystem components, retain habitat connectivity, and create transition zones between intact habitat and human development will contribute to building the resilience of Muskoka's ecosystems in a changing climate. Programs that involve landowners in the development of management systems and engage them in private land stewardship activities will be important if biodiversity is to be maintained at both the landscape and site level.

[31] Lake Simcoe Science Advisory Committee, 2008. Lake Simcoe and its Watershed: Report to the Minister of Environment, 100 pages.

Socio-Economic Impacts

Community Infrastructure

Ken Black

This section of the report draws heavily on information and data from two reports – the 2007 Natural Resources Canada study identified in the introduction to this report, and the 2007 report entitled *Adapting to Climate Change: An Introduction for Canadian Municipalities* prepared by the Canadian Climate Impacts and Adaptation Research Network (C-CIARN), a program within the same federal ministry, Natural Resources Canada.

The 2007 Natural Resources Canada study indicated that disruptions to critical community infrastructure as a result of climate change, including water treatment and distribution systems, energy generation and transmission, as well as transportation and residential damage, are likely.

That message was reinforced in the C-CIARN report in the following statement:

> Built systems are likely to endure greater exposure to extreme events in the future, resulting in increased demand for maintenance and upgrades. Energy transmission networks such as towers and their supports may suffer damage from severe windstorms or ice storms. Water and sewage networks may need to accommodate more intense precipitation. Municipalities need infrastructure that can withstand future climate conditions to ensure it is dependable and maintain safety (for example, milder winters are likely to bring about more freeze-thaw cycles, which trigger pot-hole development on roads).[32]

In 1997, an earlier report by Environment Canada, *The Canada Country Study* warned that

> More frequent freeze-thaw cycles could increase weathering. Freeze-thaw cycles, ultraviolet (UV) radiation and acid rain weather exterior surfaces. Severe weather events can damage or destroy structures. Snow and excessive rainfall affect operations on construction sites. Variations in temperature can cause building materials to expand and contract. [33]

The 2007 Natural Resources Canada (NRCan) report cited as examples recent severe storm events including the flooding associated with an intense storm system moving across south-western Ontario in August 2005 that caused extensive flood and infrastructure damage resulting in $500 million in homeowner and insured losses; as well

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[32] Canadian Climate Impacts and Adaptation Research Network, *Adapting to Climate Change: An Introduction for Canadian Municipalities*, 2007. http://www.c-ciarn.ca/adapting_e.html.

[33] Street, Roger, Atmospheric Environment Services, Environment Canada, *Canada Country Study*, 1997.

as multi-million dollar storms that caused flooding in north-western Ontario (Rainy River) in 2002, and in Peterborough in 2004.

The same report also identified concerns related to the impact of climate change on municipal
infrastructure projecting that "increased flooding, prolonged dry periods, droughts and other severe weather events will pose additional challenges for Ontario's physical infrastructure beyond the need for an aging system to respond to the increased demands and levels of service required by a growing society."[34]

It noted that

> Infrastructure failures, such as the culvert and road washout on Finch Avenue in the City of Toronto in August 2005, as well as the extensive flooding in Peterborough in 2004 caused by severe rain, raise concerns that stormwater infrastructure in many areas of Ontario may not be able to cope with the challenges of climate change, at least not in its existing condition.[35]

Another impact of weather extremes could well be reductions in hydroelectricity output. The Ontario MOE report stated: "Adaptation of the province's electricity distribution and transmission infrastructure to climate change, notably more frequent and severe windstorms and precipitation events, especially ice storms, must be a priority."[36]

It suggested that periodic assessment of the risks in the light of climate projections followed by a review of the design standards for new transmission and distribution systems will be required as trends become clearer, including shifts in the track of ice storms.

Of particular interest in Muskoka was a reference in that report urging increased development of local generating capacity:

> The climate resilience of the provincial grid, as well as the resilience of the communities it serves, will benefit from development of local generating capacity that shares and spreads the risk of climate impacts. Reducing the vulnerability of the provincial network in this manner would help protect people, communities and the economy from the adverse consequences of a system-wide failure.[37]

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[34] Canadian Climate Impacts and Adaptation Research Network, *Adapting to Climate Change: An Introduction for Canadian Municipalities*, 2007. http://www.c-ciarn.ca/adapting_e.html.

[35] Ibid.

[36] Expert Panel on Climate Change, *Adapting to Climate Change in Ontario a report to the Ontario Ministry of the Environment*. 2009.

[37] Ibid.

The report also identified that much of the physical infrastructure in Ontario – roads and bridges, along with stormwater, drinking water and wastewater facilities – was built before modern design considerations for stormwater and the impacts of climate change and changes in weather trends were evident. While natural variations in climate and historic extremes would have been considered during their design and construction, the coping range built in at that time "may not be adequate to handle future climate conditions, leaving some of the existing infrastructure vulnerable and with limited capacity to adapt."[38]

While the projections related to the impacts of climate change on community infrastructure deal primarily with challenges, there is one piece of "good news." Reduced snowfall in central Ontario could result in decreases in snow removal budgets.

Human Health

Ken Black

Projections of milder winters suggest that the stresses associated with living in a colder climate will diminish in the years ahead. That is unquestionably a "good news" story. The not-so-good news is contained in the NRCan report that identifies the danger of increased risk of illness and premature death likely to result from heat waves, smog episodes and ecological changes that support the spread of mosquito and tick-borne diseases such as West Nile Virus, Lyme Disease, and even malaria as the climate changes.

Heat-related mortality could double in southern and central Ontario by the 2050s, while air pollution mortality, compounded by warmer summer temperatures could increase about 15-25% during the same interval.

According to research undertaken by Toronto Public Health, an average of 120 acute deaths in that city every year between 1954 and 2000 were heat related. Environment Canada projections foresee a near doubling of hot days above 30°C in the City of Toronto by 2050. Toronto Public Health projects a doubling of heat-related mortality to about 240 persons per year in the 2050s as a consequence.[39]

Extreme heat also contributes to the creation of smog that worsens other health conditions related to air quality, such as asthma. Smog is a complex chemical haze of microscopic particles and gases, especially ozone, produced by the action of sunlight and warmth on tailpipe and industrial fumes, evaporated gasoline and solvents. The most damaging of the chemical reactions in smog is the creation of ground-level ozone. Its concentration is one of the main triggers for a "Smog Advisory" or smog alert.

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[38] Ibid.

[39] McGowan, D., *Summary Report – Influence of Weather and Air Pollution on Mortality in Toronto*, Toronto Public Health, June 2005.

There were 43 smog alert days in the City of Toronto in the seven years from 1994-2000. That number climbed to 152 days in the subsequent seven-year period from 2001 to 2007.[40] While an increase in vehicles entering and leaving Toronto every day is a relevant factor, smog drifting from the U.S. Midwest and warmer summer weather as the drivers of smog creating chemical reactions are also important.

More specific local information is contained in the 2008 Air Quality report issued by the Simcoe Muskoka Health Unit reflecting readings taken in Orillia and Dorset. It indicated a total of 37 smog alerts during the period from 2003-2007 lasting a total of 107 days. Of particular interest is the spike in smog alerts during the particularly hot and humid summer of 2005 of 13 alerts totalling 44 days or 41% of the total smog alert days for the period. That may well be a harbinger of things to come in this area as hot and humid summers become more common as a result of climate change. [41]

The Ontario Medical Association has estimated that in 2005, the annual illness related to air pollution in the province resulted in 5,800 premature deaths, more than 16,000 hospital admissions, almost 60,000 emergency room visits and 29 million minor illness days.[42]

In 2008, 9,500 premature deaths in Ontario were related to air pollution, with more than 1,000 occurring during or immediately after periods of increased pollution.[43] Heat wave temperatures add to respiratory stress and exacerbate the impacts of pollution.

The 2008 Air Quality report of the Simcoe Muskoka Health Unit also identified the close connection between air quality and climate change, and the fact that the same gases that pollute the air we breathe and create smog also cause the earth to warm. It referenced recent research indicating that average annual air temperatures in Ontario could be three to eight degrees higher by the latter part of this century.

That report included data from the Ontario Medical Association indicating an estimated 220 premature deaths from air pollution in Simcoe Muskoka in 2008, and a further projection that number could increase to 360 in 2026. Total hospital admissions in Simcoe Muskoka related to air pollution exposure in 2008 was estimated at 580 and is projected to rise to 820 by 2026. [44]

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40 Ministry of Environment. Air Quality Ontario -- http://www.airqualityontario.com/.

41 Simcoe Muskoka District Health Unit *Air Quality Report – Focus on Health Stats*. 2008. http://simcoemuskokahealthstats.org/Img/Content/Focus%20Reports/Air%20Quality%202008/Air%20Quality%20Report%202008.FINALpdf.pdf.

42 Ontario Medical Association. *The Illness Costs of Air Pollution in Ontario*. 2005 http://www.oma.org/Health/smog/icap.asp.

43 Ibid.

44 Simcoe Muskoka District Health Unit *Air Quality Report – Focus on Health Stats*. 2008. http://simcoemuskokahealthstats.org/Img/Content/Focus%20Reports/Air%20Quality%202008/Air%20Quality%20Report%202008.FINALpdf.pdf.

The results will be not only more serious threats to human health, but increased costs and stresses on existing healthcare services and facilities. Clearly, there will be a need for more attention to long-term planning for healthcare in Muskoka.

Tourism

Ken Black

Muskoka's tourism sector is projected to experience some challenges, but there may be some positive opportunities as a result of our changing climate. Tourism operators will have the benefit of several recent studies that provide either Muskoka or Central Ontario-based data and valuable insights related to future directions.

In 2008, the Ontario Ministry of Tourism reported that tourism accounted for $17.3 billion in the economy of Ontario in 2007, accounting for 3.4% of the province's GDP. In Muskoka the 2007 visitor spending was $350 million and the sector employed 4,800 people.[45]

Almost all tourists in Ontario are influenced by the weather, especially those choosing from a wide variety of popular outdoor activities such as alpine and cross-country skiing, snowshoeing, snowmobiling, boating, beach recreation and swimming, sailing, hiking and camping, fishing, hunting, golfing, fall colour viewing, landscape and wildlife viewing including bird watching, canoe tripping, and kayaking. Cultural attractions such as summer and winter festivals, museums, natural science centres, theatres, historical and architectural sites are also influenced by weather, albeit to a lesser degree.

Those same activities are a key part of the lifestyle that attracts and holds both seasonal residents and retirees to Muskoka. The overall economic impact of both outdoor activities and cultural activities is even more significant in this part of the province.

It is widely recognized that "A principal determinant in the diversity of outdoor recreation available in Canada is the climate. Climate plays a direct role in defining the length and quality of recreation and tourism seasons and in influencing the level of participation"[46] For example, in relation to snowmobiling, the report commented, "It would appear that the snowmobiling industry in eastern Canada is highly vulnerable to climate change. If these results are indicative of the long-term effects of climate change for the snowmobiling sector, there could be substantive economic implications."[47]

The report identified the snowmobiling season in the Georgian Bay area (where some of the province's most concentrated networks of trails occur) as about 69 days per year

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45 Ministry of Tourism. http://www.tourism.gov.on.ca/english/research/trends/visitor_spending_in_Ontario.htm.

46 Scott, D. and Jones, B. 2006 *Climate Change and Seasonality in Canadian Outdoor Recreation and Tourism*. Waterloo, ON, University of Waterloo, Department of Geography.

47 Ibid.

currently. In the 2020s, snowmobiling seasons are projected to be shorter, by 30 to 47 days. In the 2050s and 2080s, the most conservative climate change scenarios project between 39 and 52 fewer days for snowmobiling: effectively eliminating the snowmobile season.[48]

In contrast, the season for warm weather activities like golf is expected to increase in the central Great Lakes region (Orillia). Under the warmest climate change scenario, golf seasons are projected to be approximately 16 days longer in the 2020's, 37 days longer in the 2050s and 68 days longer in the 2080s.[49] However, the same report sounds two notes of caution related to golf. During the summer, moisture deficits are projected to increase, becoming particularly severe in the Great Lakes region (increasing 24% in the 2020s, 40% in the 2050s and 85% in the 2080s).[50]

As well, some aspects of pest and disease management could also be impacted by projected changes in the climate, posing challenges to the maintenance of playing conditions and the perception of what a healthy golf course resembles. Insect pests that currently have only one life cycle in many parts of Canada could begin to have two life cycles under warmer conditions.[51]

Warmer average winter temperatures and less natural snow cover could reduce the occurrence of some winter turf grass diseases (e.g., snow moulds), but summer diseases that thrive in warm humid conditions (e.g., Brown Patch and Dollar Spot) could become more problematic. Turf grass diseases and pests currently limited to latitudes that are more southerly could also expand northward and require management interventions.

Changes in irrigation and turf grass disease/insect management could affect the ability of golf course managers to take advantage of opportunities for a longer and more intensive golf season under climate change, and will require long-term planning and adaptation to minimize the impacts.

Muskoka can anticipate longer seasons for recreational water activities such as swimming and boating. However, numerous studies support the concerns identified in the report of the International Joint Commission in 2003 entitled, *Climate Change and Water Quality in the Great Lakes Basin*, which states that warmer summers may have a negative impact on water quality. As lake bodies warm, their oxygen-carrying capacity is diminished, which can contribute to enhanced algae growth and other water pollution. Bacterial contamination could also degrade the aesthetics of beaches and pose a health risk to swimmers. How climate change may affect the frequency of beach closures and swimming bans remains uncertain, but continued monitoring, assessment and communication related to recreational water quality will be essential in the years ahead.

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[48] Ibid.

[49] Ibid.

[50] Ibid.

[51] Ibid.

While the total value of tourism and its ancillary recreational equipment suppliers is unlikely to decrease and could even increase, there will be a shift in the balance of outdoor recreation from winter to warm weather activities. Scott and Jones concluded "that climate is important to outdoor recreation and tourism in Canada and that projected changes in the climate will create disparate challenges and opportunities among recreation sectors. It is apparent then that given the economic importance of outdoor recreation to Canada's economy, climate change adaptation is a necessary policy strategy for the industry".[52]

That comment has particular importance in Muskoka. Successful adaptation will require a considered and planned transition rather than disruption in this very important sector of the economy.

Agriculture

Ken Riley

Perhaps surprisingly to some, agriculture remains a significant component of both Muskoka's economy and environment. The 200 farms in the district generate over $6 million in direct farm revenue (2006 census), and produce an economic impact of over $18 million. In addition, Muskoka's farmland provides important services that protect and enhance environmental and landscape quality, and offer farm- fresh produce to both the seasonal and local communities.

In comparison with Ontario agriculture, Muskoka's farms possess several distinct features, which can affect not only adaptation to climate change, but the future role of agriculture in Muskoka. These features are true not only of Muskoka itself, but also of the larger Muskoka watersheds.

Muskoka's average farm size is more than 3 times smaller (70 ha) than the Ontario average (233 ha).

- Farms in Muskoka are found scattered in pockets of good soil, rather than in the large expanses of prime farmland found in much of southern Ontario.
- Muskoka's farm landscapes are highly diverse – on average, half of Muskoka's 15,000 ha of farm land is devoted to bush and wetland. This leaves only 7,000 ha of arable or pasture land in Muskoka.
- These diverse landscapes provide habit for greater biodiversity. A recent bird survey (Leonard Lake Stakeholders Association, 2009 summer) identified 48 bird species on the northeast shore of Leonard Lake. A further 11 species, not found around the lake, were found in the nearby farmland area.
- A recent study of Muskoka farm soils (Muskoka Soils and Crop Improvement Association, 2009) found organic matter levels of 4-6%, which is double the

[52] Scott, D. and Jones, B. 2006 *Climate Change and Seasonality in Canadian Outdoor Recreation and Tourism*. Waterloo, ON, University of Waterloo, Department of Geography.

Ontario average. Organic matter is particularly important in retaining moisture and fertility and preventing erosion.

- A higher percentage of Muskoka farmers have undertaken Environmental Farm Plans (EFPs) than anywhere else in Ontario. EFPs help maximize environmental benefits while minimizing environmental threats from farmland.
- Muskoka farm numbers have remained at approximately 200 since 1988 – in the same period, Ontario farm numbers declined by over 30%.
- From 2001 to 2006 Muskoka farm revenue increased by 20% – in that period, Ontario farm revenue remained unchanged.
- Muskoka farm enterprises are highly diverse. Ranging from cow-calf operations, exotic longhorn cattle, horses, sheep goats pigs and chickens to mushrooms, greenhouses and nurseries, berries (including cranberries), a wide variety of fresh vegetables and maple syrup.
- There is strong and growing demand for local farm products. Savour Muskoka, an organization promoting local food and culinary tourism, has grown rapidly since its inception five years ago. Six farmers' markets now operate in Muskoka.

The 2009 report "Adapting to Climate Change in Ontario" provides a well-argued prediction for change in temperature and precipitation patterns by 2050. Assuming a moderate GHG emissions scenario, the area east of Georgian Bay, including the Muskoka watersheds will experience a 2.5 - 3 ºC rise in both winter and summer. Winter precipitation (as rain or snow) is predicted to increase by 10%. Total summer precipitation may remain unchanged, but extreme weather events are expected to increase.

These changes will certainly impact Muskoka agriculture. Warmer summer and winter temperatures will increase the duration of the spring and fall growing season, and expand the range of crops that can be grown. However, the frequency and severity of summer dry periods and droughts will increase the risk of growing these crops. Higher levels of carbon dioxide will promote faster growth, but studies show that nutritional quality may be reduced. Increased winter precipitation will result in faster spring runoff, increasing the risk of soil erosion. Rising temperatures are also expected to increase the potential for the spread of pests and diseases.

However, as climate change takes place around the world, the potential importance of Muskoka agriculture is expected to expand. Global and local food prices are likely to increase, as food shortages due to water scarcity in California, Asia, and elsewhere become acute, and transportation of food more costly. Increased potential for tourism in Muskoka (as described above) can create expanded demand for fresh Muskoka farm products. The small size and isolation of Muskoka farms can be an advantage in slowing the spread of crop and animal pest and disease epidemics. The higher potential runoff and erosion due to higher winter precipitation and extreme weather events will be mitigated by the higher organic matter in Muskoka farm (and forest) soils. The high landscape diversity found on Muskoka's farmland will facilitate the migration of plant, animal and micro-organism species to new habitats, and provide havens for the evolution of new biodiversity.

However these benefits will not be realized without including agriculture in clear planning and implementation of activities that can help buffer the Muskoka watershed against the potential threats and maximize opportunities from climate change. Clearly, agriculture in Muskoka needs greater public recognition, support, and protection.

Action in three areas is needed:

- Increased awareness among policy makers, environmental advocates, and consumers of the vital role that the last 7,000 ha of arable farmland play in providing consumers nutritious local food, and maintaining environmental health.
- Increased awareness and training among farmers. This includes methods of water harvesting to keep precipitation in place through sustainable farming methods, and focusing on organic matter enhancement. Increased implementation of Environmental Farm Plans is needed. As elsewhere in the province, Muskoka farmers are ageing, and it is increasingly difficult for new farmers to begin farming. New farmers must be encouraged to begin farming though training, and implementing a variety of incentives – from land trusts to forgivable performance loans.
- Finally, changes are needed in legislation and implementation of policy. Farmland must be identified and protected through zoning that designates farmland and limits severances for development. Bylaws that prevent topsoil removal and the conversion of farmland into gravel pits, which exist elsewhere in the province, could be considered in the Muskoka watersheds.

Conclusion and Recommendation

In his final report on the Muskoka District Local Government Review (1969), Donald M. Paterson observed that "the need for sound long-term planning is undoubtedly one of the most urgent needs facing Muskoka today (1969), and the submissions to the Review gave virtually unanimous support to a strong and effective planning system for the Region." [53]

Paterson also commented that "although conservation is often considered a function quite separate from planning, under the particular conditions found in Muskoka I am convinced that the two fields are intimately related, and that any conservation activity undertaken would serve only to implement long-range planning for the region."[54]

Paterson's wisdom in making those observations has served Muskoka well over the last four decades. The implementation of his recommendations related to both planning and conservation has contributed significantly to the special place that Muskoka is today.

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[53] Paterson, D. Muskoka *District Local Government Review – Final Report and Recommendations*. 1969.

[54] Ibid.

The Canadian Water Resources Association 2009 report echoed similar sentiments in calling for the use of watersheds as planning units in preparing for adaptation to climate change on a regional basis. Such an approach allows a place-based focus on issues and strategies, encourages effective knowledge sharing and communication among stakeholders and researchers, and strengthens community and institutional capacity. All are essential for successful climate change adaptation.

It is recognized the District Municipality of Muskoka is currently undertaking many no-regrets actions that both mitigate climate change locally and begin to adapt to the evitable consequences of change. (See Appendix A and Appendix B below). A coordinated approach among and between sectors and organizations is now required to further local actions efficiently and effectively. The District Municipality of Muskoka is in the fortunate position to develop a coordinating body and lead a made-in-Muskoka approach to a responsible climate change adaptation program.

Recommendation

The District Municipality of Muskoka and the six Area Municipalities are responsible for public services that will be impacted as the climate changes. Muskoka Tourism, lake associations, the agricultural community, the Health Unit, the Ministry of Natural Resources and many others are responsible for other programs and services that impact the quality of life in Muskoka.

More severe and intense storms have implications for all these agencies and organizations. Stormwater management requirements will change, temperatures fluctuations through the freeze/thaw cycle will impact many programs, and the potential for increased number of poor air quality days will impact human health. Land use and development will impact on biodiversity, forest health and water quality. It is important for the wide variety of sectors within the watershed economic and social community to work together through our local and District governments to explore and implement adaptation strategies.

The climate change impacts referenced in this paper require a proactive approach that addresses impacts on municipal policies and programs, industrial activity, tourism, forestry, and private land stewardship amongst others to avoid the significantly higher costs associated with reactive measures that will be needed in the future. A proactive approach also enables effective adaptation strategies through no-regrets options.

The Canadian Climate Impacts and Adaptation Research Network (C-CAIRN) recommends a process that begins with a five-step vulnerability assessment. The five steps include:

STEP 1: Engage affected parties – Engage and retain decision-makers and those affected by future climate change.
STEP 2: Assess current vulnerability – Use experience to assess impact and potential damage. Understanding adaptive capacity, critical thresholds and coping ranges is helpful.

STEP 3: Estimate future conditions – Use climate, environmental and socio-economic scenarios to determine future policy and development.
STEP 4: Estimate future vulnerability and identify adaptation strategies – Use the two previous steps (current vulnerability and future conditions) to identify future vulnerability and adaptation strategies.
STEP 5: Decisions and implementation – Incorporate results into risk-management strategies and follow through with these.

Recommendations for adaptation that have been identified in this paper include:

1. Implement the following actions:
    a. Encourage the District Municipality of Muskoka and Area Municipalities to develop a regional natural heritage strategy that will provide buffer zones and refuges and protection of connected wildlife corridors across the watershed, including areas of farmland and forests.
    b. Work with other watershed interests to develop monitoring programs, waste management programs, and sound land use policies that reduce human impact on the watershed.
    c. Protect wetlands, as they are a link between terrestrial and aquatic habitats.
    d. Protect natural areas that can hold back spring freshet and stormwater.
    e. Prevent topsoil removal.
    f. Require appropriate studies in order to understand the impact of land use change on the hydrologic cycle.
2. Develop partnerships with a wide variety of organizations that value an ecologically sound watershed to identify climate change issues and develop adaptation strategies. This may include the forestry, agriculture, provincial and municipal interests and organizations, as well as private landowners and naturalists.
3. Support local resources-based industries including forestry and agriculture.
4. Increase awareness and training of young resource sector workers such as young farmers, loggers and mineral aggregate workers on issues such as water harvesting, endangered species and habitat, and the need to maintain connected natural areas.
5. Encourage active acquisition of land that fits landscape conservation targets.
6. Continue to advocate provincially, nationally, and internationally to reduce carbon dioxide emissions and support local adaptation strategies.
7. Exploration of new technologies:
    a. Periodic assessments of the risk in light of climate projections
    b. Review of design standards
8. Advocate for strong provincial and municipal regulatory framework to address both climate change mitigation and adaptation.

It is recommended that the Muskoka Watershed Council establish a steering committee to design a process engaging all affected parties to assess vulnerability of Muskoka's watersheds to changing climatic conditions and to identify specific watershed-based strategies for adaptation to climate change.

In conclusion, a recommendation from a conference on "Stewarding Our Watersheds: Joining Hands for a Sustainable Future" put it this way:

> When all is said and done, the fate of sustainable management of a watershed lies in the hands of grassroots residents as they go about their day-to-day business. It is the citizens of the watershed who must generate the interest and enthusiasm to create, continue and expand local projects which lead to positive actions and results.

It bears repeating. The fate of sustainable management of a watershed lies in the hands of grassroots residents. Responsibility for stewardship lies with all of us, and with each of us. When it comes to addressing climate change stewardship through grassroots action is also necessary. If we do not participate in adapting to climate change locally, we will miss opportunities and suffer unforeseen consequences.

Bibliography

1. Barber, D. Global News, http://news.globaltv.com/technology/Arctic+vanishing+faster+than+most+pessimistic+mo dels+researcher/2532081/story.html.
2. Battin, J., M.W. Wiley, M.H. Ruckelshaus, R.N. Palmer, E. Korb, K.K. Bartz, and H. Imaki, 2007: Projected impacts of climate change on salmon habitat restoration. *Proceedings of the National Academy of Sciences*, 104(16), 6720-6725.
3. Blehert, B.S., Hicks, A.C., Behr, M., Meteyer, C.U., Berlowski-Zier, B.M., Buckles, E.L., Coleman, J.T.H., Darling, S.R., Gargas, A., Niver, R., Okoniewski, J.C., Rudd, R.J., and W. B. Stone. 2008. Bat White-nose syndrome: an emerging fungal pathogen? *Science*. October 30th, 2008.
4. Canadian Climate Impacts and Adaptation Research Network, Adapting to Climate Change: An Introduction for Canadian Municipalities, 2007. http://www.c-ciarn.ca/adapting_e.html.
5. Carey, C., Cohen, N., and L. Rollins-Smith. 1999. Amphibian declines: an immunological perspective. *Developmental and Comparative Immunology*. 23(6): 459-427.
6. Colombo, S.J. 2008. Ontario's Forests and Forestry in a Changing Climate. Ontario Forest Research Institute. OMNR 31 pp.
7. Colombo, S.J., D.W. McKenney, K.M. Lawrence and P.A. Gray. 2007. Climate Change Projections for Ontario: Practical Information for Policymakers and Planners. Ontario Ministry of Natural Resources, Applied Research and Development Branch. *Climate Change Research Report CCRR-05*. Sault Ste. Marie, ON.
8. Etkin, E. David, 1995. Beyond the year 2000, more tornadoes in western Canada/ Implications from the historical record. Atmospheric Environmental Services, Downsview, ON.
9. Expert Panel on Climate Change, Adapting to Climate Change in Ontario a report to the Ontario Ministry of the Environment. 2009.
10. Gantress J., Maniero G.D., and N. Cohen.2003.Development and characterization of a model system to study amphibian immune responses to iridoviruses. *Virology*. 311 (2): 254-262.
11. Gutierrez, B.T., S.J. Williams, and E.R Thieler, 2009: Ocean coasts. In: *Coastal Elevations and Sensitivity to Sea-level Rise: A Focus on the Mid-Atlantic Region* [J.G. Titus (coordinating lead author), K.E. Anderson, D.R. Cahoon, D.B. Gesch, S.K. Gill, B.T. Gutierrez, E.R. Thieler, and S.J. Williams (lead authors)]. *Synthesis and Assessment Product* 4.1. U.S. Environmental Protection Agency, Washington, DC, pp. 43-56.
12. Hicke, D. Hollinger, T. Huxman, G. Okin, R. Oren, J. Randerson, W. Schlesinger, D. Lettenmaier, D. Major, L. Poff, S. Running, L. Hansen, D. Inouye, B.P. Kelly, L. Meyerson, B. Peterson, and R. Shaw (eds.)]. Synthesis and Assessment Product 4.3. U.S. Department of Agriculture, Washington, DC, pp. 151-181.
13. Inkley, D.B., M.G. Anderson, A.R. Blaustein, V.R. Felzer, B. Griffith, J. Price, and T.L. Root. 2004. Global Climate Change and Wildlife in North America. *Technical Review* 04-2, The Wildlife Society, Bethesda, Maryland, U.S.A
14. Janetos, A., L. Hansen, D. Inouye, B.P. Kelly, L. Meyerson, B. Peterson, and R. Shaw, 2008: Biodiversity. In: *The Effects of Climate Change on Agriculture, Land Resources,*

Water Resources, and Biodiversity in the United States [Backlund, P., A. Janetos, D. Schimel, J. Hatfield, K. Boote, P. Fay, L. Hahn, C. Izaurralde, B.A. Kimball, T. Mader, J. Morgan, D. Ort, W. Polley, A. Thomson, D. Wolfe, M.G. Ryan, S.R. Archer, R. Birdsey, C. Dahm, L. Heath, J.

15. Janzen, F. J. (1994) Climate change and temperature-dependent sex determination in reptiles. *Proceedings of the National Academy of Sciences*. Vol 91, Number 16, Pages 7487-7490.
16. Lake Simcoe Science Advisory Committee, 2008. Lake Simcoe and its Watershed: Report to the Minister of Environment, 100 pages.
17. McGowan, D., Summary Report – Influence of Weather and Air Pollution on Mortality in Toronto, Toronto Public Health, June 2005.
18. Mortsch, L., E. Snell, and J. Ingram, 2006. "Climate variability and changes within the context of the Great Lakes Basin" in *Great Lakes Coastal Wetland Communities: Vulnerability to Climate Change and Response to Adaptation Strategies*.
19. Ministry of Environment. Air Quality Ontario -- http://www.airqualityontario.com.
20. Ministry of Tourism. http://www.tourism.gov.on.ca/english/research/trends/visitor_spending_in_Ontario.htm
21. Natural Resources Canada-- http://imfc.cfl.scf.rncan.gc.ca/insecte-insect-eng.asp?geID=1000095&ind=A.
22. Natural Resources Canada -- http://imfc.cfl.scf.rncan.gc.ca/questions-eng.html.
23. Natural Resources Canada -- http://imfc.cfl.scf.rncan.gc.ca/insecte-insect-eng.asp?geID=9374.
24. Ontario Medical Association. The Illness Costs of Air Pollution in Ontario. 2005 http://www.oma.org/Health/smog/icap.asp.
25. Opdam, P., D. Wascher. 2004. Climate change meets habitat fragmentation: Linking landscape and biogeographical scale levels in research and conservation. *Biological Conservation* 117:285-297.
26. Pacala, S., R. Birdsey, S. Bridgham, R.T. Conant, K. Davis, B. Hales, R. Houghton, J.C. Jenkins, M. Johnston, G. Marland, and K. Paustian, 2007: The North American carbon budget past and present. In: *The First State of the Carbon Cycle Report (SOCCR): The North American Carbon*.
27. Paterson, D. Muskoka District Local Government Review – Final Report and Recommendations. 1969
28. Budget and Implications for the Global Carbon Cycle [King, A.W., L. Dilling, G.P. Zimmerman, D.F. Fairman, R.A. Houghton, G. Marland, A.Z. Rose, and T.J. Wilbanks (eds.)]. Synthesis and Assessment Product 2.2. National Oceanic and Atmospheric Administration, National Climatic Data Center, Asheville, NC, pp. 29-36.
29. Rahel, F.J., and J.D. Olden. 2008. Assessing the effects of climate change on aquatic invasive species. *Conservation Biology*, 22(3): 521-533.
30. Ryan, M.G., S.R. Archer, R. Birdsey, C. Dahm, L. Heath, J. Hicke, D. Hollinger, T. Huxman, G. Okin, R. Oren, J. Randerson, and W. Schlesinger, 2008: Land resources. In: The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States [Backlund, P., A. Janetos, D. Schimel, J. Hatfield, K. Boote, P. Fay, L. Hahn, C. Izaurralde, B.A. Kimball, T. Mader, J. Morgan, D. Ort, W. Polley, A. Thomson, D. Wolfe, M.G. Ryan, S.R. Archer, R. Birdsey, C. Dahm, L. Heath, J. Hicke, D. Hollinger, T. Huxman, G. Okin, R. Oren, J. Randerson, W. Schlesinger, D.

Lettenmaier, D. Major, L. Poff, S. Running, L. Hansen, D. Inouye, B.P. Kelly, L. Meyerson, B. Peterson, and R. Shaw (eds.)]. Synthesis and Assessment Product 4.3. U.S. Department of Agriculture, Washington, DC, pp. 75-120.
31. Schindler (2009) provides a through and accessible read; it is technically sound and written by the world's leading freshwater scientist but it reads well and rewards the patient layman.
32. Schindler, D.W. 2009. Lakes as sentinels and integrators for the effects of climate change on watersheds, airsheds and landscapes. *Limnology and Oceanography* 59(6): 2349-2358.
33. Schindler (1998) is an even more accessible review paper but discusses the boreal landscape, not the Great Lakes St. Lawrence Region where Muskoka is located.
34. Schindler, D.W. 1998. A dim future for boreal waters and landscape. *BioScience* 48 (March 1998): 157-164.
35. Scott, D. and Jones, B. 2006 Climate Change and Seasonality in Canadian Outdoor Recreation and Tourism. Waterloo, ON, University of Waterloo, Department of Geography.
36. Simcoe Muskoka District Health Unit Air Quality Report – Focus on Health Stats. 2008 http://simcoemuskokahealthstats.org/Img/Content/Focus%20Reports/Air%20Quality%202008/Air%20Quality%20Report%202008.FINALpdf.pdf.
37. Street, Roger, Atmospheric Environment Services, Environment Canada, Canada Country Study, 1997.
38. Travis, J.M.J. 2003. Climate change and habitat destruction: A deadly anthropogenic cocktail. Proceedings of the Royal Society (London B), 270:467-473.
39. Taylor, P. D., L. Fahrig, K. Henein, and G. Merriam. 1993. Connectivity is a vital element of landscape structure. *Oikos*, 68: 571-572.
40. Varrin, R., J. Bowman, and P.A. Gray. 2007. The Known and Potential Impacts of Climate Change on Biodiversity in Ontario's Terrestrial Ecosystems: Case Studies and Recommendations for Adaptation. Climate Change Research Report CCRR-09, Applied Research and Development Branch, Ontario Ministry of Natural Resources, Sault Ste. Marie, Ontario. 48pp.
41. Volney, WJA, and Fleming RA (2000) Climate change and impacts of boreal forest insects. *Agriculture Ecosystems and Environment* 82: 283-294.
42. World Meteorological Organization http://www.wmo.int/pages/mediacentre/press_releases/pr_869_en.html.

Appendix A: District Municipality of Muskoka – Climate Change Policies and Programs

Policy, Program or Project	Purpose	Adaptive/Mitigative Components
Strategic Priorities	Manage the legacy of Muskoka by sustaining a functioning natural environment, recognizing the need for a vibrant economy, and creating a caring community conscience supporting those in need	• Provides a strategic direction for adaptation • Aims to reduce the corporate carbon footprint • Supports growth within the carrying capacity of ecosystems, modernization of the tourism industry, and reliable infrastructure • Requires health and safety be protected in times of emergency • Encourages coordination and communication with other levels of government
Official Plan	Establish objectives and policies to manage and direct physical change in the social, economic, and natural environments of Muskoka	• Contains policies that support the efficient use of land and infrastructure services, protects natural features, and promotes effective community services such as healthcare that lead to strong, liveable, healthy, complete, and adaptable communities
Emergency Planning	Lead coordination, development and implementation of emergency prevention, mitigation, preparedness, response, and recovery efforts	• Plans for natural and human-induced disasters that may be worsened under climate change, such as flooding, severe storms, forest fires, extreme heat, erosion/landslides, infrastructure failure, and energy, transportation, food, human health or water quality emergencies
Storm Reserve Fund	Establish a reserve source of funding for roads damaged by severe weather	• Provides a reserve fund for roads negatively impacted by extreme summer or winter storms that are anticipated to become more common under a warming climate, including washouts, flood, freeze/thaw, and other weather-related damage

Policy, Program or Project	Purpose	Adaptive/Mitigative Components
Water Strategy	Connect and enhance existing water programs, develop new relationships, and share information for the protection of water resources	• Strives to minimize human impact on watersheds • Promotes human and environmental health • Designed to be dynamic and responsive to change • Encourages relationship building with the community
Lake System Health Program	Protect lake ecosystems and the social and economic values they provide, using a broad approach	• Monitors chemical, biological, and physical aspects of lake ecosystems and could detect early indicators of climate change • Provides data to municipalities and other organizations for planning purposes • Includes enhanced policies for shoreline development and stewardship and municipal infrastructure programs that help build resilient natural systems
Stormwater Management Strategy and Guidelines	Provide a strategic approach to stormwater in order to respond to growth and to ensure the most effective structures and processes are in place to deal with a wider variety of stormwater issues	• Provides a region-wide strategic framework for stormwater • Recommends a higher level of quality control to protect lake ecosystems • Recommends implementation of Low Impact Development (LID) and treatment train approaches
Growth Strategy	Provide a balanced approach to growth that effectively integrates the basic themes of sustainability, including cultural viability, environmental responsibility, social equity, and economic health	• Promotes compact communities, increased densities, and intensification, which reduced vehicle trips and greenhouse gas emissions • Recommends controlled rural development, the area of Muskoka that is most vulnerable to extreme weather • Encourages maximum use of existing infrastructure • Promotes protection of natural and sensitive areas

Policy, Program or Project	Purpose	Adaptive/Mitigative Components
Economic Strategy	Provide strategic directions and actions to foster and support sustainable economic development in key sectors	• Supports year-round tourism as a core sector and diversification into green, creative, and innovative industries that may be needed to deal with climate change • Encourages technology, institutional, and labour force foundations that are adaptable to changing economic conditions
Natural Heritage Strategy (In progress)	Review and identify critical natural heritage features in Muskoka	• Will examine and make recommendations respecting biodiversity, existing intact ecosystems, and environmental features that are necessary for ecosystem resilience in the face of change and moderate extreme weather events such as flooding and windstorms

Appendix B: District Municipality of Muskoka – Climate Change Actions

Activity	Undertaken by Muskoka	Details/Comments
1. Building retrofits	Yes	• Installation of energy-efficient lighting and appliances • Window replacement program to EnerGuide standards • Insulation upgrades to increase R-value • Toilet replacement to low- or dual flow
2. Change traffic lights to LED fixtures	Yes	• Ongoing
3. Replace streetlights with efficient bulbs	N/A	• Street lights are primarily an Area Municipal responsibility
4. Water conservation programs	Yes	• Water conservation rebate program for installation of low-flow toilets and water-efficient washers (ended April 2009)
5. Plant or maintain trees	Yes	• Forest Health Program • Poplar tree capping of landfills
6. Implement anti-idling for fleet vehicles	Yes	• Idling discouraged in fleet management policy
7. Provide parking incentives to carpoolers	N/A	• No paid parking at municipal facilities, more applicable to urban municipalities
8. Purchase alternative fuels or hybrids for fleet vehicles	Yes	• Hybrid fleet pilot project ongoing
9. Purchase green energy	Yes	• 10% of Muskoka's annual hydro consumption is Eco Logo Certified power
10. Create guidelines for green buildings and sites	Yes	• Green (e.g., energy efficiency, water conservation) requirements for new municipal buildings on a project-by-project basis including energy-efficient windows, upgraded insulation, and low- flow or dual flush toilets • Active transportation subdivision design guidelines (in development)
11. Community-wide composting program	Yes	• Ongoing

Activity	Undertaken by Muskoka	Details/Comments
12. Sell rain barrels at reduced prices	No	• Potential future opportunity
13. Use financial incentives to reduce waste	Yes	• Bag limits and cost for additional bags using garbage tags
14. Clean water awareness program	Yes	• Muskoka Water Strategy • Muskoka Water Web
15. Promote energy efficiency in the industrial sector	No	• Potential future opportunity
16. Create incentives for public transit	N/A	• More applicable to urban municipalities
17. Support local residential energy efficiency initiatives	Yes	• Green Initiatives Committee supports employee activities that contribute to energy efficiency at work and home • Tenant energy efficiency education with retrofits
18. Develop bike-friendly infrastructure	Yes	• Active Transportation Strategy and related infrastructure projects (in development) • District bike rack
19. Initiate a commuter challenge	No	• Potential future opportunity
20. Support community gardening or green roofs	No	• Potential future opportunity