Supporters:
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Publication designed and prepared by:
Meghan Beveridge

Publication of Parks Research Forum of Ontario
University of Waterloo
Waterloo, ON N2L 3G1
Phone (519) 888-4567 x2072
fax (519) 746-2031
coordinator@prfo.ca
www.prfo.ca

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Polar bear (*Ursus maritimus*) and their habitats along the coast of Hudson Bay may be threatened by global warming, Polar Bear (Wilderness) Provincial Park. By T.J. Beechey.

The weather station at Rondeau Provincial Park takes frequent automated readings to document local weather conditions of value for environmental monitoring in the park and surrounding area. By: S. Dobbyn, Rondeau Provincial Park.

Global warming could attenuate fire regimes in northern protected areas and their surrounding landscapes. Photo anon., Ontario Ministry of Natural Resources.

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Many people made significant contributions to the holding of this workshop on Climate Change and Ontario's Parks. The workshop is the first of what the Parks Research Forum of Ontario (PRFO) hopes will be a series of State of the Art Workshops on key park and protected area issues which would benefit from greater research. PRFO is a consortium of government and research institutions devoted to enhancing the contribution of research to understanding, planning, and decision-making for parks and protected areas in Ontario and beyond. The consortium consists currently of Ontario Parks, Parks Canada, the Universities of Waterloo (Secretariat), York, Guelph, Western Ontario, and Lakehead, with the Environmental Monitoring and Assessment Network (EMAN), Trent University, and The Canadian Council on Ecological Areas (CCEA) as observers.

We thank all members of PRFO for their support of this workshop and offer special thanks to Bob Davidson of Ontario Parks and Paul Gray of the Ontario Ministry of Natural Resources (MNR) for their extraordinary efforts in securing financial support for and participation in the workshop. Bob Davidson also made it possible to hold the workshop and house participants at the Frost Centre. The workshop was intended primarily to assist Ontario Parks personnel in understanding climate change and its implications for their work. About forty people attended the workshop and we thank them for their vigorous participation. We are also grateful to all the speakers for presenting papers and preparing them for publication. Of particular importance here was the work of Chris Lemieux, Dan Scott, and Rob Davis on Climate Change and Ontario Parks, which was supported by a grant obtained from MNR's Climate Change Fund (Project CC-03/04-002). David Welch of Parks Canada also made a special effort to attend and bring the experience of Parks Canada to the workshop—a major benefit to the participants. Barton Feilders and Adair Ireland-Smith of Ontario Parks have been strong supporters of PRFO's efforts and we are in debt to them. Many others also deserve thanks but not all can be fully recognized here. We cannot conclude, however, without thanking Stephanie Janetos for her thorough organizational work without which the workshop would not have succeeded. Meghan Beveridge did a fine job on these workshop proceedings. Chris Lemieux designed the cover and helped review the publication.

Gordon Nelson

May 30, 2005
Waterloo

PRFO Steering Committee:

Bob Davidson[1]/ Rob Davis[2], Ontario Parks
Gordon Nelson (Chair), University of Waterloo
Michael Troughton, University of Western Ontario
Bob Payne, Lakehead University
Tom Beechey, Canadian Council on Ecological Areas

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Tom Nudds, University of Guelph
Dawn Bazely, York University
John Marsh, Trent University
Brian Craig, Ecological Monitoring
and Assessment Network

[1] Representative at the time of the workshop.
[2] Current representative.

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Introduction

Evidence for climate change is mounting and many scientists, planners, and citizens are convinced that such change is affecting environment and land use and that these effects are likely to increase in the future. Many planners, citizens, and other decision makers are also convinced that we need to adapt to these changes in various ways. Such changes have potentially great significance for Ontario's parks and related environmental and land-use policies and practices. Among the anticipated effects are changes in the species composition and other characteristics of park systems, the frequency and intensity of fire, floods, and other ecological processes, and even the ecological rationale for the establishment of the park system in the first place. Planning and management responses could include changing current park boundaries, attempting to maintain or enhance processes that are stressed by ongoing climatic changes, establishing new parks, and creating new ways of linking parks with other protected areas and surrounding regions. Another major interest for park managers and other concerned persons is the effects the changes will have on recreation and tourism. These effects will have implications for communities, the economy, and society in the wider sense.

The aim of this PRFO workshop was to explore the evidence for climate change, the uncertainties involved, and the measures that have been taken and might be taken to adapt to them. The workshop was primarily intended for Ontario's park managers and other staff so that they have an opportunity to gain state of the art knowledge about climate change as it bears on their current and future responsibilities. Some knowledgeable and concerned people from Ontario Parks, universities, conservation authorities, Parks Canada, and other relevant groups also attended. Considerable opportunity was available for discussion among attendees after presentations by keynote speakers.

The papers in the workshop's proceedings cover a diversity of topics related to climate change and protected areas, including:

- understanding the evidence for climate change
- predictions and potential impacts of climate change and the implications for policy, planning, and management in Ontario parks
- the potential impacts of climate change on recreation and tourism
- strategies for park managers to adapt to climate change
- use of an ecosystem approach in coping with climate change and its effects on protected areas

Included are essentially verbatim summaries of the comments submitted by working groups convened at the end of the workshop. The papers and commentary contain many suggestions to deal with climate change and protected areas. Several seem basic and call for early attention.

- the need for policy guidance
- the need for continuous monitoring and research on climate change
- the need for internal and external collaboration and communication in Ontario Parks and other major relevant organizations
- staff training and park interpretation programs which include information on climate change

Gordon Nelson, Chair PRFO

Long Point Peninsula Biosphere Reserve, T. Beechey

Climate Change and Variability: Implications at the Scale of the Watershed

Climate Change and Variability: Implications at the Scale of the Watershed[1]

Ellsworth LeDrew

Department of Geography, University of Waterloo

Abstract

The evidence for climate change for many regions of the globe is now irrefutable. The temperature is rising at a rate that exceeds the statistical confidence limits for 'noise' over the past century of observations. The real debate is over the relative contributions of specific greenhouse gases, and the degree of the counter effect of cooling related to suspended particulate in the atmosphere. In this review, the implications of climate change at the scale of the watershed that are of interest to park managers in Canada are discussed. Issues include the difference between climate change and variability, regionalized evidence for each, the veracity of simulation model results at this scale, and the implications of uncertainty for management decisions.

Keywords: climate change, watershed scale, parks, protected areas

Introduction

With the exception of a cadre of die-hard geologists that confuses human-induced climate change with the normal climate change attributable to the long-term evolution of the planet, scientists from a variety of disciplines agree that the climate is changing and the implications are significant. The late F. Kenneth Hare, the preeminent climatologist of Canada, was the early bellringer for climate change and challenged the science community to anticipate the implications for the next 100 years and build them into decisions that affect the daily life of Canadians. We now have a variety of scenarios of climate change that are the foundations for political, economic and social strategic decisions. One notable example is *Buying Time: A User's Manual for Building Resistance and Resilience to Climate Change in Natural Systems* by Hansen *et al*. (2003).

In this review we assess the limits of such scenarios for regional scale management decisions, such as those required of managers of Canada's national and provincial parks. This discussion is based upon a clear distinction between climate change and the natural variability of a complex system. The recent climate of selected regions of Canada is discussed within this context. The validity of global-scale scenario building at the regional scale of the park is evaluated, and some examples of inference to ecological implications at this scale are considered.

Canadian Evidence of Change and Variability

David Phillips of the Meteorological Service of Canada is pressed by the media each January for the top weather stories of the previous year. Amongst those for 2003 are:

- Four years of dry weather sparked raging wildfires. The summer's tally: $500 million in firefighting costs, $250 million in insured property losses, and 50,000 residents evacuated
- New Brunswick's worst ice storm
- Avalanches killed 28 skiers, including seven on a school trip (Environment Canada, 2003)

Each year appears to bring new extreme weather events. If we examine the departures of Canadian temperatures from the normal for each season, we find that, up to 2003, 25 of the last 26 seasons are above the climate normal. This unusual anomaly seems to validate notions of recent climate change and is consistent with similar evidence in other countries. There is the one contrary season of spring 2002, however, that is actually the fifth coldest since 1948 (Figure 1). If we examine the Canadian anomaly maps for the spring seasons of 2001, 2002, and 2003 (Figure 2), we see that cooling of spring 2002 was actually spread across much of Canada with a warming restricted to the far northwest. This was the consequence of a very extensive reconfiguration of the hemispheric Westerly winds. The question is how can this unusual situation arise alongside such clear long-term evidence of climate warming?

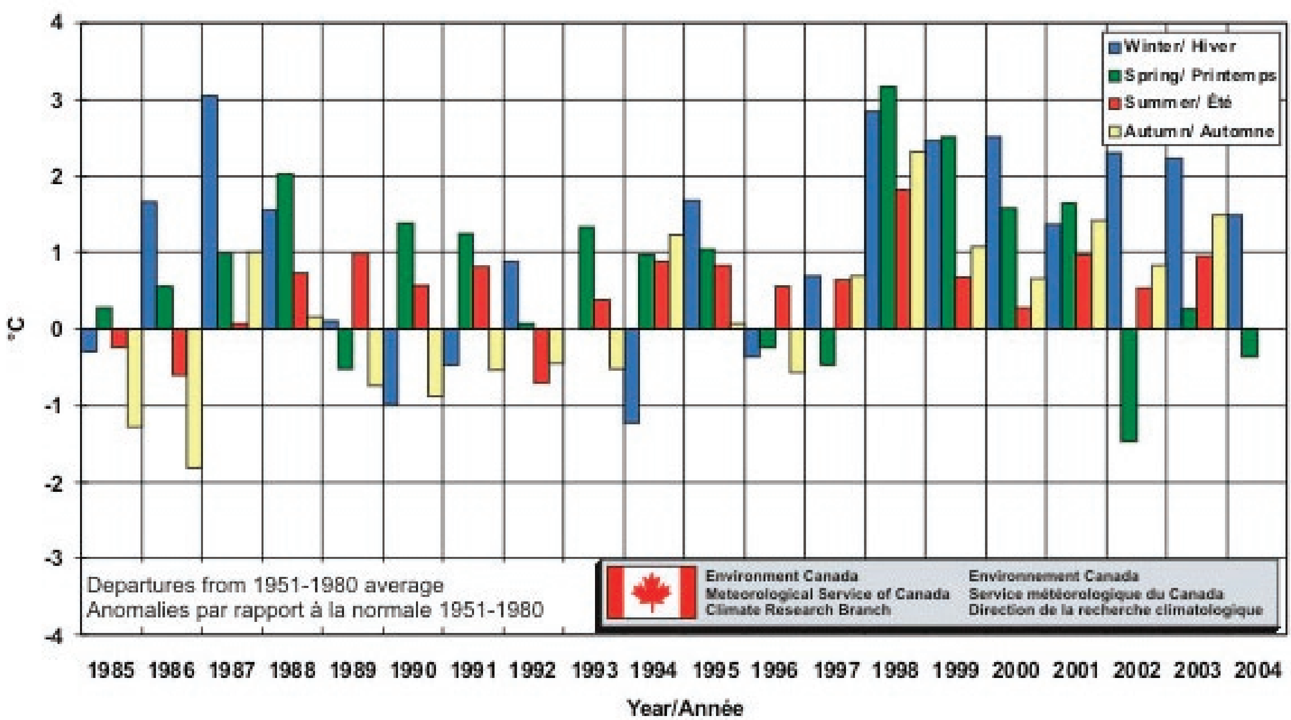
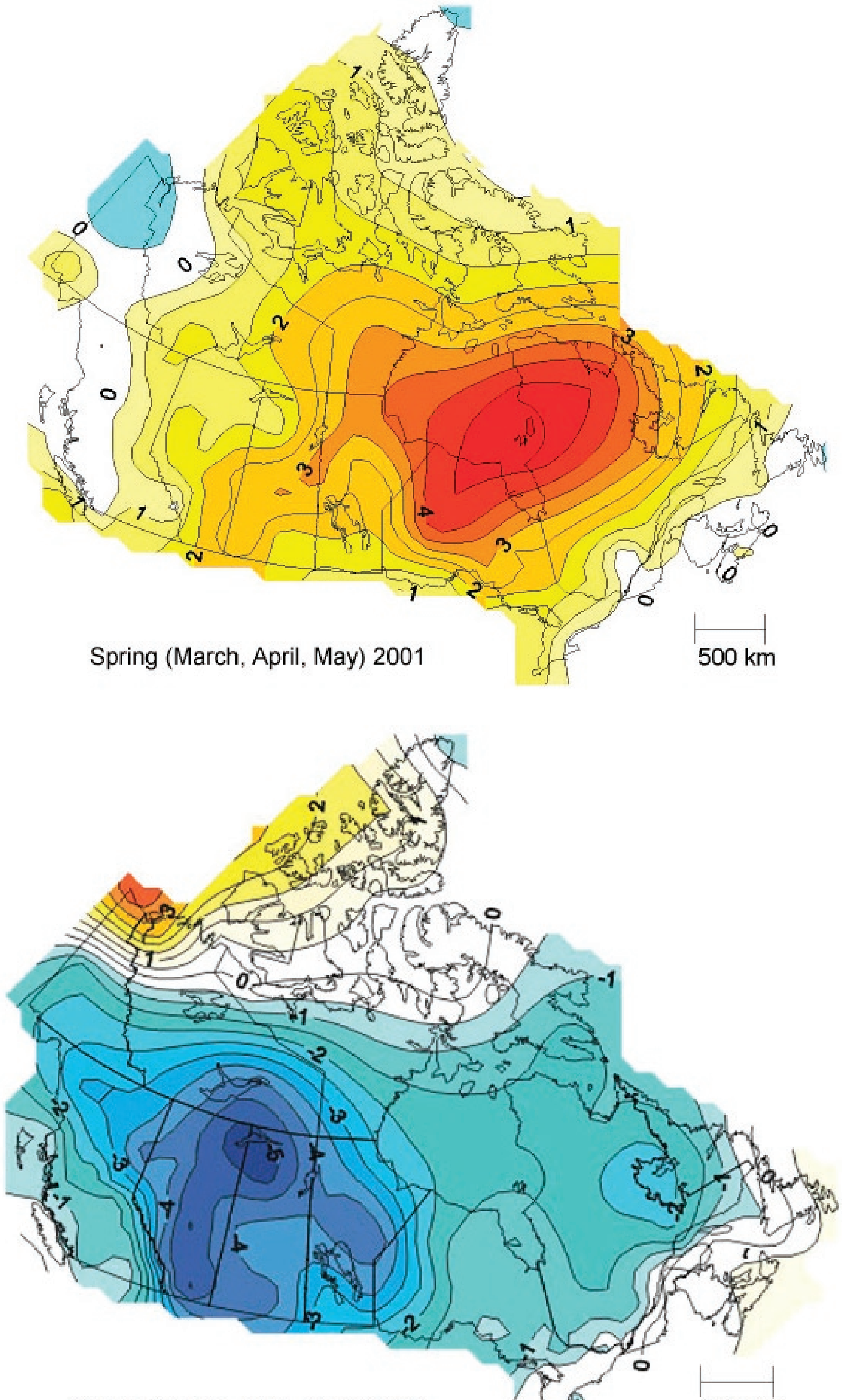
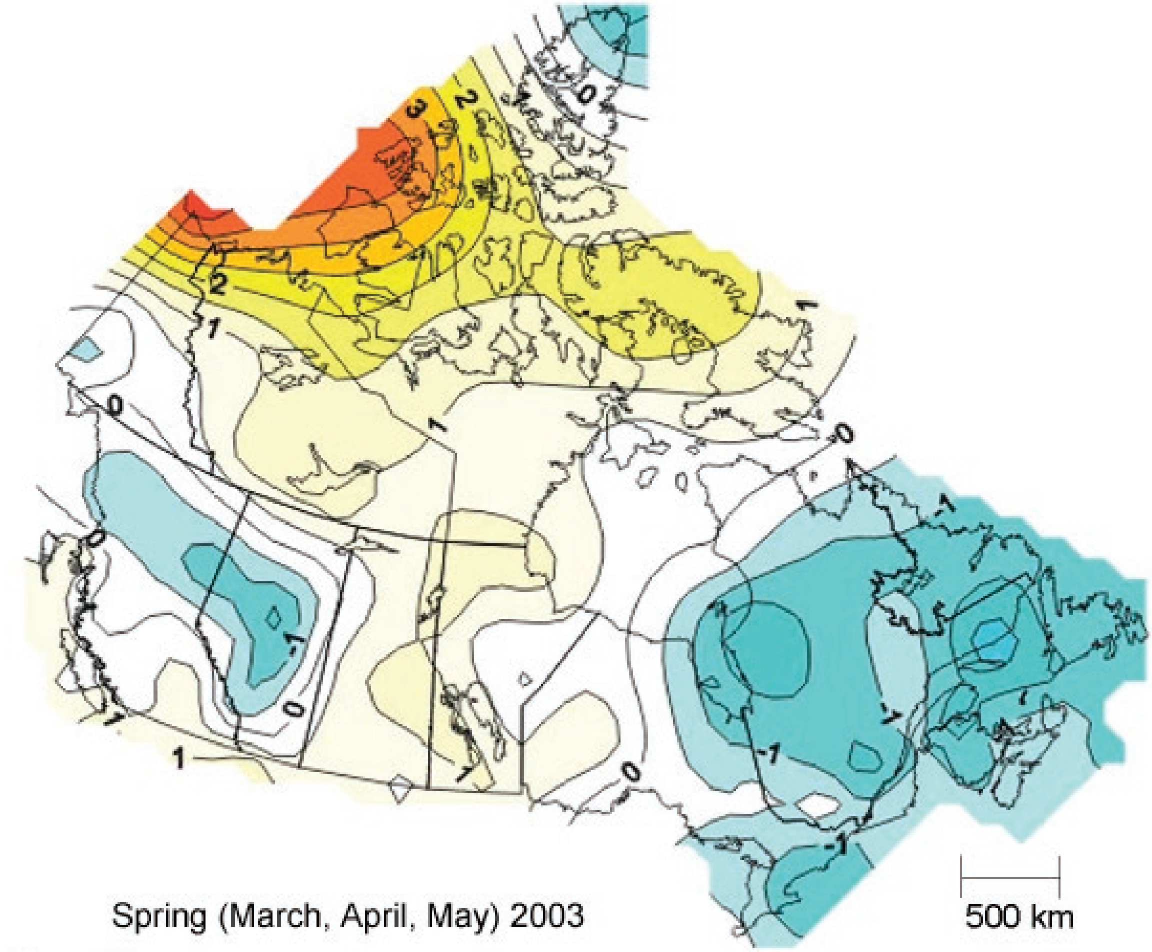


Figure 1. Seasonal anomalies for Canada from 1985–2004 (Environment Canada, 2004a).

Figure 2. Temperature anomaly maps of Canada for three spring seasons: 2001, 2002, and 2003, respectively (Environment Canada, 2004b).





The answer may be found in the distinction between climate change and variability and the effect of events as far away as the South Pacific. A schematic of the components of the climate system (Figure 3) illustrates a distinction between variables external to the climate system such as the solar output, gases ejected from the earth's interior via volcanoes, the arrangement of land and sea as a result of plate tectonics and internal variables such as the evaporation-cloud linkages and radiation balance-wind system linkages. Schneider and Dickinson (1974) proposed that climate change would be associated with changes in the external variables. These would induce a new state of the climate; whereas variability would be the result of the internal variables and associated feedback loops constantly adjusting to these new external states.

F. Kenneth Hare (1972) (Figure 4) illustrates various temporal routes that the change/variability distinction can take for an illustrative variable, such as temperature. In addition to long-term external changes in sinusoidal waves (A), such as may be attributed to the Milankovitch variations of orbital mechanics, there are abrupt changes with a variability superimposed upon the trend (B), a slow transition to a new external state (C)—again with variability superimposed upon this transition—or just a change in the degree of variability (D).

Changes can be identified in the change in sea ice extent (Figure 5). An extensive interannual variation occurs with seasonal cycles and is superimposed on the long-term trend towards reduced ice cover.

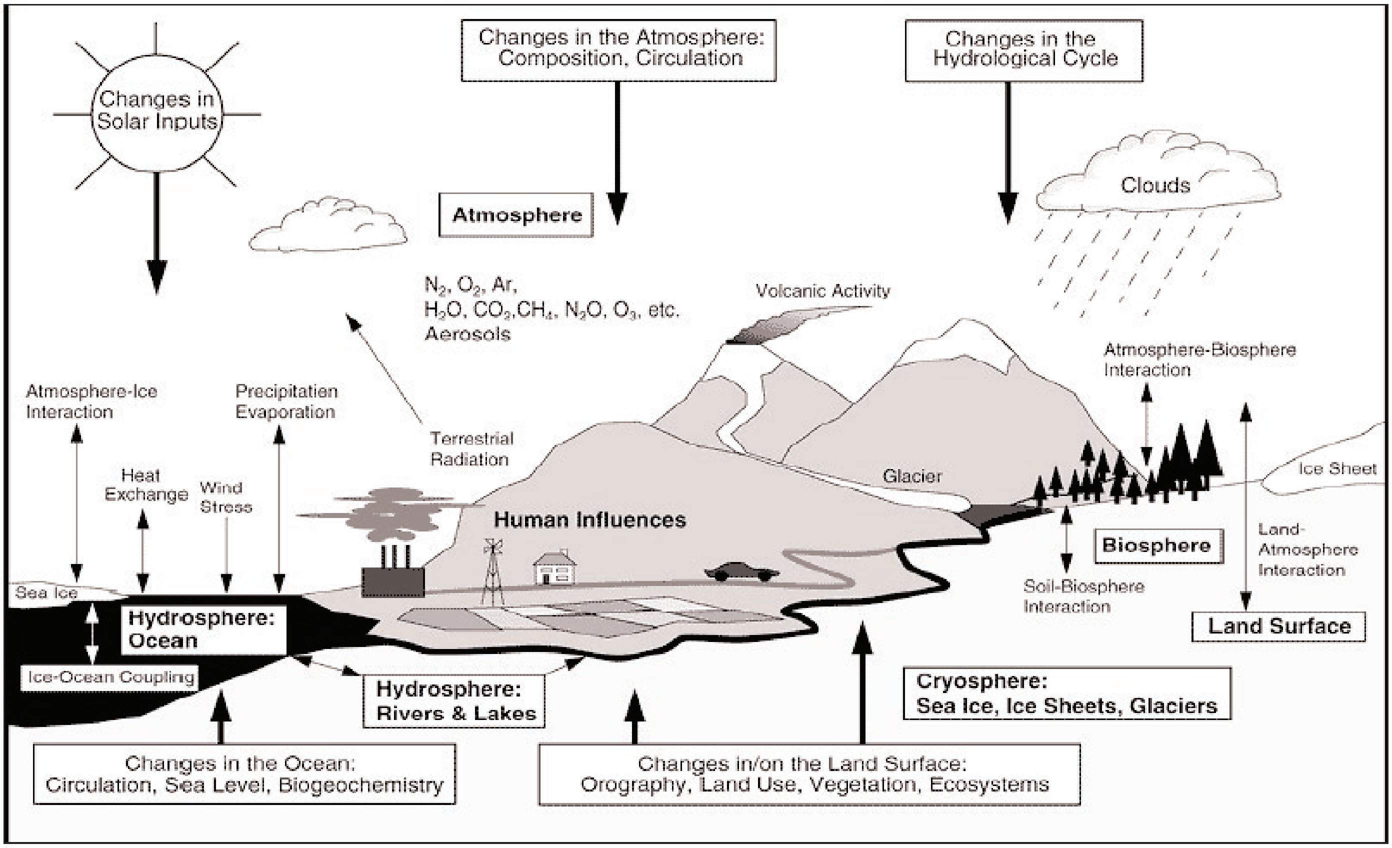


Figure 3. A schematic of the external variables (heavy arrows) and internal variables (light arrows) of the climate system (IPCC, 2001).

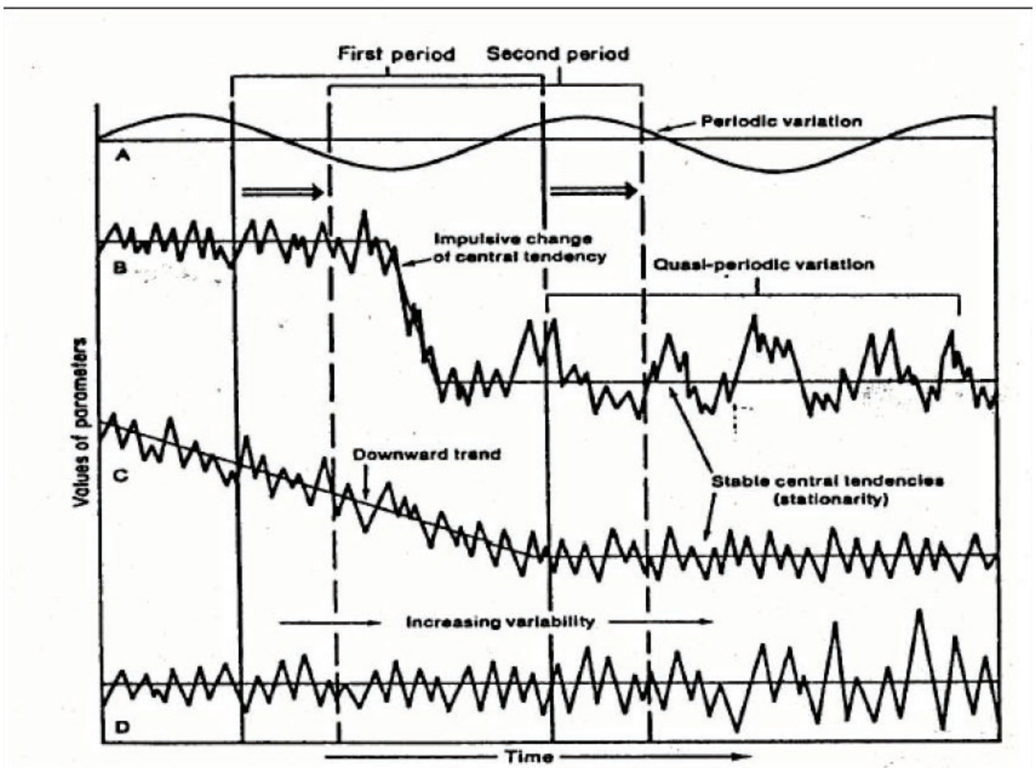


Figure 4. Schematic of types of climate change and variability for a climate variable, such as temperature (Hare, 1972).

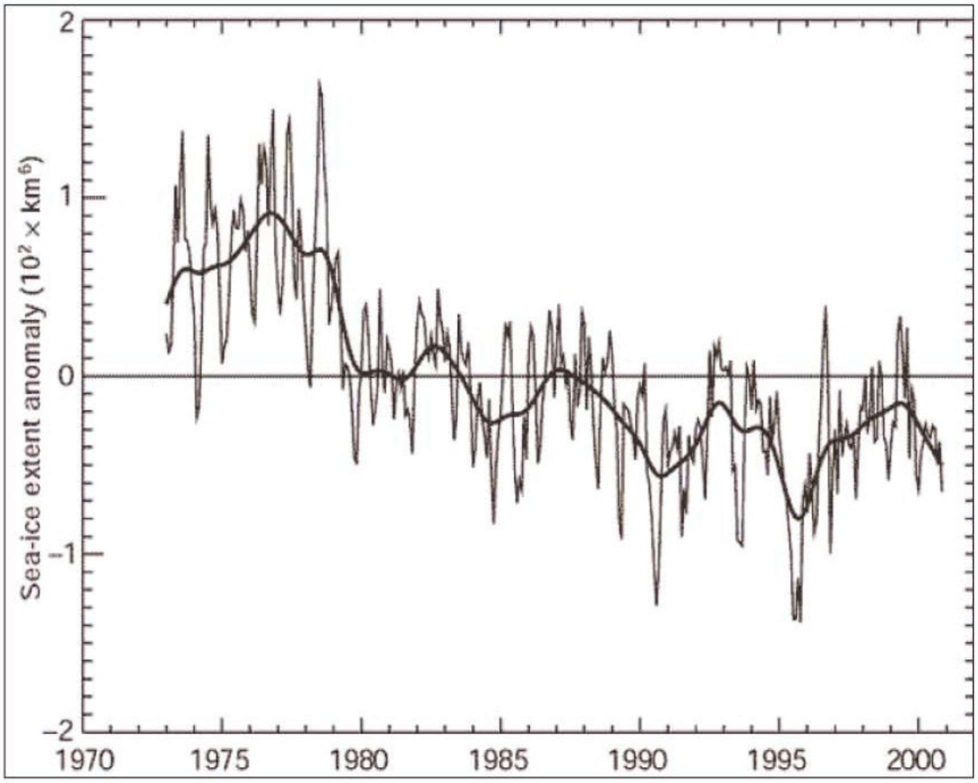


Figure 5. Temporal anomalies of sea ice extent (Parkinson, 2000).

While the foregoing discussion can help explain the variation from one year to the next that the public recalls when an unusually warm and/or dry summer prevails, it does not help explain the triggers for unusual events. This is an area of active research with many unknowns, but one possible trigger is the cyclic recurrence of El Niño—the Southern Oscillation (ENSO) of the South Pacific approximately every seven years (Trenberth, 1997). Recent studies have indicated that this event may have significant consequences for Canadian weather, with real impact on grain yields in the prairie provinces (Garnett, 2002). The mechanism is not clear, but temperature anomalies for the surface of the South Pacific can affect surface temperature in the North Pacific which may have a bearing on the wave structure of the Jet Stream (Figure 6) and thus on downstream weather patterns over North America. 'Signature' temperature anomalies for winter and spring (Figure 7) have been derived from weather statistics when El Niño was dominant and indicate extensive warm anomalies over Canada. Reality often is something different. The winter of 2002–2003 was anticipated as an El Niño winter but the actual anomaly pattern was rotated about southern Hudson Bay by 90 degrees (Figure 8) to have a dramatically different effect. There is a great deal to learn. Further food for thought is provided in the La Niña phase of the South Pacific oscillation when cold water and high pressures predominate because of the retreat of warmer water to more southerly latitudes.

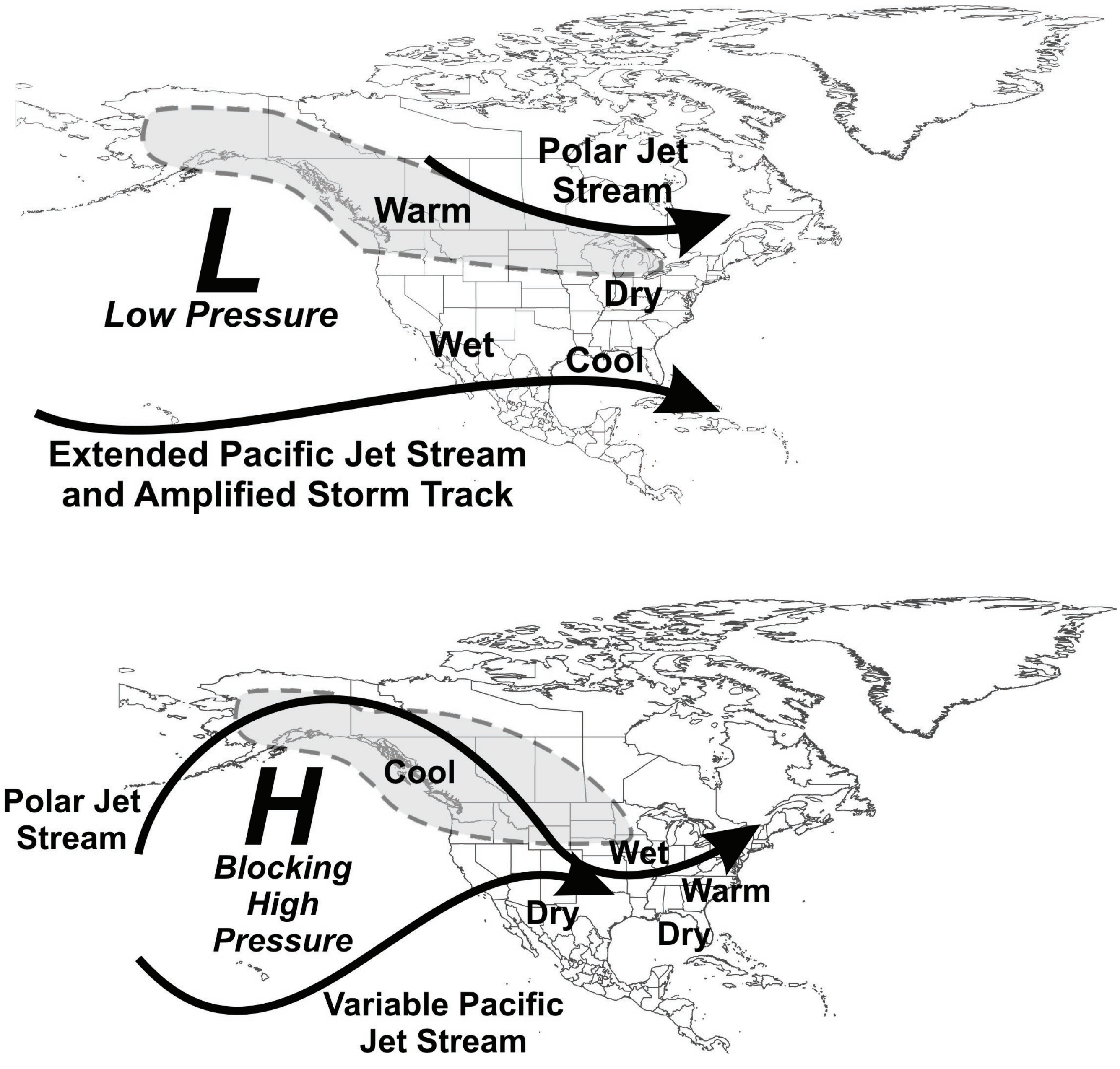


Figure 6. Jet stream configuration for an El Niño (top) and La Niña (bottom) episode (adapted from NOAA, 2004).

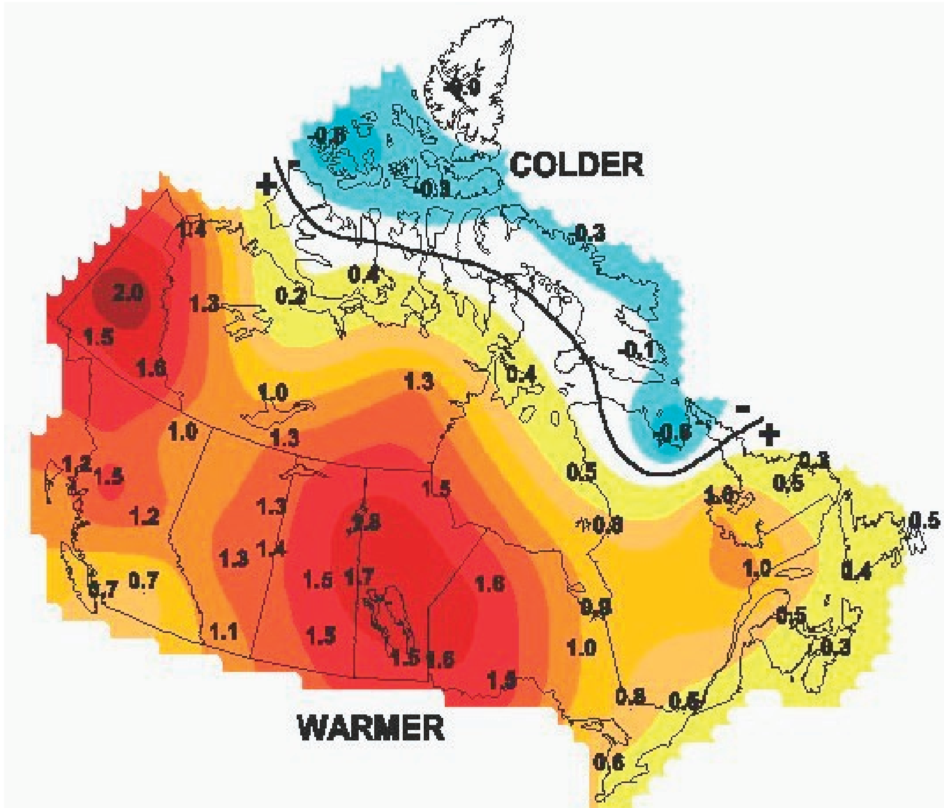


Figure 7. Expected Canadian temperature anomalies for an El Niño year (Environment Canada, 2004c).

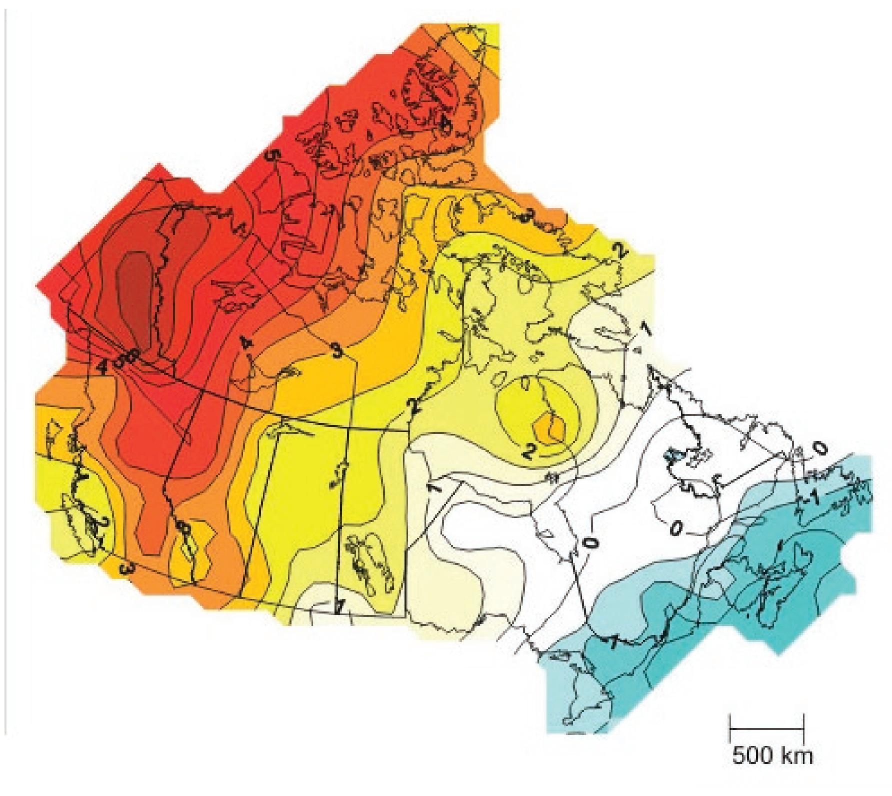


Figure 8. Actual temperature anomaly for winter 2003 (Environment Canada, 2004d).

The Long View of Canadian Climate

From 1993 to 2001 we have had the nine warmest winters since the start of instrumental record in Canada, and this is consistent with global temperature trends (Figure 9). The prediction for 2050 based upon Canadian Global Climate Models (Figure 11) is for warming over all of Canada with the exception of the Labrador Sea. Highest temperatures are found in the continental interior—the wheat belt and the Arctic Basin. If we anticipate the future climate for Southern Ontario from such simulations (Hayhoe and Shuter, 2003) we can determine that:

- The climate will feel as if Ontario has been translocated south to Virginia
- Temperature will rise 3–6 °C in summer and 4–8 °C in winter by 2100—extreme heat being more common
- Winter precipitation will increase by 15–40% and summer by -5% to +20%—water balance will decrease with more heat for evaporation and less precipitation
- Frequency of extreme storms will increase
- Great Lakes ice cover will decline—reducing protection from winter storms and having an impact on oxygenation

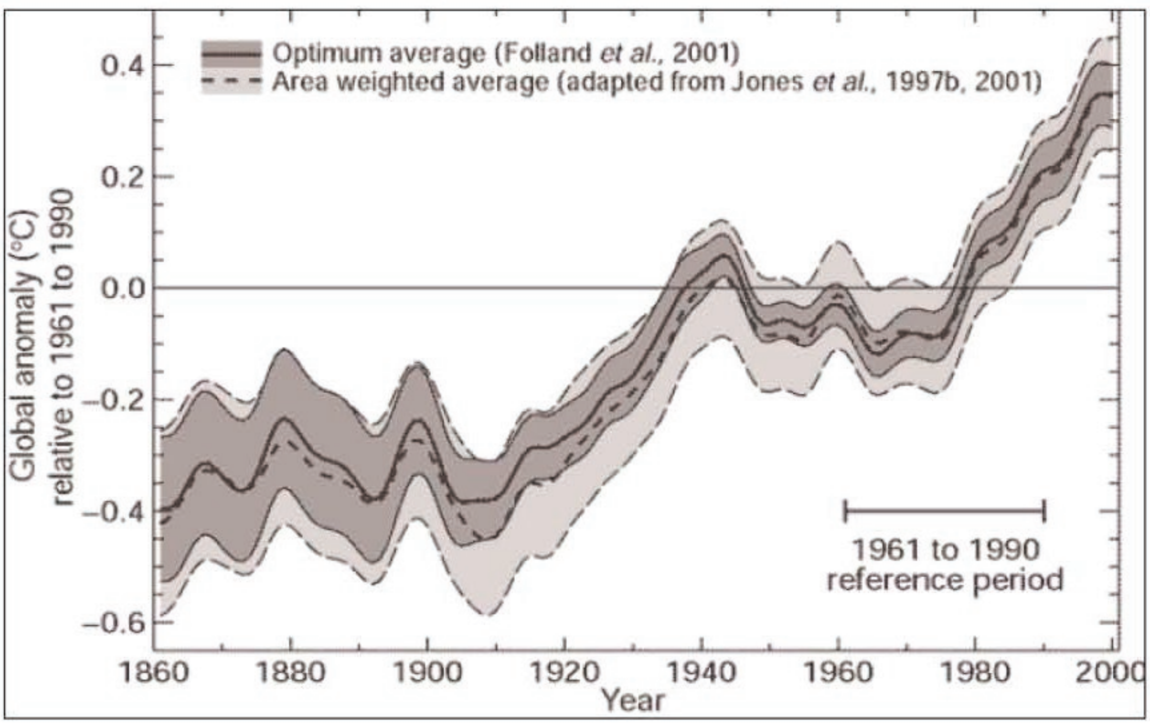


Figure 9. Global temperature anomalies from 1860 to 2000 (IPCC, 2001).

One clear lesson for future climate scenarios is that the implications will have to be assessed on a region-by-region basis. There is not an even warming in all regions as seems to be suggested in public media. In Figure 10, the temperature trends between 1950 and 1998 are shown for much of the western northern hemisphere. The reality is that over Canada the trend varies from -1.4 to +2.0 °C over that interval. This is a natural consequence of the shift in the standing waves of the westerly winds with climate change and the persistent influence of a trough of cold air in one region and a ridge of warm air in another.

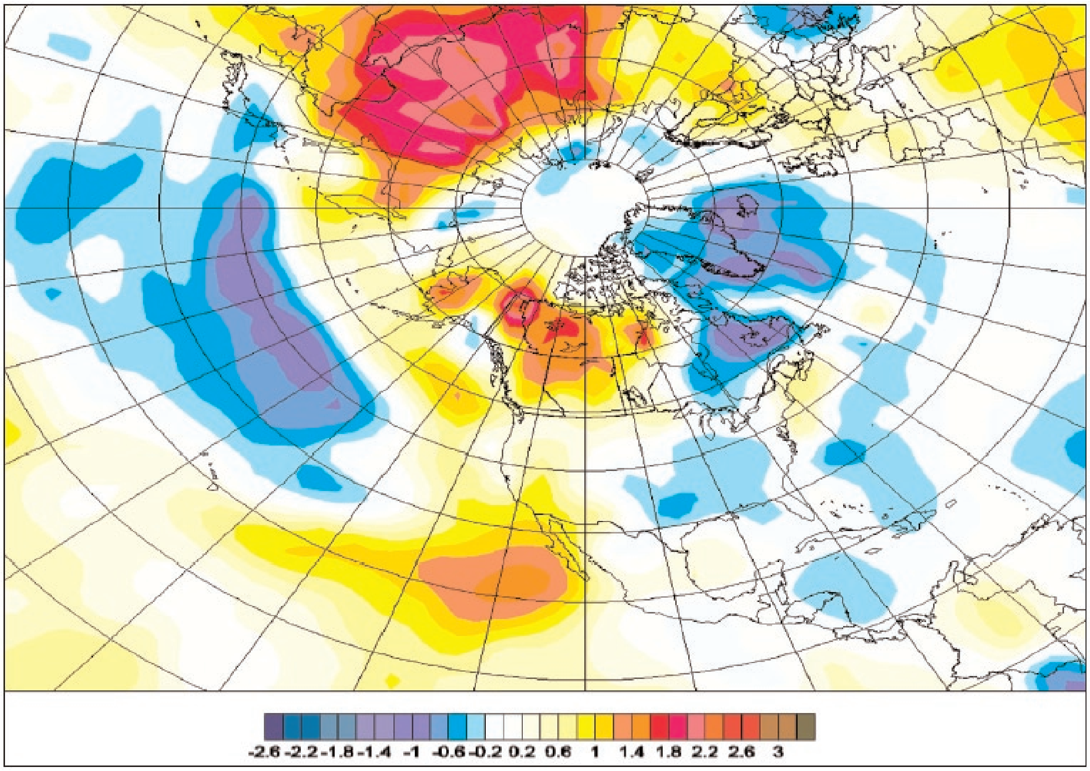


Figure 10. Observed temperature trends for Canada from 1950 to 1998 (Environment Canada, 2004f).

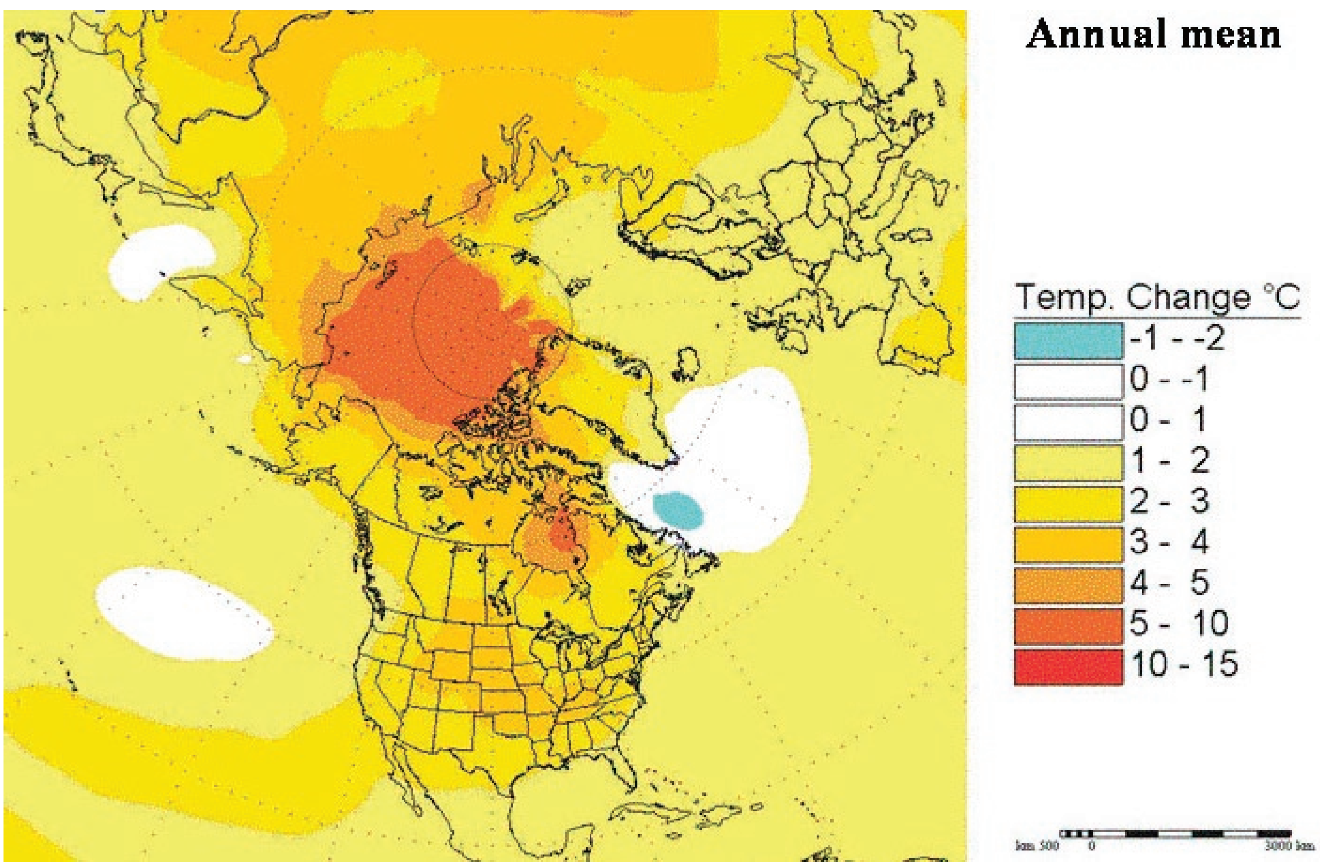


Figure 11. Projected temperature anomalies for 2050 (Environment Canada, 2004e).

Inferences at the Scale of the Watershed

Most scientists will agree that the Global Climate Models (GCM) are most valuable when considering differences in temperature over broad regions, such as the difference between a continental interior and a maritime region. We have confidence that the wheat fields of central North America will have much warmer temperatures and increased instances of drought. The scenarios for a complex environment such as Southern Ontario are more suspect. The modellers would be the first to point out the deficiencies and warn the users about the limitations.

Normally, the grid point system used for the calculations of fluid flow of the atmosphere has a spacing of a few hundred kilometers. Consequently, there are very few grid points to represent the complexities of the Southern Ontario geography. Subtle features such as the Dundalk uplands, which are so critical for the topographic uplift that releases snow from the lake-effect storms, are not included at all. Indeed, the several ranges of the Western Cordillera typically show as one sinusoidal wave in the lower topography of the model. Recent experiments with higher spatial resolution regional climate models (RCM) nested within the GCM include more detailed topography with approximately 50 km spatial resolution. They produce much more realistic simulation fields (Figures 12a and 12b).

The Great Lakes are not built into any but the most recent simulations. As a result the simulations do not include the heat or moisture sources which affect snowfall (Lake Effect Snows), nor the freeze over of the lakes which curtails the heat and moisture supply in mid-winter, further modulating the Lake Effect.

Even if the water bodies are not included in the models, the impacts, such as the length of the ice season, can be calculated. It is such a derived product that can be of most value for management decisions at the watershed scale. Table 1 provides the ice cover change expected for the Great Lakes and includes an uncertainty range. Change in lake levels due to the change in the water balance components are calculated for several lakes in Table 2. Some ecological implications are summarized in Tables 3 and 4. These data represent a considered effort to take into account the climate change scenarios as shifts in the boundary conditions for ecological assessments. As Regional Climate Models begin to include more geographical detail and replication of sub-synoptic scale processes, such as Lake Effect Storms and the implications for flooding, the uncertainty in these analyses will be reduced.

Table 1. Projected ice cover change for the Great Lakes (Kling *et al.*, 2003).

Lake	**Current Situation**	**Future Scenarios**	
		By 2030	**By 2090**
Lake Superior and Erie (6 basins)	77 to 111 days of ice cover	Decrease ice cover from 11 to 58 days	Decrease ice cover from 33 to 88 days
Lake Superior (3 basins)	No ice-free winters	Increase ice-free winters from 0 to 4%	Increase ice-free winters from 4 to 45%
Lake Erie (3 basins)	2% of winters are ice free	0 to 61% of winters are ice-free	4 to 96% of winters are ice-free
Small inland lakes	~90 to 100 days of ice cover	Decrease ice cover by 45 to 60 days with doubling of atmospheric CO_2	

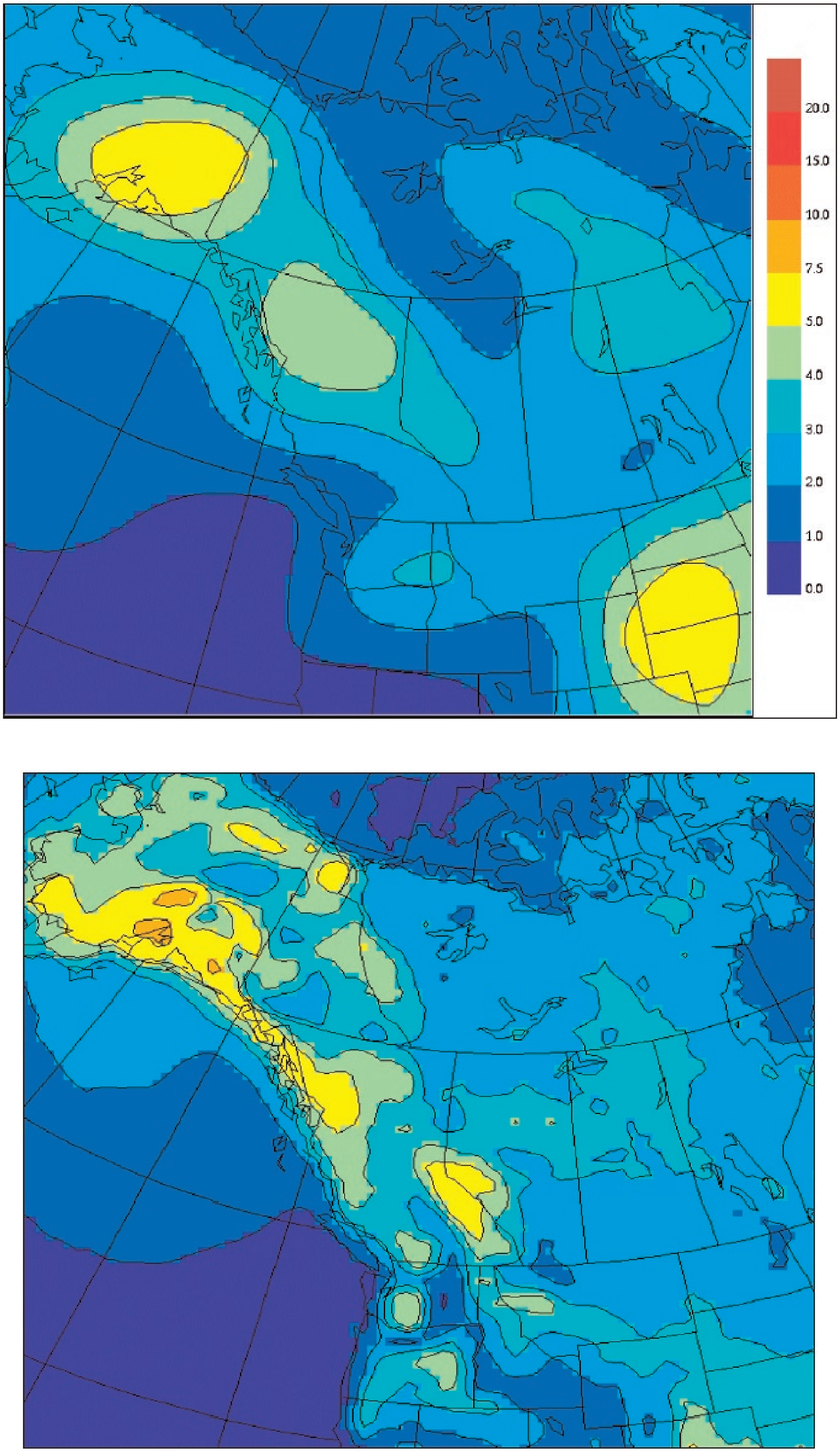


Figure 12a and 12b. Comparison of GCM temperature output with simplified topography for the Western Cordillera with that of regional climate models at 50 km spatial resolutions (Environment Canada, 2004g).

Table 2. Water levels most likely to decrease in the future (Kling *et al.*, 2003).

Lake	$2xCO_2$ (range of 4 simulations)	2030 (range of 4 simulations)	2090 (range of 4 simulations)
Lake Superior	-0.8 m to -2.5 m	-0.3 m to -0.6 m	-1.4 m to +0.4 m
Lake Huron	-3.2 m to -8.1 m	-1.3 m to -4.6 m	-4.5 m to +0.2 m
Crystal lake, Wisconsin	-1.0 m to -1.9 m (2 simulations)		
Groundwater near Lansing, Michigan		-0.6 m to +0.1 m	

Table 3. Expected effects of warmer and drier summer climate on lakes and subsequent impacts on algal productivity (Kling *et al.*, 2003).

Climate-Driven Change	Impact on Production	Most Sensitive Lake Type
Increases in both ice-free period and maximum summer water temperature	Increase in production	Moderate in area, depth, and nutrient concentration
Increase in duration of summer stratification and loss of fall top-to-bottom mixing period	Decrease in production caused by decrease in nutrient regeneration rates	Deep and oligotrophic (nutrient-poor; e.g., Lake Ontario)
Drought-induced decrease in lake water volume	Initial increase in production, followed by progressive decrease as the lake level declines	Small and shallow
Drought-induced decrease in annual input of nutrients (phosphorous) and dissolved organic carbon	Decrease in production resulting from nutrient limitation	Small and oligotrophic

Table 4. Impacts of climate change on stream ecosystems (Kling *et al.*, 2003).

Climate-Driven Change	Likely Impacts on Physical and Chemical Properties	Likely Impacts on Ecosystem Properties	Intensifying or Confounding Factors
Earlier ice-out and snowmelt	Peak flows occur earlier. Ephemeral streams dry earlier in the season. Backwater pools experience anoxia earlier.	The timing of fish and insect life cycles could be disrupted.	Snowmelt occurs earlier and faster in urban areas and where coniferous forest harvest has occurred.
Lower summer water levels	More headwater streams dry; more perennial streams become intermittent. Concentration of dissolved organic carbon decrease, thereby reducing ultraviolet-B attenuation. Groundwater recharge is reduced.	Habitat decreases in extent. Hydrologic connections to the riparian zone are reduced. Groundwater recharge is reduced. Species with resting life stages or rapid colonizers dominate communities.	Impervious surfaces and impervious soils exacerbate stream drying due to reduction in infiltration and groundwater recharge.
More precipitation in winter and spring and increased water levels	Spring floods reach greater heights. Surface runoff increases. Nutrient and sediment retention decrease. Groundwater recharge potential increases.	Floodplain habitat for fish and invertebrates grows. Hydrologic connections with wetlands increase.	Precipitation occurring when soils are frozen results in higher runoff and increases flood height.
Warmer temperatures	Stream and groundwater temperatures increase.	The rates of decomposition and respiration increase. Insects emerge earlier. Primary and secondary production per unit of biomass increases when nutrients are not limited; however, total production could decrease if aquatic habitat shrinks under drought conditions.	Impervious surfaces and both natural and human-made retention basins increase water temperatures. Woody riparian vegetation can buffer stream temperatures. In areas with porous soils and active groundwater connections, temperature extremes are smaller.
More frequent heavy rainfall events	Large floods occur more frequently. Erosion and pollutant inputs from upland sources increase. Runoff increases relative to infiltration.	Fish and invertebrate production decreases. Fish and insect life histories and food webs are disrupted by changes in the intensity, duration, and frequency of flooding.	Impervious surfaces increase runoff and stream flow. Channelized streams increase peak flow.
Elevated atmospheric CO_2		Possible changes in leaf litter quality could impact aquatic food webs.	

Conclusions

Vulnerability and uncertainty are the keywords in application of climate change scenarios to regional management decisions. Because of the thermal inertia in the climate systems associated with the heat storage of vast water bodies, changes implemented today will have an effect only in the future. Climate change is 'in the pipeline'. Any potential adjustments that address the Kyoto Protocol will only reduce the eventual change by a small fraction of that expected. We need several protocols and immediate implementation to have any appreciable effect. This is why the scientific literature has moved from discussion of mitigation to that of adaptation. The difficulty is "What do we adapt to?" in a situation where significant features such as the Great Lakes and regional topography are not included. In some simulations we have very little confidence in the modelled precipitation change. In other simulations we have confidence in the simulated temperature only for ensemble averages over very large areas.

Recognizing such limitations, we can, however, make useful decisions for managing the effects of future climate change. The significant issues include:

- Lower lake levels mean dredging and rebuilding locks, but longer shipping seasons due to less ice
- Hydropower generation will be compromised
- Effects of more extreme storms exacerbated by channeling and paved surfaces
- Implications of more intense downpours for sewer and water delivery infrastructure
- Changes in timing and severity of flood pulses will have impacts on breeding sites and wildlife migration

The climate is changing and will continue to change. We need to understand the inherent limitations of simulation models at the regional level and bring understanding of these limitations into the management process. In effect, our confidence decreases as the spatial resolution increases. All the scenarios are climate driven, there is not yet any feedback from changes in the biosphere that are known to affect regional climate. Tremendous advances are being made in climate analysis, and we expect our assessments of future climates to improve demonstrably within a short period. The Regional Climate Model nested inside the Global Climate Model represents a significant advance that will jump-start many adaptation studies.

Acknowledgements

I wish to acknowledge the financial support of NSERC for the research that led up to this summary paper. I thank Gordon Nelson for urging me to look at this problem from outside the cave of the traditional scientist.

Notes

[1] *The paper has been amended from:* LeDrew, E. Climate Change and Variability: Implications at the Scale of the Watershed. pp. 505–523. In: Lemieux, C.J., J.G. Nelson, T.G. Beechey, and M.J. Troughton. 2004. *Protected Areas and Watershed Management: Proceedings of the Parks Research Forum of Ontario (PRFO) Annual General Meeting 2003*. Waterloo: PRFO.

References

Environment Canada, 2003. The top ten weather stories for 2003. [Online] http://www.msc.ec.gc.ca/media/top10/2003_e.html

Environment Canada. 2004a. Consecutive seasons, national departures, 1985–2004. [Online] http://www.msc-smc.ec.gc.ca/ccrm/bulletin/spring04/figseasont_e.html?season=Spring&date=2004

Environment Canada. 2004b. Climate trends and variations bulletin for Canada. [Online] http://www.msc-smc.ec.gc.ca/ccrm/bulletin/spring01/index_e.html

Temperature and precipitation in historical perspective, spring 2002. [Online] http://www.msc-smc.ec.gc.ca/ccrm/bulletin/spring02/national_e.cfm

Temperature and precipitation in historical perspective, spring 2003. [Online] http://www.msc-smc.ec.gc.ca/ccrm/bulletin/spring03/national_e.cfm

Environment Canada. 2004c. Climate change and research branch. [Online] http://www.mb.ec.gc.ca/air/nino/ah00s88.en.html

Environment Canada. 2004d. Long-range forecast user's guide. [Online] http://www.msc-smc.ec.gc.ca/ccrm/bulletin/winter03/national_e.cfm

Environment Canada. 2004e. Slide 25: Temperature patterns will change substantially by 2050. [Online] http://www.msc-smc.ec.gc.ca/education/scienceofclimatechange/understanding/presentation_resources/section4/slide25_e.html

Environment Canada. 2004f. Changes in temperature are unevenly distributed. [Online] http://www.msc-smc.ec.gc.ca/education/scienceofclimatechange/understanding/presentation_resources/section2/SICC2_e.PPT#11

Environment Canada. 2004g. Models: the Canadian regional climate model (CRCM). [Online] http://www.cccma.bc.ec.gc.ca/models/crcm.shtml

Environment Canada. 2004h. Science and impacts of climate change presentation graphics. [Online] http://www.msc-smc.ec.gc.ca/education/scienceofclimatechange/understanding/presentation_resources/index_e.html

Garnett, E. R. 2002. Rejoice Canadian prairie farmers, El Niño is on the way? *CMOS Bulletin*, 30(2):29.

Hayhoe, K. and B. Shuter. 2003. *Confronting Climate Change in the Great Lakes Region: Impact on Ontario Communities and Ecosystems*. [Online] http://www.ucsusa.org/greatlakes/

Hansen, L.J., J.L. Biringer, and J.R. Hoffman (eds.). 2003. *Buying Time: A User's Manual for Building Resistance and Resilience to Climate Change in Natural Systems*. World Wildlife Fund (WWF), Climate Change Program: Berlin, Germany. 246 pp.

Hare, F. Kenneth. 1972. Lecture Notes. University of Toronto, Toronto.

Hengeveld, H., E. Bush, and P. Edwards. 2002. *Frequently Asked Questions About the Science of Climate Change*. Ottawa: Meteorological Service of Canada, Minister of the Environment, Minister of Supply and Services.

Hengeveld, H. 2000. *Climate Change Digest—Projections for Canada's Climate Future*. Ottawa: Meteorological Service of Canada, Minister of the Environment, Minister of Supply and Services. 27 pp.

IPCC (Intergovernmental Panel on Climate Change). 2001. *Climate Change 2001, the Scientific Basis*. UNEP. Cambridge: Cambridge University Press. 881 pp.

Lake Huron. 1999. *Lake Huron and Climate Change*. Blyth, Ontario: The Lake Huron Centre for Coastal Conservation. 4 pp.

Kling, G.W., K. Hayhoe, L.B. Johnson, J.J. Magnuson, S. Polasky, S.K. Robinson, B.J. Shuter, M.M. Wander, D.J. Wuebbles, D.R. Zak, R.L. Lindroth, S.C. Moser, and M.L. Wilson. 2003. *Confronting Climate Change in the Great Lakes Region: Impacts on our Communities and Ecosystems*. Union of Concerned Scientists, Cambridge. [Online] http://www.ucsusa.org/greatlakes/glchallengereport.html

NOAA (National Oceanic and Atmospheric Administration). 2004. El Niño and La Niña. [Online] http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensocycle/winter25%25.gif

Parkinson, C.L. 2000. Variability of arctic sea ice: the view from space, an 18-year record. *Arctic*, 53(4): 341–358.

Schneider, S. H. and R.E. Dickinson. 1974. Climate modeling. *Reviews of Geophysics and Space Physics*, 12(3): 447–493.

Trenberth, Kevin E. 1997. The definition of El Niño. *Bulletin of the American Meteorological Society*, 78: 2771–2777.

Short Hills (Natural Environment) Provincial Park, T. Beechey

Climate Change and Ontario's Provincial Parks:

Preliminary Analysis of Potential Impacts and Implications for Policy, Planning, and Management

Climate Change and Ontario's Provincial Parks: Preliminary Analysis of Potential Impacts and Implications for Policy, Planning, and Management

Chris Lemieux[1], Daniel Scott[2], and Rob Davis[3]

[1]Department of Geography, University of Waterloo, Waterloo, Ontario
Tel: (519) 888-4567 ext. 5783
cjlemieu@fes.uwaterloo.ca
[2]Canada Research Chair in Global Change and Tourism, Department of Geography, University of Waterloo
[3]Ontario Parks, Ontario Ministry of Natural Resources (OMNR)

Abstract

In collaboration with Ontario Parks, the University of Waterloo, and the Parks Research Forum of Ontario (PRFO), a preliminary analysis was completed on the impacts of climate change on Ontario's system of provincial parks. First, historical climate trend analyses illustrated mean temperature increases ranging from 0.26–1.2°C in a representative sample of provincial parks. Second, General Circulation Models (GCMs) projected increases in annual temperature of about 1.8–3.2°C in the 2020s, 1.8–7°C in the 2050s, and 2.5°C–10°C in the 2080s in the same representative sample of provincial parks. Third, results of the fire severity change analysis generally indicated a considerable decrease in the 'low' fire severity rankings and increases in the 'high', 'very high', and 'severe' fire severity rankings for the majority of Ontario's provincial parks by the 2050s (~2 x CO_2) and especially the 2090s (~3 x CO_2). Finally, vegetation modelling results showed the potential for substantial change in biome-type in Ontario's provincial park system (64–93% depending on the scenario used). The study identified a number of park policy and planning sensitivities, notably that the Ontario Parks system plan has been designed to protect specific natural features, species, and communities in situ*, and not take into account shifts in ecosystem structure and distribution that could be induced by global climatic change. Ultimately, however, the anticipated changes in ecosystem structure and composition expected under climatic change, coupled with some species' inability to adapt genetically to new climatic conditions or migrate to suitable climatic and vegetation zones, could hinder the ability of Ontario's protected area managers to maintain some habitats and species populations in the future.*

Keywords: climate change, Ontario parks, modelling, parks and protected areas, policy and planning

Introduction

Recent reconstructions of global mean-surface temperature from both 'proxy' (e.g., tree rings, ice cores, and lake sediments) and modern (i.e., 1850–2000) instrumental temperature records indicate that global twentieth-century warming is unprecedented over the past two millennia (Houghton *et al*., 2001; Mann *et al*., 2003). Warming trends in Canada over the twentieth century have averaged approximately 1°C with regional variations ranging from about 1.5°C in the western Northwest Territories (NWT) to 1°C in southern portions of Canada. In contrast, a cooling of 0.8°C has been recorded in Nunavut over roughly the same period (Environment Canada, 1998). Modelling and statistical studies indicate that such anomalous patterns cannot be fully explained by natural factors, but, instead, require an anthropogenic forcing during the late nineteenth and twentieth centuries (Mann *et al*., 2003; Braganza *et al*., 2004). Globally, the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report (TAR) has indicated that temperatures could rise between 1.4 and 5.8^{o}C over the twenty-first century (Houghton *et al*., 2001). As a northern country, Canada is projected to warm more than most other countries—in some areas, more than double the global average increase. Climate change of this magnitude, projected to occur over a relatively short period of time, would have significant consequences for Canadian ecosystems.

Climate plays a crucial role in determining the geographic distribution patterns of major biomes or vegetation communities (Holdridge, 1947; Woodward, 1987). An increasing number of empirical studies document the ecological effects (e.g., changes in phenology, distribution, and physiology) of recent climate change (Parmesan, 1999; Hughes, 2000; McCarty, 2001; Warren *et al*., 2001; Walther *et al*., 2002; Parmesan and Yohe, 2003; Root *et al*., 2003; Thomas *et al*., 2004; Parmesan and Galbraith, 2004). Climate change has also been linked to several recent species extinctions (Pounds *et al*., 1999; Thomas *et al*., 2004; McLaughlin *et al*., 2002). Compounding these impacts, projections of biome-type change indicate that the required migration rates of several Canadian species would need to be greater than 1000 m/year if they were to keep up with projected climatic warming and vegetation change anticipated in the twenty-first century (Malcolm *et al*., 2002).

Taken collectively, these studies indicate that the implications of projected climate change and ecosystem change on global biodiversity conservation could be considerable. Most protected areas have been designed to protect specific natural features, species, and communities *in situ*, not taking into account shifts in ecosystem structures that could be induced by climatic change. A recent report by the World Wildlife Fund (Hansen, Biringer, and Hoffman, 2003:1) emphasized that "*…protected areas offer a limited defense against problems posed by rapid environmental change [and] protected areas will themselves need to be changed and adapted if they are to meet the challenges posed by global warming.*" A number of authors (Peters and Darling, 1985; Scott and Suffling, 2000; Scott *et al*., 2002; Hannah *et al*., 2002; and Lemieux and Scott, in press) contend that climate change has the potential to undermine over a century of conservation efforts. Furthermore, the IPCC *Special Report on Climate Change and Biodiversity* (Thomas *et al*., 2004: 147) stated that "*Despite the uncertainties… the overall conclusions … establish that anthropogenic climate warming at least ranks alongside other recognized threats to global biodiversity [and] contrary to previous projections, it is likely to be the greatest threat in many if not most regions*."

This paper examines the implications of climate change for Ontario's system of provincial parks. The objectives are four-fold: (i) review the evidence for recent climate change in a representative sample of provincial parks; (ii) assess projected vegetation change within the provincial park system utilizing outputs from global vegetation model (GVMs); (iii) assess projected fire severity change within the provincial park system utilizing outputs from global circulation models (GCMs); and (iv) consider the implications these impacts have for park and protected areas management, policy, and planning at both the system and individual park levels. Due to space restrictions, the methods provided here consist of general descriptions only; sources containing more detailed descriptions of data sets and model methodologies are provided. The limitations associated with the use of instrumental temperature records, GCMs, and GVMs are also noted in these sources.

Methods

Historical Climate Trend Analysis and Climate Change Projections

Using climate stations, a representative sample of provincial parks in each of the Ontario Ministry of Natural Resources (OMNR) Ontario Parks park management zones was utilized to examine recent climatic trends (departures from the 1961 to 1990 norm) in these parks over the historic record. The availability of continuous climatic data sets was a major determining factor in both park and station selection.

Monthly values of mean temperature and total annual precipitation were acquired for each station from Environment Canada (2003a and 2003b). The Environment Canada Historical Adjusted Climate Database (Environment Canada, 2003a) of homogenized and long-term temperature time series, which has been specifically designed for climate change analyses over Canada, was used for the majority of stations utilized in the study and the identifier (adj) is used in this paper to illustrate these data sets.

This study also examined the projected range of temperature and precipitation changes for the same representative sample of provincial parks for the 2020s, 2050s, and 2080s utilizing the family of Global Circulation Models (GCMs) and the results of the Intergovernmental Panel on Climate Change's (IPCC) *Special Report on Emissions Scenarios* (SRES). The results of this analysis were derived from the Canadian Climate Impacts and Scenarios data centre (CICS, 2004).

Biome-type Change Analysis

The vegetation change scenarios for this analysis were based on modelling results developed for the IPCC-Working Group 2 (Neilson, 1998). The two Global Vegetation Models (GVMs) used were BIOME3 (Haxeltine and Prentice, 1996) and MAPSS (Neilson, 1995). A concise comparison of the vegetation discrimination criteria and ecophysiological processes modelled by BIOME3 and MAPSS is provided in Peng (2000: 43).

Fire Severity Change Analysis

The methodology of this analysis is based on the modelling results of Stocks *et al*. (1998) and Stocks *et al*. (2000). In these studies, fire weather data from the 1980s and the Second Generation Canadian Global Circulation Model (CGCM2) (Boer *et al*., 1992; McFarlane *et al*., 1992) were utilized to compare the intensity and spatial distribution of current and projected seasonal levels (2050s and 2090s) of fire weather severity across Canada. In this approach, values are used to provide an assessment of relative fire potential based solely on weather, independent of forest vegetation and fuel conditions.

Results

Historical Climate Trend Analysis

Historical climate analysis was completed for a representative sample of provincial parks to illustrate trends in mean annual temperature (MAT) and total annual precipitation (TAP) over the historical records (Figure 1). Results of this analysis are displayed as MAT (^{o}C) and TAP (mm) relative to the average of the 1961 to

1990 period. All stations utilized in the analysis illustrated an increase in MAT over their respective historical records compared to the 1961 to 1990 period. Results showed that the greatest increase in MAT over the instrumental record has occurred in Tidewater [Moosonee (adjusted) station— +1.2°C] and Quetico [Thunder Bay (adjusted) station— +1.14°C] provincial parks. Conversely, results illustrated that Rondeau Provincial Park has experienced the least temperature change over the historical record [Ridgetown ACS (adjusted) station— +0.26°C]. Interestingly, eight of the ten stations utilized in this analysis illustrated MAT trends greater than +0.8°C (two stations had increases greater than 1°C).

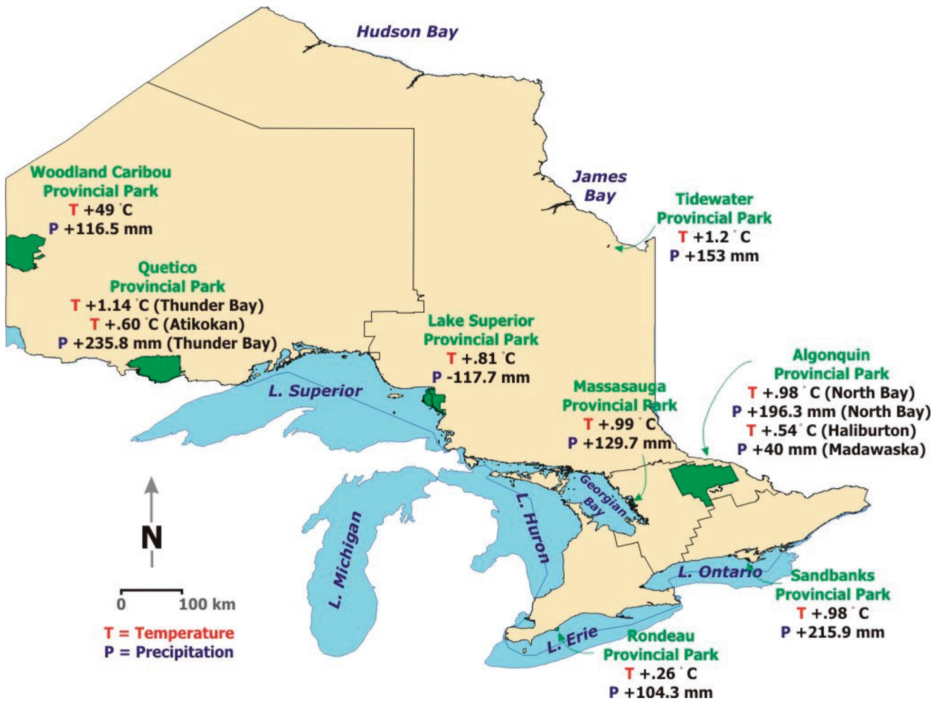


Figure 1: Mean annual temperature (°C) and total annual precipitation (mm) trends over the historical records.

For the five-year grouped period of 1997 to 2001, eight of the ten climate stations analyzed for MAT experienced the warmest five-year mean temperatures on record (Table 1). However, it is important to note that the Parry Sound station used for Massasauga Provincial Park only contained data up to 1990, and 1986 to 1990 was the warmest five-year period on record for this station. So, for nine of the ten stations utilized in this study, the last five years on record were the warmest. Interestingly, the 1997 to 2001 grouped record for Tidewater Provincial Park was the only five-year grouping to show a mean above 0°C (1.08°C). Rondeau Provincial Park was the only park to not display the warmest grouped five-year MAT in the last five years of its respective historical record (1951 to 1955).

Table 1: Warmest and coolest periods in historic climate records.

Station	Warmest five-year period	Five warmest years	Coolest five-year period	Five coolest years
Rondeau Provincial Park (Southwest Zone)				
Ridgetown ACS (adj)	1951–1955	1998, 1987, 1949, 1953, 1951	1976–1980	1924, 1926, 1978, 1940, 1976
Algonquin Provincial Park (Central Zone)				
North Bay A (adj)	1997–2001	1998, 2001, 1999, 1987, 1953	1962–1956	1940, 1972, 1943, 1976, 1980
Haliburton (adj)	1997–2001	1932, 1931, 2001, 1999, 1998	1902–1906	1904, 1917, 1940, 1943, 1934
Sandbanks Provincial Park (Southeast Zone)				
Belleville (adj)	1997–2001	1998, 1999, 1953, 1991, 1987	1921–1925	1923, 1926, 1940, 1924, 1934
Massasauga Provincial Park (Central Zone)				
Parry Sound	1986–1990	1921, 1987, 1931, 1949, 1990	1884–1888	1885, 1883, 1888, 1904, 1926
Quetico Provincial Park (Northwest Zone)				
Thunder Bay A (adj)	1997–2001	1999, 2001, 1987, 1998, 1931	1912–1916	1917, 1912, 1950, 1907, 1936
Atikokan‡	1997–2001	1998, 2001, 1931, 1987, 1999	1978–1982	1972, 1979, 1957, 1985, 1929
Woodland Caribou Provincial Park (Northwest Zone)				
Red Lake A	1997–2001	1987, 1998, 2001, 1999, 1941	1992–1996	1950, 1979, 1955, 1972, 1996
Lake Superior Provincial Park (Northeast Zone)				
Wawa A (adj)	1997–2001	1991, 1999, 1987, 2001, 1998	1972–1976	1950, 1972, 1956, 1976, 1989
Tidewater Provincial Park (Northeast Zone)				
Moosonee (adj)	1997–2001*	2001, 1998, 1999, 1987, 1952	1932–1936	1917, 1933, 1936, 1912, 1972

‡ = joined record
(adj) = adjusted

Climate Change Projections

Based on the outputs from the SRES scenarios utilized in this study, most parks are projected to experience annual temperature changes of about +1.8–3.2°C in the 2020s, +1.8–7°C in the 2050s, and +2.5°C–10.0°C in the 2080s (Figure 2). The greatest changes in temperature were projected for the northern parks, including Tidewater Provincial Park and Woodland Caribou Provincial Park. The greatest change in precipitation was projected for Tidewater Provincial Park in the Northeast Zone and the least precipitation change was projected for Rondeau Provincial Park in the Southwest Zone (Figure 3).

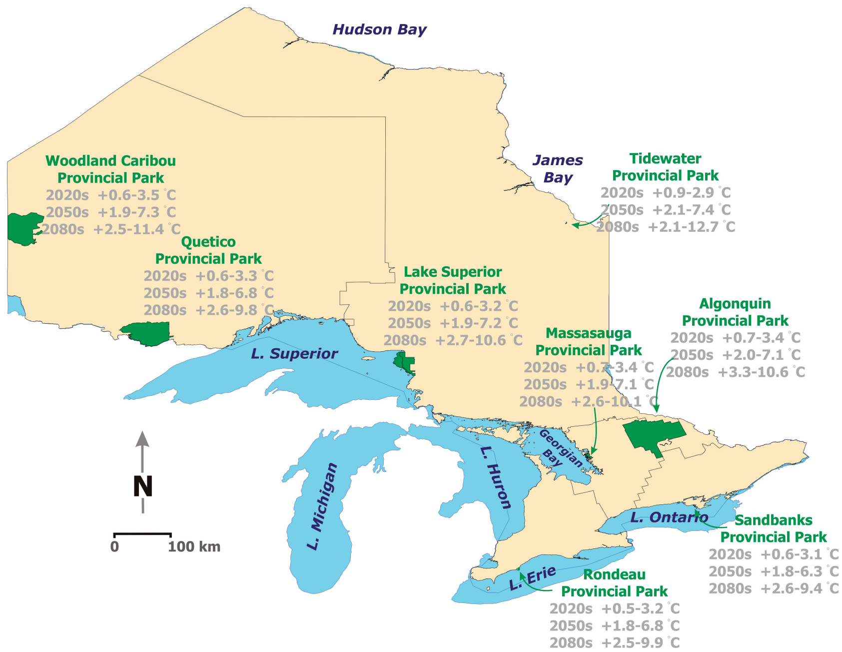


Figure 2: Climate change projections—temperature (°C).

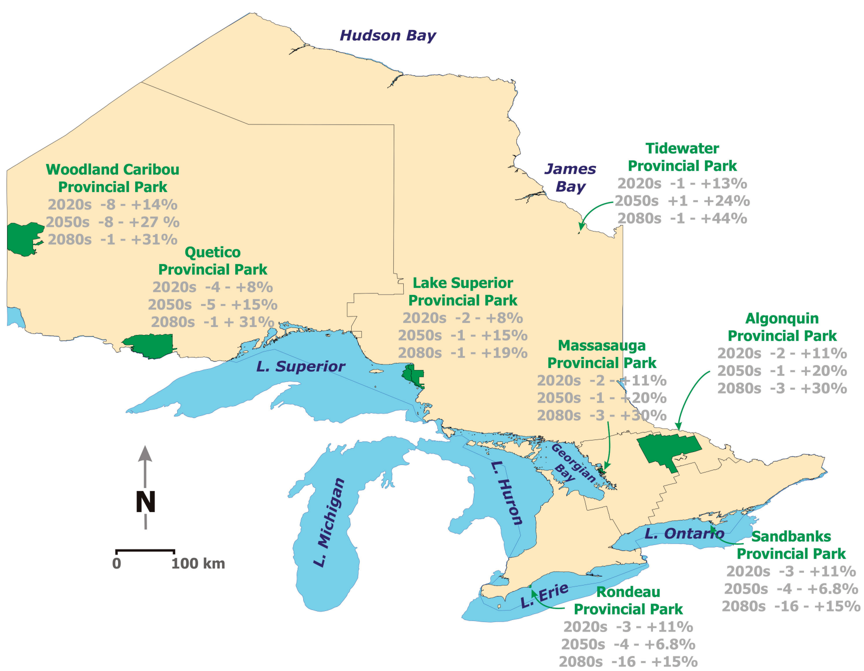


Figure 3: Climate change projections—precipitation (%).

Fire Severity Change Analysis

The results of the fire severity change analysis generally indicated a considerable decrease in the 'low' fire severity rankings and increases in the 'high', 'very high', and 'severe' fire severity rankings for the majority of Ontario's provincial parks under the 2050s (~2 x CO_2) and especially the 2090s (~3 x CO_2) scenarios (Figure 4). The scale shown is relative, with values above 6 being extreme. A real value of zero is only possible in remote cold regions where no fire danger exists in the summer months. For the 1980–1990 baseline, 13% of Ontario's provincial parks are classified within the 'low' (<1) fire severity ranking. By the 2050s and 2090s, respectively, it is projected that only 5% and 1% of Ontario's provincial parks will be classified within the 'low' (<1) fire severity ranking.

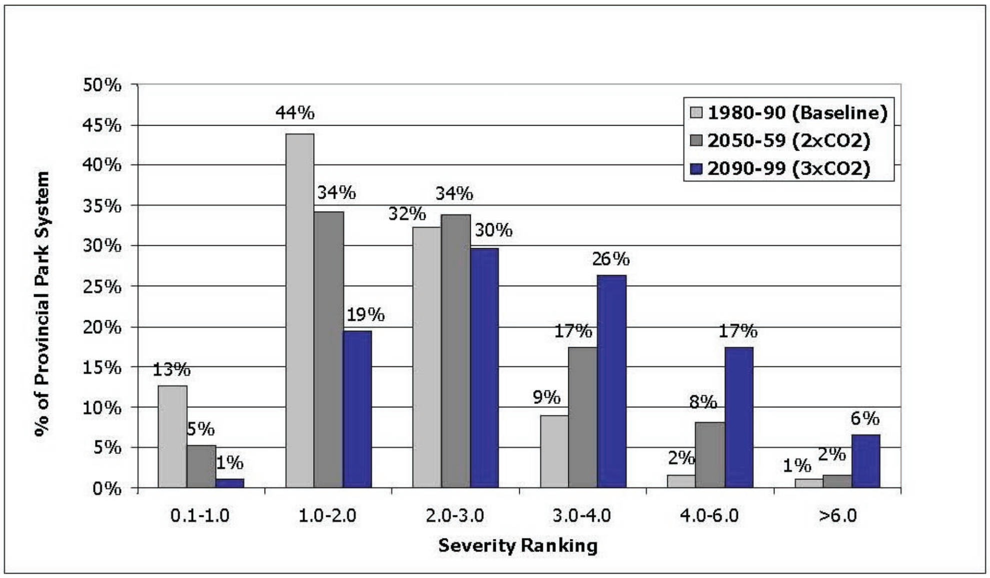


Figure 4: Fire severity change in Ontario provincial parks for the 1980–1990 (baseline) and the 2050s (~2 x CO_2) and 2080s (~3 x CO_2) utilizing the CGCM2 GCM†.

† Low severity ranking = <1.0, Moderate severity ranking = 1–3; High severity ranking = 3–4; Very high severity ranking = 4–6; Severe severity ranking = >6. The scale shown is relative, with values above 6 being extreme. A real value of zero is only possible in remote cold regions where no fire danger exists in the summer months.

Under the 1980–1990 baseline scenario, only 12% of Ontario's provincial parks fell into the 'high' (3–4), 'very high' (4–6), and 'extreme' (>6) fire severity ranking range. However, in the 2050s and 2090s scenarios, the number of provincial parks projected to experience these 'high' (>3) fire severity ratings increases considerably. The proportion of Ontario's provincial parks projected to be classified within the 'high', 'very high', and 'extreme' forest fire severity rankings is projected to increase to 27% by the 2050s and 49% by the 2090s.

Because of the high concentration of provincial parks in the south, a regional bias is evident—the majority of provincial parks utilized in this analysis are projected to experience 'moderate' levels (1–3) of fire severity under both the ~2 x CO_2 (68%) and ~3 x CO_2 (49%) scenarios. This projection is because the 'moderate' forest fire severity ranking is dominant throughout southern Ontario where a high number of relatively small provincial parks are located. Despite the relatively 'high' fire severity rankings projected for parks south of 46°N, wildfires in these forests will continue to be of negligible size under a warmer climate—this is a reflection of the relatively small forest patches which, in most instances, surround municipal infrastructures currently in place (e.g., roads, agriculture, telecommunication lines). Overall, the large numbers of provincial parks in southern Ontario comprise only a small proportion of the total PA system area. However, many of these provincial parks are significant for biodiversity conservation as they protect many rare or endangered Carolinian species.

Biome-type Change Analysis

Regardless of the Global Vegetation Model (GVM) and climate change scenario used, the vegetation modelling results showed the potential for substantial change in biome-type and biome-representation in Ontario's provincial park system under doubling CO_2 scenarios (Figures 5 and 6). The MAPSS GVM scenarios projected that the majority (72% HadCM2 [Hadley Second Generation General Circulation Model]; 93% UKMO [United Kingdom Meteorological Office]) of Ontario's provincial parks could experience a change in biome-type (Table 2). The BIOME3 GVM scenario showed only slightly fewer provincial parks with a change in biome-type (64% HadCM2).

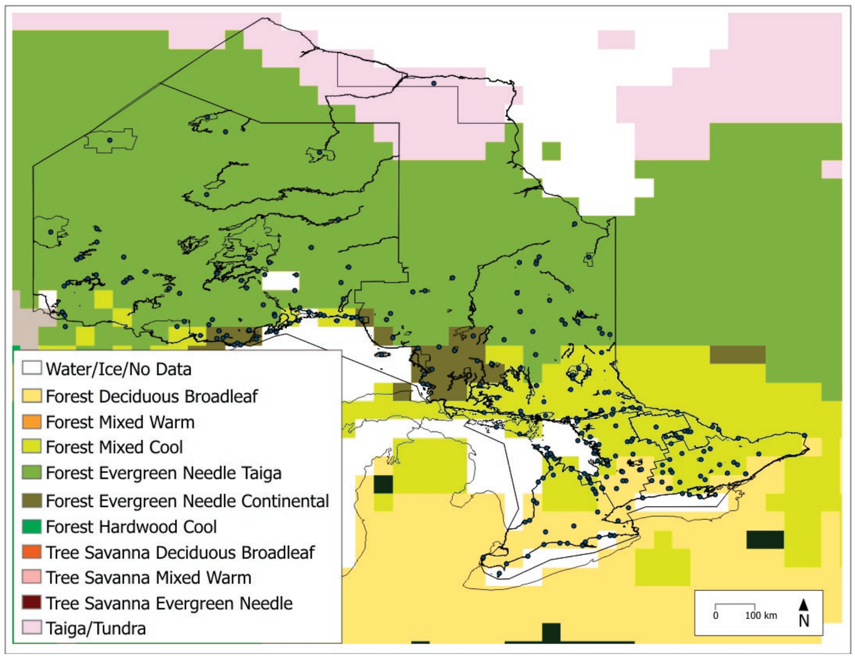


Figure 5: Current biomes and Ontario provincial parks—MAPSS Current.

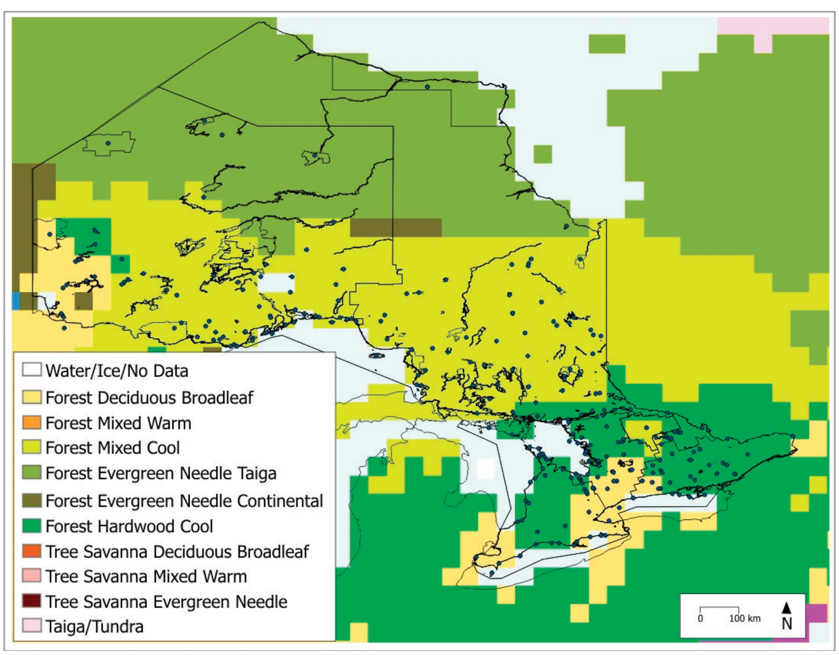


Figure 6: Biome change in Ontario provincial parks—MAPSS HadCM2.

Table 2: Biome-type change within Ontario provincial parks (under doubling CO_2 conditions).

	MAPSS		BIOME3
	HadCM2	UKMO	HadCM2
Change	72%	93%	64%

Table 3: Biome-representation change of Ontario provincial parks (under doubling CO_2 scenarios)—MAPSS.

Classification	Number of Provincial Parks Under MAPSS Current	Number of Provincial Parks Under HadCM2	Number of Provincial Parks Under UKMO
Water	28	28	24
Forest Deciduous Broadleaf	36	37	153
Forest Mixed Warm	0	0	15
Forest Mixed Cool	95	101	1
Forest Evergreen Needle Taiga	73	6	0
Forest Evergreen Needle Continental	20	0	0
Forest Hardwood Cool	0	81	0
Tree Savanna Deciduous Broadleaf	0	0	15
Tree Savanna Mixed Warm	0	0	41
Tree Savanna Evergreen Needle Continental	0	0	4
Taiga/Tundra	1	0	0

Table 4: Biome-representation change of Ontario provincial parks (under doubling CO_2 scenarios)—BIOME3.

Classification	Number of Provincial Parks Under BIOME3 Current	Number of Provincial Parks Under HadCM2
Water/Error	40	32
Boreal Evergreen Forest/woodland	29	1
Temperate Conifer Forest	125	101
Temperate/Boreal Mixed Forest	32	0
Temperate Deciduous Forest	27	119

With regards to biome representation change in the Ontario park system (Tables 3 and 4, previous page), there was general agreement among the scenarios. The GVM scenarios generally projected that Ontario provincial parks could experience increased representation of southern biome types, such as tree savanna deciduous broadleaf and tree savanna mixed warm. Conversely, the more northern biome types, such as forest mixed cool, forest evergreen needle-taiga, and forest evergreen needle continental, could decrease considerably within the provincial park system. Both the MAPSS HadCM2 and UKMO scenarios projected that the forest evergreen continental needle biome-type will experience a complete loss in representation. While both MAPSS scenarios (HadCM2 and UKMO) projected generally similar changes in biome-representation for Ontario provincial parks, there were some discrepancies. For example, where the HadCM2 scenario projected an increase in the forest mixed cool biome (+6%), the UKMO scenario projected a considerable decrease (-94%).

The BIOME3 HadCM2 scenario (Table 4) projected generally similar changes in biome-representation to that of the MAPSS HadCM2 scenario, although it is acknowledged that different classification schemes were utilized between the two GVMs, thereby limiting a more detailed comparative analysis. Generally, the BIOME3 HadCM2 scenario projected losses of all of the northern biome types, including the boreal evergreen forest/woodland biome-type (-97%). Conversely, because the BIOME3 HadCM2 scenario projected great expansion of the temperate deciduous forest biome into Ontario, considerable increases in representation of this biome-type by Ontario provincial parks resulted (92 provincial parks). Under all GVM and GCM scenarios, the only provincial park located on the taiga/tundra biome (Polar Bear Provincial Park) is projected to change biome type, leading to the loss of representation of this biome in the provincial park system.

Implications for Ontario Parks Policy, Planning, and Management

On November 25, 1992, the Canadian Parks Ministers Council met jointly with the Canadian Council of Ministers of the Environment and Wildlife Ministers Council of Canada and signed a *Statement of Commitment to Complete Canada's Networks of Protected Areas* (Federal Provincial Parks Council, 2000). In so doing, the key commitment for Parks Ministers was to "*make every effort to complete Canada's networks of protected areas representative of Canada's land-based natural regions by the year 2000 and accelerate the protection of areas representative of Canada's marine natural regions*" (Federal Provincial Parks Council, 2000: 5). As a result, most jurisdictions in Canada have adopted some type of ecoregion or biogeoclimatic classification framework as the main system-planning tool for their terrestrial protected area system.

Each of Ontario's provincial parks makes a particular contribution to the system based on the resources that it contains. Ecoregion representation is stated to be the primary concept used for identifying Ontario's network of protected areas (OMNR, 1992b; OMNR, 2004b). The *Planning and Management Policy* document states that, "*Provincial Parks are established to secure for posterity representative features of Ontario's natural and cultural heritage. Wherever possible the best representations of our heritage will be included in the park system*" (Ontario Parks, 1992a: 13). Three classification schemes—one each for life science, earth science, and cultural resources—form the basis for the park program's representation targets (OMNR, 1992a: 12).

The potential impacts of climate change have important implications for Ontario Parks' current policy and planning frameworks. Ontario Parks' approach to protected areas establishment is based on the works of Hills (1952, 1959, 1960, 1961, 1976) and Hills and Pierpoint (1960) who recognized the fundamental importance of climate in the classification of forest sites. Hills (1952, 1959, 1960, 1961, 1976) and Hills and Pierpoint (1960) utilized what they referred to as 'normal', 'uniform', 'homogenous', or 'definite' reference points for the development of vegetation for the surrounding region. In a changing climate, conservation planning based on 'normal' or 'homogenous' reference points and protecting representative samples of natural areas as *in situ* entities will have to deal with many challenges. As Scott and Suffling (2000) emphasize, protected area system planners will have to attempt to 'hit a moving target' of ecological representativeness as current protected area system plans are based on current species assemblages. Moreover, because possible non-analogue assemblages are unknown, comprehensive representation in a system of protected areas could become an increasingly difficult objective (Scott and Suffling, 2000).

Provincial park management plans are prepared for each park, in accordance with the *Provincial Park Management Planning Manual* (OMNR, 1992a). A review of management plans for several Ontario provincial parks revealed additional climate change implications for the management of individual protected areas. These include park objective statements, fire management strategies, individual species management plans and species at risk, non-native species management programs, and visitor management plans. For example, the management plan of each individual park defines the purpose of the park. The *Quetico Provincial Park Management Plan* states, "*Quetico Provincial Park will protect a* representative *portion of the ancient geological history,* modern *biological environments, and cultural features associated with site region 4W*" (OMNR, 1995a, emphasis added). The emphasis on the protection of 'modern' biological environments in these management plans renders them sensitive to changing climatic and vegetative conditions. And, as a result, these parks may no longer represent the ecological communities they are mandated to protect. Again, the principles of 'representation' and 'modern' biological environments are problematic as they assume climatic and biogeographic stability. Similar sensitivities can be found in virtually all park management plans examined to date.

OMNR mandates at the species level are also sensitive when climate change impacts are considered. For example, Polar Bear Provincial Park, as the name implies, was established to protect one of the world's largest denning areas for polar bears. Under climate and vegetation change scenarios and future sea-ice projections, the park would no longer provide suitable habitat for the species it was originally designed to protect. Reduced ice-cover in Hudson and James Bay may force polar bears northward in search of more suitable habitat and where they can more effectively hunt ringed seal. Similarly, changing vegetative conditions, would force woodland caribou northward to more suitable habitat in Woodland Caribou Provincial Park, a park specifically set up to protect this keystone species. Similarly, a re-introduced population of Woodland Caribou in Lake Superior Provincial Park may be forced northward to more suitable habitat, largely undoing the value of this conservation initiative.

As a final example, the objective of Pinery Provincial Park is "*...to protect an extensive, provincially significant, freshwater dune system with associated representative floral, faunal and cultural features and to provide high quality educational and recreational experiences*" (OMNR, 1986: 1). Moreover, the *Pinery Provincial Park Management Plan* states that the park will "*...ensure that Pinery harbours the richest* naturally occurring *communities inherent to its unique microclimate and topography*" (OMNR, 1986: 4, emphasis added). What is considered 'natural' will become more difficult to define as species' ranges change and new species, currently regarded as 'unnatural', may find suitable refuge within Pinery. As a consequence, the species requiring protection will increasingly be open to interpretation. In these cases, the ecological manifestations of climate change may be such that the established management objectives of the park are no longer viable.

Perhaps most important from a species conservation perspective are the potential effects that climate change poses for rare or endangered species. Many species at risk have very restricted habitat requirements or habitat availability and are the most vulnerable to changes. Without active intervention (i.e., translocation), many significant species are likely to be lost. The *Canadian Species at Risk Act* defines a 'wildlife species' as a species 'native' to Canada and has been present in Canada for at least 50 years (Government of Canada, 2003: 7). By this definition, species that have expanded (or will expand) their range into Canada under changing climate and ecological conditions, possibly classified as endangered in the United States, would not qualify as a species at risk under the *Canadian Species at Risk Act*, complicating the issue of endangered species conservation in Ontario and all Canadian jurisdictions.

Other OMNR strategies, such as those for control of invasive species, will also require review because of climate change. For example, the *Lake Superior Provincial Park Management Plan* (OMNR, 1995b) states that non-native plant species will be removed if they conflict with the representational values for which the park has been established. This statement does not allow for ecosystem change and the very definition of a non-native species (a species beyond its historical range) is challenged under climate change and resultant biogeographic shifts. Other policies, such as the *Fire Management Policy for Provincial Parks and Conservation Reserves* (OMNR, 2004a), may also be tested for their effectiveness in re-establishing ecological representation (one of the reasons why the policy was developed in the first place) under changing climate and fire severity conditions.

A New Approach

It is emphasized here that the traditional systematic approach to park system planning is indeed problematic. A new approach—one that incorporates ecosystem dynamics and change—is needed to safeguard against the fundamental flaws of *in situ* representation and species loss in Ontario. Like the Canadian national park system plan, Ontario's provincial park planning frameworks were designed with the assumption of essentially static biogeography and will be challenged by the dynamic nature of ecosystem evolution brought about by projected climate change in the twenty-first century. Ultimately, the results of this study contribute to a growing body of research that questions the capacity of existing protected area networks to fulfill this objective in an era of global climate change.

Although there is much uncertainty over the timing, extent, and manner in which ecosystems will respond to new climatic conditions, this does not negate the necessity of identifying and assessing adaptation strategies that might reduce the vulnerability of Ontario's system of protected areas to anticipated climate change. Recent discussions at the Parks Research Forum of Ontario (PRFO) workshop on climate change (Leslie Frost Research Centre, Dorset, Ontario, February, 2004) and an OMNR northwest zone climate change workshop (Quetico Centre, Atikokan, Ontario, December, 2004) revealed that incorporating climate change into protected area system planning and individual park management decision-making processes will be a complex and incremental process, but one that the majority of Ontario Parks' managers and planners strongly agreed is essential. Interestingly, all participants (approximately 30) who completed a survey distributed at the PRFO climate change workshop stated that they believed that either climate change is occurring or climate change is certain to occur. Results of the survey also indicated that the majority of respondents strongly agreed (67%) or somewhat agreed (22%) with the statement that climate change is going to substantially alter protected area policy and planning over the next 20 years. Finally, respondents strongly disagreed (67%) or somewhat disagreed (33%) with the statement that climate change is too far in the future to consider it in current planning activities.

The issues related to the strategic response of Ontario Parks to the challenge of climate change are very complex and will require significant input from many conservation stakeholders. Institutional financial commitment, capacity enhancement, cooperation, direction, and communication are a number of facets that will be essential to the successful implementation of any climate change adaptation related strategies in Ontario.

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References

Boer, G.J., N. McFarlane, and M. Lazare. 1992. Greenhouse gas induced climate change simulations with the CCC second generation GCM. *Journal of Climatology*, 5: 1045–1077.

Bradshaw, W.E. and C.M. Holzapfel. 2001. Genetic shift in photoperiodic response correlated with global warming. *PNAS*, 98(25): 14509–14511.

Braganza, K., D.J. Karoly, A.C. Hirst, P. Stott, R.J. Stouffer, and S.F.B. Tett. 2004. Simple indices of global climate variability and change Part II: attribution of climate change during the twentieth century. *Climate Dynamics*, 22: 823–838.

Canadian Climate Impacts Scenarios (CICS). 2004. Canadian Climate Impact Scenarios Group, Meteorological Service of Canada, Regina, Canada. [Online] http://www.cics.uvic.ca/scenarios/ [November 2004].

Environment Canada. 1998. Climate trends and variations bulletin for Canada. Meteorological Service of Canada—Climate Research Branch [Online]. http://www.msc-smc.ec.gc.ca/ccrm/bulletin/ [November 1998].

Environment Canada. 2003a. Environment Canada Historical Adjusted Climate Database. Meteorological Service of Canada. [Online] http://www.cccma.bc.ec.gc.ca/hccd/ [November 2003].

Environment Canada. 2003b. National Climate Data Archive. [Online] http://www.climate.weatheroffice.ec.gc.ca/prods_servs/cdcd_iso_e.html [November 2003].

Federal Provincial Parks Council (FPPC). 2000. *Working Together: Parks and Protected Areas in Canada*. Federal Provincial Parks Council: no place. 64 pp.

Government of Canada. 2003. Chapter 29. *Canadian Species at Risk Act.* Ottawa: Government of Canada. 97 pp.

Hannah, L., G.F. Midgley, and D. Millar. 2002. Climate change integrated conservation strategies. *Global Ecology and Biogeography*, 11: 485–495.

Hansen, L.J., J.L. Biringer, and J.R. Hoffman (eds.). 2003. *Buying Time: A User's Manual for Building Resistance and Resilience to Climate Change in Natural Systems*. Washington: World Wildlife Fund International.

Haxeltine, A. and I. Prentice. 1996. BIOME3: An equilibrium terrestrial biosphere model based on ecophysiological constraints, resources availability, and competition among plant function types. *Global Biogeochemical Cycles*, 10: 693–709.

Hills, G.A. 1952. *The Classification and Evaluation of Site for Forestry*. Research Report No.24. Maple: Ontario Department of Lands and Forests. 41 pp.

Hills, G. A. 1959. *A Ready Reference to the Description of the Land of Ontario and its Productivity*. Preliminary Report. Maple: Ontario Department of Lands and Forests, Division of Research. 142 pp.

Hills, G.A. 1960. Regional site research. *Forestry Chronicle,* 36: 401–423.

Hills, G. A. 1961. *The Ecological Basis for Land-use Planning*. Research Report 46. Maple: Department of Lands and Forests. 210 pp.

Hills, G.A. 1976. Mapping the site regions and landscape districts of Ontario 1944–1975: Introducing the 1975 version. Unpublished draft manuscript—Toronto: Ontario Ministry of Natural Resources. 61 pp and appendices.

Hills, G.A. and G. Pierpoint. 1960. *Forest Site Evaluation in Ontario*. Research Report 42. Maple: Ontario Department of Lands and Forests. 63 pp.

Holdridge, L. 1947. Determination of world plant formation from simple climatic data. *Science*, 105: 367–368.

Hughes, L. 2000. Biological consequences of global warming: is the signal already apparent? *Trends in Ecology and Evolution*, 15: 56–61.

Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson (eds.). 2001. *The Scientific Basis*. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

Lemieux, C.J. and D. Scott. In press. Climate change, biodiversity conservation, and protected areas planning in Canada. Submitted to the *Canadian Geographer*.

Malcolm, J.R. and A. Markham. 2000. *Global Warming and Terrestrial Biodiversity Decline*. Washington: World Wildlife Fund International.

Malcolm, J. R., A. Markham, R. P. Neilson, and M. Garaci. 2002. Estimated migration rates under scenarios of global climate change. *Journal of Biogeography*, 29: 835–849.

Mann, M., C. Amman, R. Bradley, K. Briffa, P. Jones, T. Osborn, T. Crowley, M. Hughes, M. Oppenheimer, J. Overpeck, S. Rutherford, K. Trenberth, and T. Wighley. 2003. On past temperature and anomalous late 20th century warmth. *EOS*, 84(27), 256–258.

McCarty, J. 2001. Ecological consequences of recent climate change. *Conservation Biology*, 15: 320–331.

McFarlane, N., G.J. Boer, J.P. Blanchet, and M. Lazare. 1992. The CCC second generation GCM and its equilibrium climate. *Journal of Climatology*, 5: 1013–1044.

McLaughlin, J.F., J.J. Hellmann, C.L. Boggs, and P.R. Ehrich. 2002. Climate change hastens population extinctions. *PNAS*, 99(9): 6070–6074.

Neilson, R. 1995. A model for predicting continental-scale vegetation distribution and water balance. *Ecological Applications*, 5: 362–385.

Neilson, R. 1998. Simulated changes in vegetation distribution under global warming. In: The regional impacts of climate change: An assessment of vulnerability. pp. 441–456. In: R. Watson, M. Zinyowera, and R. Moss (eds.). *A Special Report of IPCC Working Group 2*. Cambridge: Cambridge University Press.

Ontario Ministry of Natural Resources. 1986. *Killarney Provincial Park Management Plan*. Toronto: Queen's Printer for Ontario.

Ontario Ministry of Natural Resources (OMNR). 1992a. *Provincial Park Management Planning Manual*. Toronto: Queen's Printer for Ontario.

Ontario Ministry of Natural Resources (OMNR). 1992b. *Ontario Provincial Parks – Planning and Management Policies*. Toronto: Queen's Printer for Ontario.

Ontario Ministry of Natural Resources. 1995a. *Quetico Provincial Park Management Plan*. Toronto: Queen's Printer for Ontario.

Ontario Ministry of Natural Resources (OMNR). 1995b. *Lake Superior Provincial Park Management Plan*. Toronto: Queen's Printer for Ontario.

Ontario Ministry of Natural Resources (OMNR). 2004a. *Fire Management Policy for Provincial Parks and Conservation Reserves*. Toronto: Queen's Printer for Ontario.

Ontario Ministry of Natural Resources (OMNR). 2004b. *Creating the Ontario Biodiversity Strategy: Workbook 1*. Peterborough, Ontario: OMNR.

Parks Research Forum of Ontario (PRFO). 2004. Climate change and Ontario's provincial parks. Unpublished web page available online: http://www.prfo.ca/Climate%20Change/prfo2004_ccworkshop.htm

Parmesan, C. 1999. Climate and species' range. *Nature*, 382: 765–766.

Parmesan, C. and H. Galbraith. 2004. *Observed Impacts of Global Climate Change in the U.S.* Arlington, Virginia: PEW Centre on Global Climate Change.

Parmesan, C. and G. Yohe. 2003. A globally coherent fingerprint of climate change impacts across natural systems. *Nature*, 41: 37–42.

Peng, C. 2000. From static biogeographical model to dynamic global vegetation model: a global perspective on modelling vegetation dynamics. *Ecological Modelling*, 135: 33–54.

Peters, R. and J. Darling. 1985. The greenhouse effect and nature reserves. *Bioscience*, 11: 707–716.

Pounds, J.A., M.P.L. Fogden, and J.H. Campbell. 1999. Biological responses to climate change on a tropical mountain. *Nature*, 398: 611–615.

Root, T.L., J.T. Price, K.R. Hall, S.H. Schneider, C. Rosenzweig, and J.A. Pounds. 2003. Fingerprints of global warming on wild animals and plants. *Nature*, 421; 57–60.

Scott, D.J. and R. Suffling. 2000. *Climate Change and Canada's National Parks*. Toronto: Environment Canada.

Scott, D.J., J. Malcolm, and C.J. Lemieux. 2002. Climate change and modelled biome representation in Canada's national park system: implications for system planning and park mandates. *Global Ecology and Biogeography,* 11: 475–484.

Stocks, B.J., M.A. Fosberg, T.J. Lynham, L. Means, B.M. Wotton, and Q. Yang. 1998. Climate change and forest fire potential in Russian and Canadian boreal forests. *Climatic Change*, 38: 1–13.

Stocks, B.J., M.A. Fosberg, M.B. Wotton, T.J. Lynham, and K.C. Ryan. 2000. Climate change and forest fire activity in North American Boreal Forests. pp. 368–376. In: Kasischke, E.S. and B.J. Stocks (eds.). 2000. *Fire, Climate Change, and Carbon Cycling in the Boreal Forest*. New York: Springer.

Thomas, C.D., E.J. Bodsworth, R.J. Wilson, A.D. Simmons, Z.G. Davies, M. Musche, and L. Conradt. 2001. Ecological and evolutionary processes at expanding range margins. *Nature*, 411: 577–581.

Thomas, C.D., A. Cameron, R.E. Green, M. Bakkenes, L.J. Beaumont, Y.C. Collingham, B.F.N. Erasmus, M.F. de Siqueira, A. Grainger, L.Hannah, L. Hughes, B. Huntley, A.S. van Jaarsveld, G.F. Midgley, L. Miles, M.A. Ortega-Huerta, A.T. Peterson, O.L. Phillips, and S.E. Williams. 2004. Extinction risk from climate change. *Nature*, 427: 145–148.

Walther, G.R., E. Post, A. Menzel, P. Convey, C. Parmesan, F. Bairlen, T. Beebee, J.M. Fromont, and O. Hoegh-Guldberg. 2002. Ecological responses to recent climate change. *Nature*, 416: 389–395.

Warren, M.S., J.K. Hill, J.A. Thomas, J. Asher, R. Fox, B. Huntley, D.B. Roy, M.G. Telfer, S. Jeffcoate, P. Harding, G. Jeffcoate, S.G. Willis, J.N. Greatorex-Davies, D. Moss, and C.D. Thomas. 2001. Rapid responses of British butterflies to opposing forces of climate and habitat change. *Nature*, 414: 65–69.

Woodward, F. 1987. *Climate and Plant Distribution*. Cambridge: Cambridge University Press.


Outdoor education program, Photo anon., Ontario Ministry of Natural Resources

The Tourism Industry:

Its Vulnerability and Adaptability to Climate Change

The Tourism Industry: Its Vulnerability and Adaptability to Climate Change

Geoffrey Wall

Faculty of Environmental Studies
University of Waterloo, Waterloo, Ontario
Canada

Abstract:

In the consideration of climate change and tourism, it is suggested that more emphasis be placed on risk assessment. The vulnerability of tourism to climate change is discussed briefly and the difficulty of generalizing across a multitude of locations and activities is stressed. Mitigation and adaptation are discussed and the need for both is acknowledged. Case studies of skiing and marinas and recreational boating from the Great Lakes region of North America are presented and a variety of research needs and opportunities is suggested.

Keywords: adaptation, Great Lakes, mitigation, recreation, research needs, risk, tourism, vulnerability, uncertainty

Introduction

This contribution does not examine climate change per se. Rather, it is based upon the assumptions that climate and weather, which are inherently variable on a multitude of time scales, may change at an unprecedented rate in future decades and that such events have implications for tourism. There are many uncertainties. This term is used by cautious scientists who correctly acknowledge the complexities of the climate system and the need for further research to enhance understanding. The term, however, permits sceptics, both academics and public officials, to dismiss the growing evidence that the climate is changing. But certainty will only exist after the fact (and even then the processes may still be incompletely understood). For this reason, it is preferable to use the term “risk”. Risks are extremely difficult to calculate but risk is a more palatable and actionable term than uncertainty. What risks do tourism businesses face from climate change and variability and what can be done to reduce these risks? Are there also opportunities associated with the changing circumstances?

The uncertainties that usually surface in climate change deliberations and are given most prominence in discussions are usually those associated with physical systems. Climate modellers have been particularly successful in using these uncertainties to garner increased research funds. However, it is contended that the uncertainties of human systems are much greater than those of physical systems. While models of climate change have become more sophisticated, including the development of transient models (Scott *et al*., 2002, 2003), and the results of research vary with the scenarios adopted to drive the analyses, studies of the ski industry show that global trends in the length of the ski season are universally negative (Galloway, 1988; Konig and Abbegg, 1997; Perry, 2000). However, the magnitude of curtailment is reduced substantially by the adoption of snow-making (see below). Much more needs to be known about human responses to the vicissitudes of weather and climate.

Furthermore, climate change is one among many phenomena that are part of an increasingly turbulent environment. In the past few years, the global system, including the tourism system, has been disrupted by wars, terrorism, the Asian economic crisis and contagious diseases among other factors. It is impossible to study everything at once and just as we abstract tourism from broader human systems to facilitate analyses, it is necessary to remember that climate change is only one form of global change and may not be the most important for all places and activities, and at all temporal and spatial scales. Thus, both tourism and climate change should be considered in a broad context and the most challenging situations may be in places where the various forces of global change, both human and physical, are superimposed upon each other, such as in coastal cities and remote mountain communities that are being opened to tourism.

The Vulnerability of Tourism to Climate Change

Vulnerability refers to the extent to which a system may be (adversely) affected, disrupted, or displaced by an external force. In this case, we are concerned with components of the tourism system and the challenges associated with climate change.

The magnitude of the implications of climate change for tourism and recreation will depend upon both the distribution and importance of tourism phenomena and the characteristics of climate change. Other things being equal, locations whose economies are highly dependent on tourism appear to be at the greatest risk.

Some claim that tourism is now the largest industry in the world and few areas are untouched by tourism. In this sense it is a global industry. At the same time, tourism is widely but not evenly distributed and is highly concentrated in specific places, especially cities, coasts, and mountains. Cities are often major tourism attractions but they usually have a diversified economy. The less-populated areas often have a high dependence on tourism and many coastal and mountain locations specialize in catering to tourists. Much tourism and recreation is concentrated in high-energy environments, such as mountains and coasts—areas that appear to be particularly vulnerable to climate change through modifications in the hydrological cycle, particularly changes in water levels, stream flow, and the magnitude and timing of snowfall.

The author (Wall, 1992, 1993) has elsewhere suggested that domestic travel patterns are likely to be more stable than international travel because the former often take place in relatively short periods of free time and time limitations place constraints on the destination choices of travellers. Conversely, long-haul destinations are more at risk than those depending largely on a local market. Furthermore, destinations that rely primarily upon their natural resource base to attract visitors, such as mountains and coasts, are likely to be more at risk than those that depend upon cultural or historical attractions.

Smith (1990) pointed out that vacation travel decisions are influenced by conditions at home as well as at potential holiday destinations. He suggested that in a warmer world, many winter vacations currently taken in Florida or Mexico by residents of the colder parts of the USA and Canada may become less compelling under the relatively large increment of winter warming projected for these latitudes.

The length of the season is also of crucial importance for private sector operators of tourism facilities. Capital is invested all year round but, for many activities and destinations, the operating period is limited and profits must be made in a short period of time. A few inclement weekends may tip the balance between profit and loss. Anything that influences the length of operating seasons, be they climatic factors or otherwise (such as the length and timing of school holidays), is likely to have an impact upon the viability of tourism businesses.

In addition to the relatively direct impacts of climate upon tourism, climate also impinges upon recreation in a less direct fashion. For example, an abundance of snow may make the skiing conditions very good but the journey to the slopes impossible. Conversely, recent observations in Alberta indicated that, although snowfall was reduced, many skiers were attracted to the hills by the mild, sunny weather. On a longer time scale, climatic change will influence the distribution of vegetation types, wildlife, and fish species on which some forms of tourism depend. Much tourism takes place on or near the shoreline and the presence of water enhances many forms of tourism even if water contact is not required. Fluctuations in climate at meso and macro scales have implications for water levels and discharge, and influence amenity and property values. Hare (1985) pointed out that, at the low-water point of the mid-sixties in the Great Lakes, the water retreated hundreds of meters from some of the beaches and shores of Lake Huron. Furthermore, the volume of water has implications for water quality; in some locations, such as parts of the Mediterranean and the Great Lakes where beaches are closed periodically because of pollution, this is already marginal for body-contact recreations.

There are far-reaching consequences of weather and climate for tourism. However, it is extremely difficult to generalize the possible implications of climate change for tourism. It is difficult to think of almost any area of land or water that, with or without human modification or management, does not have potential to provide some recreation opportunities. The discussion will now turn to a consideration of what can be done to address the challenges.

Mitigation and Adaptation

Strategies to respond to global climate change are often considered under the headings of mitigation and adaptation (Task Force on Climate Adaptation, 1993). Mitigation refers to attempts to curtail the production of greenhouse gases and thereby to reduce the magnitude and speed of climate change. Adaptation accepts that climate change is likely to occur and attempts to identify steps that may be taken to restrict its adverse consequences and to take advantage of opportunities. Mitigation and adaptation should not be regarded as alternative strategies for they are interrelated and can occur at the same time.

In the early discussions of global climate change, there was reluctance to consider adaptation. As it was becoming increasingly recognized that climate change would have multiple consequences for human systems, the remedy was seen to be the reduction of greenhouse gases. Adaptation was seen as weakening the case for mitigation.

Increasingly, adaptation has become more widely recognized as a necessary strategy, in part because many believe that climate is already changing and adaptation will be required even if limitations are placed upon greenhouse gas production. Thus, mitigation and adaptation are now more frequently seen as being complementary rather than competitive strategies. It follows that tourism could be vulnerable to and will have to adjust to both climate change and to the mitigation strategies that are imposed to reduce greenhouse gas production.

Mitigation

Energy consumption in travel between origins and destinations is seen as the most important contribution of tourism to the rising concentrations of greenhouse gases. Temporary movement of people from temperate to tropical latitudes does have local implications for energy and water consumption but on-site recreational activities are usually viewed as being minor net contributors to the global production of greenhouse gases. However, the increased demands for energy and water and the generation of wastes may have far-reaching local consequences, particularly as tourists tend to make much larger demands than local residents for these scarce resources.

While trips are, by definition, discretionary activities for participants in most forms of tourism, they are certainly not discretionary for the businesses and communities that cater to tourists and depend upon their expenditures. Thus policies designed to curb travel may have considerable implications for destination areas. In the 1970s, when gasoline was in short supply in North America, the economies of tourist destination areas were adversely affected (Knapper, Gertler, and Wall, 1981). However, it was found that many urbanites elected to save their gasoline for recreation, there being more alternatives for modifying the journey to work than the journey to play in dispersed locations that were poorly served by public transportation. More recently, restrictions on mobility in the British countryside as a response to foot and mouth disease have demonstrated clearly that the economies of many rural areas depend as much on the production of leisure experiences as on agricultural products.

In summary, tourism and recreation are not usually viewed as major net generators of greenhouse gases, except perhaps in the travel phase, but policy initiatives taken to curb travel, perhaps through the pricing or rationing of gasoline, may have substantial implications for destination areas.

Adaptation

Adaptation involves adjustments to social and economic activities to enhance their viability and to reduce their vulnerability (Task Force on Climate Adaptation, 1993). Adaptation is a practical means of accommodating current climatic variability and extreme events as well as adjusting to longer-term climate change. Both natural and human systems are already adapted to an unknown extent to much of the variability in current climates. It is through changes in the magnitude and frequency of extreme events that the implications of climate change will most likely be imposed.

Three main groups can be considered with respect to the potential to adapt to climate change: the participants themselves; the businesses that cater to them; and the institutions that provide the context in which they operate.

1. Participants

By definition, tourism and recreational participation results from choices. Tourists have considerable choice concerning whether or not to participate, where to go, what activities to participate in, and when to travel. Since the product of tourism is an experience, participants may be able to substitute activities and locations without a great deal of loss in the quality of their recreation. Those wishing to observe or hunt particular species of plants and animals may find them less accessible or replaced by others, but, insofar as there are still wild spaces and provision of tourism and recreational opportunities, most potential participants will likely be able to satisfy their leisure needs.

2. Businesses

Participants' flexibility may be a problem for those catering to tourists' demands. Much recreational provision, be it a ski hill, a campground, a marina, or a national park, is fixed in location with sunk capital that cannot readily be liquidated and re-invested. If the quality of the recreational resources and associated experiences is degraded or if the length of operating seasons is curtailed below economic viability, then there may be considerable economic dislocations for recreational businesses and the communities on which they depend.

3. Institutions

Institutional decisions impinge on tourism. The timing of public holidays, school vacations, and hunting and fishing seasons, the dates of opening and closing of parks and other tourism attractions may all need to be modified in new climatic circumstances. For example, the increased length of summer may permit longer camping seasons in temperate latitudes provided conditions are not adversely affected by declining water levels or the reduced availability of water. However, if parks remain open longer, it is not known if more visits will be made or if they will be more widely spaced throughout the season. Also, enhanced economic benefits could have trade-offs in the form of increased environmental deterioration as the parks host more visitors for longer periods of time.

Case Studies

Two examples from the Great Lakes Region of North America provide some specific examples of climate-related risks and adjustments.

Great Lakes Skiing

Some of the earliest research to examine the impact of climate change on tourism was on the skiing industry in the Great Lakes region (Scott, Wall, and McBoyle, in press). McBoyle and Wall (1986), using the climate change scenarios available at the time, found that the ski season to the north of Lake Superior would be reduced by 30 to 40%. Skiing conditions would also be curtailed in south-central Ontario, resulting in the contraction or possible elimination of the ski season (40 to 100% reduction). Skiing in the Lower Laurentian Mountains of Quebec was projected to experience a 40 to 89% reduction in season length (McBoyle and Wall, 1992). Lamothe and Periard Consultants (1988) similarly projected that the number of skiable days would decline by 50 to 70% in southern Quebec. Comparable results were also projected for ski areas in the Great Lakes region of the United States.

An important limitation of these early studies on climate change and skiing in North America (and indeed the international literature) has been the omission of snowmaking as an adaptation strategy. In order to reduce their vulnerability to current climate variability, ski areas have made multi-million dollar investments in snowmaking technology and many now have complete snowmaking coverage of skiable terrain. Scott *et al*. (2002) were the first to examine snowmaking as an adaptation strategy. Using a range of climate change scenarios based on the Intergovernmental Panel on Climate Change's (IPCC) Special Report on Emission Scenarios (SRES), Scott *et al*. (2003) projected a 7 to 32% reduction in average ski season in the central Ontario study area, with current snowmaking capabilities and under doubled atmospheric CO_2 equivalent scenarios (~2050s), With improved snowmaking capabilities, modelled season losses were further moderated to between 1% and 21%. The findings clearly demonstrate the importance of snowmaking as an adaptation strategy.

Importantly, snowmaking requirements to minimize ski season losses in the study area were projected to increase 191 to 380% by the 2080s (Scott *et al*., 2003). However, it should be recognized that while snowmaking is an effective adaptation strategy, it is not without associated challenges, for both capital and operating costs are substantial as are large water requirements. Thus, it may not be the inability to provide snow on ski hills, but the cost of making additional snow and the negative perceptions related to no-snow conditions in ski market areas that could cause adverse economic impacts within the Ontario ski industry.

Large corporate ski entities in the region like Intrawest and American Skiing Company may be less vulnerable to the impacts of climate change than single ski operations because they generally have more diversified business operations (real estate, warm-weather tourism resorts, and four-season activities), are better capitalized (so that they can make substantial investments in snowmaking systems), and, perhaps most importantly, are regionally diversified (which reduces their business risk to poor snow conditions in one location). Other possible adaptations include the extension of operations in mountainous areas to higher latitudes where snowfall may continue to be reliable, as has occurred in the European Alps, but this strategy has ecological consequences, particularly where operations are conducted above the treeline.

Marinas and Recreational Boating

Almost all forms of recreation are enhanced by the presence of water. Some, such as bathing and fishing, cannot be undertaken in the absence of water of appropriate quantity and quality. Other activities, such as hiking and camping, are often associated with shorelines and may be enhanced by the presence of water even if no direct contact with water is involved. Thus anything that impinges upon the quantity or quality of water is likely to affect outdoor recreation. Furthermore, if water is in short supply, recreation will increasingly compete with other uses of this scarce resource.

The Great Lakes constitute a dramatic example of the implications of fluctuating water levels, and hence climate variability, for recreational activities. The Great Lakes have long been a mecca for recreational boating and fishing, and their shores are the location of recreational facilities such as private cottages and public parks. The lakes are also used for water supply, navigation, and power generation, and the levels of the lakes fluctuate in response to climatic variations. Fluctuating water levels are required for the maintenance of ecological processes but some users, such as power generation and navigation, would prefer greater stability and relatively high levels, whereas others, such as cottagers, would prefer relatively stable lower levels. Marinas and recreational boating are harmed by extremes of both high and low water, particularly the latter, which is the most likely situation under global climate change.

Surveys of marina operators and recreational boaters on the Canadian side of the Great Lakes, undertaken in 1992, indicated that almost all had incurred costs at some time or other associated with fluctuating water levels (Bergmann-Baker, Brotton, and Wall, 1995). There are examples of marina operators experiencing low-water problems at times when they were still paying off loans acquired to build breakwaters to protect themselves from high water.

Boaters also accrue a variety of costs but they are more mobile than marina operators and, thus, can adjust more easily. However, they may be affected in other ways. For example, global warming may increase fish productivity if water quality is not adversely affected but some desirable cold-water species may decline and alien species may find it easier to colonize the lakes.

Research Needs

Tourism and recreation is an area that is data rich but information poor. A wealth of studies of tourism and recreation exists but most are site specific and few have addressed relationships with weather and climate. The output of the General Circulation Models is very difficult to use for site or even regional studies and usually does not include variables in a form pertinent to recreation. Climate varies over short distances and with height and aspect in mountainous regions—at scales which are important for recreation but beyond the resolution of existing models. In consequence, combining the available recreation and climatic information is difficult and, where this has been done in modelling exercises, the assumptions that are involved probably invalidate the results (Mendelsohn and Markowski, 1999).

Greater spatial resolution, a greater variety of climate and climate-related variables, and a reduction in the uncertainty associated with climate scenarios generated from General Circulation Models are required if improved estimations of the likely implications of climate change for tourism and recreation are to be made. However, the improvement of such information is insufficient by itself to further such understanding. Complementary research strategies are required, such as investigation of the adaptation of participants and recreation businesses to existing climatic variability.

The wealth of existing data on current weather and climate is generally not well used by tourism and recreation operators at present. Much might be learned through the use of such data to assess current lengths of operating seasons, their temporal and spatial variability, and the associated economic viability of recreation businesses. Such studies would have considerable practical applications. One outcome of such analyses might be the more widespread acceptance of including climate change as one factor among others in assessments of recreation investment viability.

In order to make rational, objective decisions concerning responses to the vagaries of climate, the decision maker (in this case the tourist or the proprietor of a tourism enterprise) must have an explicit understanding of weather-activity relationships. The identification and measurement of the economic impact of weather variation is a key exercise in understanding climate-weather relationships. The economic assessment of weather hazards, or "*weather costing*", is not only possible and practical, but it enables comparisons to be made between sites and greater efficiencies to be achieved (Taylor, 1970). However, weather costing has yet to achieve its full potential among recreation enterprises.

Climate is only one factor among many that influence tourism and recreation, thus assessing the relative importance of climate as compared to other variables for both different activities and different locations is important.

Since tourism involves, by definition, activities undertaken by choice, it is important to understand how alternative opportunities are evaluated by potential participants. If future choices are restricted by a modified climate, participants may be able to substitute one activity for another or one location for another. The assessment of the extent to which particular recreations and locations may be substitutes may thus be a fruitful area of research.

Assessment of the implications of climate change for natural area designation and management is an important research area now receiving attention, but which merits further examination (Wall, 1989; Staple and Wall, 1996; Scott and Suffling, 2000).

Other topics which are worthy of investigation include: assessment of the means by which recreational provision can be diversified to reduce vulnerability; evaluation of the role of extreme events in influencing recreational provision; and the role of land-use zoning, insurance, and other social adjustments in influencing recreational provision in high-energy locations such as shorelines and mountains.

Summary and Conclusions

This paper has made clear the implications of atmospheric processes, particularly climate change, for tourism and has suggested that the frequent mention of uncertainties be replaced by a greater concern with risk. The vulnerability of tourism to climate change has been discussed briefly and the difficulty of generalizing across a multitude of locations and activities has been stressed. Mitigation and adaptation are distinct activities; however, both must be acknowledged and recognized as having implications for tourism. Case studies of skiing and marinas and recreational boating from the Great Lakes region have exemplified impacts and adaptation in response to climate variability. A variety of research needs and opportunities are evident. However, in the absence of comparative studies, it has not been possible to indicate whether tourism is more vulnerable than other economic sectors or has more or less potential to adapt. Similarly, it has been possible to outline vulnerabilities with respect to tourism activities and locations in only the most general way. The potential to address these vulnerabilities has been illustrated but the appropriate mix of mitigation and adaptation strategies required to address tourism vulnerabilities has yet to be ascertained.

Given the existing state of knowledge, it may be premature to make recommendations for policy but some pertinent observations can be made. Coastal areas appear to require careful attention given their susceptibility to changing water levels and their significance for tourism and recreation. Operators of ski areas in climatically marginal areas may need to upgrade their snowmaking equipment and diversify their activities—strategies that could pay dividends even in the absence of climate change. Summer activities in middle and high latitudes may benefit from extended seasons provided that coastal processes are not disrupted and water is not in short supply.

References

Bergmann-Baker, U., J. Brotton, and G. Wall. 1995. Socio-economic impacts of fluctuating water levels for recreational boating in the Great Lakes basin. *Canadian Water Resources Journal*, 20 (3): 185–194.

Galloway, R. 1988. The potential impact of climate change on Australian ski fields. In: G. Pearman (ed.). *Greenhouse: Planning for Climate Change.* Melbourne: CSIRO, 428–437.

Hare, F.K. 1985. Climatic change in the Great Lakes Basin: an appraisal. Unpublished paper presented at the Workshop on Climate Impact Assessment in the Great Lakes Basin: Research Strategies. King City, Ontario.

Knapper, C., L. Gertler, and G. Wall. 1981. *Tutankhamun in Toronto*. Department of Geography Publication Series No. 17. Waterloo: University of Waterloo.

Konig, U. and B. Abbegg. 1997. Impacts of climate change on winter tourism in the Swiss Alps. *Journal of Sustainable Tourism*, 5(1): 46–58.

Lamothe and Periard Consultants. 1988. Implications of climate change for downhill skiing in Quebec. *Climate Change Digest*, 88–03.

McBoyle, G. and G. Wall. 1986. Recreation and climatic change: A Canadian case study. *Ontario Geography*, 28: 51–68

McBoyle, G. and G. Wall. 1992. Great Lakes skiing and climate change. In: A. Gill and R. Hartmann (eds). *Mountain Resort Development: Proceedings of the Vail Conference 1991*. Burnaby: Centre for Tourism Policy and Research, Simon Fraser University, 82–92.

Mendelsohn, R. and M. Markowski. 1999. Estimated effects of climate change on selected outdoor recreation activities in the United States. In: R. Mendelsohn and J. Newmann (eds.). *The Impact of Climate Change on the United States Economy*. Cambridge: Cambridge University Press, 267–288.

Perry, A. 2000. Tourism and recreation. In: M. Parry (ed.). *Assessment of Potential Effects and Adaptations for Climate Change in Europe*. Norwich: Jackson Environment Institute, University of East Anglia, 217–226.

Scott D., B. Jones, C. Lemieux, G. McBoyle, B. Mills, S. Svenson, and G. Wall. 2002. *The Vulnerability of Winter Recreation to Climate Change in Ontario's Lakelands Tourism Region*. Department of Geography Publication Series Occasional Paper 18. Waterloo: University of Waterloo.

Scott D., G. McBoyle, and B. Mills. 2003. Climate change and the skiing industry in Southern Ontario (Canada): Exploring the importance of snowmaking as a technical adaptation. *Climate Research*, 23, 171–181.

Scott, D. and R. Suffling. 2000. *Climate Change and Canada's National Parks*. Toronto: Environment Canada.

Scott, D., G. Wall, and G. McBoyle. In press. Climate change and tourism and recreation in North America. In: M. Hall and J. Higham (eds). *Tourism, Recreation and Climate Change*. Clevedon: Channel View Press.

Smith, K. 1990. Tourism and climate change. *Land Use Planning*, 7, 176–180.

Staple, T. and G. Wall. 1996. Climate change and recreation in Nahanni National Park Reserve. *The Canadian Geographer*, 40 (2): 109–120.

Task Force on Climate Adaptation. 1993. *Adaptation to Climate Change and Variability*. Guelph: Department of Geography, University of Guelph.

Taylor, J.A. (ed.) 1970. *Weather Economics.* Memorandum No.11. Aberystwyth: University College of Wales.

Wall, G. 1989. Implications of climatic change for Prince Albert National Park, Saskatchewan. *Climate Change Digest,* 89–93.

Wall, G. 1992. Tourism alternatives in an era of global climate change. In: W. Eadington and V. Smith (eds). *Tourism Alternatives: Potentials and Problems in the Development of Tourism*. Philadelphia: University of Pennsylvania Press, 194–215.

Wall, G. 1993. Tourism and recreation in a warmer world. In: S. Glyptis (ed.). *Leisure and the Environment*. London: Belhaven, 293–306.


Rough-legged hawk (*Buteo lagopus*), Lake Superior (Natural Environment) Provincial Park, T. Beechey

Climate Change Adaptation for Park Managers

Climate Change Adaptation for Park Managers

David Welch

Parks Canada

Abstract

Climate has always been changing, is changing, and will continue to change. Since the 1960s, however, the pace of change of greenhouse gas concentrations, resulting radiative forcing, and climatic response has been, and will continue to be, more rapid than previously known in geological history. As a result, biomes, species distributions, hydrology, and the cryosphere will undergo profound changes. Protected areas management cannot contribute significantly to mitigation of this issue, but it can help the natural world adapt to it and help educate society about its causes and consequences. I propose a range of actions for consideration by park managers, organized under the acronym ALARM: Awareness of staff, Leading by example, Active ecosystem management, Research, and Monitoring. I counsel for adjusting park boundaries but not for moving parks in pursuit of migrating biomes, manipulating park resources to provide buffers or insurance against natural disasters, and modifying natural region boundaries where they guide park establishment policy.

Keywords: climate change, ecosystem management, mitigation, adaptation, park managers

Starting Point

This paper is based on Parks Canada discussions and a paper submitted for publication by the George Wright Forum (Welch, in press). The ideas have been presented to, and benefited from, several public audiences including the Atlantic region of Canada's Climate Impacts and Adaptation Research Network and the New England Governors/Eastern Canadian Premiers symposium on climate change adaptation. Notwithstanding this consultation, the following proposals are my own and are not yet Parks Canada policy.

For the sake of brevity I take it as given that climate has always been changing, is changing, and will continue to change. I also assume that readers have access to the numerous printed and Internet sources that describe climate change, its science, its impacts, and the range of adaptation options available to society at large. Here I focus on what park managers should think about and do.

Why and When to Adapt?

Protected areas will be impacted by climate change at least as much as other lands and waters in their natural regions. Indeed, the impacts may be greater. Fewer mitigation and adaptation options exist for natural areas than for those that can be routinely manipulated. Protected area custodians must therefore seek ways to adapt management practices to help maintain biodiversity and natural processes, to assist nature through her inevitable transitions, and to participate in programmes to reduce greenhouse gas emissions.

Adaptation means adjustments in practices, processes, and structures. It can be spontaneous or planned, and it can be carried out in response to, or in anticipation of, changes in conditions (Smit *et al.,* 2001). Unless it's your birthday, it is better to be prepared than to be surprised, so early adaptation is encouraged for several reasons:

- Climate change impacts cannot be prevented.
- Benefits will accrue from removing or halting maladaptive policies and practices that increase vulnerability.
- Benefits can be obtained by adapting in anticipation, rather than reactively, particularly if other stressors are mitigated.
- Visitor activities are tied to the timing and duration of annual climatic cycles and phases. Therefore infrastructure and marketing investments must take future climate into account.
- Leadership by example abets effective government. This means, for example, early achievement of greenhouse gas emission reductions from high profile public institutions like national and provincial parks will lead the public to similar reductions.

How to Adapt… Maybe

Protection strategies for protected and managed landscapes were addressed by Wein *et al.* (1990), Noss (2001), Hannah *et al.* (2002), and Hansen *et al.* (2003). They have the following recommendations:

- Locate parks with climate change in mind, develop contingency plans to expand conservation areas, and protect or establish connecting corridors.
- Avoid fragmentation, provide connectivity, and maintain buffer zones for boundary adjustments.
- Represent vegetation types and diverse gene pools across environmental gradients in reserves.
- Determine the necessity to transplant species, or to control rapidly increasing species.
- Integrate climate change into conservation plans and use active adaptive management.
- Involve local communities for management of biodiversity.
- Strengthen the research capacity of parks personnel, e.g., to identify sensitive biomes and to model biodiversity under changing climates.
- Conduct long-term monitoring to seek causality between climate and biodiversity responses at several levels of organization.

In sum, the limited protected area and climate change literature provides strong reasons to have parks and reserves, why there should be more of them, why they should be accorded enhanced protection, how they might be selected, and what ecological services they may provide to society. However, the literature provides little guidance to managers of existing protected areas. The rest of this paper attempts to fill this gap.

What to Do

Core principles

I propose the following core principles for a climate change strategy for protected areas:

- *House in order and public communications.* A park agency cannot mitigate global climate change by itself, but it can foster mitigation by putting its own emissions house in order and use its outreach and presentation activities to demonstrate leadership by example. Park visitors are generally ready to soak up information and listen to sound arguments by credible proponents. Indirect contributions through interpretation, education, and outreach can greatly improve in-house emission reductions, but credibility depends on such reductions.
- *Risk management.* Environments have a degree of resilience and in some cases can accommodate climate change by species migration or *in situ* adaptation. However, there are many other stresses impinging on ecological integrity, so I recommend a risk management approach whereby tractable stresses are reduced or eliminated. This can only happen through collaboration with interest groups and neighbours.
- *Focus on mandate, complement with partnerships.* Protected areas increasingly emphasize ecological and commemorative integrity in their mandates, outweighing tourism development, park infrastructure, and regional economic development. While these are important, they should not be put ahead of natural and cultural heritage. Place priority on actions within the responsibility of the agency, and leave to others the leadership of activities that are their responsibility. However, to the extent that internal capacity allows and that one's prime mandate is favoured, cooperate in such activities. Education, emission reduction, and national science programmes are good examples.
- *Porous landscapes.* Parks should be part of networks of ecological areas within which biodiversity can survive, move, and be appreciated. Park agencies should promote the importance of regional ecosystems characterized by connectivity and porosity for wildlife movement. Porosity means, not just defining wildlife corridors (connectivity), but removing impediments to movement across all lands. Examples include maintaining hedgerows and wood lots in agricultural areas, eliminating the cosmetic use of pesticides in urban areas, fostering dark sky preserves, and installing wildlife crossing alert lights on major highways, as in a Newfoundland pilot project.

Targets

Action plans need time-bound and measurable targets against which to assess progress and to redefine schedules and activities as appropriate. I propose three time frames and related goals:

- Within five years, appropriate climate change information is available to ecosystem and asset managers.
- Within ten years, climate change is factored into all aspects of ecosystem and asset management, and duly reflected in park management plans.
- Eventually, parks are nested within landscapes that are porous for the movement of native species and free of other significant threats to ecological integrity.

ALARMing actions

Many actions can be conceived to help reach these goals. To provide some structure, and to help see linkages between complementary activities, they can be grouped under categories that form the acronym ALARM:

- **A**wareness
- **L**eading by example
- **A**ctive management
- **R**esearch
- **M**onitoring

The following ideas are probably too many for any one agency to undertake them all. Rather, they are options from which an action plan can be developed.

A*wareness*

Staff awareness. Full engagement in any action depends on staff having an appropriate level of understanding of climate change impacts and adaptation. Actions include disseminating summary documents, newsletters, and technical reports, giving seminar and workshop presentations, and including climate change overviews in basic training components.

Stakeholder awareness. Successful adaptation depends in part on the management of surrounding natural areas. Urge your ecosystem partners to adapt in concert. Ideas include extending awareness activities, promoting ecological porosity between and around protected areas, and mitigating local and regional threats to ecological integrity.

General public awareness. The public should be made aware of the impacts of climate change upon species, ecosystems, and features and what adaptations may be required. Visitors should become aware of what they can do on vacation, at home, and at work by direct actions and by spreading the word to their friends and family. Include climate change messages in interpretation programmes. Post a climate change summary on your Internet site. Work with education authorities, other agencies, and non-government groups to deliver climate change information to children and adults alike. Collaborate with all levels of government to promote park adaptation strategies.

L*eading by example*

Reduce greenhouse gas emissions. Park agencies can use their favourable public presence to promote minimizing building energy consumption through design and operational practices, reducing fleet size, switching to more energy efficient vehicles, fuel switching, and taking advantage of emerging technologies.

Promote personal action plans for staff. Employees and volunteers can play a role through their personal actions at home and in their neighbourhoods. Employers can provide transit passes rather than subsidizing parking. They can provide incentives for carpooling, cycle commuting, and telecommuting, and promote energy-use reductions in homes and lifestyle choices.

Address climate change adaptation in park management plans. Management plans encapsulate a park's objectives and the activities that help to achieve them. These plans are also an accountability tool. Given the enduring nature of parks and the long-term implications of climate change, adaptation should therefore be addressed in management plans. For example, modify park purposes to protect processes and biodiversity rather than specific biomes and species. Review boundaries to seek opportunities for changes that optimize the protection and maintenance of ecological integrity. An example might be seeking higher elevation lands to protect Alpine tundra species. Management plans should endorse research and monitoring of indicators of climate change impacts. Take future climates and vegetation successions into account in ecosystem restoration projects such as fire restoration and land reclamation.

Report on natural and management adaptations to climate change. Whether reactive or adaptive, an integral part of management is the monitoring of progress towards a goal, assessing results, and modifying future actions accordingly. Documenting these processes is essential to full debate and support. A regular report series is the best guarantee of systematic publishing, dissemination, and readership. This does not have to be a scientific journal or series. Annual reports, quintennial or decennial state of park reports, or occasional papers are often more appropriate. Select indicators of climate change impacts for your park and its natural region, develop protocols and implement monitoring, and collaborate with regional partners to report impacts to the public and policy makers.

Active ecosystem management

Adapt natural region representation strategy. Natural region representation is often the basis for establishing new parks. It assures a distribution of parks across landscapes and ecotones, itself one of the best ways to protect biodiversity. It also deflects the strains of short- and medium-term demands for land protection when there is already a park representing a specific region. Natural regions are typically based on physiography and vegetation. While physiography remains largely constant in anything less then geological time, vegetation has changed significantly in living memory. Climate change will accelerate this process to the extent that natural successions will evolve within decades. Therefore retain map entities of natural regions, but revise their descriptions to reflect the dynamics of present and future climate. Locate and delineate new parks in ways that maximize site diversity and landscape porosity.

Eliminate or mitigate non-climate in situ *threats*. The growing body of research on interactions between climate and non-climate stresses suggests that responses are synergistic (e.g., Schindler, 2001). To maintain or rebuild ecosystem resilience one must reduce the number and/or magnitude of insults faced by an ecosystem. Fortunately, many stressors are more locally and regionally controllable than climate change. In a freshwater system this may require limiting the concentration of toxic substances in effluent. In a forest ecosystem it may mean preventing fragmentation by access roads. While not easy, these tasks are approachable on a local level through conservation partnerships.

Use adaptive management. Given uncertainty about the exact nature of climate change impacts and responses, effective management requires a responsive, flexible approach. Adaptive management allows one to proceed with only limited or uncertain knowledge. An intervention is conducted as if it were a scientific experiment (Nudds, 1998), with measurable, time-bound targets set in advance (policy = hypotheses), careful measurement of results as phenomenon happens (intervention = experiment, observation), and approaches adjusted as new information becomes available (reporting, analysis, re-setting hypotheses). Use adaptive management in impact abatements such as species protection, translocation of slow-spreading key species, or retardation of invasive pioneers. Decisions about fire management versus clear cutting in multi-use conservation lands (e.g., Bergeron *et al.*, 2004) present a clear need to use adaptive management.

Use climate change research results. There is a steep learning curve required to understand ensembles of climate change scenarios and their assumptions and uncertainties. It is not enough to have good primary science. There must be secondary products that digest and customize this knowledge for interdisciplinary professionals. Park agencies should commission reports that translate this vast body of science to regional and park-specific data sets. Parks Canada has done this through the work of Scott (2003) which resulted in spreadsheets of annual, seasonal, and monthly temperature and precipitation data for twelve GCM/emission scenario combinations for three periods in the twenty-first century for each national park, accompanied by narrative projections of physical and biotic changes for each park. By having access to localized information, it is easier for ecosystem managers to document climate change as a major stressor, to design ecological monitoring frameworks with climate change indicators in mind, and to detail research priorities.

As well as providing scientific syntheses, park managers need the tools to use climate change information in their decision-making processes. Climate change guidelines for environmental assessment are now available in Canada, covering projects that either have the potential to emit greenhouse gases, or projects that will be impacted by climate change (CEAA, 2003; Bell *at al.*, 2003).

Adjust park boundaries as needed for climate change adaptation. Changes in climate will lead to changes in habitats and species survival. Some plant species would have to migrate hundreds of kilometres to follow climate. Others might find a new home a short distance away. For the latter it may be possible to adjust park boundaries to capture the anticipated movement of habitats and species. Park boundaries could be realigned to accommodate transition zones where large changes of climate, habitat, and species distribution are expected.

Research

Understand the impact of past and future climate change. Decision-makers and park visitors alike benefit from a knowledge of Holocene landscape changes. This knowledge helps understanding of the changeable nature of climate and nature's ability to adapt autonomously, even in historical times. Research the impacts of climate change on natural processes and visitor activities before committing to expensive and irreversible ecosystem restorations or visitor infrastructure development. Rate each park for its sensitivity to a $3xCO_2$ atmosphere. However, the development of a research agenda should not be an excuse for postponing early action on awareness, leadership, and active ecosystem management when the no-regrets principle applies.

Identify values at risk of being significantly impacted by climate change. Ecosystems have too many components to understand and track them all. Identification of valued ecosystem components (VECs) provides a means to set management goals without bogging down in the minutiae of all species, all minerals, and so forth. A VEC is an "environmental attribute considered to be important for decision-making" (Munn, 2002). VECs are usually tangible things, like a keystone species or iconic vista, to which indicators for monitoring are tied. Identify a limited suite of VECs that are sensitive to climate change, such as species at the margins of their climatic range, species with limited or excessive abilities to migrate, and temperature sensitive features such as permafrost and ombrotrophic wetlands. Identify barriers to migration such as fragmented habitats and restricted vertical migration paths.

Monitoring

Data gathering and reporting actions. Each park should have long-term climate and climate change indicator data. These data should be reported at the park level and regional or national levels.

Promote parks as long-term integrated monitoring sites. Climate change will bring unexpected combinations of direct impacts, secondary effects, and new associations of processes, features, and species. Hence national parks should be managed as integrated ecosystems, not for one particular valued ecosystem component. Integrated monitoring is a complementary tool that can reveal unexpected linkages between ecosystem components and the drivers of environmental change. It can mine existing data to spot emerging influences and explain responses. Each stress does not need its own unique set of indicators. Often, several stresses can be tracked from a limited but well-selected ensemble of indicators. Integrated monitoring also fosters partnerships in which many agencies share costs while reaping benefits greater than the sum of their inputs.

What Not to Do

Do not move parks to anticipated biomes. The presence of a well-distributed system of protected areas is one of society's best adaptations to climate change. Species will have their best chance of finding new homes in a well-managed, well-distributed, well-connected, and properly sized network. While some parks might benefit from local boundary adjustments to protect ecosystems and habitats at risk from climate change, the notion of dynamic parks must be rejected. This would open the door to other reasons to move a park, e.g., to extract minerals or fibre. Also, the notion is unworkable in that few natural areas remain for new park establishment within regions that already have park representation. Rather, the present parks are often all that remains as a natural haven. Thirdly, park establishment is a lengthy process with no guarantee of success.

Do not use parks to buffer or mitigate other impacts. Parks are not an insurance policy to cover negligent or poor management of natural hazards and natural resource supply. The restoration, protection, and maintenance of natural systems preclude their manipulation to counter an anthropogenic threat. Ecosystem services may come about with the maintenance and restoration of ecological integrity, but parks should not be manipulated for flood protection, water supply, or carbon sequestration, for example. This would open the door to the commercialisation of natural resources in parks.

Do not modify natural region boundaries to fit future biomes. The natural region representation approach to national park establishment has served Canada well since its adoption by the Federal Cabinet in 1976. The constancy of the number of regions and their boundaries has ever since been a cornerstone of the national park system plan. It allows Parks Canada to pursue a consistent course towards completing a pan-Canadian system of national parks without being sidetracked by interest groups or lobbying to add a park just to satisfy vested local interests. If the precedent were to be set that the natural regions policy could be changed, then there could be no end to further pragmatic modifications of regions.

All climate scenarios are based on assumptions about future emissions, the physics and chemistry of the atmosphere, and geographical simplifications to allow world models to operate on today's supercomputers. Vegetation response is likewise modelled on plant succession assumptions. While these represent today's best science, the placement of boundaries remains notional and subject to change as models improve and as the world develops real emission inventories rather than scenarios. To change natural region boundaries on this basis would open up a never-ending process, and create an unrealistic setting for park feasibility studies and establishment negotiations that already take years or decades.

Conclusions

However well we manage protected areas, we cannot have much direct effect on greenhouse gas emissions. Yet, a good network of protected areas free of other stresses is one of society's and nature's best adaptations.

Park agencies can also influence visitors and the general public. Good parks and good interpretive, outreach, and education programmes in turn require well-researched and monitored climate change impact indicators as the basis for adaptive ecosystem management, accountability, and reporting systems. House-in-order programmes complement the messages that governments should send to their populaces. Research on the synergy between climate change and other stressors, such as habitat fragmentation and air pollution, can provide the knowledge to guide the mitigation of local and regional stressors, thereby restoring some of the natural resilience of ecosystems and wild species.

Regardless of the debate over climate forcing mechanisms and who does what to whom, we are more aware than ever that we have entered an era of rapid climate change and we had better get used to it. Protected areas should play a leadership role to ensure that wild nature also enjoys the ride.

References

CEEA. 2003. *Incorporating Climate Change Considerations in Environmental Assessment: General Guidance for Practitioners*. Ottawa: Canadian Environmental Assessment Agency. 44 pp.

Bell, A., N. Collins, and R. Young. 2003. Practitioner's guide to incorporating climate change into the environmental impact assessment process. *ClimAdapt* [Online]. 27 pp.

Bergeron, Y., M. Flannigan, S. Gauthier, A. Leduc, and P. Lefort. 2004. Past, current and future fire frequency in the Canadian boreal forest: implications for sustainable forest management, *Ambio* 33(6): 356–360.

Hannah, L., G.F. Midgley, T. Lovejoy, W.J. Bond, M. Bush, J.C. Lovett, D. Scott, and F.I. Woodward. 2002. Conservation of biodiversity in a changing climate. *Conservation Biology* 16: 264–268.

Hansen, L.J., J.L. Biringer, and J.R. Hoffman (eds.). 2003. *Buying Time: A User's Manual for Building Resistance and Resilience to Climate Change in Natural Systems*. World Wildlife Fund [Online] http://www.worldwildlife.org/forests/basic/climate.cfm 244 pp.

IPCC. 2001. Climate Change 2001. *Impacts, Adaptation, and Vulnerability*. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. McCarthy, J.J., O.F.Canziani, N.A.Leary, D.J. Dokken, and K.S. White (eds). Cambridge and New York: IPCC [Online] and Cambridge University Press. 1032 pp.

Munn, R.E. 2002. Responding to global environmental change. *Encyclopedia of global environmental change*, Vol. 4. London: Wiley.

Noss, R.F. 2001. Beyond Kyoto: forest management in a time of rapid climate change. *Conservation Biology,* 15: 578–590.

Nudds, T.D. 1998. Adaptive management and the conservation of biodiversity. pp 179–193. In: Baydack, R.K., H. Campa III, and J.B. Haufler (eds.). *Practical Approaches to the Conservation of Biodiversity*. Washington: Island Press. 313 pp.

Schindler, D.W. 2001. The cumulative effects of climate warming and other human stresses on Canadian freshwaters in the new millennium. *Canadian Journal of Fisheries and Aquatic Sciences,* 58:18–29.

Scott, D. 2003. *Climate Change and Canada's National Park System: Scenarios and Impacts*. Parks Canada Ecosystem Science and Review Reports 19 (CD-ROM).

Smit, B., O. Pilifosova, I. Burton, B. Challenger, S. Huq, R.J.T. Klein, and G. Yohe. 2001. Adaptation to climate change in the context of sustainable development and equity. Chapter 18 in *IPCC 2001*.

Welch, D. In Press. What should protected area managers do in the face of climate change? *George Wright Forum*.

Wein, R.W., J.C. Hogenbirk, B.L. McFarlane, A.G. Schwartz, and R.A. Wright. 1990. Protection strategies for parks under-predicted climate change. *Parks,* 1:17–22.

Dorcas Bay, Bruce Peninsula National Park,
K. Beechey

Climate Change, Sustainable Living, and an Ecosystem Approach to Management:

Some Thoughts

Climate Change, Sustainable Living, and an Ecosystem Approach to Management: Some Thoughts

Paul A. Gray

Ministry of Natural Resources, 300 Water Street
Peterborough, Ontario, K9J 8M5, Canada
paul.gray@mnr.gov.on.ca

Abstract

Current trends and modelled predictions indicate that the impacts of global warming during the next century will be significant and widespread. Most, if not all, ecosystems and their constituent organisms, including people, will be affected. While it is logical to assume that the best solutions for a sustained future will result from combinations of cultural-social-economic-ecological decisions, determining optimal mixes of decisions in a rapidly changing world (the ecosphere) will be difficult. In large part, effective management of climate change impacts will depend on how well societies embrace sustainable living objectives and implement an ecosystem approach. This paper examines tools and techniques that could be used in support of a commitment to sustainable living in a changing climate.

Keywords: climate change, sustainable living, ecosystem approach, adaptive management, tools and techniques

Introduction

Greenhouse gases are critical to life on Earth. For example, water vapour (the most abundant greenhouse gas) and carbon dioxide help regulate climate by trapping the Sun's energy that has been re-radiated from Earth's surface in the form of heat. This natural greenhouse effect, where the gases function as an insular blanket to maintain the Earth's surface temperature 33°C warmer than it would be if the blanket did not exist, provides enough heat for life on Earth as we know it.

People have added carbon dioxide, nitrous oxide, methane, and other greenhouse gases to the atmosphere by extracting and burning fossil fuels such as coal, oil, and natural gas. The drainage of wetlands and the conversion of forests and grasslands to other uses have also contributed to the release of greenhouse gases to the atmosphere. In fact, atmospheric carbon dioxide has increased 30% since pre-industrial times, and these additional greenhouse gas molecules have trapped new heat and accelerated the rate of global warming.

In Ontario, mean annual temperatures have increased by 0.5°C in the last hundred years and could increase another 2 to 5°C in the next century. Although temperature increases likely will be greater in winter than in summer, and in the north than in the south, there will be significant changes to all seasons in every ecosystem throughout the province. The additional heat energy will increase variability in temperature, precipitation (rain, snow, and ice), and wind patterns. For example, as more heat energy is trapped in the lower atmosphere by greenhouse gases, it is likely that the frequency and size of extreme events such as ice storms, heavy rains, droughts, and windstorms will increase.

Given that just about every ecosystem on Earth is or will be affected, managing for climate change must occur within the context of a commitment to sustainable living. While admittedly anthropocentric, the ideas and values associated with the concept of 'sustained life' signify balance—balance between the people who draw from and use Earth's processes and resources to survive and the ecosystems of which they are a part. Sustainable living, therefore, is envisioned as an ecosphere filled with healthy ecosystems and healthy people—a condition or state of ecospheric-human balance that a sustainable society would predict can be attained and maintained (Gray and Davidson, 2000).

An ecosystem approach to management is often cited as one method through which sustainable living might be achieved. During the last 30 years, thousands of journal papers, technical reports, books, and online documents have been prepared about the subject. These products describe ecosystem composition, structure, and function, outline principles, provide tools and techniques, and cite examples of ecologically oriented programs. And yet, after decades of work, a clear and concise description continues to elude us. As one approach, I suggest that program designers spend time identifying the appropriate questions that help us decide how we want and need to conduct our lives in ways that allow us to aspire to a goal of sustainable living.

An Ecosystem Approach to Management

An ecosystem approach to management is based on the idea that appropriate values combined with the required knowledge and tools can protect and maintain ecosystems and provide a range of benefits to society now and in the future. Asking the right questions helps organizations design the most suitable approach—questions about the spatial and temporal context in which to make decisions and questions that enable organizations to apply a suite of tools and techniques to keep the landscapes, the waterscapes, and the airscapes working (Figure 1). Even though all ecosystems are different, questions can be organized according to these three interrelated themes:

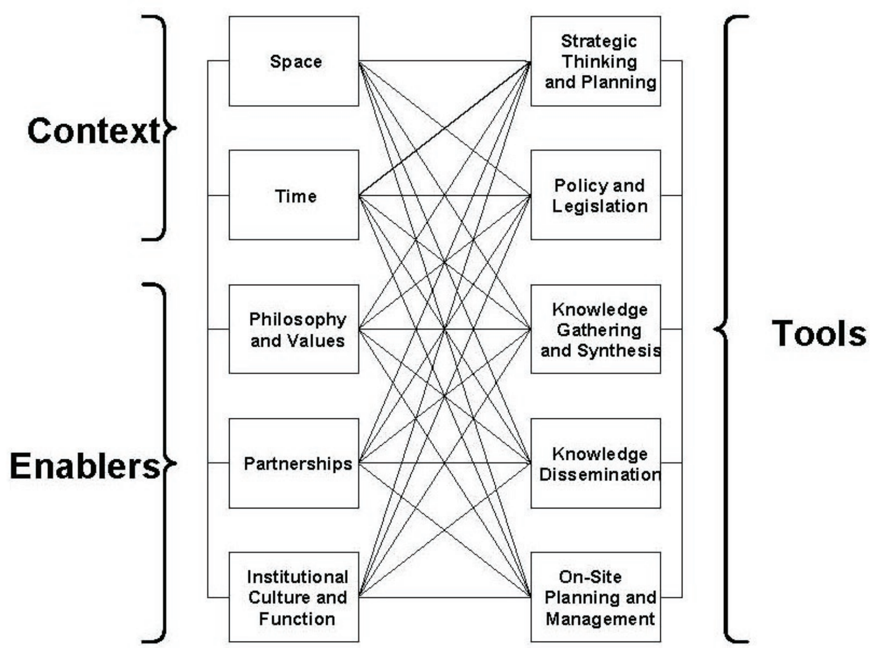

Figure 1: An ecosystem approach to management framework. The modules are linked and often employed simultaneously or in unison to develop and deliver ecologically-based programs (adapted from Gray *et al*., 1995).

Context:

1. *Space* – Have we mapped and described large and small ecosystems, and do we use these descriptions in a framework to plan and manage human activities? Now that human actions have created or contributed to significant change of continental and global proportions (e.g., climate change), an ecological context is increasingly required to identify and understand the issues, establish partnerships, and design appropriate management programs. The ecosystem provides an integrating spatial framework within which natural asset managers can work to address the spectrum of cultural, social, economic, and ecological factors and forces that shape modern life. Many ecosystem classification systems have been developed in countries around the world, such as the Ecological Land Classification system used in Ontario (Crins, 2000).

2. *Time* – Have we made the short- and long-term commitment needed to care for ecosystems in the context of climate change and other impacts? Ecosystem processes operate on a spectrum of time regimes ranging from less than a second to more than a thousand years. And our decisions about the allocation and use of ecosystem services and products must reflect the short- and long-term characteristics of ecosystem composition, structure, and function.

Enablers:

1. *Philosophy and Values* – Do our organizational philosophies allow us to care for ecosystem values? Ecosystems provide many values, including critical life support services such as breathable air and potable water, and social, cultural, and economic products associated with food, clothing, recreation, and other kinds of wealth. Our success will depend on how we use these values to guide our behaviour and pursue sustainable living goals.

2. *Partnership* – Are we involved with all the necessary partners, and do we have the tools to keep partnerships engaged and progressive? No one agency or organization retains the scientific expertise, the legal authority, or the financial resources to care for all ecosystems. Partnership is an important tool in the protection and sustainable use of ecosystems, including education, research, policy formulation and implementation, technology development, and information management.

3. *Corporate Structure and Function* – Do our organizational (corporate) structures and their functions provide a progressive and positive culture to implement an ecosystem approach? An ecosystem approach requires that participating agencies, organizations, companies, and institutions ensure that corporate structure and function supports intellectual development, participatory decision-making, and the creation of appropriate services, products, and experiences—a place where people can organize into productive groups to work in support of an ecosystem approach.

Tools and Techniques:

1. *Knowledge Gathering and Synthesis (Data and Information Management)* – Do we support and/or have access to traditional and community knowledge and to data and information collected and prepared by scientists and resource managers to allow proactive decision-making? Successful development and implementation of an ecosystem approach to management depends on how well we discover, retain, use, and share knowledge and information about the composition, structure, and function of ecosystems and the impacts of people who live and work in them. People must have the best information available to mitigate the impacts of climate change.

2. *Knowledge Dissemination (Education)* – Are we disseminating essential knowledge among staff, partners, clients, and the public in support of decision-making and life-long learning opportunities? Every person must be provided an opportunity to understand climate change and its impact on ecosystem function. Knowledge dissemination through accessible and current life-long learning opportunities (i.e., education, extension, and training programs) is a prerequisite to effective participation in decision-making, particularly in view of the fact that climate change is a complex and encompassing issue.

3. *Strategic Approach (Plan)* – Do we have a vision and/or mission statement that describes the condition or state (of the ecosystem) to which we aspire? In other words, have we described the path we want to take? We use strategic planning to determine the direction we will take and the techniques we will use to care for ecosystems. Effective strategic plans are constantly re-evaluated and modified to meet evolving needs and challenges.

4. *Policy* – Do we make a commitment to care for ecosystems with policies and plans that account for climate change? Given the complex, dynamic, risky world in which we live, policy formulation and implementation must be progressive and flexible. Policy and plans must allow managers to respond effectively to unexpected and unconventional issues and problems—it must be learning oriented, science based, and adaptive.

5. *On-site Actions* – Are we protecting, restoring, and/or using ecosystems in ways that keep the landscapes, waterscapes, and airscapes working? Effective protection and sustainable use of ecological assets depends on how well organizations allocate assets, mitigate impacts, and resolve on-site land-use, air-use, and water-use conflicts.

Concluding Remarks

The importance of a commitment to sustainable living cannot be overstated—it is critical if people expect to prepare for and adapt to a rapidly changing ecosphere (Earth's largest ecosystem) in the twenty-first century. And identifying the appropriate suite of questions is an important initial milestone. An ecosystem approach to management can be used as a framework with which to ask the questions, define the issues, and address the risks that need to be managed in a new world climate.

References

Crins, W. 2000. *The Ecozones, Ecoregions, and Ecodistricts of Ontario*. Peterborough: Ministry of Natural Resources. Map.

Gray, P.A., L. Demal, D. Hogg, D. Greer, D. Euler, and D. DeYoe. 1995. *An Ecosystem Approach to Living Sustainably: A Discussion Paper*. Peterborough: Ontario Ministry of Natural Resources. 77 pp.

Gray, P.A. and R.J. Davidson. 2000. An Ecosystem Approach to Management: A Context for Wilderness Protection. pp 59–64. In: S.F. McCool, D.N. Cole, W.T. Borrie, and J. O'Loughlin (eds.). *Wilderness Science in a Time of Change Conference—Volume 2: Wilderness within the Context of Larger Systems, May 23–27, 1999, Missoula, Montana*. Proceedings RMRS-P-15-VOL-2, Rocky Mountain Research Station, Forest Service, U.S. Department of Agriculture, Ogden, Utah.

Lesser snow geese (*Chen caerulescens caerulescens*), Polar Bear (Wilderness) Provincial Park, H. Lumsden, Ontario Ministry of Natural Resources

Appendices

Author Biographical Statements

Ellsworth Frank LeDrew (BA Honours, University of Toronto, 1972; MA, University of Colorado, 1974; PhD, University of Colorado, 1976) held an NRC post-doctoral fellowship at the Atmospheric Environment Service from 1976 to 1977. He then joined the Department of Geography at the University of Waterloo as Assistant Professor, was promoted to Associate Professor with tenure in 1982 and Full Professor in 1988, and is currently Interim Dean. Ellsworth's current research interests include the use of remote sensing in modelling feedback between atmospheric synoptic patterns and sea ice and snow cover in the Arctic as a step in understanding climate change and variability, and the retrieval of the spectral signatures of tropical coral reefs from airborne and satellite imagery to detect and monitor environmentally induced change as a means of assessing stress for coastal management.
email: ells@watleo.uwaterloo.ca

Christopher Lemieux is currently completing his PhD research at the University of Waterloo examining the implications of climate change for Canada's protected areas network.
email: cjlemieu@fes.uwaterloo.ca

Daniel Scott is a Canada Research Chair in Global Change and Tourism and Assistant Professor at the University of Waterloo. Dan's research focuses on two areas: protected areas and biodiversity conservation, and the tourism and recreation sector.
email: dj2scott@fes.uwaterloo.ca

Rob Davis is the Senior Protected Areas Ecologist for Ontario Parks, Planning and Research Section, within the Ontario Ministry of Natural Resources. Rob works on a variety of projects relating to protected areas planning, inventory, management, and applied science.
email: rob.davis@mnr.gov.on.ca

Geoff Wall is a Professor of Geography at the University of Waterloo and Director of Ecoplan China, a multi-year project on environmental planning and management in Chinese coastal areas. He is particularly interested in tourism and recreation and was among the first to address issues pertaining to tourism and climate change. For many years he was a member of the Socio-economic Committee of the now-defunct Canadian Climate Program.
email: gwall@fes.uwaterloo.ca

David Welch holds a PhD in Physical Geography from the University of Western Ontario, was a professor at the University of Winnipeg, has extensive field experience in the Arctic, and has twice been a Visiting Scientist at Australian research centres. For Parks Canada he has conducted field studies, provided advice in earth sciences, remote sensing and ecological monitoring, and introduced geographic information systems to the work place. He is now the Head of Environmental Quality for Parks Canada. In this capacity he guides the provision of advice and coordination in soil, water, and air quality issues. He is Parks Canada's principal advisor on climate change and air quality and is developing climate change adaptation guidelines for protected area managers.
email: david.welch@pc.gc.ca

Paul Gray attended the University of Waterloo and York University. He has worked on a variety of natural asset management projects in Ontario, Alberta, the Northwest Territories, and Zimbabwe. He is currently with Ontario Ministry of Natural Resources.
email: paul.gray@mnr.gov.on.ca

Original Workshop Program and Abstracts

Date

Evening Arrival — Wednesday, February 25, 2004

Workshop Sessions — Thursday, February 26 and Friday, February 27, 2004

Departure — 5:00 p.m. Friday, February 27, 2004

Location

Leslie M. Frost Centre, Dorset, Ontario

Participants

Maximum of 40 including speakers and organizers

Program

Day 1 — Thursday, February 26, 2004

8:00–8:45 a.m. **Registration** and ice-breaker, informal introductions, refreshments and breakfast snacks, and viewing of posters and displays.

8:45–9:00 a.m. **Welcoming remarks**

Barton Feilders and others

9:00–10:00 a.m. ***Theme 1*** **— Understanding Climate Change**

Ellsworth LeDrew
Professor, Department of Geography, University of Waterloo

The purpose of this presentation is to give participants a broad understanding of the nature and some of the intricacies of climate change, the kind of evidence available for it and its reliability, some of the general methods used to map and describe unanticipated changes and their advantages and disadvantages. The idea is to set a broad science-based context in which to think about the ways in which we might adapt, especially with respect to environmental changes that affect rural areas, parks, nature conservation and related policies and programs. The weight of the presentation will be on establishing the nature of anticipated changes, the evidence for them and the uncertainties involved.

10:00–10:30 a.m. **Refreshments**

10:30–11:30 a.m. ***Theme 2*** **— Gathering, Modelling, and Using Knowledge and Research in Support of Informed Decision-making About Climate Change**

Dan Scott[1] and Christopher Lemieux[2]

[1]Assistant Professor, Department of Geography, University of Waterloo

[2] PhD Candidate, Department of Geography, University of Waterloo

Much of our understanding of climate change is based on the building and use of models. These have advantages and disadvantages with respect to their approximation of reality. Some of these models have been applied to the regions and localities in which parks are located and implications drawn for their effects and their implications for planning, management, and decision-making. This presentation will address these topics and suggest ways in which the resulting information can be used in making informed decisions about adaptation to climate change in Ontario's parks.

11:30 a.m.–12:00 p.m. **Questions and discussion**

12:00–1:30 p.m. **Lunch**

1:30–2:30 p.m. Theme 3 **— Climate Change, Protected Areas, and Tourism**

Geoff Wall

Professor, Department of Geography, University of Waterloo

Among the major anticipated changes arising from climatic change are those affecting recreation and tourism. Climate change can bring changes in vegetation and wildlife and also in temperatures, precipitation, snowfall, and other current characteristics of parks and protected areas. These changes in turn can affect the environment for recreation and tourism. For example, changes in temperature and aridity can favour more fire, reduce water supplies, and decrease opportunities for skiing and winter sports. Climate change can also affect water levels, the position and condition of the shoreline, and other key characteristics of the coastal environment for recreation and tourism. Considerable research has been done on such anticipated effects and this work will be discussed in this presentation along with its anticipated implications and research needs.

2:30–3:00 p.m. **Questions and discussion**

3:00–3:30 p.m. **Refreshments**

3:30–4:30 p.m. Panel Discussion and Questions **— Climate Change Research and Its Implications for Ontario Park Planning and Management**

(Ellsworth LeDrew, Dan Scott, Christopher Lemieux, Geoff Wall, and others)

4:30–6:30 p.m. **Break**

6:30 p.m. **Refreshments**

7:00–8:00 p.m. **Dinner**

8:00 p.m. **Posters, exhibits, free time**

Day 2 – Friday, February 27, 2004

***7:30 a.m*. Breakfast**

***9:00–9:45 a.m. Theme 4* — What should park managers do in the face of climate change?**

David Welch
Head, Environmental Quality, Parks Canada

There may be debate over causes, but most scientists agree that climate has changed, is changing, and will change. Park organizations can respond to climate change in several ways, none of them exclusive of others. Examples are:

* Participating in government leadership programmes, e.g., (1) greenhouse gas emission reduction, and (2) education and outreach.
* Sharing in science, e.g., (1) development of indicators for parks and benchmark monitoring, and (2) modelling of species and ecosystem responses.
* Redefining the purpose of protected areas, e.g., (1) to act as extreme event buffers for the rest of society, and (2) to no longer represent extant biomes.
* Assisting nature's adaptation, e.g., (1) translocating species and (2) restoring ecosystems to an anticipated future state rather than an actual recent one.

However, park organizations face many other challenges that compete directly for or that divert resources and attention to other matters. Examples are: species at risk now; budget restraint; competing resource demands on lands around parks; tourism pressures; exotic invasive species; air and water pollution; fire management; public safety; and more. Directed adaptation will remain problematic as long as climate change is perceived to be a long-term problem rather than an immediate one, as long it is perceived to be inevitable, and as long as major uncertainties remain in the science of ecosystem responses to altered drivers.

***9:45–10:30 a.m. Theme 5* — Thinking and Planning Strategically**

Paul Gray
Ontario Ministry of Natural Resources

Current trends and modelled predictions indicate that known and potential impacts of global warming during the next century will be significant and widespread. All ecosystems and their constituent organisms, including people, will be affected. And there are significant implications to management programs, including protected areas. While it is logical to assume the best solutions for a sustained future will result from combinations of cultural-social-economic-ecological decisions, determining optimal mixes of decisions in a rapidly changing world (ecosphere) will be difficult, and in large part will depend on how well societies think and plan strategically. This presentation describes the role that strategic planning can play in helping people concerned with the long-term management of protected areas understand climate change, predict and mitigate the impacts of climate change, and adapt to climate change.

***10:30–10:45 a.m.* Refreshments**

***10:45 a.m.–12:15 p.m.* Working Groups**

***12:15–1:15 p.m.* Lunch**

***1:15–2:30 p.m.* Plenary: Report on the Working Groups Results**

***2:30–3:30 p.m.* *Panel Discussion and Questions* — Planning and Thinking Strategically about Climate Change in Ontario's Parks**

***3:30 p.m.* Refreshments**

***4:00 p.m.* Depart**

Working Group Notes

We publish here summaries prepared from the notes submitted by the Chairs of working groups established towards the end of the workshop. The intent was to seek reaction from the participants. A set of possible questions was provided to the groups as an initial basis for discussion—although these were not necessarily to be followed closely, nor did that occur.

Proposed Questions:

1) What is your view of the evidence for climate change? What are the major research needs and why?

2) What are the major planning needs for climate change in Ontario's parks?

3) What should be the priorities?

4) Who should have responsibility for addressing them, according to what timetable?

5) What interactions should occur with what organizations and groups in making decisions, in particular how should the public be involved in planning for overall policy and in planning for specific parks and park regions?

6) What role can the universities play in addressing planning needs and approaches?

Our editing has been guided by the desire to bring out the main points made in the Working Group Notes so as to provide highlights and further food for thought by readers.

Editors

Working Group 1:

Maggie Bowman	**Susan Grigg**
Pauline Haarmeyer	**Brian Huis**
Tracey Snarr	**Christine Vance**
Charlene Vantyghem	**David Welch**

1. Emphasis, Capacity, Priority?

- From the park level, this is the first opportunity to be exposed to an academic perspective.
- All types of stresses at parks. Climate change needs to be put in context, integrated with other monitoring.
- Fairly complex and huge.

What steps can someone take at park level?

- Research: we don't know what the effects are.
- Data rescue.
- Funding issue (not available; e.g., research plots)
- Assume most impacts are negative, but for some species changes could be positive.
- If we focus only on representation, then SAR (Species at Risk) may need to re-evaluate whether it's positive or negative.

Solution: have enough parks filled in to have adequate areas protected.

Set strategies at corporate level before trying to tackle at park level.

- Need policy in place to adapt to climate change.
- Set goals to implement green technologies.
- In Parks Canada—main office provides examples (house-in-order concept discussed by David Welch).
- Specific actions are up to the park.
- Involves fair amount of work at clerical level and software level to be able to report it.

Some actions can occur at grassroots level (save money, be able to do our jobs better; e.g., turn off lights and monitors when away from desk)

Monitoring, top-down direction:

- Good link to climate change.
- Educate operationally (tell others what you are doing)
- We can control our operations.

- e.g., parks could only buy wood from certified forest products.

Investigate developing a formal environmental management system. Parks Canada environmental management system has two approaches.

Identify your own issues that you can deal with through operations.

Climate change has not been identified as a priority within Ontario Parks; but after this workshop, a feeling exists that it should be.

2. What Do Park Managers Need?

- Planners need to develop a template or statement for each park.
- Management plans
- Begin by giving corporate recognition to climate change.
- Need data to make decisions.
- More information could lead to stronger policies. What is already out there?
- Identify gaps—where do we need more data?
    - raw primary data (often appears in journals)
    - secondary data (useful to managers to make decisions)
    - tertiary (public information to make decisions)

May not need raw data. Could get highly reliable scientific sense of what's in each park without having a monitoring station in each park.

Exception: e.g., Eastern Prickly Pear Cactus. Site-specific monitoring needs to be done.

- Get direction on what species are likely to be of concern.
- For managing parks, the indicators may be <u>more</u> site specific.
- Develop indicators and measures through main office for direction at park level.
- Work with public to collect information.
- Look for partnerships.
- Take advantage of all the data being collected.
- Make information easier to access and easier to use at all different levels.
- Stand-alone system versus integrate.

Parks Canada

- Information by park (X_2 CO_2 scenario; 2050 and 2090 timeslots; 3–4 model/emission scenarios).
- Information on precipitation and temperature seasonally and annually.
- 2–3 page narrative based on existing literature .

- Other tools also now exist, online.
- Free to register.
- Download Canadian maps with a variety of information (projected widespread impacts, projected temperature/precipitation, etc.).

Consider developing an overview at provincial scale of potential/projected changes and create a summary for each park.

Assign someone to follow and report on policy/science interface.

Need a professional network for routine information trading.

Encourage staff to look at climate change at park/manager level, as well as visitation, revenues, and other current priorities.

3. System Plans?

- Systems plans have served a good purpose, perhaps now need some adjustment.

Work on infilling and connecting:

- Infilling in Southern Ontario – lots of private land (do not have luxury of Crown land).
- Do not worry if there is more than one nature reserve in a particular ecodistrict.
- Ecodistrict boundaries, adjusted based on Bill Crin's work.

Keep database up to date and identify gaps

- Gap analysis (perhaps bring in a theme on climate change; if there are new landform vegetation units update them and incorporate them into identification of new gaps).
- No need to radically change direction, we are always adapting and finding new alternatives.
- Accept there will be change, and accommodate it.

When identifying species to monitor, incorporate climate change considerations.

Do we intervene? Or do we say it is evolution?

Broad database—is broader species diversity changing and what are the possible measures (e.g., invasive species)?

4. Role of Strategic Planning?

- Provide us with top-down direction.
- Integration of plans is difficult, but good to try.
- Linkages are desirable.

- Show parks and protected areas on maps to see size, shape, buffers, and other patterns and where the gaps are.

Find big picture examples that already exist; keep them current, including changes due to climate change, and disseminate occasionally.

Strategic planning may not occur specifically because of climate change, it is one more stress but can be brought into the package and filtered down to park level

- Promote landscape-level analysis.
- Promote acquisitions, easements, and the like.
- Park activities/operations (e.g., prescribed burns).
- Remember to take climate change into consideration.

5. Communications?

Park Visitors

- Have someone write an article for park tabloids to public (e.g., CPAWS, Parks Canada pamphlet, Ministry of Education).
- "Hop To It" was well received.
- Need to introduce people to the issue.
- What may be most successful in long run is when we interpret it to children, who then put their parents onto it.

Staff development

- Workshop such as today.
- Part of the audience for publications.
- When read park management plans, if we incorporate message it filters to park operations.
- How do we convince people it is another thing we should be considering?
- How to get buy in at individual park level that is cost effective?
- Ties in to top plan and support.

Working Group 2:

Tim Bellhouse	**Peter Brand**	**Bill Crins**
Paul Gray	**Mike Green**	**Jim Murphy**
Dan Paleczny	**Dan Scott**	**Mark Taylor**
Don Tyerman		

1. Emphasis, Capacity, Priority?

Philosophical Question

- Change—relative to other issues?
- One of many stresses on parks.
- Climate change is a 'key' trend.
- Little emphasis at 'park' level on climate change.

Beyond Our Capacity

- Separation of responsibility.
- Planning policies to address climate change.
- Enable discussion.
- Proactive planning (design/engineering) of park projects (e.g., infrastructure).

Real Priority

- Concern about extreme weather events.
- Ice storms.
- Tornadoes.
- But not a tangible concern.
- Greater integration of policies at the ground level.

2. What Do Park Managers Need?

- Increasing information at all levels.
- Revisions to 'Blue Grey' Book and their key documents.
- Reviews and update PPA/OP policies.
- Science ('Applied Approach.').
- NGOs (greater advocacy/collaboration).
- Governments need to engage the public more than in the past.

- Need ‘policy’ models.
- Evaluation/criteria to determine positive/negative effects.

3. Park Systems Plans?

(Are they obsolete? Process versus Feature Representation)

Think about adapting ecoregion mapping to reflect what is known of climate change.

- Planning process must incorporate new info/res.
- Developing options in system plans to adapt to change.
- What do we need at a park level, system level?
- Ecosystem community.
- How do we undertake adaptive management at each level?

4. Role of Strategic Planning?

- Ecosystem-based approach—collaboration at many levels for a common vision.
- Must be ‘dynamic’ process.
- 5–20 year planning levels.
- ‘Strategic’ plan for Ontario Parks with a climate change component.
- NGOs—Facilitate ecosystem-based approach to planning—Yukon to Yellowstone, Algonquin to Adirondacks.
- CPAWS (Canadian Parks and Wilderness Society).
- CCEA (Canadian Council on Ecological Areas)—‘Natural Working Groups,’ e.g., Climate Change.

5. Communications?

- Training workshops.
- Website content – messages on climate change.
- Curriculum-based on climate change.
- Merchandising.
- Leverage funds from NGOs, government, Canadian Parks Council for climate change communications.
- Level of awareness of park visitors about climate change (identify the appropriate mediums to educate).
- Local-level participation/interaction – Conservation Authorities, watershed level.
- Sharing information on economic impacts (e.g., winter tourism).
- Kyoto is not enough.
- Change is not all bad.

Working Group 3:

Jennie Aikman **Kirsty Dickson**
Mark Shoreman **Hank Van Luit**
Geoff Wall

1. What role should strategic planning play in responding to climate change?

- Consider the definitions of parks (i.e., municipal, provincial, national).
- The impacts seem to be consistent (lower water levels, changes in vegetation) then use those models to develop similar approaches.
- We should all be using similar approaches to deal with the impacts.
- Scope/scale come into play; global issue – global planning at ecosystem level not park level.
- How do we as park managers deal with this at park level?
- Benchmark monitoring and reporting.
- Small pieces of representation.
- What is strategic planning?
- Long-term planning versus how can we create protected areas?
- Parks will still be representative of how the ecosystem has changed.
- Strategic planning—'what if' scenarios—cooling, warming.
- Emphasis on natural processes still important.
- We have to control the human system impacts.
- Consider climate change in context of land-use planning in the far north.
- Protected areas will be larger in size.
- Parks cooperative agreements use strategies, development strategies.
- Considering the greater park ecosystem—this is critical to protect values from adjacent/external influences.
- Create potential parks/reserves.
- Planning in too short timeframes.
- Strategic planning done at global level where individual governments don't have the control or influence that they have right now.
- Strategically looking at economic impacts of not considering climate change.
- Countries, such as China, create nature reserves partly for protection and partly as development strategies (deal with desertification, climate change).
- Need to buy into climate change and variability; need to understand variability now.
- It's best to consider those two words together especially politically—climate change and variability.
- Need to be building our emergency response procedures/processes especially at park level.

- Do we want to plan for ecosystem change or specific ecosystems?
- Why do we have restoration projects?
- Why do we write recovery plans for SARS (Species at Risk)?
- Biggest role is educating public on what we can do to make the difference.
- Relate primary values to the economy, social growth.
- Encourage natural processes (they change) versus do we want to loose species (SAR), do we try to deal with that?
- Interconnected areas.
- Understanding/awareness for park users.
- Showing specific/real time examples; highly visual.
- Need to understand that global climate change might not seem so bad for us (Virginia climate) but other places in the world will come to rely more heavily on us.
- Need the broader framework.
- Build in long-term vision statements (50–100 year).
- Faith in humanity—we will be able to adapt, or will we outpace our ingenuity?
- The role for North America is to not allow history to repeat itself in other countries; provide resources to them.
- As wealth of people increases, we have ability to think about nature.

2. What forms should climate change communications take?

Park visitors

- Don't cause crisis or scare them; no doom and gloom.
- Common messaging approach, thrust between agencies (major issue) comes back to strategic planning.

Policy Development

- Caught up in short-term issue management.
- Ministry of Natural Resources has pulled back; they used to be more into outreach.
- Provide direction to develop programs.
- Canadian Accord on Climate Change for Protected Areas—where all agencies that manage protected areas are signatories to the Accord—it can be bottom up as opposed to top down.
- Who—science sector (CCEA, CPAWS, Parks Canada).

Staff Development

- Message is good message but not being directed from higher levels.

- Move communication/authority to work with local municipalities/local planning boards.
- Need to let people know what the impacts are.
- Tourism with a message.
- We don’t always demonstrate through our own actions.
- Greening our own operations.
- Using our examples in interpretation.
- Value in using a survey on climate change with our own visitors.
- Need to use our partners (friends, cottagers groups).
- Develop a canned program—link to our campsite 24 to promote ideas for outreach.
- Implement through zone NHE strategies.

Working Group 4:

Chris Lemieux

Robin Reilly

Ellsworth LeDrew

Bob Davidson

1. Are we placing too much emphasis on climate change?

- No. Ontario Parks is moving in the right direction. The important question is where and what do we respond to first?
- Communication—seen as a high priority. Specific things that are observable and that people and visitors can relate to.
- Educational Modules spread around at different parks. Fire ecology and Quetico; dune building at Pinery, they indicate observable impacts.
- Capacity—some parks have capacity, others do not (objectives in management plans, no staff at many parks). Rethink management plans with climate change considerations.
- Capacity at upper level—more opportunity lately to set up monitoring program.
- Capacity to do public consultation, development, and review of management plans, not there.
- Review of Legislation—1954—Integration of ecological integrity, environmental management, and climate change. Policy and public opinion allows Ontario Parks to move forward.
- Field staff have to move towards resource management and facilities management—problem of "profit" focus.
- Indicators—tools needed in management plan.
- Focus is on time is too short or narrow in management plans.
- Climate change just one of several issues in environmental management—long way from making it a priority at the park level—NOT at integration phase.

2. What role should strategic planning play in responding to climate change?

- Current Plan still viable—less emphasis on vegetation in delineation of boundaries.
- Forest management—important to work with neighbours when considering climate change.
- Outreach function—linkages with neighbors, e.g., planting grass to reduce erosion.
- Stewardship Approach—soft stewardship.
- HOW LONG? Things haven't changed in 10 years. Generation—young people moving up in organization. Change in corporate structure needed to incorporate climate change. Let others move the system, grey areas.

3. Are park system plans obsolete?

- No. Need a starting point? What is it?
- Let vegetation change in an adaptive management approach?
- Focus on Education

4. Moving in the right direction?

- Issue of capacity—don't really understand what we're dealing with, largely due to uncertainty.
- Resources—not there to do anything about climate change.
- Embrace environmental management and adaptive management where climate change is integrated.
- Hard to define the context the system is in.
- Receptive to do climate change research—scientists needed to identify research priorities.
- Crisis + knee jerk reactions—immediate threat.
- Problem—scientists tend not to communicate back to Ontario Parks.
- Not an immediate priority.

In Summary

- In general, although not too much attention is being paid to climate change.
  Ontario Parks seems to be moving in the right direction.
- Communication is key (with specific features, things that are observable and people can relate too).
- Modules spread around at different parks (Quetico, Pinery).
- Build capacity.

Key Points Submitted by Some Participants:

Key points from Brian Huis:

- Context is important—climate change is one more in the extensive list of stressors.
- Research—capacity, availability of resources. Change not all negative. Some species may benefit.
- Re-evaluate—not only about species at risk, representation.
- Integrate statements of climate change. Need DATA to make decisions that will lead to informed decision making— species of concern.
- Access to information—tap into sources not previously aware of.
- System plan is NOT obsolete but needs revision. Good snapshot, benchmark.

Key points from Jim Murphy:

- Question—what stressors are of immediate concern other than climate change?
- Little emphasis by managers on the ground. Need to incorporate climate change into management plans and documents (capacity).
- Proactive planning—specific projects at the park level.
- Priority? Comes off the radar as it is not an immediate threat.
- What needs to be done? Adapt education plans to include climate change in relation to humans in the environment, impacts on park values. Dust off grey and blue book. Need for advocacy and cooperation among groups. Important to evaluate, define criteria.
- Obsolete? No. Need some adaptation. Common elements still in place.
- Look at park management at all levels, support model. Look at climate change from an environmental assessment.
- Education—interpretation program to include climate change at park level. Visitor centres, internet, outreach.

Key points from Robin Reilly:

How Quetico is adapting?

- Climate is considered in stress assessments.
- Use of hybrid cars for transportation.
- Fire policy changed to include 10% more burning.
- Research on extreme events, blow down (900 ha)
- Tree slicing, accurate dating.
- Survey on loon breeding (dates).
- Identifying grasslands at park, pockets of residual grasses, repository species.

- Vegetation mapping is satellite based.
- Inventory on vegetation for vegetation management planning.
- Environment Canada monitoring ice thickness.

Key Points from Bill Crins:

- Climate change signal now strong enough to pull out the warming trend from the shorter term variability.
- Meta-analyses of biotic change support this—birds predictive.
- Sensitivity of Canadian climate enhanced because of dynamics in the cryosphere.
- Frequency and intensity of extreme events will increase.
- Current protected area frameworks may not be adaptable to the rate and extent of the change.
- Wording in existing policies relate to "beyond the historical range," etc. "representation" - policy change needed to adapt to climate change.
- Biome change analysis and fire severity analysis indicate that changes will occur throughout the broader system (national and provincial).
- Implications of climate change relate to protected area framework and system, as well as the users and stakeholders (specifically tourism).
- The hydrological cycle and changes in it are critical in understanding the impacts on ecosystems and use patterns.
- Behavioural adjustments are needed to adequately deal with climate change, in terms of limitations and adaptations of or to the change.
- Communications at all levels are needed to convey the importance and implications of the process—ecosystem services, economic implications.
- Regardless of the details of protected area systems, ecological integrity should be the first priority for protected area management at any point in time, including monitoring and reporting requirements.
- Policy development should attempt to account for uncertainty, change, and variability—it should focus on ecosystem-based approach to management, using an adaptive management design.
- Needs to deal with short-term and long-term change.
- And before new policies are developed and before monitoring programs are designed, we need to ensure what we ask the right questions, to focus our activities and to generate relevant information.
- "Many competing threats share the same solution."
- "It's about civics—the rights and duties of citizens."

State of the Art Climate Change Workshop Participants

Note: This list includes all those who participated in the working groups and may not include all who attended.

Name	Organization
Jennie Aikman	*Ontario Parks (OMNR)*
Tim Bellhouse	*Ontario Parks (OMNR)*
Maggie Bowman	*Ontario Parks (OMNR)*
Peter Brand	
Bill Crins	*Ontario Parks (OMNR)*
Bob Davidson	*Ontario Parks (OMNR)*
Kirsty Dickson	*Ontario Parks (OMNR)*
Barton Feilders	*Ontario Parks (OMNR)*
Paul Gray	*Ontario Ministry of Natural Resources*
Mike Green	*Balsam Lake Provincial Park, (OMNR)*
Susan Grigg	*Ontario Parks (OMNR)*
Pauline Haarmeyer	*Ontario Parks (OMNR)*
Brian Huis	*Ontario Parks (OMNR)*
Stephanie Janetos	*Parks Research Forum of Ontario*
Doris Krahn	*Ontario Ministry of Natural Resources*
Ellsworth LeDrew	*University of Waterloo*
Chris Lemieux	*University of Waterloo, PRFO*
Kevin Loftus	*Ontario Ministry of Natural Resources*
Greg Maude	*Ontario Parks (OMNR)*
Jim Murphy	*Ontario Ministry of Natural Resources*
Gordon Nelson	*Parks Research Forum of Ontario*
Dan Paleczny	*Ontario Parks (OMNR)*
Brian Pfrimmer	*Ontario Parks (OMNR)*
Tom Purdy	*Pinery Provincial Park (OMNR)*
Robin Reilly	*Quetico Provincial Park (OMNR)*
Dan Scott	*University of Waterloo*
Mark Shoreman	*Wasaga Beach Provincial Park (OMNR)*
Tracey Snarr	*Samuel de Champlain Provincial Park (OMNR)*
Lisa Soloman	*Ontario Parks (OMNR)*
Dave Sproule	*Ontario Parks (OMNR)*
Dan Strictland	*Algonquin Provincial Park (OMNR)*
Rick Stronk	*Algonquin Provincial Park (OMNR)*
Mark Taylor	*Stantec Consulting*
Don Tyerman	*Pres'quile Provincial Park (OMNR)*

Christine Vance	*Ontario Parks (OMNR)*
Hank Van Luit	*Ontario Parks (OMNR)*
Charlene Vantyghem	*Ontario Parks (OMNR)*
Geoff Wall	*University of Waterloo*
David Welch	*Parks Canada*
John Waithaka	*Parks Canada*